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Rail Delivery Group

Assessing the Value of Rail Freight

April 2021

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Executive Summary

Rail freight plays a key role in the UK economy, but the benefits it delivers to users and broader society have historically been less well understood

The role of rail freight in the economy

As of 2018/19, rail freight services across Great Britain are provided by six operators, generating annual revenues of approximately £800m per year and supporting businesses across a number of sectors (see right), including: [1]

- Moving intermodal containers as **part of an integrated supply chain** with road and waterways between large ports such as Felixstowe in the East of England to major logistics hubs like Daventry in the Midlands for onward delivery to customers ranging from fast-moving consumer goods to supermarkets and furniture and hardware;
- Forming a **key artery from quarries and regional distribution centres** to large building sites around the country, including supporting a number of the country's biggest buildings projects (including recently the Shard in London);
- Transporting large volumes of **vital inputs and outputs to and from energy generation processes**. While such activity has declined over time with significant reductions in coal transport, it is still a material market owing to biomass and nuclear material (see bottom right);
- Transporting raw and manufactured metals throughout the country from and to **key steel production** plants; and
- Utilising its rolling stock and staff to support Network Rail in the **upkeep of the passenger railway**.

In addition, rail freight supports a broader freight industry operating across roads, waterways and air with each mode playing its role, often in combination with one another.

Scope of this work

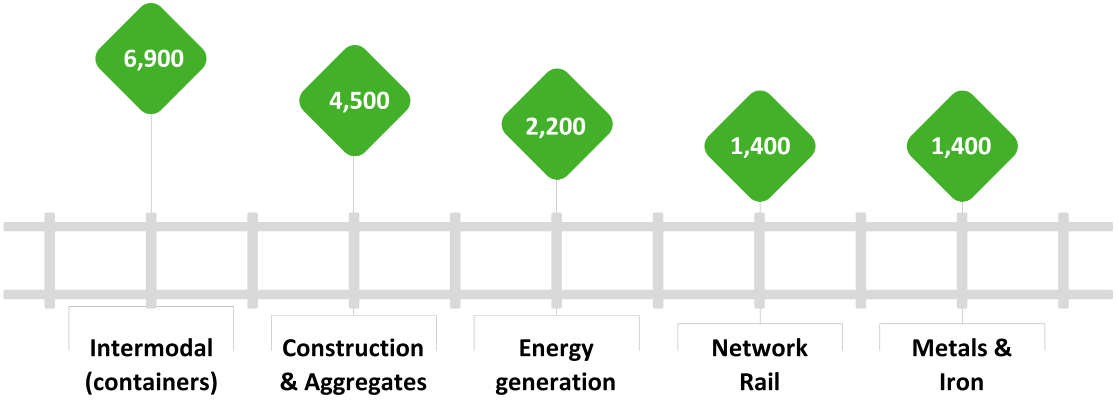
While this role is clear, the type and size of benefits rail freight delivers are less well understood.

Deloitte have been commissioned by the Rail Delivery Group Ltd (RDG) to carry out an economic study on the value of rail freight to:

- Articulate a **holistic set of benefits** that rail freight may generate for UK economy and wider society;
- Assess such benefits qualitatively, and where possible, quantitatively; and
- Utilise this work to develop a **framework to support future decision-making** on the railway, so that rail freight can play a bigger role in the economy going forward.

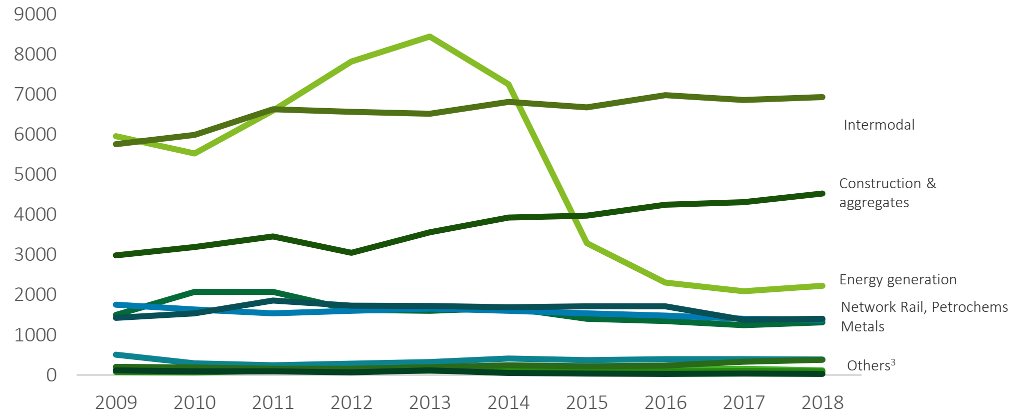
[1]ORR data

Top five sectors by freight volume carried (2018/19 – million tonne km (Mtkm)[2])



Source: Network Rail, DfT

Evolution of freight sectors served over time (2009/10-2018/19 – Mtkm)



Source: Network Rail, DfT

[2]Tonne kilometres are a common measure of rail freight activity as they represent both the distance travelled by freight operators to transport goods as well as the number of goods transported.

[3]Including General Merchandise, Domestic Waste, Iron, Automotive and other

Industry engagement has shown that rail freight offers a range of benefits to both its customers as well as wider society

To assess freight benefits, a wider-ranging engagement exercise was undertaken. This included consulting with 15 rail freight customers comprising some of the UK's largest logistics businesses and grocery and general merchandise suppliers, its most important energy generators and well known construction and aggregates and metals businesses.

In addition, Network Rail, freight operators, RFG, ORR, DfT and Transport Scotland were also consulted to test potential freight benefits and consolidate existing work and frameworks on rail freight benefits. Insights from this engagement are set out to the right.

Engaging with industry has shown rail freight offers significant benefits to its customers/users...

Key rail freight benefits identified by customers, called **User Benefits,** include:

- the **direct costs savings** to users that could arise from being able to transport goods over longer distances, at greater volumes or through more dense areas more cheaply on average than alternatives, especially when considering transhipment costs**;**
- the **direct time savings** that could accrue to users when compared to alternatives that utilise slower routes leading to longer delivery times for certain journeys; and
- **reliability benefits** from potentially more certain journey times of goods relative to other modes over particular routes (and when transporting larger volumes of goods)

... as well as significant societal benefits through modal shift from road and potentially agglomeration

Stakeholders more widely also identified a number of wider **Social Benefits** including:[1]

- **environmental, safety and congestion** benefits realised through modal shift; and
- potential **productivity gains** through improved efficiency of integrated supply chains and firm agglomeration (arising through the channels set out to the right).

Having identified these types of benefits, each sector served by rail freight was qualitatively and quantitatively assessed to understand the potential significance of value offered to the UK economy and wider society and how the composition of benefits generated differed across the sectors.[2] However, owing to the state of literature and data on agglomeration in the freight sector, such benefits have not been estimated as part of this work, but could be analysed as part of future research.

Key benefits identified by rail freight customers and stakeholders

Offering efficiencies and cost savings

"Using road to access inner cities could as much as double our costs compared to rail

– Aggregate Industries"

Creating value for wider society through relief of congestion, carbon emissions and noise

"Rail freight is key in reducing our environmental footprint and in enabling us to contribute to net zero

– Tesco"

Enabling carriage of strategically important materials

"Some of our products would be operationally infeasible to move by other modes

- Tata Steel"

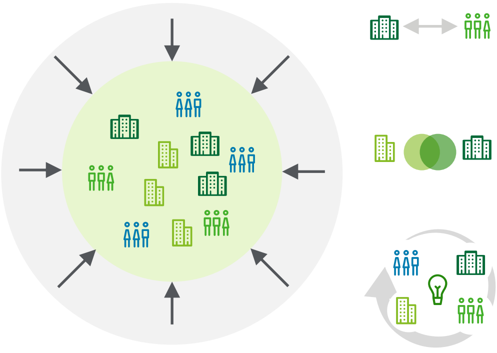
Supporting the functioning of the wider rail network

"Without rail freight services a number of key network functions, such as track clearing, would need to be brought into Network Rail

– Network Rail"

Source: FOCs, Network Rail, Rail Freight Customers

Other identified freight benefits – improved productivity through agglomeration



Matching

Ability to find suitable suppliers and workforce more quickly

Sharing

Ability to share inputs, supply chains and infrastructure (e.g. rail terminals)

Learning

Ability to share knowledge and ideas

[1]Throughout this report, non-user benefits, i.e. benefits of rail freight that do not accrue to rail freight customers, are termed social benefits and cover environmental effects, wider social impacts and other economic effects that accrue to wider society (such as through agglomeration). It is important to note in Transport Appraisal Guidance (TAG) published by DfT such effects are distinguished in a similar way. A mapping of the benefits assessed in this report and those in TAG is set out in Part 5 of this report.

[2] The initial approach to the quantitative assessment pursued was to gather detailed data from FOCs and wider industry to estimate distinct user benefits and distinct social benefits (as detailed above). However, the granularity and form of data required to do this was not possible to obtain at the time of writing. As such, the approach taken looks to estimate the broad magnitude of benefits delivered by rail freight (in terms of user and social benefits) in aggregate, and where possible breaks these down further. Further detail on the approach used is in part 4 of this report..

Rail freight is estimated to deliver £2.45bn of economic benefits to the UK each year, made up of £1.65bn of benefits to customers and £0.8bn to wider society

Based on the articulated benefits, operator, NR, ORR and DfT data has been used to estimate the broad magnitude of benefits for the UK economy in terms of economic welfare. It should be noted that such benefits are estimated agnostic to potential taxation implications (further discussion on this is detailed in Part 4).

Central estimates from this analysis are set out to the right and show benefits of **£2.45bn to the UK annually as of 2018/19,** roughly **three times the size of industry revenues**[1] comprised of **£1.65bn of user benefits** (including cost and time savings and reliability improvements) and **£800m in social benefits from modal shift** (including congestion relief, reduced carbon emissions, noise, better air quality and reduced safety incidence).[2]

In undertaking this assessment there is an extent of uncertainty with resulting estimated benefits due to the adoption of a number of assumptions, particularly regarding the nature of demand in the markets that rail freight serves. This includes making use of estimates for key relationships that have been developed for ORR (see Part 4 and the Appendix for more details). Further work should be undertaken to verify and refine such assumptions and is suggested as Part 6 below.

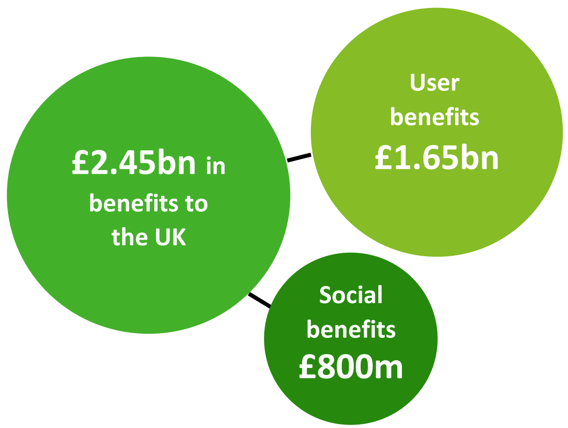
These benefits vary in their size across sectors. For sectors with high user benefits freight is an 'essential facility' as part of their businesses, while for sectors associated with high social benefits transporting by rail helps avoid congestion and emissions that would otherwise occur if transporting by other modes. Benefits overall are driven by:[3]

- Around **£1.1bn** in user benefits to **energy generating businesses** from providing an essential facility today with alternative modes of transport not readily available;
- Approximately **£500m** in environmental benefits from **intermodal and construction and aggregates transportation**, by facilitating haulage to be readily shifted from road to rail, resulting in reduced congestion and emissions; and
- Over **£250m** to the economy and wider society from **supporting the wider running of the GB rail network** through services provided to Network Rail.

In addition to these, limitations in the data imply that **the contribution of intermodal and construction and aggregates sectors may be underestimated**. For example:

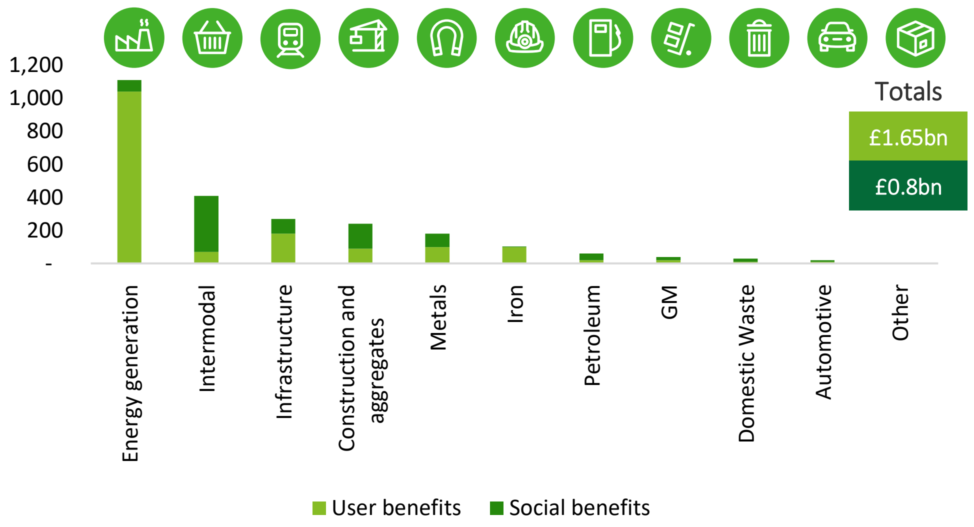
- Unquantified agglomeration benefits could be particularly pronounced in these sectors. For example, as rail freight has enabled the clustering of businesses at different stages in the intermodal supply chain (in places such as Doncaster iPort and East Midlands Gateway) in and around logistics hubs (see Part 2 for more information); and
- As benefits have been estimated using national values for specific inputs, specific higher value constructions flows into dense areas are potentially underplayed in the analysis (further detail on this is set out in Part 4)

Central estimate of rail freight benefits by type, 2018/19 (volumes and prices)



Source: Deloitte Analysis

Central estimate benefits of rail freight by commodity and type, 2018/19 (volumes and prices)[4]



Source: Deloitte Analysis

[1] Freight operator revenues are sourced from ORR. The comparison of estimated benefits to revenues is made to set the magnitude of estimates in context. It is not intended to provide an estimate of the split between user and producer value achieved in rail freight markets. Furthermore, the relationship between benefits and revenues is uncertain and is likely to change in future given the evolution of sectors served and the mix of growth expected across industries analysed (both of which have not been factored into this work).
[2] Deloitte Analysis
[3] IBID
[4] Overall benefits figures rounded to the nearest £50m throughout this report unless specifically set out otherwise

Rail freight supports economic activity and delivers social benefits across the country

While rail freight has been shown to generate economic benefit for the entirety of the UK, to provide an illustration of how benefits may accrue regionally (user benefits to customers, and social benefits to UK society), data from Network Rail on the origins and destinations of rail freight journeys made in 2018/19 has been used to apportion national estimates to NUTS1 administrative regions.[1] Further detail on the approach to apportionment is set out in Part 4 of this report.

Results of this analysis are set out in the table below and show that 90% of benefits likely accrue to freight customers and wider society outside of London and the South East[1] with notable concentrations generated by:

- Power stations and industrial centres in Yorkshire and the Humber and North West England;[2]
- Logistics and manufacturing hubs in the Midlands and Wales; and
- Container traffic from Deep Sea Ports to and between inland domestic terminals across the length of the country, from the South of England to the Central Belt of Scotland.

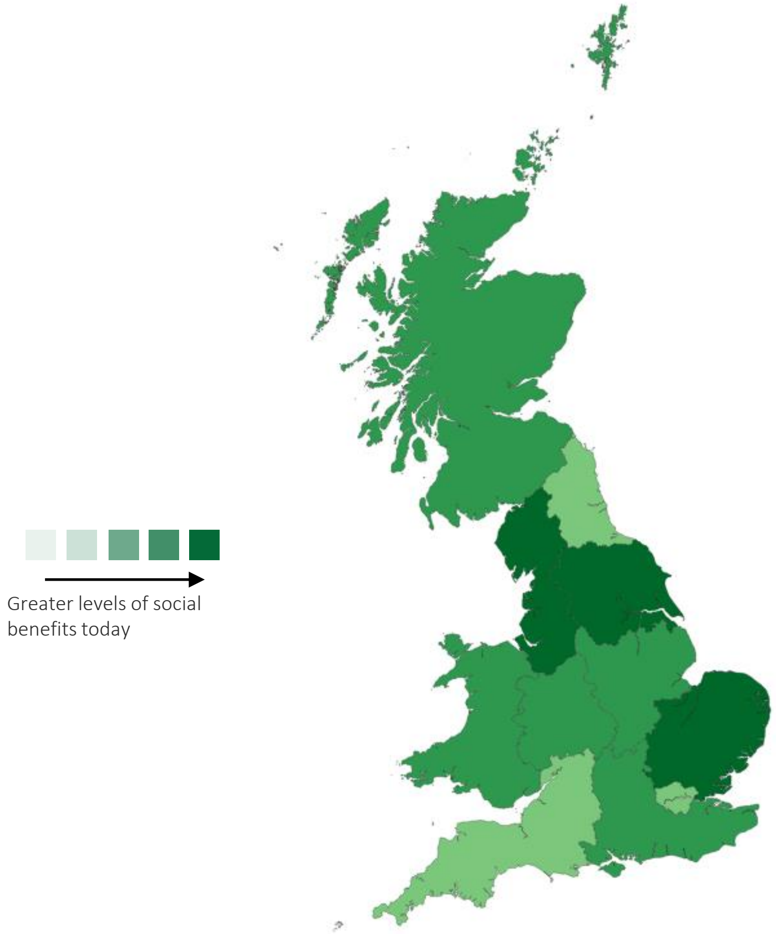
In addition, and as shown in the map to the right, social benefits are spread across the country.

Rail freight's economic contribution across the UK[3]

Region	Total benefits (£m, 2018/19)	% share (of total)	User benefits (£m, 2018/19)	Social benefits (£m, 2018/19)
Yorkshire and The Humber	860	35%	735	125
East Midlands (England)	375	15%	300	75
Wales	260	11%	200	60
North West (England)	225	9%	125	100
East of England	190	8%	45	145
South East (England)	120	5%	45	75
Scotland	105	4%	45	60
North East (England)	100	4%	65	35
West Midlands (England)	95	4%	35	60
London	75	3%	35	40
South West (England)	45	2%	10	35

Source: Deloitte analysis, Network Rail data

Dispersion of social benefits across the UK in 2018/19 (volumes)



Source: Deloitte Analysis

[1] NUTS1 regions split the UK into 12 areas varying by particular administrative definitions across the devolved nations. For more information on the regions please see: https://www.ons.gov.uk/methodology/geography/ukgeographies/eurostat
[2] The majority of benefits that accrue to Yorkshire and the Humber are accounted for by benefits from energy generation attributed by power plant location. In reality, the benefits of energy generation are distributed across the UK among onward consumers of power.
[3] Rounded to the nearest £5m.

Rail freight has the potential to play an important role going forward in supporting priority policy initiatives, such as net zero

Rail freight has the potential to support three key policy initiatives for UK Government going forward…

Going forward rail freight has the potential to facilitate and support the achievement of wider policy goals:

- **Net Zero** – through growth in sectors that facilitate a shift from road to rail, congestion can be relieved, and with decarbonisation of the rail network, rail freight can play a significant role in reducing emissions towards 2050;
- **Build Back Better** – through further investment, rail freight can '*oil the wheels*' of the economy and take pressure off roads and urban infrastructure to support the economic recovery post COVID-19; and
- **Levelling up** – through transporting larger volumes of goods over longer distances, rail freight can bolster connections to support dispersion of economic activity across the country.

… and could be especially in key in efforts to reach net zero carbon emissions

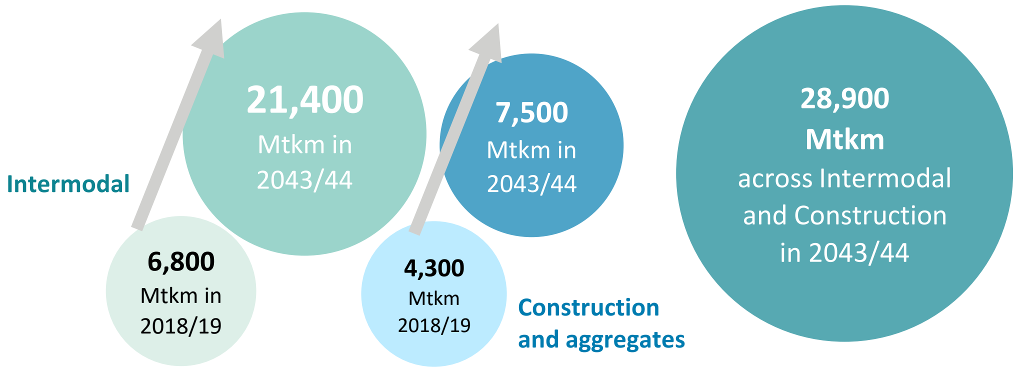
Today, the majority of social benefits delivered by rail freight are accounted for by congestion relief (and its impact on journey times), with other environmental benefits, for example, in respect of carbon reduction and air quality much lower than could be expected. However, this could change materially going forward as a result of:

- **Network Rail's Traction Decarbonisation Network Strategy** which establishes that rail is the best means for reducing emissions for the whole transport sector. It recommends the electrification of lines most utilised by freight traffic;[1]
- **Anticipated growth by Network Rail in intermodal and construction and aggregates** (see top right), which have the greatest ability to transfer goods to rail from road (which faces much larger technological challenges to decarbonise than rail); and

As an example of the potential 'size of the prize' in supporting efforts to decarbonise rail freight and support growth in these sectors, assuming decarbonisation were to decrease emissions by 90% from today's levels relative to road freight today, and that expected growth in intermodal and construction and aggregates was realised by 2043/44 (leaving all other sectors fixed) this could **increase social benefits by £400m-£600m per year**[3], depending on carbon price assumptions (see right). Furthermore, in multi-year appraisals **potential revisions to the Green Book discount rate applied to environmental benefits** could further increase the value contributed going forward.

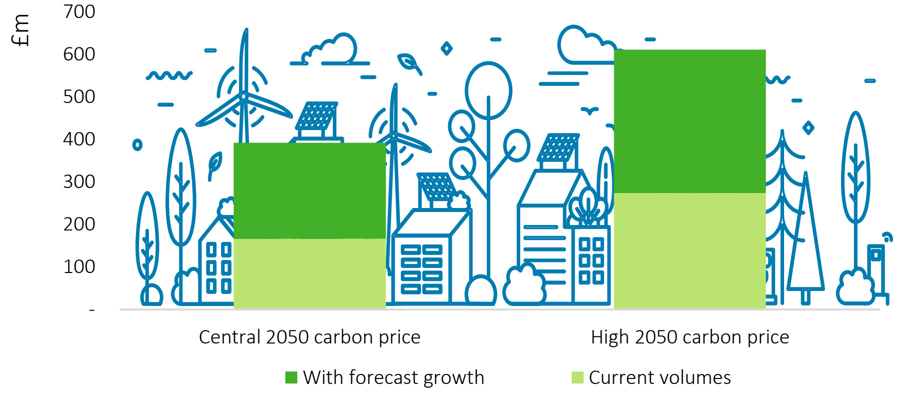
It should be noted that the analysis of changes in the size of environmental benefits with decarbonisation, changes to carbon prices and anticipated volume growth assumes no decarbonisation of road transport relative to today. This is likely to overestimate the impact of traction decarbonisation on rail benefits compared to road in the future. However, such an assumption has been made at the time of writing given that (i) road (HGVs), has more technological challenges to overcome to decarbonise than rail and (ii) as assumptions regarding decarbonisation of road freight are more uncertain.

Forecast growth in Intermodal and Construction & aggregates by 2043/44[2]



Source: Deloitte Analysis, Network Rail

Potential social benefits released (£m per year by 2043/44) were decarbonisation and volume growth realised



Sources: Deloitte Analysis, Network Rail, DfT, ORR

[1]Network Rail, 2020. Traction Decarbonisation Network Strategy: Interim Programme Business Case.
[2]Forecasts taken from Scenario E (central case/do-minimum) in Network Rail, 2020. Rail Freight Forecasts: Scenarios for 2033/34 & 2043/44
[3] Further detail on the approach taken to estimate such in incremental social benefits is set out on Page 56 of this report

For rail freight to play its part going forward, appropriate consideration of the benefits of rail freight in decision-making frameworks will be necessary

Today, the economic framework for industry decision-making only partially accounts for the role of rail freight…

Within the rail industry, **considerations for key strategic decisions vary between organisations** with different levels of emphasis being given to the economic benefits and costs of particular services:

- Investment decisions and analysis to inform modal shift strategy within DfT, Transport Scotland and Network Rail do incorporate an economic case for new policies, with analysis following principles aligned to the DfT's Transport Appraisal Guidance (TAG), as well as equivalent Scottish Transport Appraisal Guidance (STAG); and
- Capacity allocation decisions, train planning and access applications considered by ORR and Network Rail have some element of cost-benefit analysis rooted in similar principles, but also involve a range of operational and commercial considerations (for example, ORR's decisions must be made in line with all its Statutory Duties and Network Rail's in line with service plans and contractual obligations).

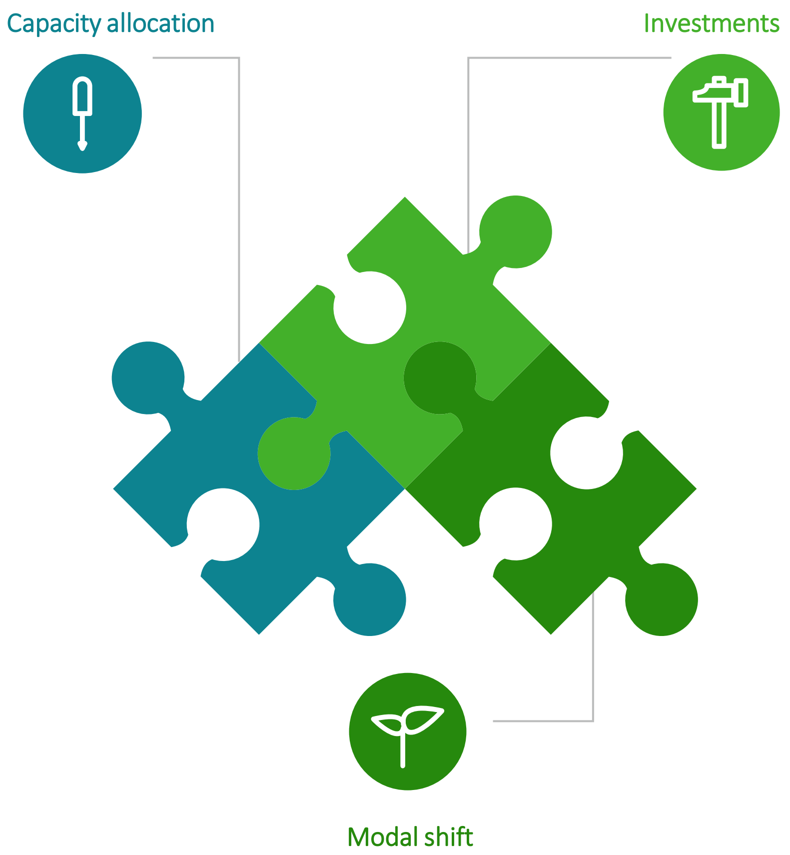
Notwithstanding these differences, **guidance followed and methods employed to assess the economics of particular decisions are typically based on articulating and quantifying a subset of potential freight benefits (especially non-user benefits)**.

DfT, Transport Scotland, Network Rail and ORR are conscious of this and **there is a wider impetus in the industry to move towards a net-benefit led approach to investment and capacity allocation decisions**. Furthermore, in making such decisions, in line with the recently revised Green Book, benefits analysed should be context-specific and holistic so that appropriate trade-offs can be weighed up between different options (including, in rail, both passenger and rail freight services).

… and to meet policy objectives most effectively will require a more holistic framework of assessment

For rail freight to play its role in supporting net zero, build back better and levelling up, the right investment, capacity allocation and modal shift decisions will be required from decision-makers across the industry including DfT/Transport Scotland, ORR and Network Rail. **To help inform such decisions there is a need to move forward to an integrated framework** which provides greater coverage of potential freight benefits and allows for them to be compared to the benefits of other services in a way that builds on established methods and guidance.

Areas of strategic decision-making important to inform freight's future role



This report has developed a potential framework to recognise freight benefits more fully and allow for comparison to other services for strategic decisions

The quantitative assessment of rail freight benefits yields useful values for decision-makers

The quantitative assessment of rail freight benefits yielded an overall figure for each sector served of the user and social value delivered to the UK today. Scaling this by the volumes for each sector served allows benefits to be expressed on a per tonne kilometre basis (as shown to the top right). This is important as the per tonne km values can then be used to estimate the benefits of particular services based on what commodity they carry, how much they carry of it and how far.

These, together with established guidance, have been built on to develop a framework for a more holistic assessment of freight benefits and value for money, particularly when compared to passenger services[1]

For investment and modal shift decisions as well as capacity allocation/access considerations, these values need to be integrated with established guidance on passenger benefits to allow for comparison between services. As part of this work a potential framework has been developed to do this, centred around four key steps:

1. Articulating the value of proposed freight services in general: drawing on the identified freight benefits (as set out in the table to the top right) together with assumptions of a particular service being considered to estimate the 'general' user and social value created.

2. Incorporating the value of a particular path/slot: if applicable, undertaking further analysis, to understand whether utilisation of a particular path by a freight service at a particular time offers benefits in excess of those estimated in this work.

3. Assessing the value of alternatives: assessing the value of a compare service by 'matching' freight benefits to the benefits assessed to the comparator service (e.g. time and cost savings of both services, environmental benefits through modal shift) – for instance, these may be passenger impacts (following guidance in the DfT's TAG/Transport Scotland's STAG) or another freight service (repeating 1 and 2).

