

Department for Transport
**Understanding and Quantifying
Transformational Impacts from
Transport Interventions**
Literature Review

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This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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1 Introduction

1.1 Background

Cambridge Economic Policy Associates (CEPA) and Ove Arup & Partners (Arup) have been appointed by the Department for Transport (DfT) to research how the context surrounding a transport investment may determine whether it leads to the economic or social transformation of an area.

The main objective of the assignment is to describe how, and under what contexts, transport interventions have had, a ‘transformative’ impact on a locality or region, and how this has affected the economy and the wellbeing of the community. The DfT would like to understand and quantify the effect of contextual factors behind transformational impacts (e.g. underlying socio-economic factors, inclusion of local development strategies, use of social and human capital, other related investments and wider policies), and to understand the transmission mechanisms through which the transport intervention has worked with other contextual factors to affect the economy and community wellbeing.

We understand that the DfT plans to use the results of this study to better integrate the strategic and economic cases of future transport investments. In particular, the DfT would like to use this study to better understand which types of transport interventions may be able to support the government’s objective to ‘level up’ areas that currently perform poorly against key economic and wellbeing metrics (such as personal life satisfaction).¹ The scope of this project includes understanding why certain transport interventions have succeeded, whereas others have failed to have the impact originally envisaged. The project findings are also intended to support scheme promoters in making the case for investment where objectives include supporting local economic growth or transforming an area.

As the scope of our study is largely limited to investments in transport infrastructure, this literature review similarly focuses on infrastructure (both small and large). Nevertheless, most of the theory and evidence found can be applied to other changes in the transport system as well (such as a change in pricing or behaviour of users).

1.2 Approach

We developed a list of potential sources for the literature review based on input from DfT, the academic panel and a search of academic databases. We then sifted and scored the sources to determine how relevant they were, applying the following criteria: relevance to transformational impact, methodological rigour, and transport mode. We then agreed a list of sources to review in detail and developed a definition of transformational impact with input from the academic panel. Finally, we synthesised our findings for this report which included holding an internal workshop on the definition of transformational impacts, likely

¹ DLUHC (2021) ‘New levelling up and community investments’

transmission mechanisms, and how the definitions apply to the different transport modes.

2 Literature Review of Transformational impacts

2.1 Overview of the chapter

Despite being used regularly, the term ‘transformational impact’ is not precisely defined anywhere in the literature, nor in economic theory