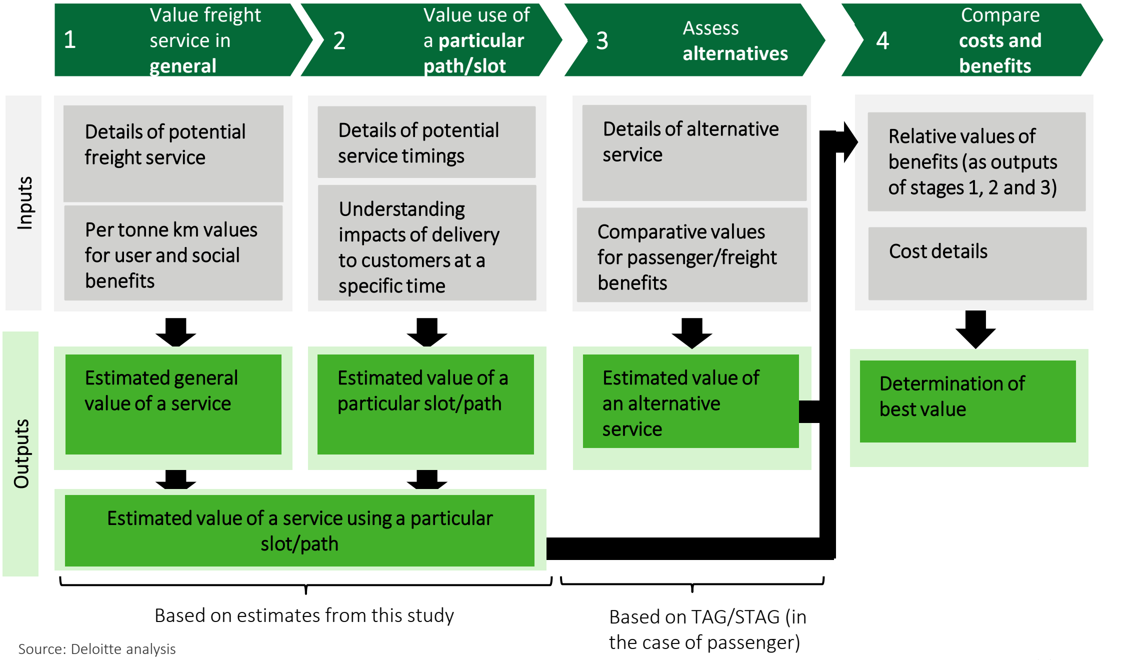
4. Comparing costs and benefits: drawing on the outputs from 1-3, to holistically compare benefits (value) across different services being considered. This may include further analysis of any differential costs between services/options as appropriate.

User and social benefits on a per tonne km basis for use in appraisals

Sector	User benefits (£m)	Social benefits (£m)	Volumes (Mtkm)	User benefits £ per Mtkm	Social benefits £ per Mtkm
Energy generation	1,040	70	2,200	470,000	30,000
Intermodal	70	340	6,900	10,000	50,000
Infrastructure	180	90	1,400	130,000	60,000
Construction and aggregates	90	150	4,500	20,000	30,000
Metals	100	80	1,300	80,000	60,000
Other	162	100	2,500	60,000	60,000
Total (all segments)	**1,640**	**820**	**18,800**	**90,000**	**40,000**

Figures are rounded. Source: Deloitte analysis

Overview of decision-making framework



Source: Deloitte analysis

[1]It should be noted that the results produced in this report and applied in the potential decision-making framework give an indication that the structure of the approach can be adopted for decision-making, but would require further analysis and research to overcome data limitations, in order to be used for accurate results and applicability to decision-making. As stated below in Part 2, the short-run nature of analysis implies that the current decision-making framework is best used for marginal network changes.

Illustrative case studies demonstrate how this can be used and could be built on by the industry to inform key decisions going forward

The framework has been applied in three instances to show how it can be used by decision-makers …

To illustrate how to apply the framework practically three high-level case studies have been analysed using rail freight operating company (FOC) and Network Rail assumptions to look at decisions that are likely to be relevant in making the case for capacity and investment in particular. These concern:

1. replacing an off-peak passenger service with a freight service on a semi-rural route carrying intermodal containers (as currently being considered due to congestion around the Port of Felixstowe);
2. passenger service with a freight service into a dense urban area in the peak and off-peak (for example, when considering further potential for transporting construction and aggregates into London); and
3. utilising a longer freight train, displacing a passenger service in the off-peak.

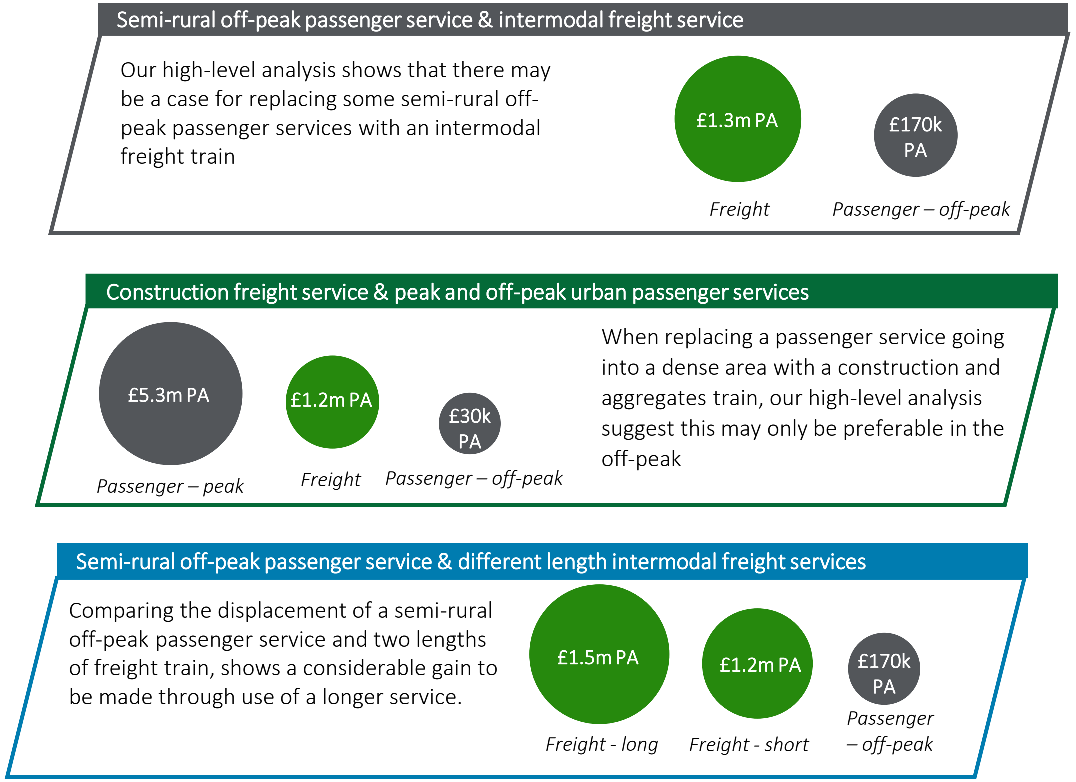
To showcase the kinds of comparisons that can be generated using the framework we have set out the results of the case studies to the right, with rationale and further detail set out further in Part 5.

… but to be most useful the work should be taken forward by industry for further development and integration into decision-making to inform key policy initiatives

The analysis of freight benefits and the decision-making framework developed as part of this work provides a step forward for the industry's tool-kit to support decision-making that could inform capacity allocation, modal shift and investment to support net zero, helping to build back better and levelling up. However, for the work to be to become embedded within the industry it will require three key next steps:

1. For the industry to **work together to develop, utilise and share further data to provide assurance on the type and size of freight benefits** for use in future (for example, to help distinguish between the different types of user benefits – time savings, cost savings, and reliability improvements, as set out for passenger appraisals)
2. For DfT and Transport Scotland to take the work on-board to **support a more holistic assessment of freight benefits in further iterations of transport appraisal guidance** alongside the recently revised Green Book; and
3. For Network Rail and ORR to **utilise the work practically as one of the inputs when considering train planning, capacity allocations and access decisions** as far as possible alongside operational and other considerations.

Illustrative comparison that can be made using the framework (based on 2018/19 volumes and prices)[1]



Source: Deloitte analysis, FOC and NR assumptions

[1]It is important that the comparison made in these case studies are simple, partial and high-level and are dependent assumptions provided by freight operators and Network Rail. Were alternative assumptions to be utilised results would differ to those set out above.

Part 1

Introduction

An introduction to the GB rail freight sector

Rail freight supports a diverse number of sectors across the economy and plays a key role in GB logistics chains

An overview of the structure of the rail freight industry

In Great Britain,[1] rail freight historically carries around 10% of total goods[2] in the wider freight and logistics sector. Services are provided by a small group of private companies including DB Cargo UK, Freightliner, GB Railfreight, Colas Rail, Devon and Cornwall Railways and Rail Operations Group as well as public subsidiary Direct Rail Services (DRSL). As of 2019/20 DB Cargo has the largest market share by train kilometres used (37%), closely followed by Freightliner (33%) and GB Railfreight (21%).[3]

Rail freight's role in the UK economy today

The sectors served by rail freight companies are set out to the right, together with the size of freight operations (in Mtkm).[4] As shown:

- the largest segments are intermodal (carriage of containers within GB to and from ports and between distribution hubs) as well as construction and aggregates (including key flows into building sites in dense urban centres);
- rail freight supplies significant services to Network Rail including to support maintenance through movement of material and upkeep and resilience of the network to support passenger operations (e.g. clearing Autumn leaves from the tracks); and
- the industry also supports key strategic sectors from an energy perspective – carrying biomass and nuclear material for/from power generation facilities across the country and to a lesser extent coal (whose volumes have significantly decline over the last 5-10 years.

Rail freight's role in integrated supply chains

Rail freight is often chosen by customers ahead of road and waterways when they require transport (i) of large volumes, (ii) over long distances and/or (iii) through dense areas. In contrast road is typically used when carrying small volumes over small distances or when flexibility is required with respect to diversionary routes (e.g. time-sensitive delivery).

However, for the largest sectors served (intermodal and construction and aggregates), each mode forms part of an integrated supply chain. In these circumstances, rail freight takes on the roles set out in (i-iii) above with road facilitating first/last mile delivery and shorter rural journeys, or performing excess haulage under capacity constraints endemic to the rail network. The same is also true for export and import of goods from/to ports, with rail freight forming a key 'artery' to the rest of the UK in particular sector (particularly intermodal) and relieving significant road congestion.

This type of complementarity has led a number of customers to set up their business models to optimise rail-road-waterway usage to deliver in the most efficient and timely manner. For example, in the case of biomass – transporting wood pellets to ports from abroad and then utilising rail to get this to energy generators; or in the case of metals, using rail to traverse long distances and road as a last mile alternative between a localised delivery or works area.

Rail freight volumes 2018/19, by sector served

Segment	Description	Size (volume: Mtkm)
Intermodal	Freight transported in containers. This can cover a variety of different goods, often finished consumer goods. This includes, domestic, deep sea and international intermodal traffic.	6,900
Construction/ aggregates	Construction materials, including aggregate materials.	4,500
Energy generation	Power station fuels including coal, biomass pellets and nuclear material	2,200
Network Rail	Services provided to Network Rail to support the wider rail network with maintenance and other activities.	1,400
Petro/Chem	Oil, petroleum, chemicals, and industrial minerals	1,400
Metals	Metals and steel, including finished and intermediate products.	1,300
GM	General merchandise, including products such as mineral water, wood and paper.	400
Domestic Waste	Domestic waste, e.g. to landfill.	400
Iron	Iron ore.	120
Automotive	Finished cars and components.	100
Other	Other rail freight including Royal Mail and premium logistics.	30

Source: Deloitte Analysis, Network Rail Data

[1]Note that the transport infrastructure considered for analysis excludes links in Northern Ireland. Therefore, references to infrastructure apply to GB, though benefits accrue the UK collectively.
[2] Volumes of goods - ORR (2020) "Table 1350 – Rail freight market share", see here
[3]ORR (2020) "Table 13.25 – Freight train kilometres by operator", see here,
[4]Network Rail Data 2018/19

The need for a better understanding of the benefits of rail freight

Existing work has established channels of rail freight benefits, but has not articulated these fully

Existing work and analysis on the economic benefits of rail freight

Given the role played by rail freight today it is likely to offer a number of benefits to the UK economy. In addition, due to environmental advantages of rail transport in certain circumstances compared to road in respect of carbon, noise and other factors, carriage of goods by rail may also provide broader social benefits. Work to understand and assess these benefits includes:

- Work undertaken for RDG (2018) which found significant cost savings and environmental benefits from the use of rail freight over road to transport current volumes (see right); and [1]
- The analytical framework to assess transport benefits as set out in the Department for Transport's (DfT's) Transport Appraisal Guidance (TAG) [2] and Scottish equivalent, STAG[3], which identify the benefits from modal shift environmental benefits that could arise through use of rail freight and vehicle operating cost savings to operators – also see right. Note that a subset of these would be quantified in practice.

However, this previous work and guidance focuses only on a subset of potential freight benefits, and of those analysed, full 'transmission mechanisms' have not been articulated.

Opportunities for advancing the understanding of its benefits to inform rail freights role in supporting policy imperatives

Going forward rail freight has the potential to facilitate and support the achievement of wider policy goals:

- **Net Zero** –through growth in sectors that facilitate a shift from road to rail, congestion can be relieved, and with decarbonisation of the rail network, rail freight can play a significant role in supporting the UK's achievement of net zero emissions by 2050;
- **Build Back Better** – through further investment, rail freight can '*oil the wheels*' of the economy and take pressure off roads and urban infrastructure to support the economic recovery post COVID-19; and
- **Levelling up** – through transporting larger volumes of goods over longer distances and connecting cities across the country.

To play its part though will require the right decisions to be made concerning investment, capacity allocation and modal shift across the industry. Given the current evidence, guidance and wider literature on the benefits of rail freight there is a need to articulate a fuller understanding of rail freight benefits; quantify a wider set of benefits than previously understood and develop a framework which allows for freight benefits to be compared to the benefits of other services.

Existing studies/guidance on the benefits of rail freight

RDG (2018)

RDG commissioned consultants to undertake a high-level assessment of freight benefits to the UK economy. They estimated total benefits of £1.7bn (2016 prices) to the UK economy focussing on:

- *Cost savings* from use of rail freight to transport current volumes than road; and
- *Environmental benefits* which represent the modal shift benefits in respect of carbon, noise, air quality and other factors over use of a road alternative for current volumes.

DfT/TS – TAG/STAG (2020)

Within the DfT's TAG, freight benefits are confined to the analysis of:

1. *Environmental benefits* focused on modal shift when compared to freight transport on road; and
2. *Benefits to operators* (rather than customers) in respect of operating cost savings (e.g. in respect of staff, rolling stock etc); and

Further analysis of benefits would be considered within DfT's 'supplementary economic modelling guidance' used to assess effects not captured within TAG – creating the need for a greater evidence base to assure DfT of the robustness of these benefits for inclusion in decision-making.

[1] RDG, Rail Freight working for Britain 2018.
2 DfT (2018), "TAG Unit A5.3 – Rail Appraisal", see here https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/940959/tag-a5-3-rail-appraisal.pdf & DfT (2019), "TAG Unit A3 – environmental impact appraisal", see here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/940947/tag-unit-a3-environmental-impact-appraisal.pdf
3 STAG is aligned to the principles of TAG and so when references are made throughout the document to TAG they also apply in relation to STAG also, unless specifically noted

Scope and structure of this report

The remainder of this report is structured as outlined below

Scope:

Given the need for a greater understanding of the benefits of rail freight to the UK economy, Deloitte has been commissioned by the Rail Delivery Group Ltd (RDG) to carry out a study on the value of rail freight.

The key objectives of the work are to:

- Articulate a holistic set of benefits that rail freight may generate for customers, the UK economy and wider society (including the environment);
- Assess such benefits qualitatively, and where possible, quantitatively (including at a disaggregated level); and
- Utilise this work to develop a potential framework to assess the benefits of freight services, building on what is set out in existing appraisal guidance, to support future decision-making on the railway, for example where alternative services are considered under conditions of scarce capacity.

This report sets out the technical work and results that Deloitte have undertaken in this regard as a first step in supporting RDG and the wider industry in addressing the current gap in the evidence base, and in supporting future decision-making. However, this work is not the end in itself, and for it to support decision-making in relation to upcoming key policy initiatives will require the work to be taken forward for further development.

Given the technical nature of the report, it is intended for use by analysts and decision-makers across the industry. It is supplemented with a shorter, non-technical report for wider consumption entitled “*The Role and Value of Rail Freight in the UK*” which is available alongside this document.

Structure:

This report is structured into the following parts:

2	Benefits of rail freight	This sets out an articulation of the economic benefits of rail freight at a conceptual level
3	Assessing the benefits of rail freight	This describes the qualitative and quantitative approach to assessing freight benefits
4	The value of rail freight to the UK economy	This sets out the assessment of freight benefits from both a qualitative and quantitative perspective
5	Applying the framework for decision-making	This outlines how the conceptual and quantitative work can be used to inform decisions relating to rail freight policy going forward
6	Conclusion and next steps	This highlights the opportunities for building upon this work to expand the evidence base further in future
A	Appendix	This sets out supporting detailed material for the main document

Part 2

Benefits of rail freight

Overview

Principles of the approach

To articulate the benefits of rail freight, understand the value the sector brings to the UK economy and establish a basis for decision-making, three principles have been adopted:

A framework that captures a holistic set of freight benefits value of rail freight

Previous work has tended to look at the economic effects of rail freight through a narrow lens as set out above. However, in reality rail freight offers a number of benefits to both users and society more widely. The approach is to develop a wide-ranging framework that recognises freight's role in allowing its customers' industries to operate more effectively than they otherwise could, as well as the support it offers to the environmentally friendly transport of goods.

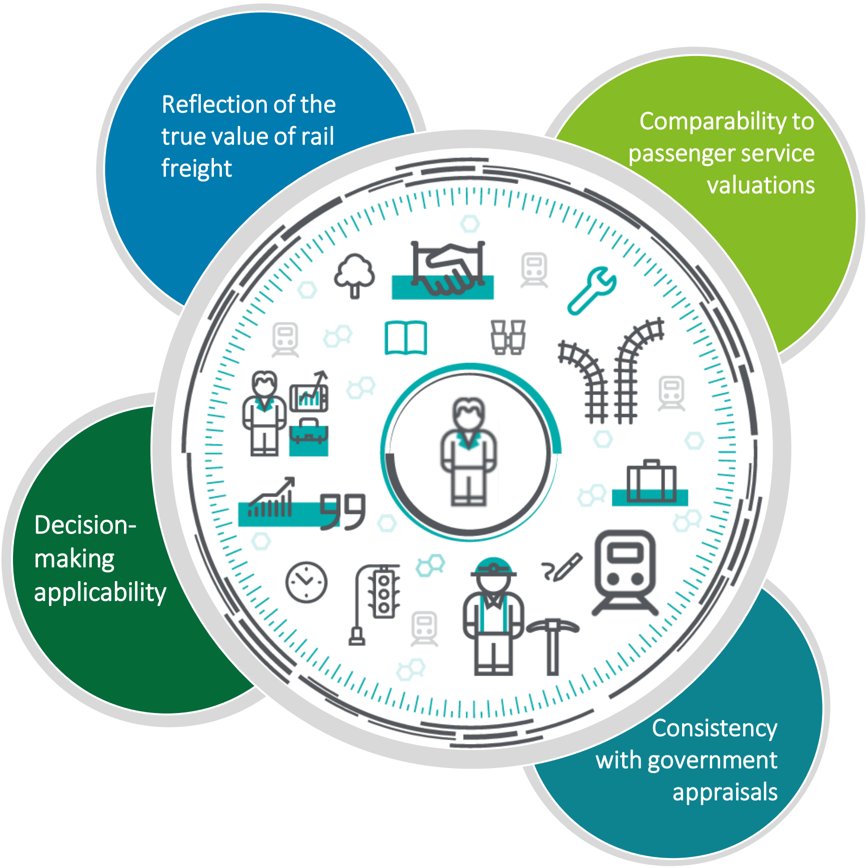
To achieve this, the framework looks to draw on practical customer and stakeholder insight as well as principles of microeconomic theory, which considers the decisions made by market participants (i.e. FOCs and freight users) and the value generated as a result. The framework also draws on analysis of social and environmental effects as used by Government Departments for appraisal.

A framework that is consistent with core principles of transport appraisal

To enable decision-making in a policy context, the framework seeks consistency with core principles for appraisal including, but not limited to, HM Treasury's Green Book, DfT's TAG and Transport Scotland's STAG. The approach is intended to enable the method to be built upon and deployable across a range of decisions, including investments and business cases, capacity allocation and modal shift decisions and access determinations (where possible and balanced against other considerations). This aims to extend the frameworks and principles already in place, and apply them in a freight context.

A framework that enables comparison with passenger service valuation

The appraisal framework for making decisions in a passenger context in rail is already well-established through TAG and STAG. For rail freight to be assessable at this level, and to enable potential trade-offs to be based on evidence, the framework for rail freight must closely correspond to the passenger framework.



Approach to articulating the benefits of rail freight

To articulate the benefits of rail freight two key steps have been followed

Establishing a base for comparison

The benefits of rail freight have been assessed as the implied social loss from the removal of all rail freight services today. This means assuming that benefits are assessed relative to a counterfactual in an economic 'short run' scenario, where at current sector volumes all rail freight services are removed, with goods transported by alternative modes (leaving all else fixed). Such an approach is appropriate given the intended use of the outputs of the work to support decision-making at a marginal level across the network.

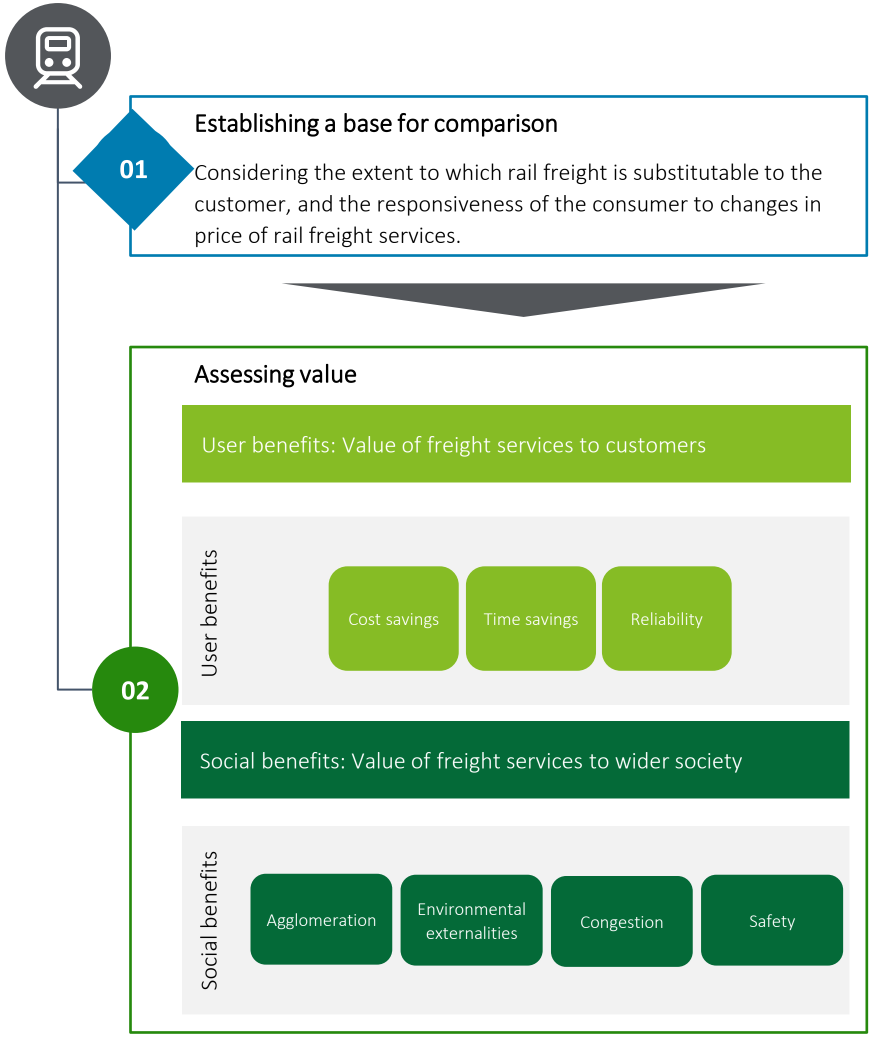
In utilising such a counterfactual it is important to note that:

- in assuming current sector volumes this will underplay the benefits of growth in the coming years in specific sectors (e.g. in respect of construction and intermodal traffic – as set out in Part 4); and
- were a long-run assessment undertaken, where there was more flexibility in the economy, benefits would be expected to be lower as freight customers could re-optimise how they ship goods across modes over time.

Assessing value

Following the assumption of a short-run counterfactual, two main components of the value rail freight creates have been defined.

- **User benefits** including:
  - **direct costs savings** to users from being able to transport goods over longer distances, at greater volumes or through more dense areas more cheaply on average than when compared to alternatives;
  - **direct time savings** to users when compared to alternatives that utilise slower routes for particular journeys; and
  - **reliability benefits** from more certain journey and delivery times of goods relative to other modes for certain routes.
- **Social benefits** including:
  - **productivity gains through facilitating more efficient supply chains and agglomeration**; and
  - **environmental, safety** (avoided incidents) and **congestion benefits** through modal shift[1].



[1]Note that these accrue through consumption of the freight services employed in the value chain, rather than the production or consumption of the commodity transported. This, for instance, enables environmental benefits in the transport of fuel (including coal and biomass) and nuclear material as the use of rail saves emissions relative to the use of other modes.

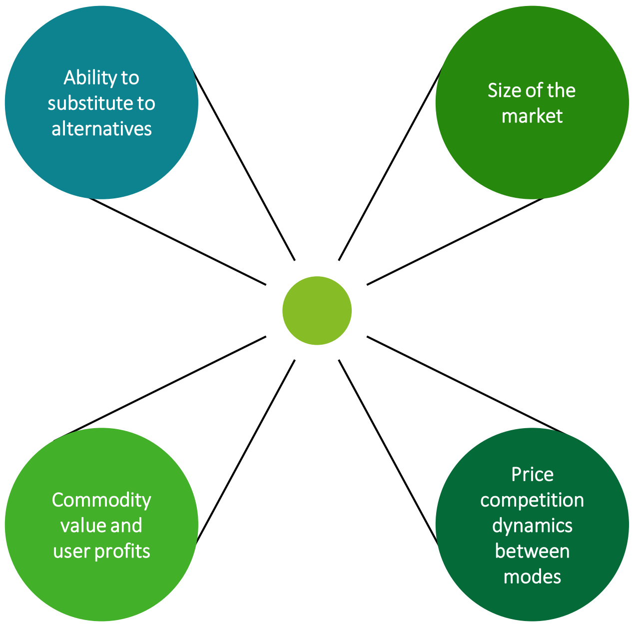
Segmentation of the rail freight market

The size of the value to users may differ across users, i.e. across commodities

Based on the counterfactual, both user and social benefits are likely to differ across segments of the market. This is driven by a number of factors, which are outlined below and detailed further throughout the remainder of this report in relation to specific sectors.

The table on the right then summarises the customer segmentation of the rail freight market utilised in this analysis to articulate the different magnitudes of user and social benefits in the assessment.

Factors that may influence user value



Segment	Description
Intermodal	Freight transported in containers including domestic, international and deep-sea intermodal. Containers transported can cover a variety of goods, often finished consumer goods.
Construction/aggregates	Construction materials, including aggregate materials.
Network Rail	Services provided to Network Rail to support the network with maintenance and other activities.
Petro/Chem	Oil, petroleum, chemicals, and industrial minerals.
Metals and iron[1]	Metals and steel, including finished and intermediate products. Also includes iron ore.
Energy generation	Power station inputs including coal, biomass pellets and nuclear material.
GM	General merchandise, including products such as mineral water, wood and paper.
Domestic Waste	Domestic waste, e.g. to landfill.
Iron	Iron ore.
Automotive	Finished cars and components.
Other	Other rail freight including Royal Mail and premium logistics.

Source: Network Rail

[1]Note that metals and iron are treated individually in quantitative analysis, though are grouped as "metals and iron" in qualitative analysis and written narrative to reflect the common industry they serve.

Part 2-1

User benefits

Assessing user benefits

An overview

User benefits are those that customers of rail freight obtain by choosing rail over alternatives. Based on a number of consultations with customers, and with a view to establishing parallels with the passenger framework, several benefits have been identified. These benefits generally represent areas where rail freight allows customers to transport commodities more effectively than they otherwise could - be that more cheaply, quickly, efficiently, or practically and operationally effectively and may be summarised into three key types:[1]

- **Cost savings** relative to available alternatives, including fees. Users of rail freight may reap cost savings due to scale economies offered by rail and the comparative advantage offered by rail in performing transhipment services. Such cost savings may be passed on to end consumers of commodities across sector (e.g. in respect of power costs in the energy generation sector)

- **Time savings** compared to the journey times of available alternatives to rail freight. Rail may offer quicker transportation than other modes in certain circumstances (although customer are constrained when services can run), and thus improve productivity.

- **Reliability** in terms of deviations of actual from expected journey times. Rail may offer increased reliability over other alternatives on average, but it should be noted that road transport in particularly offers great flexibility in relation to diversionary routes when incidents occur.

In assessing rail freight user benefits today relative to the counterfactual, the extent of such benefits depends on the extent to which customers could switch to use of alternative modes (i.e. how substitutable road and waterways for instance are to transport goods). For example:

- for customers that have set up their businesses to transport goods from ports to hubs using rail over long stretches with less motorway coverage for the analogous route, road freight may be a less viable alternative. This in turn means if it was used as an alternative it would cost significantly more and may take significantly more time to transport the goods; but

- in some cases rail may be difficult to use, with other modes being more advantageous. For example, road or water can be significantly cheaper and more flexible than rail freight in certain places or over certain distances.

Substitutability itself is affected by the factors set out to the right.

Example of user benefits

The value of rail freight to a construction company operating in central London, Edinburgh or Cardiff is the **money** and **time** saved by using rail freight compared to an alternative (say, moving aggregates into London by road). Regulations, capacity limits and physical restrictions may likely make using road a highly cumbersome and costly activity. In addition, rail may be more effective at delivering materials at **reliable** pace for some customers, particularly at peak times, as rail is not subject to similar congestion variability.

Factors that impact substitutability

Access
It may be unlikely that other modes would be able to obtain sufficient access to the location, e.g. if the alternative would run danger of overburdening local roads through higher volumes of traffic in rural areas.

Cost
Other modes may be too costly to be a viable alternative. For example, the construction industry achieves low profit margins, and these may run danger of being eroded through costlier modes.

Regulations
There may be safety regulations prohibiting other modes, e.g. nuclear material. Rail infrastructure offers diminished dimensionality of threat relative to alternatives.

Size
Other modes may not offer sufficient capacity to be able to accommodate the size of some bulky materials, or transporting similar volumes may be infeasible.

Operations
It may be operationally inefficient or infeasible to use other modes. For example, achieving a reliably stable flow of high volume inputs is key to some industries, and rail freight is best placed to meet this.

[1]Note that these impacts are not conditional on particular permissible freight train loads. Due to variability and commercial sensitivity, train loads and locomotive types are treated on an average basis across the work.

Assessing user benefits

Cost savings result from economies of scale, whereas time savings may arise from efficiencies at terminals

Cost savings

A key potential benefit to rail freight users derives from cost savings. Rail freight customers have explained that rail tends to offer cost advantages over other modes when high volumes are transported (in terms of quantity, bulk or weight), or when goods are transported over large distances – i.e. rail has economies of scale, in both volumes and distance. While in contrast, road for instance has a fairly constant average cost/price per mile or per tonne, and excels when used to carry small volumes over small distances. This said, in some segments – particularly those providing door-to-door service such as retail and parcel segments – road can and does serve high volumes and long distances at competitive cost.

To illustrate this benefit the right hand diagram illustrates a 'price function' for rail freight and its closest alternative. It sets out how these price functions could look when relating per unit price to distance (although this may also apply for a range of other factors) when transporting commodities by road, the total price per unit increases at a constant rate, based on actual data. However, whilst rail incurs high fixed costs (for example, the cost of a locomotive or of trailers), the incremental cost of additional units tends to decrease as larger distances are covered to 'spread' fixed costs.[1] For example, for intermodal traffic into and out of ports, charges and transfer costs are fixed per train or per 'lift' onto trains. As such, for low volumes per unit costs are high while for larger volumes these are spread more thinly.

Customer views: Customers tend to state that rail becomes the cost effective mode:

- When transporting **large volumes**;
- When transporting goods **over long distances**;
- When exploiting outbound and **return journeys**; and
- When it is necessary to deliver into **large urban centres**.

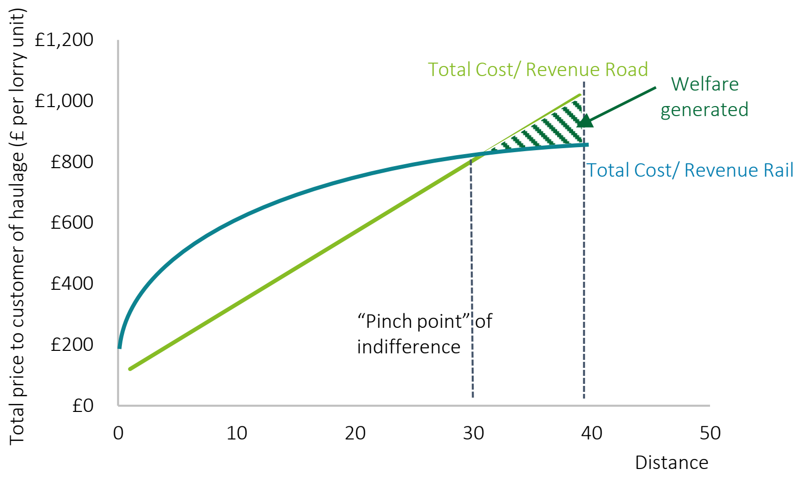
> "The low cost and bulk of our product makes road a commercially unviable option
>
> **– Construction and aggregates business**"

Time savings

A further benefit to customers from using rail freight over and above cost savings is the benefit they experience in terms of increased productivity and/or utility from faster delivery times versus the closest alternative for certain journeys. These time savings tend to arise from the ability to cover greater distances more quickly, or less congestion in key parts of the logistics chain compared to alternatives, such as at terminals at ports. Customers tend to note that in order for rail to generate such time efficiencies in practice though, careful logistical planning may be required.

[1]Note that in some instances there may be some impact of rail and road usage on each other, for example when using rail with road for first- or last mile road haulage. In addition, the costs of transhipment while important are not factored into this analysis.

Illustration of cost savings benefit



- As shown above, for average data on actual road haulage, prices tend to rise in a linear fashion (green line) with distance transported.
- Though data was not available at the required granularity for comparison for rail, based on engagement of customers and other stakeholders it is expected that there are economies of scale such that the equivalent rail prices follow the blue line.
- Given this, cost savings to customers for use of rail freight are expected beyond this point and are realised through gains in economic welfare.

Source: Deloitte analysis of average road haulage price data sourced from FOCs

Assessing user benefits

Reliability benefits refer to lower variability of rail journey times compared to other modes

A final potential user benefit identified by customers and stakeholders is the decreased variability in journey and delivery times it offers relative to other modes for certain routes, with benefits expected to be particularly pronounced when transporting large volumes.

In the passenger context this is referred to as reliability and is often conceptualised as the reduction in the standard deviation in journey times between modes (primarily driven by decreases in actual and expected journey times).[1]

Reliability gains, if present, are likely to vary between customers depending on the potential for and type of disruption that could occur over time. This in turn may depend on a range of factors such as:

- location of supply routes to or from customers;
- Used or spare capacity on the network;
- Interfaces with other rail service types or transport networks.

In addition, while the 'average' reliability of rail measured by delays is expected to be superior, when delays do occur in specific circumstances on the railway, short-term impacts tend to be much more pronounced for customers (see right).

Furthermore, while reliability benefits focus on the variance of overall journey times, it is important to note that other modes, particularly road, offer certain flexibility with respect to time-sensitive deliveries that may not be realised in observed variances of journey times, but nonetheless have value. Consider, for instance, the impact of the availability of auxiliary diversionary routes. In practice, freight users design their logistics paths carefully to capitalise on the advantages each mode can offer within their supply chain, particularly to help minimise disruption.

Customer views

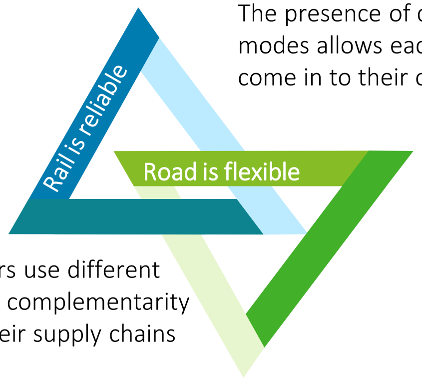
"Rail freight is not just about cost savings for us – it is reliable and enables a better business model"
– Construction and aggregates business

"Reliability of our supply chain is key for our business. Rail generally offers this"
– Drax

"Rail freight is generally more reliable, but we incur contingency costs to hedge against disruption"
– Aggregate Industries

Rail freight tends to be very reliable, though incidents of delay tend to have larger impacts

The presence of different modes allows each to come in to their own



Customers use different modes in complementarity to suit their supply chains

[1]Note that when referring to reliability, what is meant is the average level of deviation from expected journey times for users. However, conceptually there may be benefits over and above this accruing to others (non-users/wider society) from variances in reliability around peak and troughs in traffic (for example at ports).

Part 2-2

Social benefits

Assessing social benefits

There are also benefits on wider society from customers choosing to use rail freight

When customers choose rail freight, there may also be consequences for wider society, here referred to as social benefits. These are also often referred to as 'externalities' or external impacts.[1]

Similarly to wider impacts in a passenger context, and as outlined in TAG, these tend to comprise the following:

- **Societal economic benefits (e.g. agglomeration):** Agglomeration benefits refer to improvements in productivity brought about by increases in effective economic density. Rail freight can support such increases in effective economic density by allowing for more efficient supply chains and facilitating the creation of logistics hubs where firms can co-locate.
- **Environmental benefits:** These refer to net reductions in emissions generated by mode shift and the use of different fuel types in hauling freight.
- **Other social benefits:** Customers choosing rail freight instead of other alternatives may also impact on wider society in other ways. For example, different modes tend to have different
  - **congestion benefits;**
  - **safety benefits** capturing avoided incidents;
  - **wear and tear effects** on the infrastructure network; and
  - **other benefits.**

Each of these is described in more detail overleaf.

Example of social benefits

The social value of rail freight for a construction company operating in an urban centre and using rail over road to transport aggregates to the city centre includes:

- **environmental benefits,** as rail produces fewer emissions that harm air quality and the climate;
- **congestion impacts**, as usage of the road network in cities tends to be high, such that additional use imposes high costs on other users in the form of congestion and delays; and
- **safety impacts** as rail on average tends to be a *safer* mode than others (for example compared to road), due to the reduced labour intensity of rail haulage, the relative distance from other transport users, and the limited dimensionality of threats to safety and security on rail infrastructure.

[1]Note that these impacts are not conditional on particular permissible freight train loads. Due to variability and commercial sensitivity, train loads and locomotive types are treated on an average basis across the work.

Assessing social benefits

Agglomeration refers to productivity improvements from increases in effective economic density

As set out above, rail freight allows for the development of more efficient and integrated supply chains allowing for increases in productivity (which may ultimately be passed on to users in the form of cost and time savings and reliability improvements). However, in addition to these there is also conceptually the potential for rail freight to play a part in supporting firm agglomeration, which could generate further productivity benefits.

Transport infrastructure and agglomeration

Transport infrastructure investments can lead to agglomeration through increases in effective economic density in the form of:

- **Static clustering**, where transport connections, such rail terminal expansions, enable travel time reductions to bring people and businesses 'effectively closer', without people or businesses physically moving; and/or
- **Dynamic clustering**, where transport connections induce individuals and businesses to physically co-locate.

Higher Economic density may then improve productivity through better sharing, learning and matching between individuals and businesses (see a consolidated list of potential mechanisms to the top right).

Potential agglomeration gains from rail freight

Similar to the effects generated by other major transport hubs, such as ports and development around major road links, clustering of firms around a rail freight head could improve productivity through increased:

- sharing of goods and facilities, for example from co-location at rail heads;
- sharing of risks between freight operators and their customers; and
- sharing gains from variety by rail freight providing a wider variety of goods to potential customers than absent its availability.

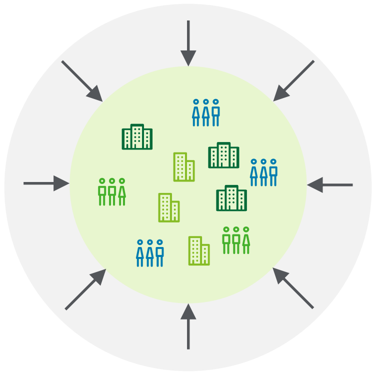
Such sharing may then increase firm productivity and promote other beneficial spillover effects for businesses.

Empirical evidence[2,3,4] suggests that agglomeration economies observed to date, particularly generated by 'static clustering', are predominantly generated from worker related interactions, rather than the transportation of goods – as with freight. This may suggest that the size of these potential benefits is modest.

However, available evidence does not preclude the potential for rail freight to support productivity improvements from 'dynamic clustering' where a rail head induces inward investment and the clustering of businesses related to sectors where freight creates greater value over alternatives modes.

Examples of where such clustering has occurred can be seen across the UK in the form of new logistics hubs (see right) and the historical experience of how aggregates businesses have designed their operations.

Sources of productivity improvements through agglomeration – from Duranton and Puga (2004)[1]



Matching

Ability to find suitable suppliers and workforce more quickly

Sharing

Ability to share inputs, supply chains and infrastructure (e.g. rail terminals)

Learning

Ability to share knowledge and ideas

Examples of firm clustering in logistics hubs

The existing empirical literature does not allow for an assessment of freight productivity gains from agglomeration. However, contextual evidence of rail freight facilitating firm clustering can be found. Intermodal hubs such as Doncaster iPort and East Midlands Gateway in England provide evidence of where a rail head has been established, around which businesses from across the intermodal supply chain have invested and co-located.

For those lower down in the supply chain who have logistics arms such as Maritime, DHL, IKEA, Amazon, this will be to achieve cost savings, but for others further up, such as manufacturers like Nestle and Fellowes, there are likely to be advantages from learning and sharing facilities with these other businesses, that are not available elsewhere. These advantages could then enable productivity improvements for companies.

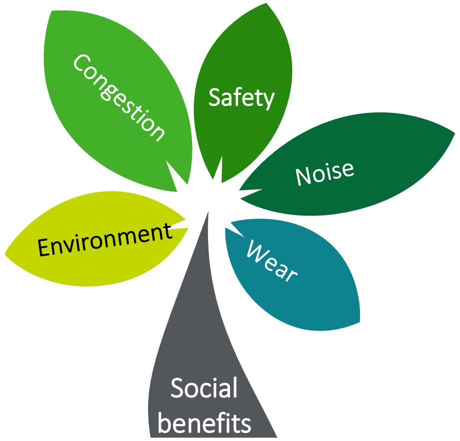
See: iPortrail, 2020. Leicester Mercury, 2018.

[1] Duranton & Puga (2004) Chapter 48 Micro-foundations of urban agglomeration economies. *In:* Henderson & Jacques-Francois (eds.) Handbook of Regional and Urban Economics.
[2] Carlsen, Rattso & Stokke (2016) Education, experience, and urban wage premium. Regional Science and Urban Economics.
[3] Orpi & Clark (2017) Migration and occupational careers: The static and dynamic urban wage premium by education and city size. Papers in Regional Science.
[4] De la Roca & Puga (2017) Learning by Working in Big Cities. The Review of Economic Studies.

Assessing social benefits

There are also other benefits to society from modal switch

The other social benefits from modal switch (i.e. from using rail compared to other alternatives) include those listed below.[1,2]



Environmental benefits: Different modes vary in terms of fuel intensity and have different emission profiles. Rail tends to have lower emissions of gases that impair air quality or harm the climate, compared to other modes – particularly road. **Emissions from rail are 76% lower than those from road,** and rail reduces the social cost of **greenhouse gas emissions** by 86%, and improves **air quality** costs by 16% per avoided lorry km. Rail thus plays a key role in decarbonising the UK economy. Notably, the ongoing decarbonisation of the rail network itself may further contribute to rail's environmental a contribution (see Part 4). However, this will require significant further investment going forward (see Parts 5/6)

Congestion benefits: Social costs imposed on other users of the network in terms of journey time or reliability differs across modes. Additional rail traffic tends to impose 98% less congestion on the network than road.

Safety benefits: Incidence of adverse safety implications from carriage including medical and human loss costs which differ between alternatives. Rail tends to be less likely to lead to injury or loss of life than other modes of transportation, and in particular road.

Noise benefits: DfT estimates that rail freight imposes 82% less noise nuisance compared to lorry traffic.

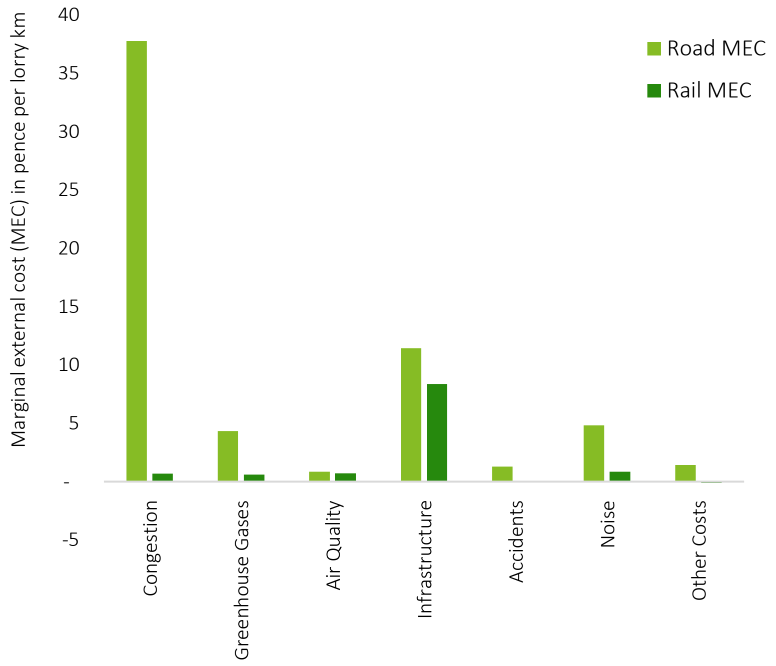
Wear and tear effects: Transporting goods by rail imposes 25% less **infrastructure** wear than the road equivalent, at the margin. This may be an even larger discrepancy when considering the additional infrastructure costs from moving rail freight to road in extremis, as roads would have to be designed to cope with much greater traffic.

> "We see the environmental benefits rail offers over road as a key advantage of rail freight
>
> – Tesco"

The graph to the right compares the marginal external costs between rail and road

The social costs imposed by rail are generally lower than road with the total social costs imposed by rail being 10% of those imposed by road. Rail costs range from approximately 0% to 98% of road costs.

Example of social benefits (2018/19 prices) – differences in marginal external costs (MEC) of rail and road



Source: DfT, ORR

[1] Data from DfT's Mode Shift Revenue Support Technical Report, Analysis by Deloitte.
[2] Note that these impacts are estimated gross of taxation implications – taxation impacts are set out later in this report as a sensitivity

Part 3

Assessing the benefits of rail freight

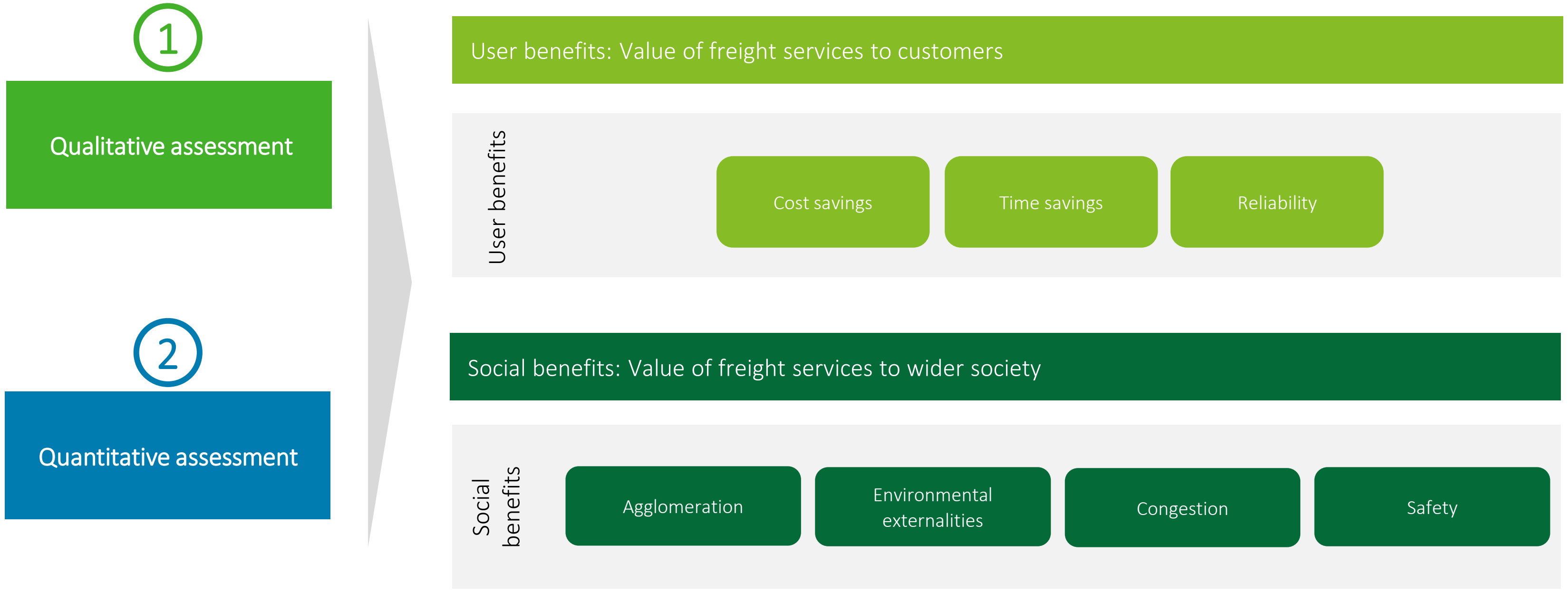
Overview

This Part sets out how the value of rail freight has been qualitatively and quantitatively assessed in this report

This report presents a first step in expanding the evidence base on rail freight for decision-making. To assess the economic benefits of rail freight two approaches have been employed. Firstly, a qualitative approach has been taken through customer conversations and contextual evidence. Secondly, a quantitative approach has been taken through application of a bespoke economic framework. While Part 2 outlined the potential types of benefits rail freight delivers to users and wider society, this Part details the approach taken to qualitatively and quantitatively assess this in practice.

It should be noted that the approach to assessing the value of rail freight quantitatively has aimed to employ an approach founded in first principles of economic theory and aligned to comparable practical implementations (e.g. the passenger framework in TAG/STAG, or similar assessments of value in transport). Following the benefits set out in the previous Part, the initial approach pursued was to gather detailed data from FOCs and wider industry to estimate distinct user benefits and distinct social benefits (as set out below). However, the granularity and form of data required to do this was not possible to obtain at the time of writing. As such, the approach taken looks to estimate the broad magnitude of benefits delivered by rail freight (in terms of user and social benefits) in aggregate, and where possible breaks these down further. That said, this does not include analysis of user benefits by type or quantification of agglomeration benefits. The work has also required some assumptions, which are outlined here and discussed in more detail in the Appendix.

Outline of this Part



Part 3-1

Approach to qualitative assessment

Qualitative assessments

The approach is centred around industry engagement and a contextual literature review

As part of the qualitative assessment a wider-ranging stakeholder and customer engagement exercise has been undertaken

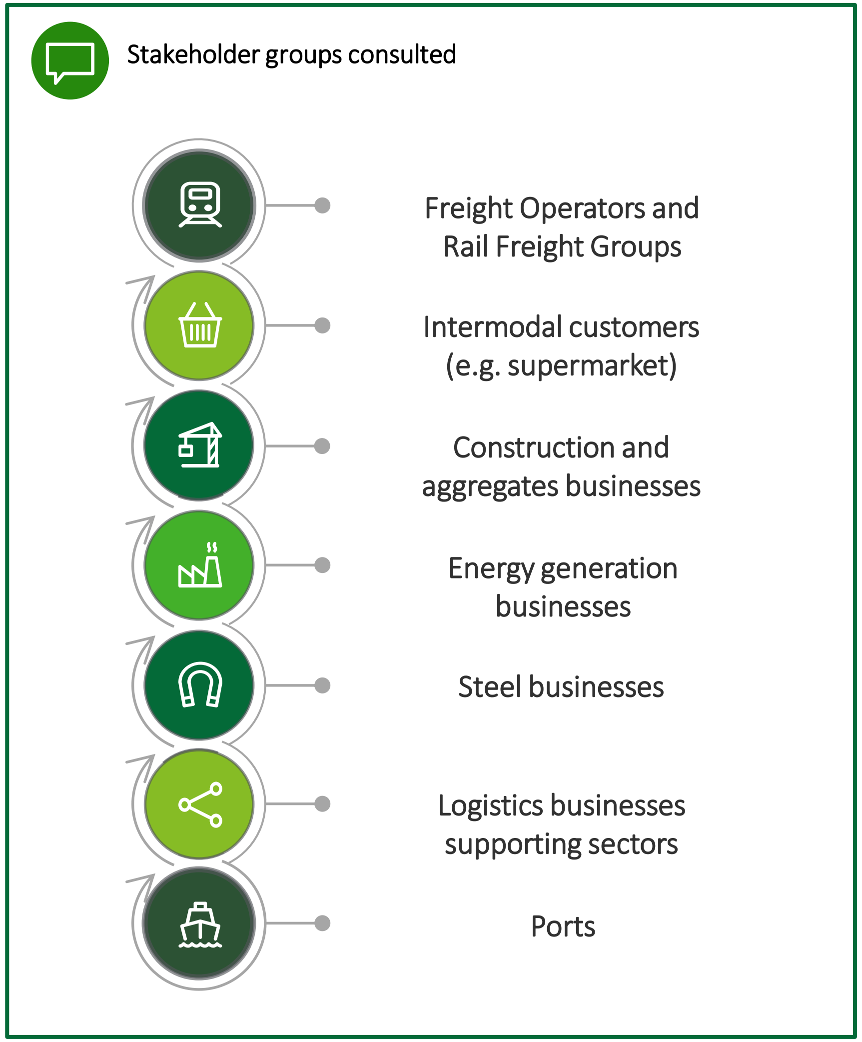
- 15 customers and other stakeholders have been interviewed to understand the value of rail freight to their business, how they may react were rail freight to not be available in the short-run and their perspective on how this may change going forward.
- A number of discussions with key industry stakeholders such as RFG, RDG's Freight Board and Freight Policy Group to test identified freight benefits as well as a number of other conversations with ORR, NR, DfT and Transport Scotland were also held to consolidate existing work and frameworks on rail freight benefits.

This has been complemented by a wider contextual literature review

- The interviews have been supplemented with a wider contextual literature review. This considered past and anticipated trends in the sector, the characteristics of the different sectors, as well as evidence on user and social benefits where available.

Our interviews and literature search focused on the following questions

- **The value of rail freight**
  For example, questions focused around gaining an understanding of the business and types of commodities/goods transported, as well as how rail freight builds into the customer's wider supply chain or offering.
  The discussions also centred around when and why customers use rail freight rather than an alternative. Further to this, sources of advantages of rail freight were discussed, such as cost savings, agglomeration, or environmental benefits. The discussions also touched on constraints to the value of rail freight and further expanded use of rail freight (e.g. lack of flexibility, or logistic challenges)
- **Alternatives to rail freight**
  What customers would do or how they would adjust in the absence of rail freight was also discussed, as well as which other modes they would use to understand the substitutability to other modes.
- **Pathing and on-time delivery**
  The impact of pathing decisions and how on-time delivery can also matter to some customers. This will be important when comparing potential freight benefits to those that may be generated by passenger services (see Part 5).



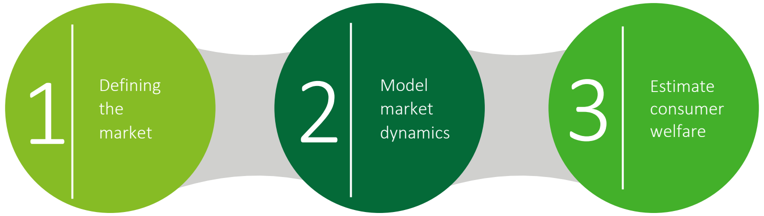
Part 3-2

Approach to quantitative assessment

User benefits

User value is estimated by drawing on economic welfare analysis and empirically modelling the freight market

Part 2 of this report outlined that the first major category of rail freight benefits relates to its users. The approach taken to quantify these user benefits relies on economic welfare analysis, where user benefits are defined as the welfare derived from the choice made by the customer in selecting rail freight. To estimate net consumer welfare a three-step method is used. It should be noted that benefits estimated using this approach are agnostic to potential taxation implications (further discussion on this is detailed in Part 4).



Defining the market

To estimate such a welfare model, a simple economic representation of the rail freight market has been created. A market, in economic terms, refers to the collection of buyers and sellers exchanging a good or a service. In the case of rail freight, the FOCs as sellers exchange freight services that transport certain commodities of a certain quantity over a certain distance against a price paid by their customers - the buyers. Publicly available data and information from FOCs is then used to quantitatively characterise these interactions and hence analyse the market.

Modelling the market dynamics

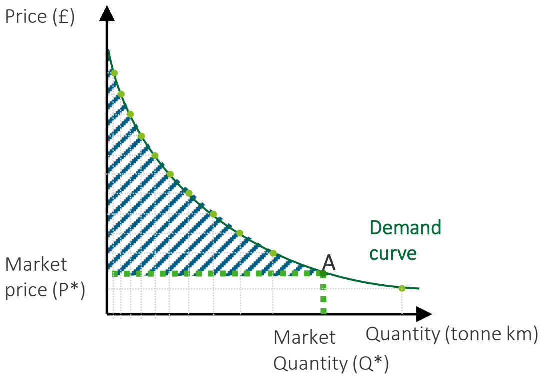
This conceptualisation of the market allows for the impacts of the exchange of rail freight services to be analysed. Precedent for such analysis is limited, and as such data to model these market dynamics empirically are sparse. However, theoretical economics and regulatory precedent offer a way forward. The analysis draws on the most commonly used specifications, or structures, for modelling the market dynamics in academics and practice: a constant elasticity of demand specification (CED), a linear curve, and a negative exponential demand curve. These have a bearing on final results; see Part 5 and the Appendix for full discussion and as further outlined in the Appendix, a conceptual rather than empirical definition of market dynamics introduces some uncertainty into results. As such, a range of estimates for the results are produced, and sensitivity testing and a cross-check have been carried out using alternative approaches.

Estimating consumer welfare

The previous steps 'define' the parameters of the graph depicted on the right – they estimate the demand curve. Bringing together the previous steps, one can then derive and estimate the shaded area in the graph on the side – consumer/user welfare.

User benefits: Value of freight services to customers

Approach to assessing user benefits



The chart above sets out a theoretical, illustrative market demand curve for a particular freight customer segment – i.e. how levels of rail freight services demanded change in response to a change in market price.

In this market, the **price (P*)** is that currently charged for the current level of market **volumes delivered (Q*).** However, given customers would have valued volumes below this point at a higher level than the current price they enjoy a level of 'consumer welfare', or user benefit from use of rail freight services at this level. This is captured as the shaded area in the diagram, which is estimated to quantitatively assess rail freight user benefits.

The results of this welfare analysis will be driven by the shape of the demand curve which is determined by the price elasticity of demand. As such, graphical depictions of the demand curve included in this report are illustrative for explanatory purposes.

The analysis has also involved relying on limited data to inform these inputs. The central assumption for the shape of the demand curve has previously been used by regulators. While there may be limitations to these estimates in terms of timeliness and granularity, they provide a step forward compared to previous studies.

User benefits

Commercial and public data is utilised to model the freight market

As described above, applying a welfare approach to estimating the user benefits of rail freight requires market data. Depending on the modelling approach, the requirements scale from simple characterisation in **demand approximation analyses** to granular, in-depth databases for **statistical demand estimation.** Given the limited available data on the freight market, a demand approximation approach has been used. The preceding pages have outlined how a welfare approach has been implemented to estimate benefits.

The following table summarises the data and sources used to implement this approach. Since the evidence base for rail freight currently remains relatively sparse, some data has been difficult to obtain, and has required use of assumptions. While analysis is at a more detailed level than previous work on the value of rail freight, the analysis could still have benefited from more granular data. Overall, the data allows results to be produced with a degree of confidence at the aggregate level, but with clear next steps for future research, in particular to obtain more certainty on more granularity. See Part 6 for full discussion.

Data Type	Description	Source	Use	Granularity	Commodity sector coverage	Market representativeness
Price data	Average revenue per tonne mile	Provided by a sample of FOCs.	Used to estimate market price for each commodity			
Price component data	Effective percentage of revenue constituted by the Variable Usage Charge (VUC)	Provided by a sample of FOCs	Used to derive price elasticity of demand			
VUC elasticity of demand	An indicator of the relative change in quantity of rail freight services provided in response to a marginal change in the VUC.[1]	Sourced from ORR's MDS Freight Track Access Charge analysis and corroborated by ORR representatives.	Together with price component data, used to derive the price elasticity of demand in order to characterise the demand curve			
Quantity data	Total volumes (tonne km) supplied and demanded	Sourced from Network Rail	Used to estimate the market quantity for each commodity to give the current market position together with price			

Extensive coverage/granularity, minimal assumptions required

Coverage of most areas, some assumptions required

Poor coverage, mostly assumptions driven or insufficient

[1] VUC elasticities utilised in this analysis have been modelled by MDS Transmodal with no explicit controls for capacity constraints. Further analysis would be required to understand how such elasticities would change in the presence of such constraints

Social benefits

Established methods have been built upon for valuing modal shift

In addition to the welfare analysis of user benefits, the framework takes account of wider benefits triggered for society through the use of rail freight rather than alternatives. As stated previously, the evidence base for agglomeration benefits does not currently allow for quantification of these in the context of rail freight. As such, this Part focuses on the approach to quantifying other social benefits of rail freight.

Existing DfT research provides a basis for the approach

Our analysis to quantify social benefits builds on existing DfT analysis to assess the benefits of Mode Shift from road to rail for the Mode Shift Revenue Support grant scheme. For this, DfT used TAG estimates on marginal social benefits of different modes to derive the net benefits of using rail over road per avoided lorry mile. This does not take into consideration commodity-specific differences; for instance, safer nuclear transport would drive a large benefit that is not captured in overall MSRS parameters. It is also based on existing road and rail technologies (so does not take into account the potential for decarbonisation of either mode in central estimates – this is flexed for rail in Part 4 but not for road as this faces a significantly greater challenge to decarbonise road haulage).

DfT's marginal external cost (MEC) estimates are used to derive net benefits by social benefit type

1. Use **MSRS marginal external cost** data as estimates for the total average external impacts of using rail versus road;
2. Derive **rail marginal external costs** by type of external cost using MSRS data and supplementing this with ORR estimates to approximate additional categories of rail external costs;
3. Multiply values by data on **avoided lorry kms** by sector implied by the rail freight volumes transacted in a given year.

These results can only capture the current valuation of social benefits. To understand future impacts of rail freight usage, further factors should be taken into account:

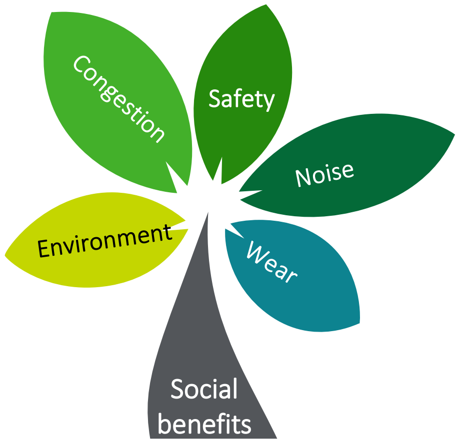
Future considerations

- Alternative carbon prices / values
- Changing congestion of the rail network
- Implications of traction decarbonisation on social impacts, e.g. air quality
- Social implications of pathing configurations

In addition, benefits estimated using this approach are agnostic to potential taxation implications (further discussion on this is detailed in Part 4).

[1] Estimated using ORR data on Variable Usage Charge, which reflects the marginal cost of using the infrastructure but does not include long-term infrastructure costs
[2] Estimated using ORR data on the Capacity Charge, which reflects the marginal capacity cost

Social benefits: Value of freight services to wider society



Marginal external costs (MEC) and net rail impacts

Pence per avoided lorry mile	Road MEC	Rail MEC	Net Rail MSB
Congestion [2]	38	1	37
Infrastructure[1]	11	9	3
Noise	5	1	4
Greenhouse Gases	4	1	4
Safety	1	-	1
Air Quality	1	1	0
Other Costs	1	-0	2
Total MEC	**62**	**11**	**51**

Figures are rounded.
Source: DfT, ORR

Social benefits

DfT analysis and data from ORR is utilised to derive social benefits

As described overleaf, the analysis has drawn on existing analysis and data from various sources to derive social benefits. The available data have allowed a breakdown of results by sector and by type of benefit, however, this required a number of assumptions. Further granularity was not possible due to insufficient data. The data used are outlined below:

Data Type	Description	Source	Use	Granularity	Commodity sector coverage	Market representativeness
Rail demand	Data from Network Rail estimating the demand for rail freight services in tonne kms	Sourced from Network Rail,	Quantity data to estimate observed demand for rail freight.			
Avoided lorry kms	Data from ORR estimating the number of lorry kms that would have to be travelled to fulfil current rail freight journeys by road.	Sourced from the ORR.	Quantity data to estimate the extent to which observed demand for rail freight effectively enables avoidance of lorry journeys.			
Marginal External Costs	Value estimates from DfT on the external impacts of mode shift, specifically in terms of avoided lorry journeys.	MSRS inputs. Publicly available from DfT.	Value data to estimate the net impacts of rail usage compared to alternative modes.			
Marginal External Costs	Value estimates from the ORR	Price controls determinations and price lists. Publicly available from ORR.	Value data to estimate the net impacts of rail usage compared to alternative modes, specifically to supplement DfT's estimates and estimate net impacts at a more granular level.			

Extensive coverage/granularity, minimal assumptions required

Coverage of most areas, some assumptions required

Poor coverage, mostly assumptions driven or insufficient

Part 4

The value of rail freight to the UK economy

Part 4-1

Qualitative assessment

Qualitative assessment

Customers have highlighted the key role rail freight can play in their sectors

As part of the qualitative assessment wider-ranging stakeholder and customer engagement was undertaken…

- 15 customers and other stakeholders were interviewed to understand the value of rail freight to their business, how they may react were rail freight to not be available in the short-run and their perspective on how this may change going forward. Examples of responses from this exercise are set out to the right. This included some of the UK's largest logistics businesses and grocery and general merchandise suppliers, its most important energy generators and well known notable construction and aggregates and metals businesses.
- This engagement also involved a number of discussions with key industry stakeholders such as RFG, RDG's Freight Board and Freight Policy Group to test identified freight benefits as well as ORR, NR, DfT and Transport Scotland to consolidate existing work and frameworks on rail freight benefits.

These have allowed an assessment of the benefits of rail freight to particular sectors

Rail freight supports a number of different sectors, but the qualitative assessment has established that five may offer significant benefits to customers and the wider economy. In particular:

Intermodal represents the largest customer segment by volumes, and forms a key part of integrated logistics chains with road and waterways. Its major value to the economy and society is expected to come from the ability to shift container traffic from roads to yield reductions in carbon, noise and congestion. This relief is particularly prevalent for deep-sea intermodal to alleviate congestion and emissions around ports.

Construction and aggregates is the second largest segment with Rail freight being critical for key infrastructure projects, particularly in dense areas of GB (for example, most recently the construction of the Shard, and previously Heathrow's Terminal 5). Its benefits are likely mixed with high value traffic in urban areas as well as the benefits of alleviating congestion on roads to transport large volumes.

Energy generation is comprised of coal, biomass pellet and nuclear freight, delivering strategically important solid fuels to UK power plants from ports and quarries to support the running of the GB economy at large. Rail freight is a necessity from a practical perspective within these energy generation supply chains and without it, short-term fuel supply would be infeasible, meaning user benefits are likely to be high.

Network Rail services in the form of maintenance activities and support to ensure the safe, successful performance of the passenger railway (via removal of Autumn leaves or the movement of infrastructure materials, for example) represents the largest customer for some freight operating companies (FOCs). This, with low substitutability to other modes, is likely to mean that rail freight generates significant user value.

Metals and iron are smaller rail freight sectors, supporting intermediate stages of production for a variety of downstream industries. Rail freight's efficiency at scale may be particularly prominent in this sector, and a key differentiator for its use over other modes. As a result of this efficiency and reliance on rail freight, it is likely that user value generated by this sector is large relative to volumes.

The following pages set out more detail on the qualitative assessment of benefits potentially offered by these sectors, providing a high-level 'scoring' of the size of the expected benefits to customers and wider society for comparison to the quantitative analysis (detailed later in this Part).

Key examples of customer interview responses

> "Using road to access inner cities could as much as double our costs compared to rail
> – Aggregate Industries"

> "Rail freight is key in reducing our environmental footprint and in enabling us to contribute to net zero
> – Tesco"

> "Some of our products would be operationally infeasible to move by other modes
> - Tata Steel"

> "Without rail freight services a number of key network functions, such as track clearing, would need to be brought into Network Rail
> – Network Rail"

Source: Various customer conversations

Qualitative assessment for key customer segments – Intermodal and Construction & Aggregates

Intermodal, as well as construction and aggregates, may generate high social value

The intermodal segment is highly competitive with other modes, with likely implications for value

Sector overview

No. 1 Largest rail freight sector with 6,900 Mtkm in 2018/19[1]

6% increase over the last 5 years in intermodal volumes[2]

The role of rail freight for the sector

- The intermodal sector is diverse representing container haulage comprised of domestic container freight – typically serving warehouses and other supply chain nodes – deep-sea container freight – taking containers to/from ports and international container freight travelling cross-border.
- Whilst volumes for intermodal overall are very high, rail only plays part of the role in transporting containers around the country with road freight carrying larger volumes and facilitating first and last mile haulage.

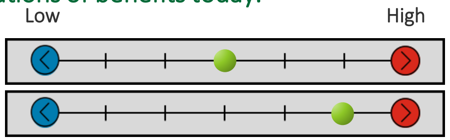
Customer views on value of rail freight

- Customers highlight that the user value through cost savings can vary across different sub-segments. Deep-sea customers tend to use rail based on cost savings or superior service quality, while domestic intermodal customers have noted that cost savings are modest with greater competition.
- Environmental benefits are also a key factor for choosing rail, particularly for domestic intermodal and, given the sectors' overall size, environmental benefits could be sizeable.

Customer expectations of benefits today:

User value

Social value



> "In Intermodals, consumers are very price sensitive – neither rail nor road are very profitable for the operator"
> - WH Malcolm

Construction is a large and growing sector, where rail and road play important roles

Sector overview

No. 2 Second largest rail freight sector with 4,500 Mtkm in 2018/19[1]

27% increase over the last 5 years in C&A volumes[2]

The role of rail freight for the sector

- Construction is the second largest segment and has remained a steadily rising sector.[1] The sector relies heavily on rail freight for transporting aggregates, steel and other materials for use in supporting building projects of different sizes across the country. This also includes high large projects of national significance such as Heathrow T5, the Olympic Park and the A14.
- Construction is a highly competitive market with price sensitive customer, low margins and transport costs comprising a large component of final prices.

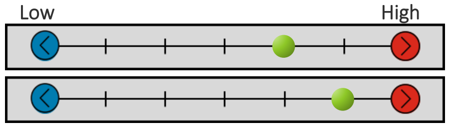
Customer views on value of rail freight

- Customers note that rail freight is critical to some parts of the market, but for the majority of construction and aggregates freight uses road. The advantages offered by rail freight are illustrated by the investment made by some businesses in their own rail infrastructure despite the large up-front costs involved.
- Customers emphasise the importance of rail freight to their industry, however the value rail provides to users may differ starkly across parts of the market – depending on how feasible road alternatives are.

Customer expectations of benefits today:

User value

Social value



> "Using road to access inner cities could as much as double our costs compared to rail in our current operating model"
> - Aggregate Industries

[1] Network Rail Data 2018/19
[2] DfT, 2020. Rail Statistics

Qualitative assessment for key customer segments – Energy Generation

The energy generation segment is highly dependent on rail freight

The energy generation sector is likely to draw significant value from rail freight. The nuclear component of this segment carries unique challenges met by rail freight.

Sector overview

No. 3 Third largest rail freight sector with 2,200 Mtkm in 2018/19[1]

Coal volumes are declining and have reduced by 88% over the last 5 years[1] – previously constituting one third of the whole market[2]

Biomass volumes rose 206% over the last five years, but have plateaued going forward[1]

Nuclear material haulage is likely to rely **nearly entirely** on rail freight, with road occupying only a limited role.

The role of rail freight for the sector

- The majority of the energy generation sector's volumes are comprised of coal and biomass pellet freight, delivering solid fuels to GB power plants from ports and quarries. As coal enters its final decommissioning phase as part of the decarbonisation agenda biomass will comprise an increasing share of this segment.
- In much smaller volumes is the transport of spent nuclear material, uranium-bearing fuel elements used in nuclear reactors, or fuels and materials being decommissioned as part of the UK's energy strategy. Due to the criticality of safety and security around nuclear material, and the large societal risks were either to be compromised, rail freight plays a standalone role in this sector, providing uniquely equipped trains manned by specialist staff with road only used for first/mile journeys.
- For the energy generation segment, rail freight is a necessity from a practical perspective. Specialist rail freight routes have been established to link power plants with domestic quarries and international ports in order to secure a stable and reliable supply of fuels from international sources. Without rail freight, short-term fuel supply at current levels would be infeasible, with significant costs incurred in the medium to long-term in re-establishing freight links.
- For Nuclear material in particular, the necessity of rail is borne out of the superior security and safety features offered. Without rail freight, the low-probability but extremely high-impact risks generated through transport of nuclear material by road would be increased relative to current road usage for transfer of material over first and last miles of journeys.

Customer views on value of rail freight

- Energy generation customers state that rail freight is essential to their business, and that very little practical alternatives are available to them in the short-run. In the case of nuclear alternatives using a different mode-mix to today may also be prohibited. As such, given such limited substitutability, energy generation customers expect high user value.
- Customers also note that environmental benefits are also an important feature of their choice to utilise rail freight meaning they would expect the environmental benefits for use of rail freight to also be material.

Customer expectations of benefits today:

Low — High

User value

Social value

> "Without rail freight, we would not be able to operate our business
> - Drax"

> "The enhanced security requirements and the geographical challenges to transport nuclear material by road is considered prohibitive
> - **Direct Rail Services**"

[1]Network Rail Data 2018/19
[2] DfT, 2020. Rail Statistics.

Qualitative assessment for key customer segments – Metals & Iron and Network Rail

Metals, iron and Network Rail infrastructure demonstrate the niches that rail freight can fill

Parts of the metal and iron sectors are heavily reliant on rail freight

Sector overview

No. 4 Together the 4th largest rail freight sector with 1,450 Mtkm in 2018/19[1]

20% decline over the last 5 years in Metals and Iron volumes[1]

The role of rail freight for the sector

- Metals and Iron Ore are smaller rail freight sectors, supporting intermediate stages of production for a variety of downstream industries.[1] There is some degree of differentiation within this segment, which contains both standardised commodities and larger metal specifications.
- Rail freight's efficiency at scale may be particularly prominent in this sector, as large or unwieldy goods are more easily transported via wagon than by lorry, implying that substitutability may be low. In addition, some products such as Hot Rolled Coil would incur inefficiencies if rail was unavailable.

Customer views on value of rail freight

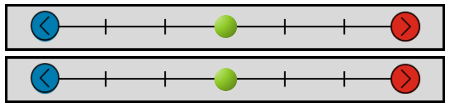
- Customers note that rail freight is vital for their business to function effectively and efficiently. In fact, many customers have noted that they are limited by network capacity and regulations from expanding their business, indicating that the value of rail freight may be quite large for this sector. However, while parts of the sector have designed their supply chains around rail and rely on rail for 80-90% of their movements, road remains a key mode for others, e.g. delivery to end-customers.

Customer expectations of benefits today:

Low — High

User value

Social value



"Some of our products would be operationally infeasible to move by road."
- Tata Steel

The Network Rail infrastructure segment is vital and solely operated by rail freight

Sector overview

No. 5 Fifth largest rail freight sector with 1,400 Mtkm in 2018/19[1]

18% decrease over the last 5 years in Network Rail volumes[2]

The role of rail freight for the sector

- This sector comprises services provided by FOCs exclusively for Network Rail, including maintenance, rolling stock mobilisation and seasonal track upkeep.
- These services are exclusively provided by rail freight, which offers unique capabilities, staff and equipment that would otherwise be highly costly to obtain and maintain. For instance, rail freight offers a 'moving factory' approach whereby maintenance and renewals are completed at-site by the haulier. Road vehicles would encounter difficulty accessing and servicing the infrastructure in a similarly efficient manner.

Customer views on value of rail freight

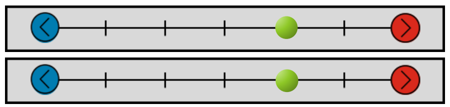
- Network Rail have stated that there are no short-term alternatives to rail freight for provision of some of these services as use of road or other modes would be infeasible. The value obtained from rail freight services are therefore considered quite high.
- Absent rail freight infrastructure services, other social short-term disbenefits would be expected to be triggered; for instance, fewer passenger trains may run owing to network conditions.

Customer expectations of benefits today:

Low — High

User value

Social value



"FOC services are key in supporting Network Rail to undertake maintenance, testing and resilience works - **GB FOC**"

[1]Network Rail Data 2018/19
[2] DfT, 2020. Rail Statistics.

Part 4-2

Quantitative assessment

Summary of quantitative assessment

Based on the qualitative assessment, operator, NR, ORR and DfT data have been used to estimate the broad magnitude of benefits that rail freight generates for the UK economy. The results of this quantitative assessment are set out to the right.

In undertaking this assessment there is an extent of uncertainty with resulting estimated benefits due to the adoption of a number of assumptions. This includes making use of estimates for key relationships that have been developed for ORR (see Part 4 and the Appendix for more details). Further work should be undertaken to verify and refine such assumptions and is suggested as Part 6 below.

As shown, the benefits generated by rail freight are **around £2.45bn per year**, these include: [1]

User benefits of around £1.65bn which capture cost savings, time savings, and other benefits such as reliability for different customer segments.[2] Similar to the qualitative assessment, Energy generation, Network Rail and Metals and Iron contribute significantly for the reasons already outlined. However, construction is perhaps more modest than would be expected from the qualitative assessment. This is expected to be due to the national level of the analysis not recognising nor taking account of particular high value flows into and out of dense urban areas.

Social benefits of around £800m which are particularly large for high volume sectors, where the total benefits of shifting to alternative modes of transport would be significant – for example, intermodal and construction and aggregates. Compared to previous studies, the benefits captured here reflect more granular estimates of sector-level avoided lorry miles and provide updated social impact values. The chart to the bottom right breaks down the estimates of social benefits outlined by benefit. Points to note are:

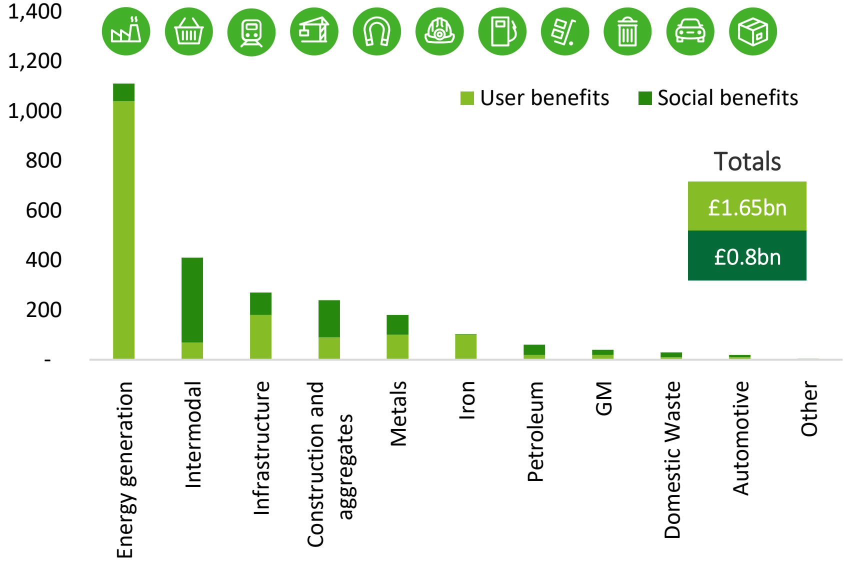
•Congestion impacts are by far the most prominent component. At over £600m, this estimate demonstrates the constraints on GB road networks, and the significant alleviatory potential of rail freight in addressing these constraints; and

•Environmental benefits which are likely to grow over time. Given potentially reduced travel times and more efficient loading offered by rail freight, less pollutants are emitted than by road freight on average. However, these effects could currently appear relatively small compared to congestion effects. However, this is likely to change going forward as:

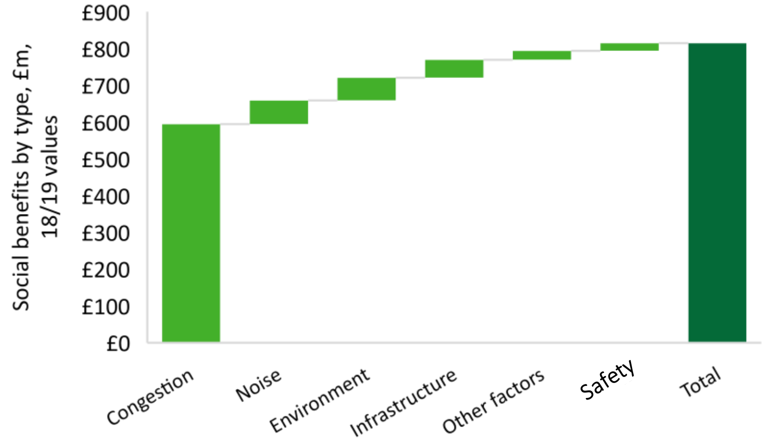
- current analysis does not account for the move to electric traction and is based on the use of whole or part diesel locomotives, meaning the relative benefit of using rail is likely to grow ever larger as electrification is adopted
- these figures do not account for significant anticipated growth over the coming decades in intermodal and construction traffic, the two modes with the greatest propensity to shift freight from roads and achieve incremental environmental benefits; and
- analysis is currently based on a 'core' carbon price utilised in the public sector. Research suggests that carbon prices are currently suppressed, are on an upward price trend, and could be several times larger in reality. There is a similar expectation that air quality values will also be 'uprated' going forward.

A series of scenario analyses are presented later in this Part to highlight how the environmental contribution of freight could change going forward taking these factors into account.

Central estimate of benefits of rail freight, 2018/19 (volumes and prices)



Social benefits by type, 2018/19 (volumes and prices)



Source: Deloitte Analysis

[1] Note that such figures relate to impacts at the national scale and for use in more detailed assessments (e.g. of freight paths, or particular investments), key aspects of options under consideration must be taken account of – further detail on the approach to do so, making use of these estimates, is set out in Part 5 below

[2] Note that user benefits represent all benefits to users, including cost savings, time savings, and reliability improvements, which have been estimated jointly as set out in Part 3. Further work is required to segment user benefits into each specific benefit.

Overview of user benefits by customer segment

User benefits vary across sectors according to their ‘substitutability’ to other modes

As shown to the right the level of user benefits generated varies significantly by customer segment/sector. In particular, with the extent to which customers could switch to other modes has a large bearing on results; for those segments with no viable alternative in the short-run – a lack of substitutability – (such as for energy generation and Network Rail services), rail freight is estimated to generate higher value to users than others, since prices are competitive across the industry. This is implicitly captured in estimated price elasticities used with the analysis (which measure the responsiveness of demand to changes in price), and drives the results with lower magnitude (i.e. closer to zero) elasticities indicating less substitutability to other modes.

Accordingly, the sectors contributing the highest aggregate value to users are either:

- **Reliant on rail freight –** energy generation, metals and infrastructure, though being smaller segments in terms of volume, yield high value as customers have few alternatives for transporting goods (evidenced by a low elasticity);
- **Subject to higher prices already** – where customers pay higher prices.; and/or
- **Large in volume -** intermodal traffic, which is the largest customer segment, accounts for the 7th highest proportion of total value even though it is by far the segment that has the greater ability to utilise other modes were rail not available (evidenced by its large elasticity)

As noted previously, the results presented here are a central estimate based on particular assumptions on freight demand, and vary if alternatives demand assumptions are used. Sensitivity analysis is set out later in this Part for alternative assumptions to show their impact on results. The sensitivities also show application of an alternative methodology to ‘cross check’ the broad order of magnitude of estimated user benefit.

User benefits by sector, 2018/19[1] (volumes and prices)[2]

Estimated Price Elasticity	-0.05	-0.05	-0.46	-0.05	-0.96	-1.90	-0.54	-1.15	-1.37	-1.15	-1.07
Market Demand, Mtkm	2200	200	1300	100	4500	6900	400	1400	100	400	30

Source: Deloitte Analysis

[1]The majority of the elasticity estimates are estimated using market data in combination with elasticities of freight volumes with respect to access charges (specifically Network Rail’s variable usage charge – VUC) generated using MDS Transmodal’s GB Rail freight model (see here for more details: MDS Transmodal, 2012. Impact of changes in track access charges on rail freight traffic. Available here), which was utilised to inform regulatory determinations in PR13 by ORR. Nuclear, as a component of “energy generation”, Iron and Network Rail service elasticities were assumed to be consistent with those of characteristically similar commodities. These assumptions were necessary as elasticities for Iron and Nuclear were estimated to be zero with respect to VUC for the range of volume changes looked at by MDS Transmodal (implying infinite user benefits) and as no VUC elasticity was available for Network Rail services.

[2]It should be noted that estimates presented for user benefits do not take account of certain sectoral details that could affect the overall levels of estimated benefits. In particualr, elasticities applied are whole-sector UK averages and do not reflect the potentially higher value of flows into urban areas (e.g. construction and aggregates) nor the potentially higher value for certain sector sub-segments (such as deep-sea intermodal)

Overview of social benefits by customer segment

Social benefits are driven by the lorry journeys rail freight has enabled to avoid through modal switch

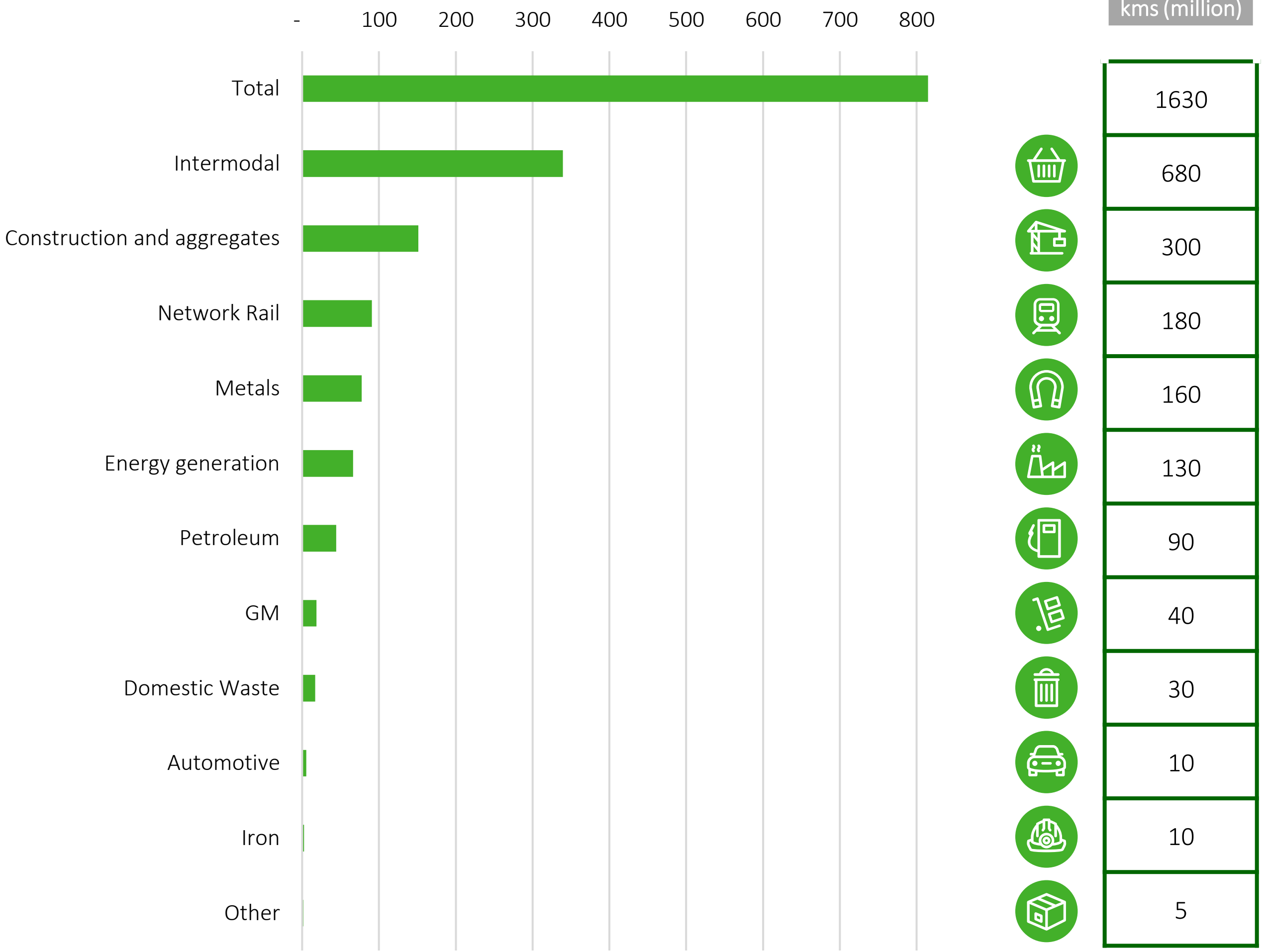
Social benefits, as set out above are estimated by analysing the value created to society through modal switch from road transportation. As such, the greater road journeys (or lorry miles as often quoted) that can be avoided, the greater social benefits delivered.

On the right, the social benefit generated by each customer segment is displayed alongside the total lorry miles avoided by rail freight carrying current volumes. The results are striking when compared to user benefits, with many of the low user benefit segments generating far higher social benefits:

- **Intermodal is by far the highest social welfare-generating segment.** This is due to it allowing for the largest amount of lorry miles to be avoided by across the industry meaning that the greatest gains can be made to relieve congestion, reduce environmental degradation and safety risk. This lends more weight to the argument that intermodal transport provide complementary benefits to the road industry, and indeed to society, by handling long-distance or high volume journeys that enable first and last mile road haulage (at much less levels of environmental harm).
- **Construction and aggregates alleviate substantial social and environmental disbenefit.** Construction and aggregates are also a large rail freight sector by volumes, partly driven through the bulky nature of the commodities. If these rail journeys were conversely undertaken via road, the congestion impacts and infrastructure costs from greater volumes of road journeys in the absence of rail freight would be significant. This applies to both urban locales and large buildings sites within cities as well as in rural areas and along on local roads near smaller sites.
- **The lower-volume and non-inter-urban services offer lower social benefits.** Some segments, including coal, biomass and nuclear, offer less social benefits relative to their high user benefit estimates.

Note that the estimates are gross of tax implications with taxation impacts set out later in this Part. In addition, the results rely on national weighted average values for the social benefits of shifting road journeys to rail. However, social benefits are known to vary across different localities, for example, congestion tends to be worse in urban areas, compared to rural areas. Depending on the locality profile of different segments, the results may therefore diverge across sectors and geographies. This could be refined if more granular data could be obtained, however, the order of magnitude of benefits is unlikely to change.

Social benefits by sector, 2018/19 (volumes and prices)



Source: Deloitte Analysis

Regional distribution of user and social benefits (1/2)

Allocating national benefits on a regional basis

While rail freight has been shown to generate economic benefit for the entirety of the UK, to provide an illustration of how benefits may accrue regionally (user benefits to customers, and social benefits to UK society), data from Network Rail on the origins and destinations of rail freight journeys made in 2018/19 has been used to apportion national estimates to NUTS1 administrative regions.[1] In particular, by:

- Mapping freight flow origins and destinations (in tonne km terms) to NUTS1 regions of the UK; [2]
- Scaling user and social benefits by tonne kms for each sector to derive benefits on a per tonne km basis;
- Multiplying up user benefits per tonne km by tonne kms for individual freight flows, allocating user benefits to origins and destinations based on the expected location of the customer receiving the benefit in each sector (e.g. for intermodal the destination, for domestic waste the origin); and
- Multiplying up social benefits per tonne km by tonne kms for individual freight flows, allocating benefits 50:50 between origin and destination to recognise that these effects are diffuse along the route travelled.

It should be noted that by taking such an approach this may concentrate the allocation of user benefits to primary customer locations when as a result of further levels of the supply chain end customers may be in other areas of the country. For example, a large amount of energy generation benefits are attributed to Yorkshire and the Humber due to power station location, but of course the end power produced is utilised throughout the country.

Results of the regional analysis

Results of this analysis by type of benefit are set out in the table to the right and show that 90% of benefits likely accrue to freight customers and wider society outside of London and the South East[1] with notable concentrations generated by:

- Power stations and industrial centres in Yorkshire and the Humber and North West England;[2]
- Logistics and manufacturing hubs in the Midlands and Wales; and
- Container traffic from Deep Sea Ports to and between inland domestic terminals across the length of the country, from the South of England to the Central Belt of Scotland.

Maps are presented on the following page which show these figures visually by type of benefit.

Estimated regional economic contribution across the UK in 2018/19[1] (volumes and prices)[3]

Region	Total benefits (£m, 2018/19)	% share (of total)	User benefits (£m, 2018/19)	Social benefits (£m, 2018/19)
Yorkshire and The Humber	860	35%	735	125
East Midlands (England)	375	15%	300	75
Wales	260	11%	200	60
North West (England)	225	9%	125	100
East of England	190	8%	45	145
South East (England)	120	5%	45	75
Scotland	105	4%	45	60
North East (England)	100	4%	65	35
West Midlands (England)	95	4%	35	60
London	75	3%	35	40
South West (England)	45	2%	10	35

Source: Deloitte Analysis

[1]NUTS1 regions split the UK into 12 areas varying by particular administrative definitions across the devolved nations. For more information on the regions please see: https://www.ons.gov.uk/methodology/geography/ukgeographies/eurostat
[2]Origin and destinations for rail freight volumes have been mapped to closest UK NUTS1 centroids to apportion benefits using GIS methods. This does not include Network Rail service volumes as these were not available with associated origin/destination data and as such, have been apportioned based on regions' share of benefits across the country.
[3] Rounded to the nearest £5m.

Regional distribution of user and social benefits (2/2)

The maps below present the allocation of national user benefits(see left) and social benefits (see right) to regions of the UK. As shown:

- **User benefits are concentrated in areas of the UK where the sectors for which rail freight generates the most value are concentrated**. This includes Yorkshire and the Humber and the North West of England (energy generation and construction and aggregates) and Wales (metals and Iron) for example.
- **Social benefits are more diffuse across the country reflecting that they accrue to wider society across train routes** with hotspots relating to areas where the largest flows of intermodal containers and construction and aggregates are sent from or received into (the sectors with the greatest propensity to transfer freight from road to rail and achieve relative social benefits).

Dispersion of user benefits across the UK in 2018/19 (volumes)

Greater levels of user benefits today

Source: Deloitte Analysis

Dispersion of social benefits across the UK in 2018/19 (volumes)

Greater levels of social benefits today

Source: Deloitte Analysis

Quantitative assessment for key customer segments – Energy Generation

Biomass, coal and nuclear commodities demonstrate significant value for customers due to their reliance on rail

Energy generation estimates are high, reflecting lack of alternatives to rail

Quantitative assessment

- Given the extent of substitutability for customers in the energy generation sector, high estimated user benefits are unsurprising at £1,040m. However, estimated user benefits in relation to other sectors served by rail freight (see below) are somewhat higher than customers could have expected.
- The low volumes carried in this sector relative to others mean that social benefits are estimated to be relatively low at £70m per year as expected in the qualitative assessment.

Considerations

- The high user benefits and relatively lower social benefits are estimated at an overall level for the sector and may not reflect a number of factors which differ between different sub segments such as coal, biomass and nuclear. For example:
  - over the past 5-10 years the market has shifted from coal towards biomass and nuclear, but as the demand elasticities utilised in the analysis of user benefits are based on existing ORR data and analysis applied at an aggregated level they are unlikely to capture the effect of such shifts. Use of more disaggregated data and elasticities would be expected to change estimated benefits, which at present could be overstated; and

Considerations (cont'd)

  - for nuclear, that both (i) there are specific requirements in place that prevent substitution to other modes which may mean that user benefits estimated using an elasticity-based approach may not represent the true value created; and (ii) the beneficial safety aspects of using rail over alternatives are an outlier compared to other sectors and the overall approach used to estimate safety benefits (as part of social benefits) may underestimate these.
- Based on current volumes forecasts, coal is expected to disappear as a significant sector in the future with the move to decarbonise the UK economy. Biomass volumes are forecast to fall moderately, but be maintained over the longer-term. Given lower volumes overall though, the size of user benefits could decline going forward.
- Given the short-run nature of this analysis in relation to the use of rail freight, longer run changes are not picked up and market dynamics modelled in the analysis do not reflect the significant future changes in the market. As such, future research could be undertaken to understand how demand dynamics could change across the three markets and how this would affect results.

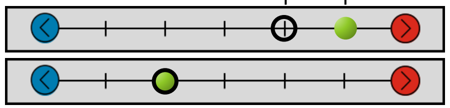
Quantitative estimates vs. customer expectations of benefits today:

Expected value[1]

Estimated value

User value

Social value



Forecast growth of segment[2]

↓ Biomass -9% by 2043/44

↓ Coal -100% by 2043/44

[1] The comparison of expected value and estimated value compares the expected scale of value based on the qualitative assessment of customer conversations in the preceding Part to the value estimated in the quantitative analysis.

[2] Forecasts represent segment size in terms of tonne-kilometres. Sourced from Network Rail (2020), Rail freight forecasts: Scenarios for 2033/34 and 2043/44. Available here. All forecasts are central, "do-minimum" estimates (Scenario E). Owing to the relative decline in passenger rail as a result of the COVID-19 pandemic, future market conditions are unclear so these forecasts may under or overestimate future trends.

Quantitative assessment for key customer segments – Construction & Aggregates

Construction and aggregates estimates may mask more granular effects

Construction and aggregates results may mask differences within the sector

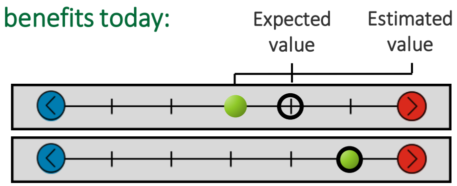
Quantitative assessment

- Construction and aggregates are a high volume segment. As a result, high social benefits of £150m per year are estimated. However, Despite customers noting somewhat low substitutability of rail for other alternatives (e.g. relative to intermodal), the user value of £90m against a market size of 4,500 Mtkm per year may appear small.

Considerations

- For this sector, the estimated user value of the segment may mask more granular dynamics at play in reality. Customers note that the ability to efficiently transport construction materials into urban sites – both for large and small projects – where using rail freight is highly valuable for their operations, and can drive key competitive advantages for companies.
- At the current granularity of data, it is not possible to distinguish between these high value services enabled through rail freight, and other uses of rail freight to the sector in other localities (such as rurally) where rail may be more easily replaced by other modes as elasticities used for the sector are at a 'whole sector average level'. Use of more granular elasticities would be expected to increase user value. The right box provides an illustration of this.
- Going forward, construction volumes in rail freight are expected to grow significantly, which may increase the value accruing to users . However, the extent of this will depend on which types of flows are grown and any corresponding changes in the customer demand relationship over time.
- There may also be additional benefits through agglomeration as noted above not captured in the quantitative analysis.

Quantitative estimates vs. customer expectations of benefits today:

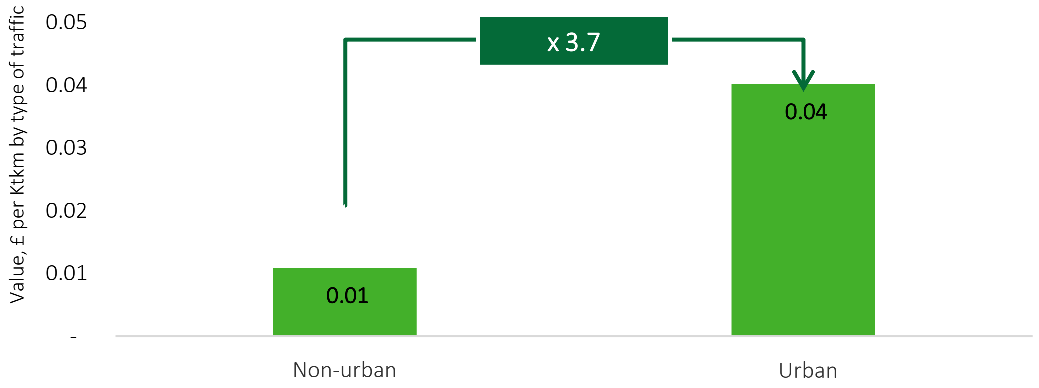


Forecast growth of segment

65% by 2043/44

Hypothetical example: Rail freight may create nearly twice as much value to users for inner city traffic

The graph below shows the results of analysis undertaken whereby estimated construction volumes within and outside the M25 (as a proxy for urban traffic) are treated differently. It is assumed that the urban segment is less substitutable to road and apply the same (lower) elasticity as the Metals sector. The remainder of volumes are then treated as the 'residual' of the overall estimated benefits of £90m from the sector as a whole. The results show that the value of rail freight in inner cities may be nearly four times as high as outside on a per 'ooo tonne KM (Ktkm) basis.



Source: Deloitte Analysis

Key assumptions	
Urban traffic	Available data on construction volumes within and outside are sourced from Network Rail for 2020 (with 21% of all construction volumes within the M25).
Elasticity: urban	Urban traffic is assumed to be more inelastic than other construction and aggregates traffic, and to have similar road substitutability to the Metals sector.
Elasticity: non-urban	Based on the assumed urban elasticity and the elasticity for the whole construction and aggregates segment, an implied elasticity for non-urban traffic is derived so the overall benefits to the sector (£90m) remains the same.

Quantitative assessment for key customer segments – Intermodal and Metals & Iron

Intermodal highlights the impact of road-complementarity on quantitative results

Rail-road complementarity in intermodal implies lower user benefits

Quantitative assessment

- Although intermodal is the largest sector by volumes, the ready availability of road alternatives in general limits the potential user value. As such, estimated user benefits are low at £70m. The large volumes carried however, and the ability to move significant volumes from road to rail mean estimated social benefits are much larger, with 680m lorry kilometres avoided generating benefits valued at £340m.

Considerations

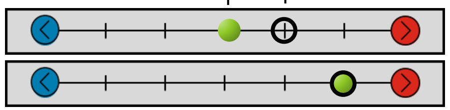
- While generally containers are readily transportable via road, there may be segments (such as deep-sea intermodal) where rail freight has a key advantage over road (for example, due to less congestion at ports). These granular impacts cannot be captured with current data and elasticities. Being able to break down this segment and apply granular elasticities, could lead to estimated benefits increasing (similar to construction above) in line with customer expectations.
- Intermodals is also expected to significantly grow going forward meaning both user and social value may increase in the future. However, the extent of this will depend on which types of flows are grown and any corresponding changes in the customer demand relationship over time.
- There may also be additional benefits through agglomeration as noted above not captured in the quantitative analysis.

Quantitative estimates vs. customer expectations of benefits today:

Expected value | Estimated value

User value

Social value



Forecast growth of segment

209% by 2043/44

Metals and iron offer contrasting benefits to users and society when compared

Quantitative assessment

- User value for the iron sector, at £100m is very high relative to the 120Mtkm of market demand . This may be due to the fact that metals infrastructure is well-set up for using rail freight, with direct links to processing plants for domestic metals and to ports for imported equivalents. For other metals, values indicate that rail freight is far less valuable relatively speaking, with an equal value of £100m but via 1300Mtkm of demand.
- Social value appears to accrue relatively more to other metals than iron, with metals accruing £80m per annum whereas iron accrues only £3m.

Considerations

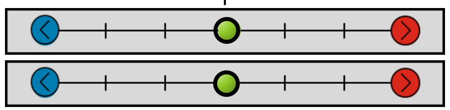
- Compared to iron ore, metals is a more diverse sector, with some components of the sector being more reliant on rail freight than others. Given the diversity in products in metals the quantitative results may mask underlying differences for particular products. For instance, intermediate products are likely to generate higher user value due to a reliance on rail relative to finished metal products (which are hauled across rail and road).
- The sector is only expected to grow moderately going forward, such that any changes in user value would likely be driven by changes in substitutability to other modes across different products.

Quantitative estimates vs. customer expectations of benefits today:

Expected value = Estimated value

User value

Social value



Forecast growth of segment

Metals 5% by 2043/44

Iron 30% by 2043/44

Quantitative assessment for key customer segments – Network Rail

Network Rail is estimated to draw moderate value from rail freight

Network Rail services benefits are as expected, generating moderate value.

Quantitative assessment

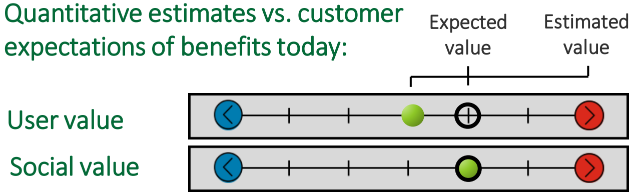
Network Rail is highly reliant upon rail freight, at least in the short-term, to perform infrastructure services and maintenance across the network:

- The user value estimates generated through the analysis, at £180m, are perhaps slightly lower than expected, given the size of the segment and the criticality of services provided.
- Social value, on the other hand, is large at £90m, reflecting that a disproportionate number of notional lorry miles can be avoided through using rail freight instead of relying on trucks or other means, due to inherent efficiencies.

Considerations

- The Network Rail segment has so far not been studied in detail. The evidence here is therefore only emerging, and is based on a number of assumptions owing to data availability. Furthermore, the methodological approach to estimate social benefits may oversimplify value created given a number of tasks rail freight performs that are practically infeasible to do via other modes
- Future research should emphasise understanding the price-demand relationship in this sector, as well as the counterfactual to relying on FOCs to undertake these services. There is also likely further benefit through Network Rail's use of FOC resources 'at the margin' when they are not deployed (e.g. at weekends).
- The results are also dependent on the short-run counterfactual utilised throughout and would likely change materially if the analysis considered the longer term (see right)

Quantitative estimates vs. customer expectations of benefits today:



Forecast growth of segment

21% by 2043/44

Hypothetical example: Substitutability can vary greatly between the short-run and long-run

According to the timeframe considered, the elasticities used in analysis – which approximate to the degree of substitutability between rail freight and alternate modes, can vary strongly. The estimates are designed to provide a 'snapshot' of the rail freight sector, and thus should be considered to be valid in the short term, i.e. where **marginal changes to the network** are feasible.

To illustrate this important relationship between time and substitutability, consider Network Rail infrastructure services in more detail. Despite being very difficult to substitute from, even a portion of these highly rail-dependent services could hypothetically be mode-shifted in the long-run, with implications for the user value of the segment.

Network Rail services can encapsulate a range of possible activities, including:

Possessions	High Output Ballast Cleaning	Network Distribution	High Output Service Support	Bulk Ballast
Specials	LDCs	Locomotive Maintenance	Rail Head Treatment Trains	Multi Purpose Vehicles

In the short-run, very few of these services could be mode-shifted as they are only viable completed using rail capital and infrastructure and any wholesale attempt to mode shift would be infeasible or prohibitively costly to maintain service provision.
In the long-run, these fixed constraints become far more variable. Given sufficient time, some of the above services could be mode-shifted by altering aspects of the market, though likely at great cost. For example:

- **Service specifications:** altering the characteristics of the service, for instance by allowing maintenance activities to occur in lorry-friendly depots.
- **Infrastructure:** to make the railway road-accessible, significant infrastructure spending would be required, which is only possible at longer timeframes.
- **Market design:** from a governance perspective, industry standards would have to be revised to make road-based support services feasible and competitive.

Nonetheless, the greater substitutability in the long-run would lead to lower benefits stemming from rail freight as the transport system could be increasingly reoptimized over time.

Part 4-3

Scenario analysis of future social benefits

Social impacts for rail freight in the future (1/2)

The environmental benefits of rail freight are likely to increase in the future

Rail freight delivers significant environmental benefits today, but these could grow going forward

Rail freight already offers significant social benefits to the UK economy today at an estimated £800m,[1] but these are likely to grow forward as a result of:

- **Fundamental changes in the sector over the next 20-30 years**: decarbonisation of rail freight, coupled with growth in intermodal and construction sectors (see below) are likely to increase environmental benefits through modal-shift. However, such benefits are likely to be relatively tempered to an extent by the decarbonisation of road transport (not factored into the analysis in this report); and
- **Changes to the way environmental impacts are valued:** revisions and consultations on the Green Book suggest carbon values currently used within economic appraisal understate the value of reductions and that application of lower discount rates for environmental benefits should be looked at (see below, with an example related to the latter set out right).

Decarbonisation of the railway and growth in strategic sectors

Decarbonisation: Current analysis is based on whole or part diesel locomotive use, meaning environmental benefits of rail freight could increase should efforts like Network Rail's Traction Decarbonisation Network Strategy (TDNS) be put in place.[2]

Strategic growth in key sectors: analysis by Network Rail shows that in a conservative scenario sectors such as intermodal and construction and aggregates, which have the greatest ability for modal shift, are likely to significantly grow.[3]

Upcoming changes to the appraisal of environmental impacts on economic analyses

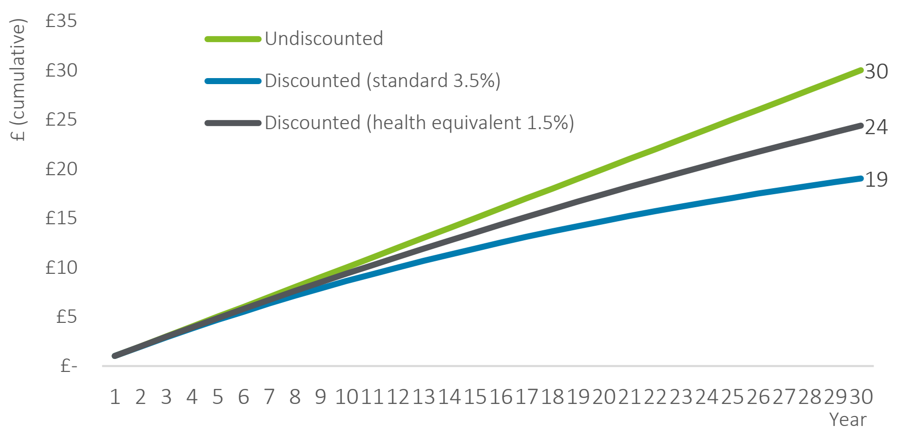
Potential changes to carbon pricing The literature suggests carbon prices utilised used in appraisal today underestimate the true cost of emissions.[4,5] Given this, the recent revision to the Green Book proposes use of higher carbon values in the future in appraisals.

Potential changes to the discount rate applied to environmental benefits Though results in this report are annual, consultations on the Green Book suggest for multi-year appraisals it may be appropriate to apply a lower discount rate for environmental benefits realised in future periods than used today.

Hypothetical example: Impacts of application of alternative discount rates on total benefits in a multi-year appraisal

As part of the Green Book review and consultation process, the size of discount rates applied to streams of benefits in multi-year appraisals were considered. Indeed, it was suggested to recognise the importance of environmental benefits it may be appropriate for such benefits to be discounted at a lower rate than standard, similar to the treatment of health benefits. Were lower discount rates for environmental benefits to be utilised this would increase the size of future benefits in todays terms and hence, could increase the size of rail freights environmental contribution over the coming years.

An example to illustrate this is set out below. Here, a constant stream of £1 in benefits over 30 years is set out on three bases (i) undiscounted, (ii) discounted at the standard Green Book 3.5% per year and (ii) discounted at 1.5% per year as with health benefits.[6] As shown in the chart below over a 30 year period £30 in undiscounted benefits equates to £19 when using (ii) and £24 when using (iii). As such, were the discount rate applied to environmental benefits to decrease to a level similar to that applied to health outcomes, over a 30 year period this could increase their value today by over 25%.



Source: Deloitte Analysis

[1] Deloitte analysis , as set out above in this report
[2] Network Rail, 2020. Traction Decarbonisation Network Strategy: Interim Programme Business Case.
[3] Forecasts taken from Scenario E (central case/do-minimum) in Network Rail, 2020.Rail Freight Forecasts: Scenarios for 2033/34 & 2043/44
[4] OECD, 2018. Effective Carbon Rates. Available here.
[5] The Zero Carbon Commission, 2020. How Carbon Pricing can help Britain achieve Net Zero by 2050. Available here
[6] HM Treasury (2020) "The Green Book: Central Government Guidance on Appraisal and Evaluation", See here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf

Social impacts for rail freight in the future (2/2)

Given decarbonisation, growth and anticipated rises in carbon prices, benefits could increase by £400-£600m in future

To illustrate the impact of such changes a scenario has been developed to 'size the prize' of potential future environmental benefits

The approach to estimate social benefits set out above in this report has been used in combination with assumptions to reflect each of the factors on the previous page to understand the potential increase in the social benefits of rail freight going forward. These assumptions are:

- In line with Network Rail's Traction Decarbonisation Network Strategy, a 90% reduction in emissions for rail vis-à-vis road is assumed to capture the potential impact of decarbonisation.
- Based upon Network Rail's latest forecasts for rail freight, intermodal and construction and aggregates volumes have been grown to 2043/44 from today's level (holding other sectors served constant).[1]
- To capture potential increases in Carbon prices, BEIS's central and high 2050 published carbon prices (as utilised in DfT's TAG) have been applied when calculating social benefits.

Based on these assumptions, the potential 'size of the prize' in extra benefits could be £400m-£600m annually[2]

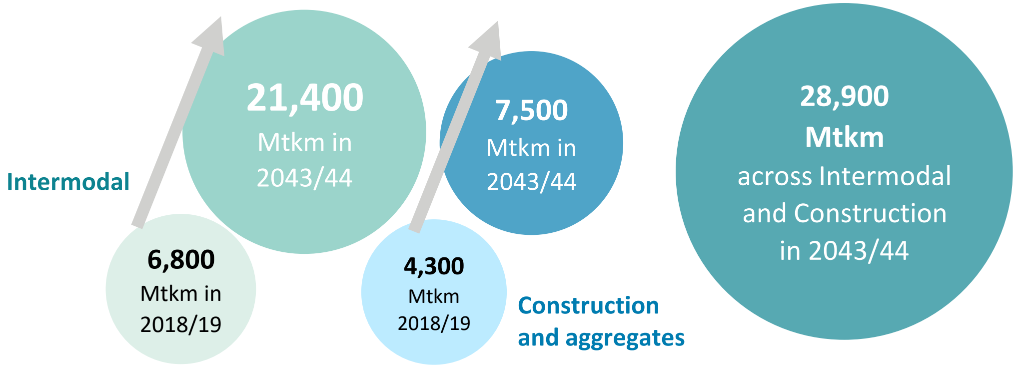
Given these assumptions the potential size of additional environmental benefits could:

- Save **over double the level of emissions compared to today**; and
- Deliver **additional quantified benefits of between £400m - £600m annually** by 2043/44 (depending on carbon prices used to value impacts).

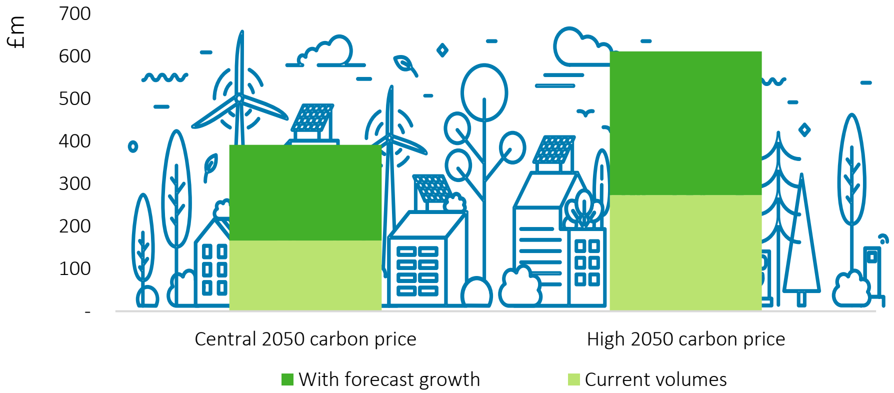
It should be noted that the analysis of changes in the size of environmental benefits with decarbonisation, changes to carbon prices and anticipated volume growth assumes no decarbonisation of road transport relative to today. This is likely to overestimate the impact of traction decarbonisation on rail benefits compared to road in the future. However, such an assumption has been made at the time of writing given that (i) road (HGVs), has more technological challenges to overcome to decarbonise than rail and (ii) as assumptions regarding decarbonisation of road freight are more uncertain.

Achievement of further improvements in environmental benefits as illustrated in these scenarios will require further investment to achieve and as such are uncertain. Further research should account for road decarbonisation in projections of future impacts.

Forecast growth in Intermodal and Construction & aggregates by 2043/44[1]



Potential social benefits released (£m per year by 2043/44) were decarbonisation and volume growth realised



Sources: Deloitte Analysis, Network Rail, DfT, ORR

[1] Forecasts taken from Scenario E (central case/do-minimum) in Network Rail, 2020. Rail Freight Forecasts: Scenarios for 2033/34 & 2043/44
[2] Deloitte analysis

Part 4-4

Sensitivity testing

User benefits

The demand curve specification utilised in the analysis significantly affects the total size of benefits

When estimating user benefits a range of demand specifications are utilised. While each produces consistent and intuitive results in how benefits are distributed across sectors, the particular choice of specification significantly affects the magnitude of results.

In particular, for each the three specifications utilised (CED with Taylor Approximation, negative exponential and linear – see Appendix for full details) a key determinant of the level of user value generated is the 'intercept' of the price axis in the market demand diagram set out to the top right (i.e. the market price at which quantity demanded equals zero) where as shown, the higher the intercept relative to current market price, the greater level of user benefits estimated (as user benefits is estimated as the area under the curve above the market price).

The figure to the bottom right illustrates the results of varying the demand specification with high, central and low estimates for user benefits reflecting how the different specifications affect the size of the intercept:

- **High:** the higher estimates reflect the use of CED functional form with a Taylor approximation where required (which implied the highest intercept);
- **Central:** the central estimates detailed throughout Part 4 of this report represent the negative exponential demand curve estimates; and
- **Low:** the lowest estimates reflect the linear demand curve specification (which implies the lowest intercept)

As shown, the impact of such uncertainty is largest for sectors where reliance on rail is high and there is a lack of substitutability to other modes. This is because the lower magnitude elasticities which capture this lack of substitutability amplify the impact of the demand curve specification on the size of the intercept.

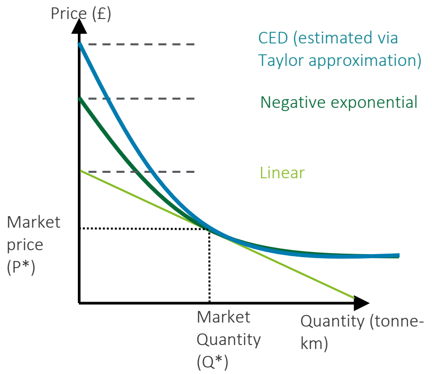
Given the range of uncertainty overall, a cross-check of the analysis has been undertaken which is set out on the next page.

Sensitivity analysis on user benefits of rail freight: demand curve specification

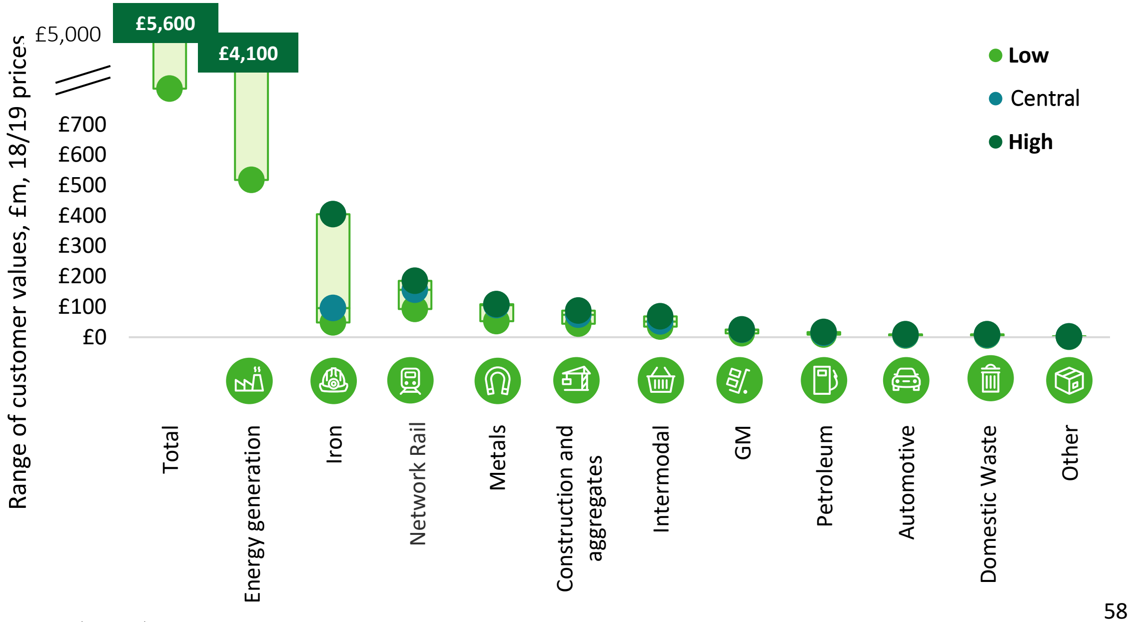
CED functional form: highest intercept, highest welfare estimation

Negative exponential: Likely lower intercept than CED, and lower welfare estimate

Linear functional form: Lowest intercept, and lowest welfare estimate



Results of sensitivity analysis on demand specification (18/19 volumes and prices)



Source: Deloitte Analysis

User benefits

A 'top-down' cross-check on the overall magnitude of user benefits shows a comparable aggregate quantitative estimate

Given the uncertainty with respect to estimated user benefits set out on the previous page, as a cross-check for the size of estimated user benefits, a supplementary analytical exercise has been undertaken. The aim of this is to assess the broad order of magnitude of user benefits priced into differences between average levels of rail freight prices and road transportation costs - i.e. cost savings to users[1].

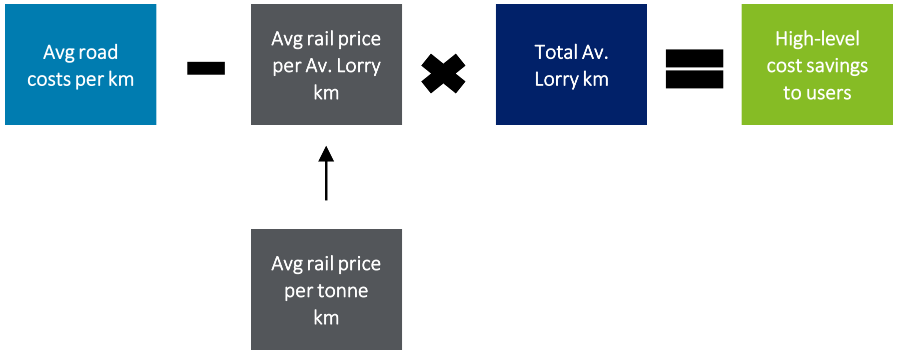
This analysis is based on previous work undertaken by RDG and involves:

- Using the FTA Manager's Guide to Distribution Costs (Jan 2020 edition) to estimate average road costs on a per km basis for each sector.
- Utilising data consistent with that used to generate the central estimate of user benefits on average rail revenues (prices) from FOCs along with data from the DfT and ORR on volumes of freight (tonne km) and equivalent avoided lorry km from ORR on a per commodity basis.
- Taking the difference in average road costs and rail prices on a per km basis by commodity and multiplying these by the associated number of avoided lorry km to yield a high-level aggregate estimate of cost savings to users.

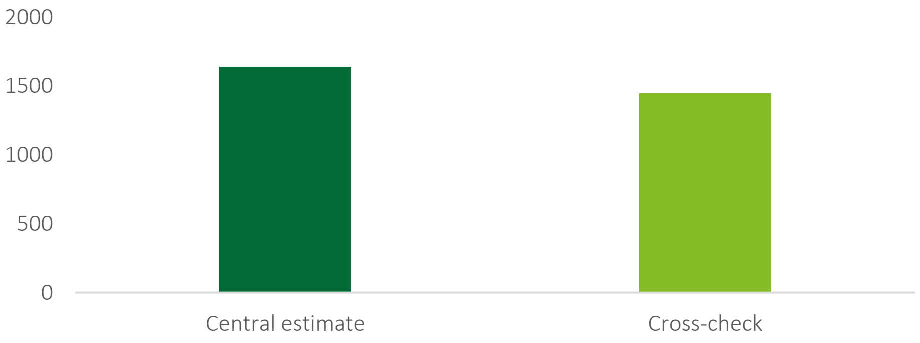
As shown to the right, **this cross-check results in estimated user benefits of £1.45bn per annum, compared with the central estimate of user benefits of £1.64bn.**

Based on this the cross-check as such provides a degree of confidence in the broad magnitude of the central figures (noting the uncertainty on the previous page). However, it should be stressed that this is a high-level analytical comparison and further work should be undertaken to take the work forward (as set out in Part 6).

Approach to high-level cross-check of user benefits estimation



Results of high-level cross-check compared to central estimate (18/19 volumes and prices)



Source: Deloitte Analysis, FTA Manager's Guide to Distribution Costs (Jan, 2020)

1 Road costs, rather than prices have been utilised owing to data availability, but it should be noted was a profit margin to be added to this and compared with estimated rail freight prices, this would increase the size of user benefits estimated under this approach

Tax impacts

Taxes are transfers between users of freight and wider society and do not feature in the main results

Approach in the core analysis

Social benefits that are considered in the main results of this report are focussed on the wider environmental and other social impact of rail freight usage today relative to road/other modes. They do not include consideration of any impacts, positive or negative on taxation revenues. In particular, as from a societal perspective, taxes represent transfers rather than net gains or losses.

Taxation impacts within appraisal guidance

Within the Green Book and TAG/STAG it is often the case that the impact on public finances is considered alongside benefits generated. For example, in the case of modal shift, impacts on:

(i) taxes paid by customers who use rail freight to achieve incremental profit over an above that achieved through use of other modes (i.e. producer taxation effects); and/or

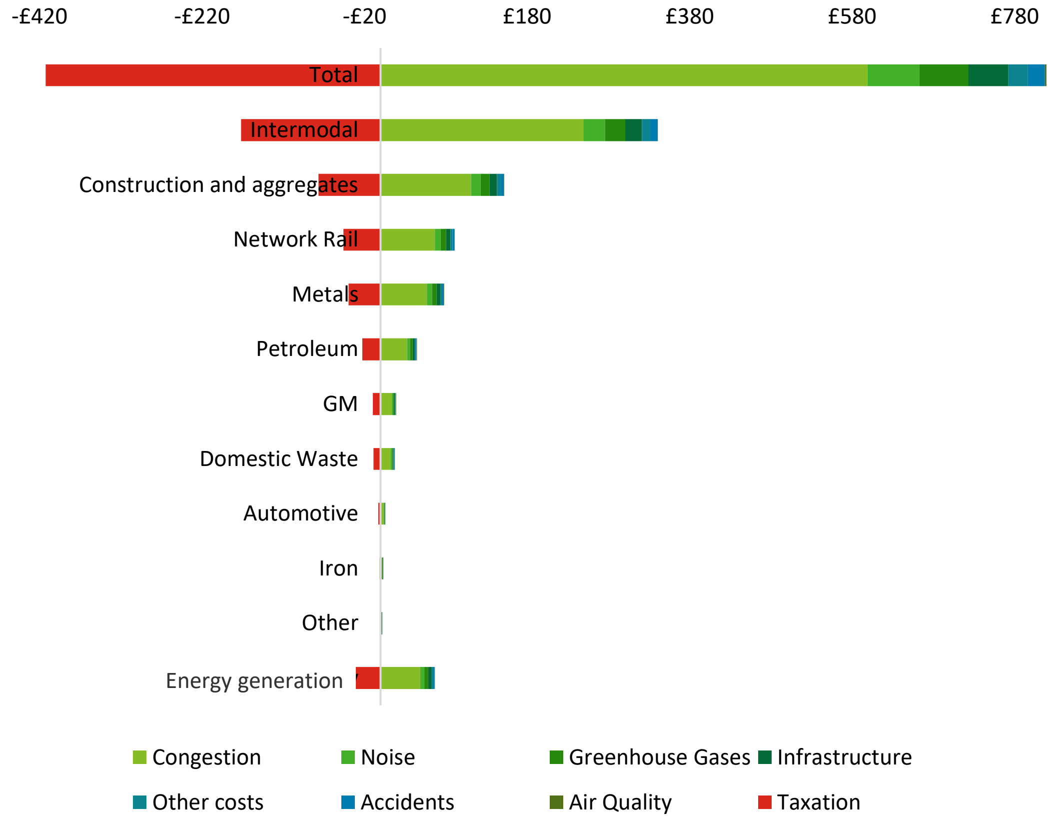
(ii) lost taxation revenues through use of rail freight vis-a-vis vehicles which yield supplementary revenues (e.g. through road tax, fuel duty).

Illustrative taxation impacts

A full study on the taxation impacts of rail usage over road is beyond the scope of this report, but for purposes of illustration, in line with TAG/STAG, we provide estimates of the potential losses in tax revenues from mode shift from road to rail based on (ii) above in the chart to the right. At the time of writing data was insufficient to analyse taxation impacts associated with (i).

As shown, owing to the significant differential of taxes paid by road vs rail vehicles, the implied tax effects of current rail freight usage over road are significant. However, this only represents a partial picture. As noted above, for a complete analysis including taxation, other impacts such as the positive tax effects of enabling incremental profits for businesses through supplying rail freight as a service (i.e. (i) above) would need to be factored in as they would work to counteract this effect.

Sensitivity analysis on social benefits: taxation effects (18/19 volumes and prices)



Source: Deloitte Analysis

Part 5

Applying the framework for decision-making

Part 5-1

Informing decision-making

The need for a decision-making framework

Rail freight could play a bigger role going forward, but there is a need for an integrated framework to recognise its benefits alongside other services

Rail freight has the potential to play a bigger role in the economy going forward

As set out above in Part 4, rail freight already creates substantial value for the UK economy. Rail freight has the potential to facilitate and support the achievement of wider policy goals over the coming decades (see right). However, to play this role will require the right strategic decision to be made in respect of investments, capacity allocation and modal shift.

Freight strategy is currently based on a partial picture of freight benefits

Within the rail industry, considerations for key strategic decisions (see right) vary between organisations with different levels of emphasis being given to the economic benefits and costs of particular services:

- Investment decisions and analysis to inform modal shift strategy within DfT, Transport Scotland and Network Rail do incorporate an economic case for new policies, with analysis following principles aligned to the DfT's Transport Appraisal Guidance (TAG), as well as equivalent Scottish Transport Appraisal Guidance (STAG); and

- Capacity allocation decisions, train planning and access applications considered by ORR and Network Rail have some element of cost-benefit analysis rooted in similar principles, but also involve a range of operational and commercial considerations (for example, ORR's decisions must be made in line with all its Statutory Duties and Network Rail's in line with service plans and contractual obligations).

Notwithstanding these differences, guidance followed and methods employed to assess the economics of particular decisions are typically based on articulating and quantifying a subset of potential benefits in the case of freight.

Towards a more holistic assessment of rail freight benefits to inform strategic planning decisions

There is a wider impetus in the industry to move towards a net-benefit led approach to investment and capacity allocation decisions. Furthermore, across UK Government, through both DfT's issuance of supplementary guidance to TAG (as well as research such as Venables et al (2014) 'Transport Investment and Economic Performance' (TIEP) [1]) and as part of the recent revised Green Book, there is increased emphasis on taking account of benefits for particular interventions aligned to their strategic case.

Such advances provide flexibility for investment and other strategic planning decisions to take account of context-specific aspects (such as the role of freight) that currently go beyond TAG/STAG and other methods of appraisal used within the industry. However, to fully inform strategic decision going forward requires a comprehensive framework to be developed which builds upon existing guidance, but provides greater coverage of freight benefits and allows for them to be compared to the benefits of other services in a way that is in line with recent Green Book revisions.

Key policy areas rail freight could support going forward

Given current technologies available rail freight presents significant potential to support decarbonisation, and together with growth in sectors that facilitate modal shift, can bolster efforts to **achieve UK net zero** emissions by 2050

Supporting the effectiveness of the UK to 'build back better' from COVID-19 through *'oiling the wheels'* of the economy and taking pressure off road and urban infrastructure

Contributing to the UK Government's 'levelling up' of the UK economy, through transporting larger volumes of goods over longer distances and connecting cities across the country.

[1] Venables, AJ, Laird, J and Overman, H (2014) "Transport Investment and Economic Performance: Implications for project appraisal", see here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/386126/TIEP_Report.pdf

Application for decision-making

The framework employs four simple steps to enable decisions

Given the analysis of the benefits of freight to the UK economy above, a potential framework has been developed that builds on and is compatible with DfT's existing TAG/ Transport Scotland's STAG. The graphic on the right hand side describes how the framework can be used to assess value across alternatives, and trade off costs and benefits of different options under consideration for a particular decision. Key steps include:[1]

1. Articulate the value of proposed freight services in general: The first step is to draw on the framework set out in Parts 2 and 3 of this report to understand the value of the proposed service in general – assessing user and social benefits.

2. Incorporate the value of a particular path/slot: For some decisions, it will be important to be able to assess the value of specific slots over others. To enable assessment of this, an approach is outlined in the following pages.

3. Assess the value of alternatives: To compare different options, the value of alternatives needs to be assessed. This may require 'matching' freight benefits to benefits of the other service or option, for instance to passenger benefits, for comparison.

4. Compare costs and benefits: The final step involves drawing on the outputs from steps 1-3, and comparing both costs and benefits (Value) across all options. This may include further analysis, e.g. in accordance with the recently revised Green Book or other guidance.

1 Value freight service in **general**

Inputs

Details of potential freight service
- Type/volume of commodities transported
- Distance transported
- Expected modal switch

Per tonne km values for user and social benefits (based on the value of rail freight to the UK economy)
- User benefits for each commodity type per tonne km
- Social benefits from modal switch per tonne km

Outputs

Estimated general value of a service
- Quantitative value of a particular service/investment
- Qualitative articulation of wider benefits not quantified

2 Value use of a **particular path/slot**

Inputs

Details of potential service timings
- Expected path/slot time
- Counterfactual path/slot time (or if not delivered)

Understanding impacts of delivery to customers at a specific time
- Articulation/quantification of lost revenues to customers
- Articulation/quantification of extra costs incurred by customers and/or FOCs

Outputs

Estimated value of a particular slot/path
- Quantitative value of revenue losses and costs that would be avoided through use of the expected path/slot

Estimated value of a service using a particular slot/path
- Quantitative value of benefits from freight utilisation of a particular path/slot

3 Assess **alternatives**

Inputs

Details of alternative service
- *If passenger*: expected type, and number of PAX, distance travelled, time, reliability and costs saved versus alternatives
- *If freight*: same details as in Step 1 and 2 (to left)

Comparative values for passenger/freight benefits
- If passenger – from TAG
- If freight – the per tonne km values based on the value of rail freight to the UK economy

Outputs

Estimated value of an alternative service using a particular slot/path
- Quantitative value of an alternative passenger/freight service utilising the same path/slot

4 Compare **costs and benefits**

Inputs

Relative values of benefits to compare (as outputs of stages 1, 2 and 3)

Details of any incremental/investment costs between services/options

Outputs

Determination of service/option that represents best value for money
- Articulation of comparable benefits and costs in the form of benefit:cost ratio (BCR) and net present values (NPVs)

[1]It should be noted that the results produced here (Part 4 and for illustration applied in Part 5) give an indication that the structure of the approach can be adopted for decision-making, but would require further analysis and research to overcome data limitations, in order to be used for accurate results and applicability to decision-making. As stated previously, the short-run nature of analysis implies that the current decision-making framework is best used for marginal network changes.

Applying the framework for decision-making

Step 1 is to articulate and value freight service benefits in general

To support decision-making, the first step in the framework involves articulating and valuing potential economic and social benefits of services to be introduced (or enabled by new investment) in general (i.e. irrespective of the particular path/slot time being considered).This allows for use of the analysis of the economic and social value freight contributes to the UK economy (see Part 4) based on service-specific details (see below).

Articulating and valuing benefits using the quantitative assessment of benefits to the UK economy

The identified list of freight benefits can first be used to articulate the benefits of the introduction of a service in general qualitatively. The results of the quantitative assessment in this report (user benefits on page 46 and social benefits on page 47) can then be scaled by the size of volumes for each sector served to allow for benefits to be expressed on a per tonne km basis (as shown to the right).[1] This is important as the per tonne km values can then be used to estimate the benefits of particular services based on what commodity they carry, how much they carry of it and for how far.

Even though the marginal benefit of a particular tonne km that is transported varies with overall volumes (as captured in the changing slope of the demand curve – see Appendix) an average value is adopted so that: (i) it is in keeping with the approach utilised in the appraisal of other services (such as passenger services which utilise average user values of time)[2] and as (ii) for a specific decision/intervention, it is uncertain which particular change in volumes is being valued at the national level (i.e. it is uncertain whether volumes being effected are 'marginal' or not).

Defining the service(s) being analysed

The benefits expressed on a per tonne km basis can then be used in combination with information on the three key points below to assess benefits delivered by running a new service (or by making an investment to enable one to run). Specifically:

- **The type/volume of commodities transported -** the type of customers being served by new freight services will benefit the type and level of benefits delivered as these vary by sector;
- **Distance transported –** the longer the distance new services transport goods over, the higher the benefits; and
- **Expected modal switch** – to understand whether the new services could lead to social benefits it is important to understand whether freight transported would be expected to take freight off the road (or from other modes), and if so to what extent.

Estimated freight benefits per sector on a per tonne km basis (18/19 volumes and prices)[3]

	User benefits £ per Mtkm	Social benefits £ per Mtkm	Total benefits £ per Mtkm
Iron	800,000	20,000	**820,000**
Energy generation	470,000	30,000	**500,000**
Automotive	100,000	60,000	**160,000**
Network Rail	130,000	60,000	**190,000**
Metals	80,000	60,000	**140,000**
Other	60,000	50,000	**110,000**
GM	60,000	50,000	**110,000**
Domestic Waste	20,000	50,000	**70,000**
Intermodal	10,000	50,000	**60,000**
Construction and aggregates	20,000	30,000	**50,000**
Petroleum	10,000	30,000	**40,000**
Total	**90,000**	**40,000**	**130,000**

Source: Deloitte Analysis

[1] User and social benefits used to generate benefits on a per tonne km basis as set out on this page are detailed in Part 4 with assumptions set out in the Appendix
[2] DfT (2017) "TAG Unit A1-3 User and Provider impacts", see here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/603254/webtag-tag-unit-a1-3-user-and-provider-impacts-march-2017.pdf
[3] It should be noted that estimates presented for user benefits do not take account of certain sectoral details that could affect the overall levels of estimated benefits. In particualr, elasticities applied are whole-sector UK averages and do not reflect the potentially higher value of flows into urban areas (e.g. construction and aggregates) nor the potentially higher value for certain sector sub-segments (such as deep-sea intermodal)

Applying the framework for decision-making

Step 2 incorporates the value of use of a particular path/slot and delivery at a specific time

Step 1 allows for the general quantification of benefits for a service when it otherwise would not be transported by rail freight. However, it does not recognise the value of use of a particular path at a particular time of day over another.

It is important to also account for the value to customers for delivery of products at a particular time (see below) as for other service types, the value of transport at a particular time is incorporated in appraisal methods. For example, with passenger services, specific passenger types have alternate values of time and the mix of passengers (and hence values of time) vary between different hours in the day.

Delivery at a particular time matters for freight

Should the decision at hand involve the transportation of rail freight between two alternative time slots it is important to take account of the incremental value for customers due to expected delivery at a particular time, versus an alternative (later or earlier) time. In particular, as should goods arrive early or late this could lead to:[1]

1. **Losses in revenues** – for example, if perishable goods are unable to be sold (in the case of grocery delivery and/or certain intermodal traffic) or if cycles of freight deliveries are interrupted which impacts business productivity (in the case of construction and aggregates) and volumes that could have been sold; and/or

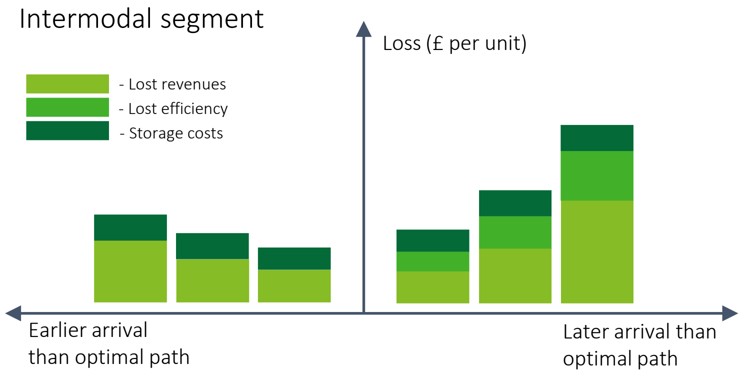
2. **Extra costs incurred** – for example, if extra storage needs to be acquired for goods that arrive early (such as in the case of coal or biomass), if contractual fines are issued due to late arrival (as in the case with intermodal) or for alternative transport to be laid on to meet fixed delivery windows).

Conceptually, the losses for customers if goods are delivered at an alternative, rather than expected time, can be shown through 'loss functions' (see right) whereby deviations from the ideal delivery time lead to losses to customers and increase as the time deviation increases. Examples of losses referenced by customers include spoilt perishables, unusable cement, or requiring storage space to hold and stock-pile goods near client locations to ensure timely delivery (with two specific quotes are set out to the right).

To understand the impacts of a particular path/slot requires context-specific analysis of customer losses

Depending on the specific decision/investment at hand, supplementary evidence gathering would be required from potentially affected customers to understand their losses should goods be delivered using an alternative rather than the expected path/slot. The value of such losses would then be treated as a benefit (avoided loss) for the particular path/slot that was being analysed and added to the general impacts for the service (estimated in Step 1).

Illustrative example of a loss function



Views on potential losses from freight customers

> "If goods do not reach us in time before shelves are stocked the store is opened, we risk losing revenues and incur reduced productivity"
>
> - Tesco

> "Due to infrequent rail paths yet increasingly time conscious customers, we need to incur additional storage costs that let us meet our demand flexibly and quickly."
>
> – Aggregate Industries

[1]The time criticality factors considered in Step 2 may not be relevant to all investment decisions, or indeed to all sectors. For instance, domestic intermediate aggregates rail freight haulage may be freely delivered to sites with large or unbounded storage capacity, with no resultant implications for losses incurred due to arrival being earlier or later than optimal.

Applying the framework for decision-making

Step 3 is to 'match' quantified freight benefits against impacts of comparable service/option

The first two steps focus on assessing the freight option under consideration. The third step is to assess the alternatives.

When comparing only freight-specific options, the first step in the framework can simply be repeated for the alternatives. However, in the case that a different option is considered, e.g. a passenger service, this third step may require 'matching' the freight benefits against impacts of the comparable service.

This framework has been designed to be consistent with the transport appraisal framework used to assess value in the context of passengers. The table to the right outlines how the freight impacts assessed *in this report* compared to the corresponding passenger framework *in TAG*. Note that for Scottish regional assessment, Transport Scotland's analogous STAG framework should be referred to.

The table to the right illustrates how each of the freight framework components aligns to a component in the passenger framework. This mapping is relatively straight forward as the freight framework builds on the same economic concepts underpinning the passenger framework (consumer surplus and external cost), such that impact and benefit channels across the two are easily comparable.

Mapping of freight benefits set out in this work ton passenger benefits set out in TAG/STAG

	Freight framework component (set out in this work)	Passenger framework component (as set out in TAG/STAG)	TAG/STAG component
	User benefits (consumer surplus)	**User benefits (Consumer surplus)**	
Quantified jointly as user benefits in this work for freight	Cost savings	Vehicle operating costs	TAG unit A1-3 user and provider impacts
	Time savings	Journey time savings	TAG unit A1-3 user and provider impacts
	Reliability	Reliability	TAG unit A1-3 user and provider impacts
	Social benefits (externalities)	**Social benefits (externalities)**	
Quantified jointly as social benefits in this work for freight	Environmental externalities	Marginal external costs	TAG unit A3 environmental impact appraisal
	Congestion	Marginal external costs	TAG unit A3 environmental impact appraisal
	Safety	Marginal external costs	TAG unit A5-4 marginal external costs
Unquantified in this work for freight	Agglomeration: static	Agglomeration: static	TAG unit A2-1 wider economic impacts appraisal
	Agglomeration: dynamic	Agglomeration: dynamic	TAG unit A2-1 wider economic impacts appraisal

Applying the framework

Step 4 compares the costs and benefits across options and may involve decision-specific analysis

Final steps for applying the framework

The final step to applying the framework is to draw on the results from Steps 1-3 and compare costs and benefits across all options, to enable an assessment of the value for money each option provides.

According to general practice and government guidance such as the Green Book, this may involve some further, decision-specific analysis, including:

- **Deriving the Net Present Value of each option**: assessing the likely accrual of the benefit and costs over time, including incorporating discount factors and adjusting for inflation;
- **Compiling Benefit-Cost-Ratios**: BCRs tend to be a key metric in transport decision-making. Options with higher BCRs are preferred over options with lower BCRs in economic terms. As noted in the preceding step, the passenger framework tends to attach different levels of priority to different components of the BCR.

The outcome of such analysis can then be cast alongside the strategic need for a particular intervention to determine the way forward for decision-makers in line with revised Green Book guidance.

Example applications – Case studies

The following pages outline examples for how this framework can be used in practice for particular decisions at a high-level. It outlines the following three cases studies:

01 **Value of a freight vs. a passenger path:** Illustrative impacts of replacing **a passenger service with a freight service on a rural route**

02 **Value of a freight vs. a passenger path:** Illustrative impacts of replacing **a passenger service with a freight service on a commuter route in the off-peak compared to the peak**

03 **Value of train lengthening:** Illustrative impacts of adding a shorter or longer freight train on a rural service

Other types of decisions this framework can support

While the walk-though of the potential decision-making framework set out in this Part primarily focusses on investment/capacity allocation contexts, the principles and values it uses can also inform a much broader set of strategic planning decisions. For example:

- **Strategic decisions for rail freight growth**: The evidence collated here can also provide a basis for strategic decisions, such as where to focus efforts for rail freight growth, including understanding customer segments where particular growth may yield higher values of benefits to the economy than others.
- **Informing benefits of and derivation of modal shift targets:** the framework can be drawn upon to deduce the environmental benefits of achieving further mode shift, and which sectors, may be most impactful for this. Furthermore, the values of modal shift per commodity used in combination with an overall carbon reduction target may be used to estimate the number of road or other journeys that need to be transferred to rail to meet such an overall goal.
- **Evidencing the benefits of train lengthening:** train lengthening allows for the transport of greater volumes of goods within the same network capacity for incremental increases in running costs. The value of benefits derived in this work can be used to weigh up the benefits and costs of train lengthening based on the commodities that may be carried by longer trains. Note, however, that shorter trains may have their own advantages such as greater flexibility on lines used in parallel with passenger services.

Part 5-2

Examples of applying the framework

Applying the framework

An introduction the case study approach

Purpose and format of case studies

The case studies presented in this Part are intended to illustrate how the framework set out above can be used in practice to inform decision-making. The case studies are high-level and hypothetical, but have been chosen specifically to represent the types of decisions that are likely to be needed to make the case for making better us of capacity and/or further investment for specific freight services. They are based on a range of specific assumptions set out on the following pages. Each case study considers adding one new freight service per day on to a hypothetical route:

01 **Value of a freight vs. a passenger path:** Replacing a passenger service in the off-peak with a freight service on a semi-rural route

02 **Value of a freight vs. a passenger path at different times:** Replacing a passenger service with a freight service on a commuter route in the off-peak compared to the peak

03 **Value of train lengthening:** Adding a shorter or longer freight train on a semi-rural route, which replaces an off-peak passenger service

The case studies are presented on the next three pages as set out to the right.

Key assumptions for case studies

- They consider only user benefits for comparison, and in the case of passenger services only time savings (meaning this does not include vehicle operating cost savings and reliability as further detailed information would be required to build these in to the work). Social benefits (including from mode shift), extra "avoided" losses and agglomeration impacts are therefore not considered;
- Where analysed assumptions for passenger services on the value of time and composition of passengers have been taken from the DfT's TAG databook.
- As in the core analysis, the case studies do not include analysis of any associated taxation impacts
- In the peak, capacity is constrained so displaced passengers are not be able to travel by rail if a service is removed, instead needing to travel by an alternative (assumed to be road);
- In the off-peak, it is assumed that passengers from a displaced service can use other off-peak rail services. The disbenefit of removing an off-peak service (or benefit of retaining the service) is the increase in headway (i.e. increased journey time costs); and
- Freight trains would carry full capacity on each service.

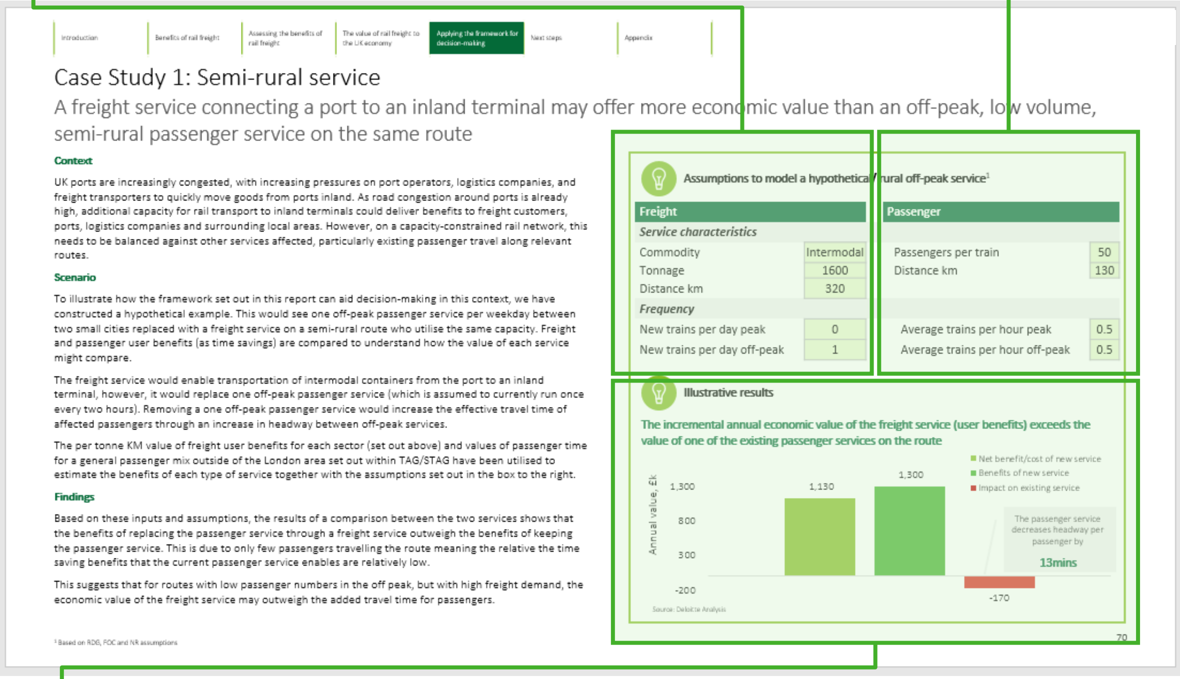
1 Value freight service in general → **2** Value use of a particular path/slot → **3** Assess alternatives → **4** Compare costs and benefits

1 Assess value of new freight services using the benefits on a per tkm basis developed in this report, alongside service characteristics (volumes and commodities) and frequency

User benefit per tkm x volume x trains per year = annual freight user benefit

3 Assess value of the alternatives or counterfactuals, here the continued running of an existing passenger service

Time savings impact x value of time x passengers per year = annual passenger benefit


Introduction | Benefits of rail freight | Assessing the benefits of rail freight | The value of rail freight to the UK economy | Applying the framework for decision-making | Next steps | Appendix

Case Study 1: Semi-rural service

A freight service connecting a port to an inland terminal may offer more economic value than an off-peak, low volume, semi-rural passenger service on the same route

Context

UK ports are increasingly congested, with increasing pressures on port operators, logistics companies, and freight transporters to quickly move goods from ports inland. As road congestion around ports is already high, additional capacity for rail transport to inland terminals could deliver benefits to freight customers, ports, logistics companies and surrounding local areas. However, on a capacity-constrained rail network, this needs to be balanced against other services affected, particularly existing passenger travel along relevant routes.

Scenario

To illustrate how the framework set out in this report can aid decision-making in this context, we have constructed a hypothetical example. This would see one off-peak passenger service per weekday between two small cities replaced with a freight service on a semi-rural route who utilise the same capacity. Freight and passenger user benefits (as time savings) are compared to understand how the value of each service might compare.

The freight service would enable transportation of intermodal containers from the port to an inland terminal, however, it would replace one off-peak passenger service (which is assumed to currently run once every two hours). Removing a one off-peak passenger service would increase the effective travel time of affected passengers through an increase in headway between off-peak services.

The per tonne KM value of freight user benefits for each sector (set out above) and values of passenger time for a general passenger mix outside of the London area set out within TAG/STAG have been utilised to estimate the benefits of each type of service together with the assumptions set out in the box to the right.

Findings

Based on these inputs and assumptions, the results of a comparison between the two services shows that the benefits of replacing the passenger service through a freight service outweigh the benefits of keeping the passenger service. This is due to only few passengers travelling the route meaning the relative the time saving benefits that the current passenger service enables are relatively low.

This suggests that for routes with low passenger numbers in the off peak, but with high freight demand, the economic value of the freight service may outweigh the added travel time for passengers.

Assumptions to model a hypothetical rural off-peak service[1]

Freight		Passenger	
Service characteristics			
Commodity	Intermodal	Passengers per train	50
Tonnage	1600	Distance km	130
Distance km	320		
Frequency			
New trains per day peak	0	Average trains per hour peak	0.5
New trains per day off-peak	1	Average trains per hour off-peak	0.5

Illustrative results

The incremental annual economic value of the freight service (user benefits) exceeds the value of one of the existing passenger services on the route

[1] Based on RDG, FOC and NR assumptions

70

4 Compare costs and benefits across the different options considered to understand which delivers more value overall.

Net-benefit of option = value of freight service – value of alternative

Case Study 1: Semi-rural service

A freight service connecting a port to an inland terminal may offer more economic value than an off-peak, low volume, semi-rural passenger service on the same route

Context

UK ports are increasingly congested, with increasing pressures on port operators, logistics companies, and freight transporters to quickly move goods from ports inland. As road congestion around ports is already high, additional capacity for rail transport to inland terminals could deliver benefits to freight customers, ports, logistics companies and surrounding local areas. However, on a capacity-constrained rail network, this needs to be balanced against other services affected, particularly existing passenger travel along relevant routes.

Scenario

To illustrate how the framework set out in this report can aid decision-making in this context, a hypothetical example has been constructed. This would see one off-peak passenger service per weekday between two small cities replaced with a freight service on a semi-rural route which uses the same capacity. Freight and passenger user benefits (time savings) are compared to understand how the value of each service might compare.

The freight service would enable transportation of intermodal containers from the port to an inland terminal, however, it would replace one off-peak passenger service (which is assumed to currently run once every two hours). Removing a one off-peak passenger service would increase the effective travel time of affected passengers through an increase in headway between off-peak services.

The per tonne km value of freight user benefits for each sector (set out on Page 65) and values of passenger time for a general passenger mix outside of the London area set out within TAG/STAG have been utilised to estimate the benefits of each type of service together with the assumptions set out in the box to the right.

Findings

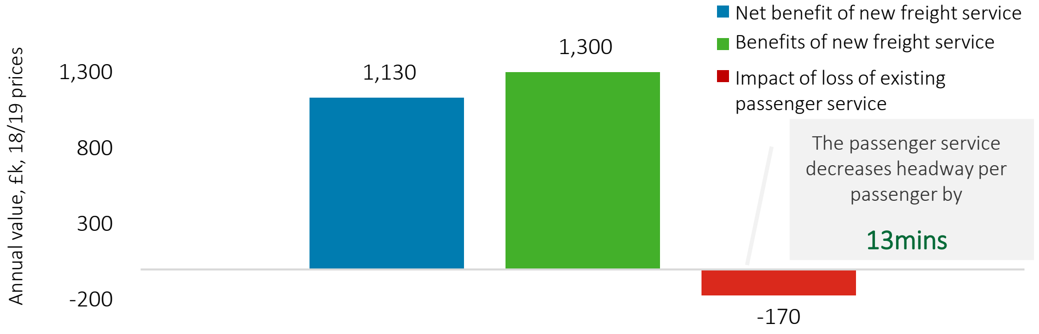
Based on these inputs and assumptions, the results of a comparison between the two services shows that the benefits of replacing the passenger service with a freight service outweigh the benefits of keeping the passenger service. This is due to the relatively small number of passengers assumed to be travelling on the route, meaning the time saving benefits that the current passenger service enables over alternatives (and which would be lost with utilisation of capacity for the freight train) are relatively low.

Assumptions to model a hypothetical/ rural off-peak service[1]

Freight		Passenger	
Service characteristics			
Commodity	Intermodal	Passengers per train	50
Tonnage	1600	Distance km	130
Distance km	320		
Frequency			
New trains per day peak	0	Average trains per hour peak	0.5
New trains per day off-peak	1	Average trains per hour off-peak	0.5

Illustrative results

The incremental annual economic value of the freight service (user benefits) exceeds the value of one of the existing passenger services on the route



Source: Deloitte Analysis

[1] Based on RDG assumptions. The numbers used in these case studies are indicative, with passenger services based on pre-COVID-19 passenger demand assumptions. Freight services are based on standard characteristics, but longer and heavier freight services regularly run on the network.

Case Study 2: Commuter services

Passenger services may create more value at peak times, while freight may offer more benefits in the off-peak

Context

Rail capacity on mainlines into cities is particularly scarce as both passengers and freight require access to undertake key economic activities. Depending on the time of day, passengers need to travel to for work and freight operators to transport important commodities to customers (such as building materials). Understanding how to utilise this scarce capacity to best effect is important to policy-makers as they look to optimise network usage across the day to deliver greatest benefit.

Scenario

To illustrate how the framework can help understand the impacts of the difference in the timing of a potential new freight service into an urban area, we consider a hypothetical example of replacing an existing passenger service with a freight service in the peak versus the off-peak on a commuter route into London. The 'new service' enables freight transportation of construction and aggregates materials once per weekday, replacing one passenger service.

In the case of the peak train, any passengers displaced by the potential freight train, would be required to use an alternative mode to travel given the network is at capacity (for simplicity we have assumed this is the analogous road journey). In the case of the off-peak train, as for the first case study, losses to passengers from a displaced service would be the increase the effective travel time through an increase in headway between off-peak services.

The per tonne km value of freight user benefits for each sector (set out on Page 65) and values of passenger time for a general passenger mix into the London area set out within TAG/STAG have been utilised to estimate the benefits of each type of service together with the assumptions set out in the box to the right.

Findings

As the box to the right shows, whether a passenger service or freight service may be more beneficial depends on the time of day analysed. As shown:

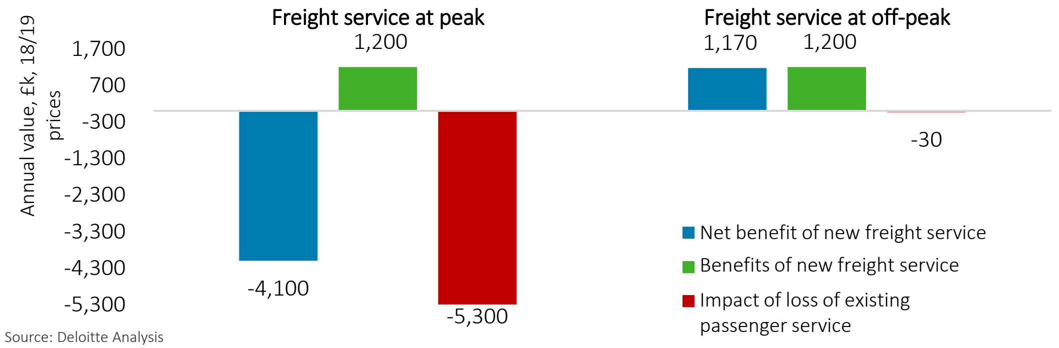
- the representative peak train generates substantial economic value by allowing high volumes of passengers to travel into London utilising a much quicker rail route than through use of road transport. This means compared to the fixed value of the freight service, a passenger service may offer greater benefit; but
- when comparing the same freight benefits to an off-peak service the opposite result arises. In particular, as while the service still carries sizeable passenger volumes, frequent passenger services in the off-peak mean time savings for the use of one particular off-peak service are relatively low.

Assumptions to model a hypothetical commuter route[1]

Freight services		Passenger services	
Service characteristics			
Commodity	Construction	Passengers per train peak	850
Tonnage	2400	Passengers per train off-peak	200
Distance km	100	Distance km	80
Frequency			
New trains per day peak	1	Average trains per hour peak	15
New trains per day off-peak	1	Average trains per hour off-peak	10

Illustrative results

The incremental economic impact of the peak freight service is less than the passenger impact, which would result in a loss of value. The off-peak freight service would add value.



Source: Deloitte Analysis

[1] Based on RDG assumptions. The numbers used in these case studies are indicative, with passenger services based on pre-COVID-19 passenger demand assumptions. Freight services are based on standard characteristics, but longer and heavier freight services regularly run on the network.

Case Study 3: Train lengthening

Train lengthening on a semi-rural route may create additional economic benefits

Context

With an increasingly constrained network, train lengthening could help to increase capacity and efficiency into and out of heavily congested areas (for example, at some of the UK key ports), at the same time as offering social and environmental benefits through reduced congestion and emission savings per tonne moved. Longer freight train services hold potential benefits for rail users, but may also require costs to be incurred. For example, a longer train may require a passenger train to be displaced to leave enough headway between trains or (ii) additional investment (e.g. to improve signalling and the size of 'loops' for freight services may be needed). The latter potential cost is compared to the benefits of train lengthening in this case study.

Scenario

To illustrate the application of the framework in a train lengthening scenario, we consider a hypothetical decision of introducing a longer freight intermodal service, which displaces a single off-peak passenger service[1] on a semi-rural route in the off-peak (as in case study 1). As set out above, replacing the passenger service with a freight service in the off-peak increases headway for passengers who would have to travel on the next available off-peak service.

For means of comparison, and to show the incremental benefit of the ability to carry greater tonnage on a single train, we also include as a reference points the benefits that could be realised by another freight service of normal length (and tonnage) consistent with case study one.

The per tonne km value of freight user benefits for each sector (set out on Page 65) and values of passenger time for a general passenger mix outside of the London area set out within TAG/STAG have been utilised to estimate the benefits of each type of service together with the assumptions set out in the box to the right.

Findings

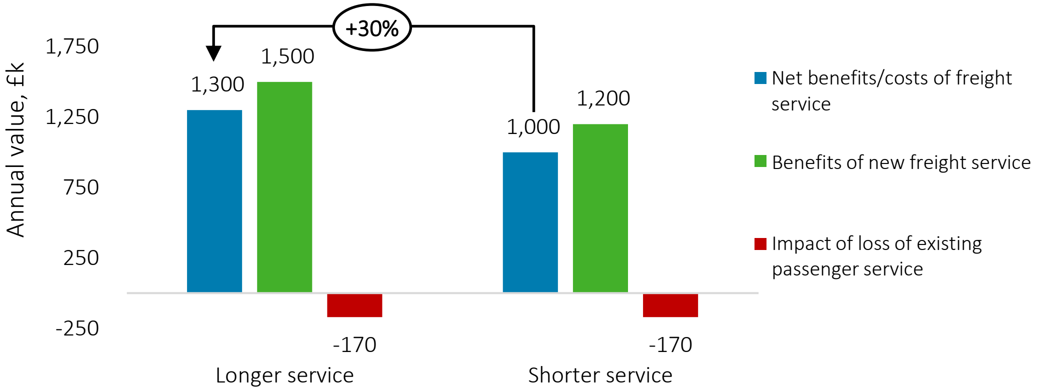
As the box to the right shows the longer freight train is expected to deliver significantly more benefits than the shorter train, due to its ability to carry more goods in one go. This conclusion also holds when a longer train impacts two passenger services rather than one. As such, the case study adds weight to considerations to be made for the introduction of further train lengthening. However, it is important to note this case study assumed no additional investment required to enable the operation of such services. Were this to be required investment costs would need to be compared to net benefits generated by the longer freight services vis-à-vis the passenger service(s) it displaced to determine whether the policy change should be made.

Assumptions to model a hypothetical rural off-peak service[2]

Freight		Passenger	
Service characteristics			
Commodity	Intermodal	Passengers per train	50
Tonnage (long train)	1800	Distance km	130
Tonnage (short train)	1500		
Distance km	320		
Frequency			
New trains per day peak	0	Average trains per hour peak	0.5
New trains per day off-peak	1	Average trains per hour off-peak	0.5

Illustrative results

The longer train service delivers more economic benefits than the shorter service



Source: Deloitte Analysis

[1] Depending on section of the network analysed, the number of passenger trains displaced may be higher, but for simplicity it assumed to be only be one service for this case study

[2] Based on RDG assumptions. The numbers used in these case studies are indicative, with passenger services based on pre-COVID-19 passenger demand assumptions. Freight services are based on standard characteristics, but longer and heavier freight services regularly run on the network.

Part 6

Conclusions and next steps

Conclusions and contributions of this work – taking stock

Advances made by this work in developing the evidence base on rail freight benefits:

This economic study contributes to and advances the evidence base and thinking on the benefits of rail freight usage in a number of ways:

- It provides **a detailed qualitative articulation of the benefits of rail freight** over alternatives based on wide ranging stakeholder engagement with freight customers, policy-makers and other industry bodies;
- It produces **new quantitative estimates of user and social benefits** offered by rail freight to the UK economy (see right) amounting to £2.45bn per year (as of 2018/19);
- For the first time in the UK such **benefits are analysed on a granular sector/customer segment basis** with accompanying rationale for the size of benefits in particular sectors based on the views of freight operators, customers and wider industry;
- It provides an illustration of how **benefits are dispersed across the UK**, based on current freight activity, with the North and East of England as well as Wales accounting for the majority; and
- It provides analysis to '**size the prize' of the potential environmental benefits in the future to support decarbonisation** based upon the realisation of infrastructure investment and strategic sector growth.

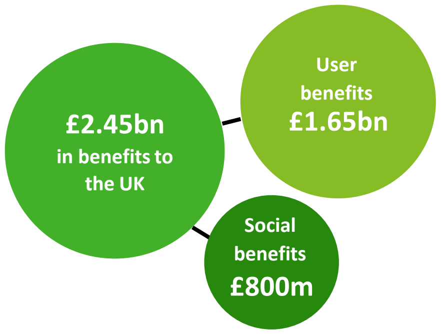
Advances made by this work in developing a framework to support future decision-making

In addition, the work also makes a first step for the industry in developing a **new potential decision-making framework which brings together the assessment of rail freight benefits with other services** (see bottom right).

This **builds upon existing appraisal guidance** such as the DfT's TAG/ Transport Scotland's STAG **incorporating outcomes of the quantitative analysis** to bolster the tool-kit to inform capacity allocation, investments and modal shift decisions from an economic perspective.

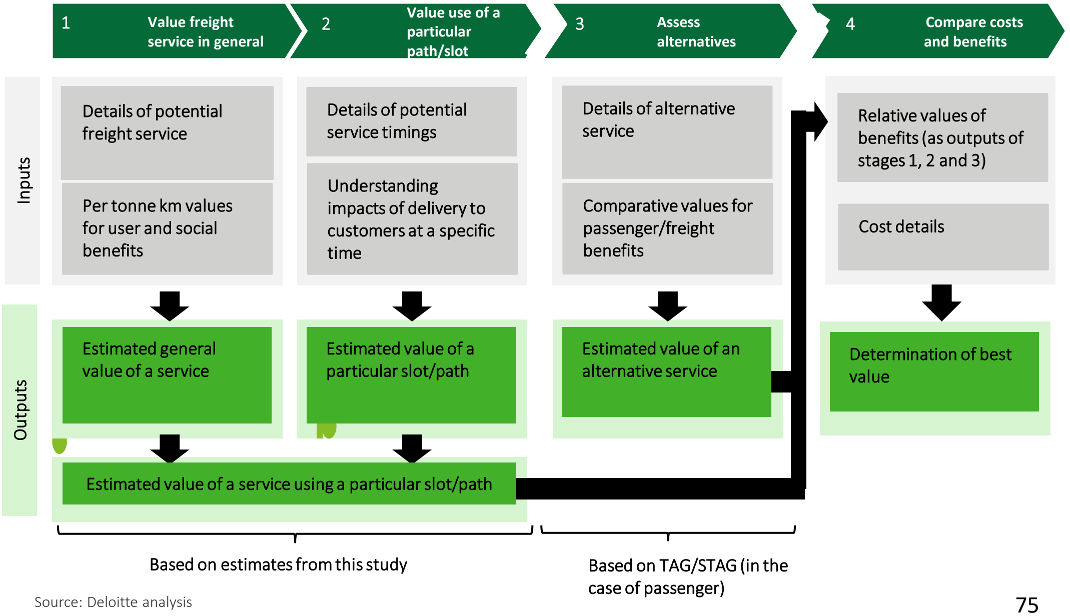
The framework could also be used more broadly to support further rail freight development as part of decision-making alongside housing and planning for wider city and regional development.

Outcomes from quantitative assessment



Source: Deloitte analysis

Overview of decision-making framework



Source: Deloitte analysis

Next steps for the industry and policy-makers

To enable application of this framework in decision-making, policy-makers could build on this work to incorporate it into existing guidance and work together to facilitate its practical application

The work set out above contributes to and advances the evidence base and thinking on the articulation and quantification of the benefits of rail freight, and provides a step forward for the industry and wider Government's tool-kit to support more evidence-based economic decision-making. However, for the work to be fully embedded into industry and wider Government decision-making to support rail freight in playing its part in supporting net zero, helping to build back better and levelling up will require three key next steps:

Developing the framework for practical application

The potential decision-making framework already illustrates practical steps towards incorporating a more holistic analysis of the economic benefits of rail freight into train planning, access and capacity allocation decisions. However, a full tool or practical model with set of standard assumptions/inputs of freight benefits vis-à-vis other services may facilitate Network Rail and ORR to utilise the work practically as one of the inputs when considering train planning, timetabling and access decisions as far as possible alongside operational and other considerations.

The framework could also be further developed for practical application by considering rail freight benefits alongside work on housing and planning to support wider city and regional development

Integrating with existing appraisal frameworks

For the wider set of rail freight benefits articulated and quantified in this work to be incorporated into strategic decisions across Government, DfT and Transport Scotland could build upon this work for subsequent iterations of TAG/STAG for common application of the analysis across the industry.

To do this further assurance around the analysis and data used (see next page) and consideration of other effects (eg taxation) analysed for decision-making will be needed. In addition, further industry consultation may also be required to consider how it is best incorporated and to ensure any updates are made in line with the recently revised Green Book (which aims to align the strategic purpose of investments or particular policies to the assessment of economic benefits).

Recognising current decision-making structures

The decision-making remits and duties of different industry bodies vary across the sector with DfT, Transport Scotland, ORR, and Network Rail have various objectives that must be balanced when making decisions (including legal, regulatory, and contractual factors).

While current policy and institutional structures may limit individual organisations' ability to apply the framework in some instances, it could be taken forward to help identify and inform trade-offs to be made by organisations based on the different criteria they weigh up when making decisions.

Next steps for this analysis

Industry and policy-makers should work together to keep evolving the evidence base

This report has set out the springboard for industry and policy-makers to be able to advance rail freight insights for decision-making. To build on this, it will be instrumental for industry to work together to develop, utilise and share further data to develop the understanding and quantification of rail freight benefits further, with key focus areas set out below. In addition to these points it is also important that industry and policy-makers continue to develop and refine the strategic aspects and wider 'case' for rail freight in a way that is aligned to the understanding and quantification of benefits.

Improved data collection and sharing

The granularity and accuracy of the data available on the rail freight market could be improved, particularly as relates to data on pricing, costs and granular service information as much of this is commercially sensitive.

An improved sharing of data between industry and policy-makers may increase policy makers' confidence in incorporating a more evidence-driven benefits-led approach to how they treat rail freight in their decision-making. This would require industry and policy-makers to work together develop and share data for mutual benefit.

Evolving the quantitative approach

The quantitative assessment focussed on estimating aggregate user and social benefits and is heavily dependent on relationships between regulatory charges and volumes (elasticities) taken from existing literature at an aggregated level. As such:

- Updated and refined analysis utilising elasticities that recognise differences across regions (that are likely to be important for construction and aggregates) and within sectors (such as for deep-sea intermodal) would provide a more robust picture of benefits and allow for further cross-check of the results in this report; and
- Updates to the quantitative approach could be looked at to allow for estimation of (i) the breakdown of user benefits (in terms of cost/time savings and reliability improvements); and (ii) other benefits such as agglomeration.

Gaining a better understanding of rail freight benefits

Improved data availability and accuracy would also allow industry and policy makers to gain a better understanding of rail freight benefits. For example, taking forward the understanding of how user and social benefits vary across geographies and how benefits within certain sectors/customer segments vary by sub-segment, which would be valuable for future decision-making and strategic planning at a more detailed level than currently possible.

Appendix – approach and assumptions to the quantitative assessment

Appendix – Part A, approach to assessing user benefits

User benefits

User value is estimated drawing on economic welfare analysis and empirically modelling the freight market

Part 2 of this report outlined that the first major category of rail freight benefits relates to its users. Part 3 outlined the steps to apply an economic welfare model to estimate user benefits at a high-level. Here the rationale behind this approach, and the steps taken, are set out in more detail.

It is important to note that application of the approach set out below represents a step forward in the quantification of rail freight benefits, but requires adoption of a number of explicit and implicit assumptions on market demand and competition. Future work should be undertaken to verify and refine such assumptions.

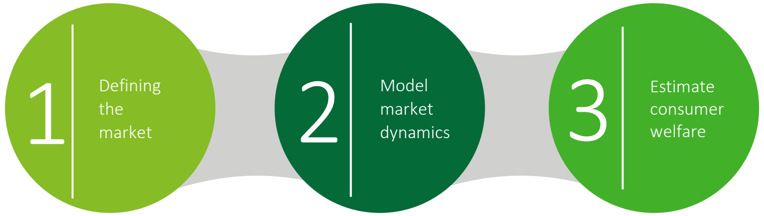
Employing first-principle economics to understand user value as consumer surplus

Consumer surplus is a measure of this welfare, defined as the value consumers enjoy in excess of the costs that they incur or perceive in securing and consuming rail freight services. In other words, it is the monetised difference between price paid by consumers and the value each consumer places on being able to use rail freight. As described in the box on the right, this encapsulates all components of user benefits described in Part 2 of this report.

Modelling the market to estimate user value

Economic welfare analysis allows for the quantification of consumer surplus through an **empirical market welfare model.** This involves empirically modelling the market under consideration, in order to estimate user value. In more technical terms, a welfare model seeks to estimate the level of consumer surplus generated for participants in a market; that is, a monetised level of utility that they enjoy by consuming a good or a service.

To estimate such a welfare model, a simple economic representation of the rail freight market has been developed. A market, in economic terms, refers to the collection of buyers and sellers exchanging a good or a service. In the case of rail freight, the FOCs as sellers exchange freight services that transport certain commodities of a certain quantity over a certain distance against a price paid by their customers - the buyers. For purposes of this study the demand side of the market is focussed on given the primary interest in consumer welfare. The following pages set out the framework and steps employed in more detail:



User benefits: Value of freight services to customers

Welfare encapsulates all user benefits

When consumers purchase rail freight services, they do so with an understanding of their own valuation of rail freight services. Of course, **cost savings** are a key consideration; if rail freight is cheaper than the alternative mode, then rail freight may appear more attractive.

However, **non-price features of rail freight** will also come into consideration, with expectations of **time savings** and **greater reliability** factoring into the consumer's ultimate decision to procure rail freight services. So too will other sources of value-add, such as efficiencies.

The consumer's overall perception of rail freight value influences the maximum price they would be hypothetically willing to pay for rail freight services – i.e. the monetary amount that would leave them with no **consumer surplus.**

However, as a competitive market, the rail freight industry's price is **self-regulating.** If one FOC offers high prices, a competitor may undercut them and the consumer will switch to that competitor. If all rail freight prices are too high, the perceived value of an alternative's features become more attractive and the consumer will **substitute** between modes.

Therefore it is likely that the market price does not fully capture consumers' private value of frail freight, thus leaving them to enjoy consumer surplus, or welfare in excess of the price paid. This value encapsulates all user benefits.

User benefits

A conceptual economic framework is utilised to define aspects of the markets rail freight serves

1 | Defining the market for freight service provision to different customer segments/sectors

In terms of rail freight, there are some key features of the markets that it serves are important to define conceptually:

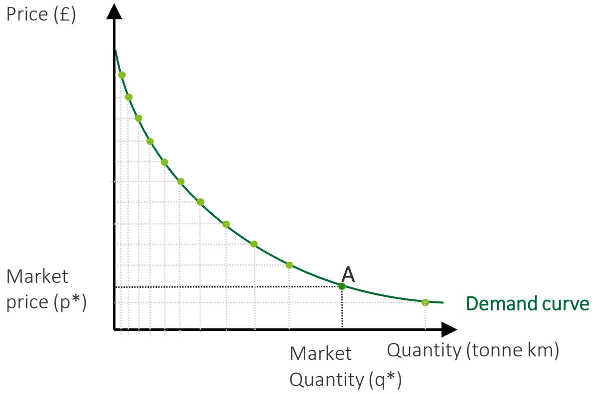
- **Product** – the rail freight services being exchanged between FOCs and consumers (i.e. the customer segment/sector served)
- **Price** (P) – the price at which services are sold in a transaction
- **Quantity** (Q) – the number of tonne-miles sold in a transaction
- **Market price** (P*) – the market price in equilibrium - in this case, the average price paid across all transactions
- **Market quantity** (Q*) – the quantity purchased at the equilibrium market price, the total quantity purchased across all transactions
- **Price elasticity of demand** – the sensitivity of demand to a change in prices in a given price-quantity pair.

The conceptual economic picture of the market based on these aspects is set out to the right.

A note on elasticities.
The price elasticity of demand describes how sensitive customers are to changes in price. This is driven by a number of factors: **income effects**, by which an increase in price implies customers cannot afford to purchase more, and **substitution effects**, by which the increase in price causes customers to choose a different product (in this case, mode) instead. The substitution effect depends on just how viable alternative modes are compared to rail freight, and as such the elasticity provides a compelling concept by which to understand the availability of alternatives to rail freight.

User benefits: Value of freight services to customers

Illustrative depiction of the market demand model



This Figure depicts the market demand curve for freight, modelled through price and quantity data. Note again that the parameters of this demand curve are illustrative; in practice the slope and intercepts of the curve will vary by commodity, though the curve will be downward sloping.

Given that the market captures a collection of a large number of consumers, these consumers are considered on average – i.e. a **representative consumer** is considered that transacts the total market quantity. This allows modelling of the market using a price that can be considered as the average of the large set of actual prices.

Whilst this **market price (P*)** is the only price that is realised, giving rise to the current (observed) market level price-quantity pair at point A in this Figure, the possibility that the price could be higher or lower than this point gives rise to **market dynamics –** demand reactions to changes in price, captured by the elasticity. Therefore, there are implicitly a large number of possible **price-quantity pairs** that can be set out graphically as shown above.

1

User benefits

Market data is used to define and model the market

To define the markets that rail freight serves in line with the conceptual framework set out above requires at minimum three key inputs. These are:

- **Current market prices (p^* in the diagram above) –** to estimate this for each sector average revenue data on a per tonne km basis was utilised directly from FOCs. Where different FOCs served the same sector prices were estimated as the weighted average of data inputs provided and where not data from single FOCs was assumed to be representative of the market price.[1]
- **Market quantity (q^* in the diagram above) –** Network Rail provided detailed data on volumes in the form of tonne kms carried by sector which were mapped to the sectoral definitions set out in Part 2. This was supplemented with data from DfT in respect of services FOCs provided by FOCs to Network Rail.
- **Price elasticity of demand** – Elasticities of demand for detailed sectors served by rail freight were not available at the time of writing, but previous research was undertaken by MDS Transmodal for ORR to estimate the sensitivity of the quantity demanded by customers with respect to changes in the variable usage charge (VUC) payable by operators (i.e. 'VUC elasticities').[2]

  Assuming that changes in the variable usage charge are passed on to customers (i.e. there is 100% 'pass-through' in charges and prices), the estimates from the MDS Transmodal have be utilised, together with data from FOCs (in accordance with prices set out above) on the proportion of prices accounted for by VUC payments (see right for more detail) to estimate price elasticities.[1]

  It is important to note that for some commodities however, that even VUC elasticities are not available to estimate price elasticities. As such, a number of assumptions have been adopted on elasticity levels so that benefits generated for commodities in question. Further detail on such assumptions is set out in Part C of the Appendix below.

Approach to estimating price elasticities of demand per sector

Definition of price elasticity of demand

Price elasticity of demand $= \varepsilon = \frac{dq}{dp} \cdot \frac{p}{q}$

Approach to estimation and data sources

$$\varepsilon = \underbrace{\frac{dq}{dVUC} \cdot \frac{VUC}{q}}_{\text{VUC elasticity of demand (data from MDS Transmodal)}} \cdot \overbrace{\frac{P}{VUC}}^{\text{Data from FOCs}} \cdot \underbrace{\frac{dVUC}{dp}}_{\text{100\% passthrough (Assumed = 1)}}$$

[1] Data used in the analysis was restricted to two FOCs given timelines of the work, this could be supplemented with others in future to give a more defined picture of market prices

[2] MDS Transmodal, 2012. Impact of changes in track access charges on rail freight traffic. Available here.

User benefits

A range of assumptions on utilised to model market dynamics

2 | Modelling market dynamics

Having defined the market parameters, the next step is to fully model the market dynamics. This is important since the welfare generated is determined by the area between the demand curve (comprising the hypothetical price at which consumers would value a given level of quantity) and the horizontal line implied by price actually paid (see Figure A).

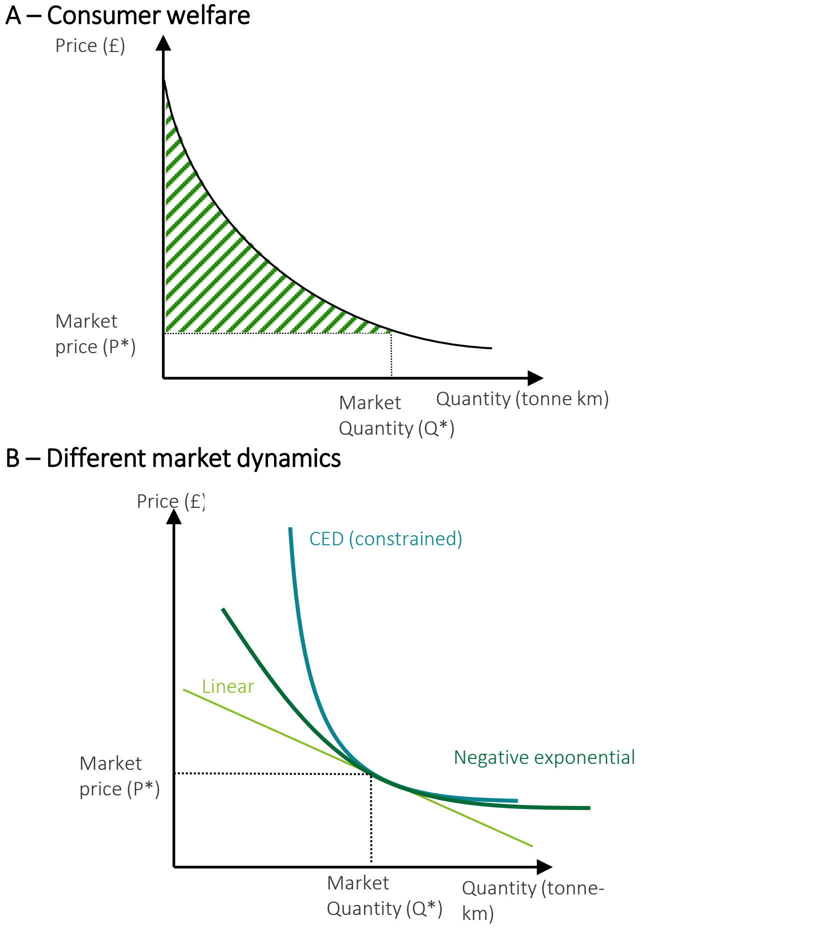
Economic theory and empirical evidence suggest that generally (and in the context of rail freight), demand curves are downward sloping and, as the name suggests, curved (convex to the origin) – customers value additional quantities less and less (capturing the concept of diminishing marginal utility/value).

A constant elasticity of demand specification (CED) is the most commonly used demand curve in economic modelling. Given the available data on the price-demand relationship from evidence compiled for ORR, small changes in price do appear to follow a CED demand curve. [1] However, this may be more accurate for local estimation (for current freight volumes), considering small changes, rather than for inference on the whole market. For commodities where demand is very insensitive to changes in price (e.g. due to a lack of alternatives), CED implies that user value could be infinite. In fact, applying this method to some sectors of rail freight produces estimates that tend toward infinity.

To resolve this, three alternative methods for demand curve specifications are adopted from the literature – a 'constrained CED' function (where a 2nd order Taylor approximation is utilised for commodities with insensitive demand), a negative exponential function and a linear demand function. Figure B shows how these relate to one another and indicates that depending on which one is utilised the estimated welfare/customer value delivered by rail freight may differ significantly.

Each of these demand specifications is set out on the following pages in more detail.

User benefits: Value of freight services to customers



[1] MDS Transmodal, 2012. Impact of changes in track access charges on rail freight traffic. Available here.

User benefits – specification of demand model

Different demand specifications are utilised to obtain a range of estimates

As set out above the form of the demand function adopted in the work is likely to have a significant impact on the welfare estimates generated through the quantitative assessment of user benefits. The following two pages provide an overview of the characteristics and behaviours of the three specifications utilised in this work.

Constrained CED demand (see top right)

- Constant elasticity of demand specifications are the most common specification used in the theoretical literature as its properties are intuitive and convenient – the responsiveness of demand to price is constant but proportionate to the price/quantity pair observed. This defines its curvature.
- Constant elasticity approaches are however more complicated, in a mathematical sense, to use in practise. Specifically, the approach is limited if demand (quantity) is particularly unresponsive to changes in price – i.e. the price elasticity of demand is inelastic, which is true for some commodities.
- Where demand is inelastic, mathematically the welfare estimates become infinite (as the demand curve does not intercept the price axis - see Figure A). As such, when assessing welfare in reality this becomes non-viable for use in its pure form.
- In order to approximate the welfare that would be estimated under a CED approach, a 2nd order Taylor Approximation for those commodities where demand is inelastic has been utilised. This in effect 'dampens' the curvature of CED demand curve such that welfare estimated for these commodities is finite and tractable. However, given that the approximation is to a CED demand curve, the approach is likely to set an upper bound to welfare owing to its shape at higher market prices and lower market quantities.

Negative Exponential Demand (see bottom right)

- Negative exponential demand is another popular demand formulation that is frequently used in theoretical and empirical literature owing to similar intuitive and analytically convenient features.
- It has a similar shape to the CED demand curve, being convex to the origin, albeit with the extent to which quantity demanded declines as price rises being less pronounced (see right). This latter particular feature means that the demand function is more resistant to the issue CED has with welfare estimates tending to infinity at low quantities and high prices. It also means welfare estimates generated utilising this functional; form are likely to be lower than a CED form.
- The form has been used historically in the context of regulatory and market assessment exercises. For example, by CMA (then Competition Commission[1]) in its market investigation into local transport competition.

Illustration of Constant Elasticity Demand Curve

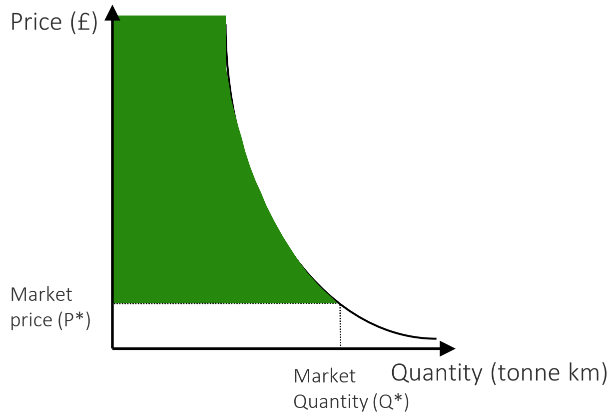
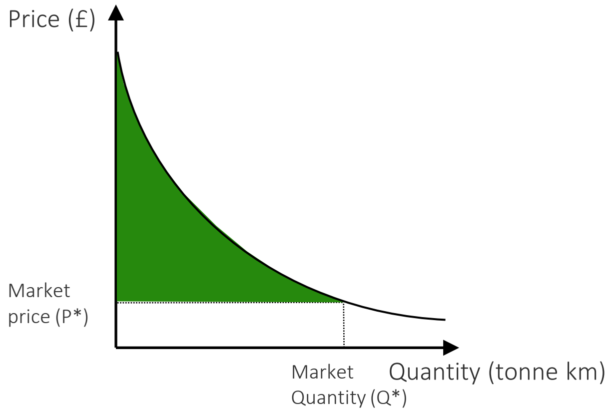


Illustration of Negative Exponential Demand Curve



[1] Competition Commission (2011). Local bus services market investigation: A report on the supply of local bus services in the UK. Available here.

User benefits – specification of demand model

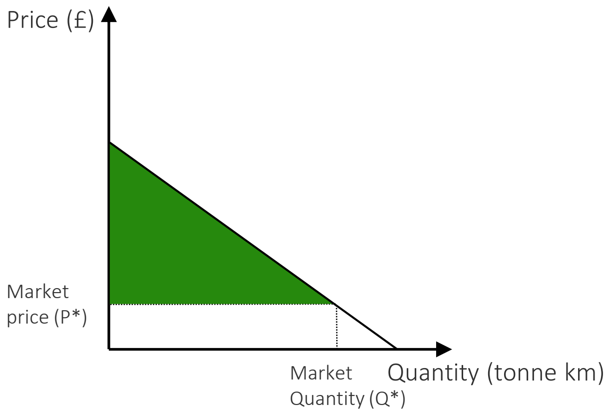
Different demand specifications are utilised to obtain a range of estimates

Linear demand (see right)

- Linear demand, as shown in the figure to the right, is the most simple specification of demand. It assumes that, along the entire curve, there is a constant marginal relationship between price and quantity (i.e. for a 1 unit change in price there is a constant 1 unit change in quantity). This is not to be confused with a constant elasticity (where what is constant is the percentage change in quantity for a given percentage change in price). Such a constant unit for unit relationship is not typically observed as it is likely that demand will respond differently to changes in price for given levels of existing prices. Therefore, empirically its use is limited.

- In addition, it is not convex to the origin and intercepts the price axis at a specific point. This means that it does not suffer from similar drawbacks as the CED and negative exponential functional forms. However, this also means that in this context, where substitutability to other modes is limited for some commodities (reflected in the curvature of the demand curve), it does not recognise the sizeable benefits available at low volumes by having access to rail freight in general (e.g. for energy generation). This means it will underestimate welfare and form a lower bound on estimates.

Figure A – Illustration of Linear Demand Curve



Approach adopted in this work

- As set out above, the choice of demand specification is centrally important to this work as it has a large impact on the level of estimated customer welfare generated by rail freight. Each of the above demand formulations possess their own characteristics, attractive features and limitations and there is little consensus on which may be applicable for empirical context such as in this work.
- Due to the characteristics of each specification:
    - The constrained CED approach is considered a high estimate; and
    - The linear approach is considered to be a lower estimate.
- Within this range the negative exponential approach is treated as an approximate central estimate owing to the balance it offers compared to the other specifications and owing to its precedent in relation to similar applied contexts.
- The main part of the report quotes the central estimates (utilising the negative exponential demand curve) throughout. However, additional detail is also provided on the range of estimates when using the other demand specifications with the true value of rail freight lying within the range.

User benefits

Customer welfare is then estimated through calculations of areas based on the market framework

3 | Assessing welfare

As described above, total consumer welfare can be calculated by estimating the area between the demand curve and the market price. This is because consumer welfare can be understood as the aggregation of all consumers' valuations minus the price they paid to purchase the service. The final step to assessing user welfare is thus to estimate the shaded area set out to the right. in Figure A.

Bringing together steps 1 and 2, specifically the current market price, quantity, price elasticity and assumed demand specification, the market and its dynamics are defined. The final step is then based on this to estimate the size of welfare illustrated as the area set out in the diagram to the right.

How this is undertaken in respect of the three demand specifications is set out on the following pages.

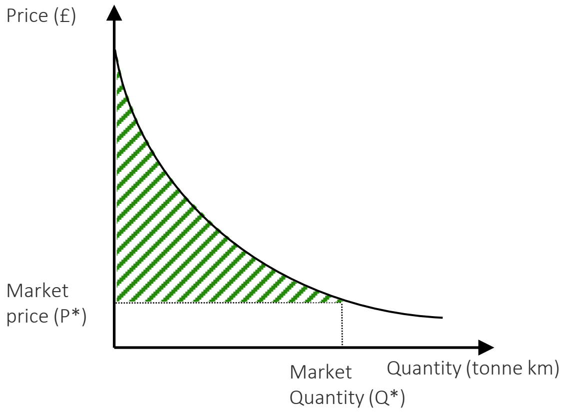
Improving the evidence base

As noted before, in undertaking this analysis there are certain assumptions it relies upon that could be expanded and improved upon in future. In particular, this would be possible by:

- **Capturing market dynamics empirically:** Rather than conceptually deriving the market dynamics (specifically the shape of demand curve), in theory this could be modelled empirically. For example, statistical exercises could be employed to ascertain a better view of the drivers of market dynamics and obtain more certainty as to which specification best reflects the market. This would also allow the more accurate capture of operational constraints, which are to some extent abstracted from in this approach.
- **Drawing on external validity:** The data drawn upon for the estimation of elasticities were derived based on small price shocks and based on old market data. While it is reasonable to assume the derived elasticities are fit for purpose (e.g. ORR re-used the same estimates in its 2018 Price Control), there may be value in estimating new values or updating the analysis going forward, such that new market trends (e.g. increased emphasis on decarbonisation) that may affect customers' preferences, and hence their price sensitivity, can be reflected as the framework is used going forward.

User benefits: Value of freight services to customers

Consumer welfare



User benefits

Customer welfare is then estimated through calculations of areas based on the market framework

Constrained CED demand

As described above, to estimate welfare generated by rail freight entails estimating the area between the demand curve/function and the price paid in the market for current volumes.

When utilising a constrained CED specification as described this involves undertaking two separate sets of calculations:

- Where a given sector has an estimated price elasticity less than minus one (ε<-1) a conventional CED functional form (as set out in the box to the right) can be utilised and welfare calculated as the integral between current volumes (q^*) and zero, subtracting off current market revenues ($p^*.q^*$); and
- Where a given sector has an estimated price elasticity greater than or equal to minus one ($\varepsilon \geq$-1), for reasons outlines above a 2nd order Taylor approximation needs to be utilised. This is more complex than the CED function, but has the advantage of not tending to infinity given the size of elasticities (this is also set out to the right). Similar to the conventional CED functional form this can then be integrated as shown to the right between between current volumes (q^*) and zero, then subtracting off current market revenues ($p^*.q^*$) to estimate welfare.

To determine the parameter A, current prices and volumes supplied by FOCs and Network Rail are used by substituting these figures into the demand functions (formulae in top right box), together with estimated price elasticities. The same data is then used in the formulae set out in the bottom right box to estimate welfare (user benefits) delivered by rail freight in each sector.

Estimating welfare utilising a constrained CED demand specification

Definition of constrained CED specification

CED (where ε<-1)

$$\boldsymbol{p = Aq^{1/\varepsilon}}$$

2nd order Taylor Approximation (where $\boldsymbol{\varepsilon} \geq$-1)

$$\boldsymbol{p}(q^*) \approx \boldsymbol{Aq^{\frac{1}{\varepsilon}} + \frac{1}{\varepsilon}Aq^{\frac{1-\varepsilon}{\varepsilon}}(q - q^*) + \frac{\frac{1-\varepsilon}{\varepsilon^2}Aq^{\frac{1-2\varepsilon}{\varepsilon}}(q - q^*)^2}{2!}}$$

Where:
A = constant
ε = elasticity of demand

Approach to estimation of welfare

CED (where ε<-1)

$$\text{Welfare} = \int_0^{q*} Aq^{\frac{1}{\varepsilon}}\, dq \; - p^*.q^*$$

$$= \text{A} * \frac{q_n{}^{\left(\frac{1}{\varepsilon}+1\right)}}{\left(\frac{1}{\varepsilon}+1\right)} - p^*.q^*$$

2nd order Taylor Approximation (where $\boldsymbol{\varepsilon} \geq$-1)

$$\text{Welfare} = \int_0^{q*} Aq^{\frac{1}{\varepsilon}} + \frac{1}{\varepsilon}Aq^{\frac{1-\varepsilon}{\varepsilon}}(q-b) + \frac{\frac{1-\varepsilon}{\varepsilon^2}Aq^{\frac{1-2\varepsilon}{\varepsilon}}(q-b)^2}{2!}\, dq - p^*.q^*$$

$$= -Aq^{*\frac{1}{\varepsilon}}q^* + \frac{\frac{1}{\varepsilon}Aq^{*\frac{1-\varepsilon}{\varepsilon}}q^{*2}}{2} - \frac{1}{\varepsilon}Aq^{*\frac{1-\varepsilon}{\varepsilon}}q^{*2} + \frac{\frac{1-\varepsilon}{\varepsilon^2}Aq^{\frac{1-2\varepsilon}{\varepsilon}}q^{*3}}{6} - \frac{\frac{1-\varepsilon}{\varepsilon^2}Aq^{\frac{1-2\varepsilon}{\varepsilon}}q*^2}{2}$$
$$+ \frac{\frac{1-\varepsilon}{\varepsilon^2}Aq^{\frac{1-2\varepsilon}{\varepsilon}}q^{*3}}{2} - p^*.q^*$$

Where:
b = q^* ,0

User benefits

Customer welfare is then estimated through calculations of areas based on the market framework

Negative exponential demand

Estimation of welfare in different markets served is more easily undertaken for the negative exponential specification (set out in the upper right box) as the same limiting problem for more price insensitive goods does not occur mathematically (i.e. with estimated welfare tending to infinity).

To estimate welfare requires:

- Determining the parameters α, β by substituting current prices and volume data supplied by FOCs and Network Rail as well as the estimated price elasticity into the formulae set out to the top right for each sector; and
- Calculating welfare using the same price and quantity data together with the elasticity estimate integrating between current volumes (q^*) and zero and subtracting off current market revenues ($p^*.q^*$) as set out in the second box to the right.

Linear demand

Estimation of welfare using linear demand is the simplest approach and does requires integral methods instead utilising formulae for straight line demand (as set out to the bottom right) together with standard formulae on estimating the areas of a right-angle triangle (i.e. the area bound by the demand curve and the current market price as illustrated above).

In this case, to estimate welfare requires:

- Determining the parameters *K, C* (i.e. the slope and incept of the demand curve respectively), by substituting current prices and volume data supplied by FOCs and Network Rail as well as the estimated price elasticity into the formulae set out to the bottom right for each sector; and
- Calculating welfare using the formulae for the area of a right angle triangle set out to the bottom right in the final box.

Estimating welfare utilising a negative exponential specification

Definition of a negative exponential specification

Negative exponential $p = \ln(\frac{q}{\alpha}) * \frac{1}{\beta}$ Where: $\beta = \frac{\varepsilon}{P}$ α = constant

Approach to estimation of welfare

Negative exponential Welfare $= \int_0^{q^*} \ln(\frac{q}{\alpha}).\frac{1}{\beta}\, dq - p^*.q^* = \frac{q^*}{\beta}(\ln(\frac{q^*}{\alpha}) - 1) - p^*.q^*$

Estimating welfare utilising a linear specification

Definition of a linear specification

Linear $p = kq + c$ Where: c = constant

$k = \frac{dp}{dq} = \frac{1}{\varepsilon}\frac{p}{q}$

Approach to estimation of welfare

Linear Welfare $= \frac{1}{2}.q^*.(\mathrm{c} - p^*)$

Appendix – Part B, approach to assessing social benefits

Social benefits

Social benefits are estimated by applying estimates of net rail marginal external costs to avoided lorry kilometres

Analysis of social benefit builds on existing DfT research with granular ORR data

As set out above in Part 3 the approach to estimate social benefits builds on existing DfT analysis to assess the benefits of Mode Shift from road to rail for the Mode Shift Revenue Support (MSRS) grant scheme. How this has been applied in this work, on a per sector basis, is set out below with information on calculations set out to the right.

Key steps followed were:

- ***Sourcing data on the marginal external costs of rail and road haulage:*** data on the marginal external costs of utilising road transport (MECs) and the net marginal external costs when compared to rail (NMECs) on a per 'avoided lorry[1] km' basis was sourced from the recently published DfT Mode-Shift Benefits Update which contains the values currently applied for the MSRS grant for the 2020-25 period.[1]
- ***Applying propositions to disaggregate net marginal external costs by type:*** values set out in Mode-Shift Benefits Update for 2020-25 do not break down NMECs by external cost type (congestion, noise, environment, infrastructure, safety, other). Therefor, proportions from the equivalent 2009 DfT analysis sere applied to estimate marginal external costs of rail use and derive NMECs by external cost type (as set out to the right).[2]
- ***Supplementing DfT data with additional rail costs in relation to congestion and infrastructure external costs:*** The 2009 analysis did not specify rail marginal external costs for congestion and infrastructure costs so, to be conservative, applicable rates of Network Rail's previous average Capacity and Variable Usage access charges were used to derive net marginal external costs for each respectively (further detail on this is set out on this in Part C of this Appendix).
- ***Multiplying estimated net marginal external costs by avoided lorry kms per sector.*** ORR provided data on the number of avoided lorry km per sector/customer segment for 2018/19 freight volumes. The net marginal external costs were multiplied by these to generate social benefits of the use of rail freight for each sector served and then summed together to give an overall figure.[3]

Estimating social benefits per sector

Approach to estimation of social benefits per sector

Estimating net rail marginal external costs	$NMEC_i = MEC\ Road_i - MEC\ Rail_i$ $i = congestion, noise, environment, infrastructure, safety, other$
Estimating social benefits	Social benefits $=$ Avoided Lorry km. $(NMEC_{Congestion} + NMEC_{Noise} + NMEC_{Environment} + NMEC_{Infrastructure} + NMEC_{Safety} + NMEC_{Other})$

[1]DfT (2020) "Mode-Shift Benefits: Update", May 2020, See here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/905413/mode-shift-benefit-values-update-document.pdf
[2]DfT (2009) "Mode Shift Benefit Values: technical Report", April 2009, See here; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/905558/Mode_Shift_Benefits_technical_report.pdf
3 ORR currently only publishes overall levels of avoided lorry km on its website, but provided these broken down by equivalent sectors used elsewhere in this analysis to support estimation of benefits at a more granular level

Appendix – Part C, assumptions for quantitative assessment and future areas for research

Key technical assumptions

Further key technical assumptions utilised in the quantitative assessment are listed below

Component	Assumption	Rationale
User benefits		
Prices	The market price is equal to the weighted average of average revenue per unit from available FOC data.	The data collected from FOCs represents the majority of the market, and therefore this is likely a reasonable assumption.
Elasticities	The elasticity of demand with respect to the variable usage charge (VUC – an access charge which varies with volumes charged by Network Rail to freight operators) is proportionally equal to the elasticity of demand with respect to price.	There is regulatory precedent for using this approach to 'convert' elasticities from price components to price elasticities utilising mathematical identities. In particular, in the CAA's market Strength determination for Stansted Airport[1]
Elasticities	The VUC elasticities of demand for nuclear (as a component of the energy generation segment) and iron were estimated to be zero (perfectly inelastic) by MDS intermodal for its CP5 study for ORR. The price elasticities of demand for nuclear and iron are assumed to be non-zero, and instead akin to the price elasticity of demand for coal.	An assumption of zero implies infinite user value, which appears unlikely. For analytical reasons it is therefore practical and conservative to apply this assumption. From a conceptual perspective, for large changes in prices, rather than marginal, it's unlikely that the price elasticity of demand for these sectors is truly zero. Using the lowest elasticity available in the sample for a similar sector is a useful estimate of an appropriate non-zero elasticity.
Elasticities	No elasticity has yet been estimated for the Network Rail segment. It is assumed that this is akin to the price elasticity of demand for construction.	Maintenance activities are akin to construction work, albeit on the functional railway indicating use of the construction elasticity may be appropriate. In addition, Network Rail have indicated that there are few if any viable alternatives to commissioning the FOCs. This is due to prohibitively high costs of e.g. in-sourcing these services. This implies an elasticity lower in magnitude than -1 (as the construction elasticity is).
Elasticities	The 'Other' segment elasticity is equivalent to the average elasticity for the total market.	The 'Other' segment is a small and varied segment. The average elasticity may best capture this.
Elasticities	The research that estimating VUC elasticities assumed that the rail network is not capacity constrained.	The VUC elasticities have been taken as given for the purpose of the analysis based on their previous use to inform regulatory determinations. However, further work, could look to understand how the elasticities change with capacity constraints introduced.
Social benefits		
External costs of rail	No up-to-date breakdown of the Marginal External Cost data was provided by DfT. It is assumed that the rail external cost compared to the road external cost is the same proportion in 2020 as in 2009 for noise, environmental impacts, taxation, and 'other impacts'.[2]	The assumption is necessary to provide a breakdown of external costs in the absence of more granular data. It is likely to be a conservative estimate particularly for environmental impacts due to the process of decarbonisation of the railway.
External costs of rail	Congestion external costs are considered to be zero for rail in the DfT MSRS estimates of 2009. These are approximated by the capacity charge for freight users of the railway set by ORR in 2012, the last estimate of this. [2,3]	The assumption is necessary to obtain a more accurate view of congestion impacts in the absence of more up-to-date data. The charge is estimated to represent the extra financial costs incurred due to delay from additional services on the network (captured by Network Rail's Schedule 8 performance regime). The congestion impacts of rail are likely to be underestimated this way, however, the estimate is preferable to zero estimate.
External costs of rail	Infrastructure external costs are considered to be zero for rail in the DfT MSRS estimates of 2009. These are approximated through the latest variable usage charge rates set by ORR, using a weighted average across sectors. [2,4]	The variable usage charge is designed to recuperate from operators the marginal infrastructure costs ('wear and tear') imposed on the network.

[1] UK Civil Aviation Authority, 2013. Stansted Market Power Assessment
[2] DfT, 2009. Mode shift benefits values: technical report.; DfT 2020. Mode shift benefit values: update
[3] ORR, 2012. CP5 Price list and calculations of effective charge per tonne km based on RDG, 2014. Charges and incentives user guide.
[4] ORR, 2020. CP6 Price list

Areas for research to further the approach set out in this work

The assumptions underpinning the analysis point towards areas for future research to further develop the work

The table below sets out a number of key assumptions made in this work and highlights where future work could be undertaken to confirm and refine such assumptions to further its usefulness for RDG, operators and decision-makers.

Assumption	Rationale	Potential insight generated by moving forward from assumption
FOC pricing data provided by a subset of companies can be used as a representative basis for the entire industry	As the market is highly competitive, it is unlikely that an individual FOC could price substantially above or below market price. However, this may not apply to bespoke commodity freight.	Obtaining pricing data from remaining FOCs would allow for confirmation of this assumptions and refining of the analysis. In addition, understanding the variance and dynamics of industry pricing through obtaining anonymised 'order' level data can shed more insight on the commodities or geographies of greatest value, or those that would benefit most from interventions.
Current volumes are appropriate to assess the value of rail freight	The purpose of this work is to assess the value of rail freight to the UK economy today. As such, use of current volumes is appropriate.	Were forward looking volumes and elasticities available for use this work could be refreshed to analyse the forward looking picture of freight benefits. This could be particularly useful given major changes to the industry going forward that are likely to affect the assessment of rail freight benefits (e.g. traction decarbonisation, growth and contraction of particular market segments).
Up-to-date elasticities	The elasticities are derived from analysis originally conducted in 2012. It is therefore assumed that the market dynamics have not changed since then. This is reasonable as ORR drew on these figures for the 2018 price control to set charges for CP6.	Updated elasticities, and elasticities measured specifically for this purpose, may be a useful refinement to this analysis to reduce uncertainty in quantitative estimates as the industry structure transitions (e.g. declines in coal volumes which would affect elasticities).
Benefits for consumers are constant within commodity groupings	To account for data inconsistencies across sources, a consistent segmentation of commodities (often bringing several together) has been utilised. This assumption implies that the responsiveness of prices 'matches' across certain commodities, for instance different types of intermodal traffic (domestic vs. international). While these broadly serve similar needs and have similar attributes, price responsiveness may yet differ, and the assumption to smooth across these more granular characteristics may underplay the complex dynamics at play (e.g. urban vs rural construction freight). This may limit the applicability of the framework overall.	If segments can be further differentiated and used in combination with detailed elasticities (see below), this could lead to a greater understanding of how reliant customers are on rail freight, and as such, how much benefit rail freight services yield (e.g. for example, potentially in the cases of deep-sea and international intermodal).
Benefits for consumers are constant across geographies	As data on freight elasticities is only available nationally benefits expressed on a per tonne km basis are assumed constant for each commodity across geographies.	It is likely that elasticities for certain customer segments vary across geographies (e.g. construction and aggregates into urban areas are likely to be more inelastic than nationwide). As such, refined analysis of elasticities to understand any geographical difference could help incorporate such nuances into the work.
The demand curve can be specified as linear, CED or as a negative exponential.	Owing to lack of research on freight demand curves, conventional and established functional forms to estimate user benefits have been assumed. Using a demand approach to welfare estimation in principle can be construed as arbitrary, though is no less arbitrary than other modelling approaches including previous expenditure analysis and more data-intensive approaches including I/O modelling. Demand modelling has been used by the CMA, and this approach is no less arbitrary in principle. The limitations of data used in this approach is the largest cause for caution rather than the approach itself.	A wider market study on the shape of freight market demand curves would provide further assurance on the shape of the demand curve and associated elasticities for particular market segments.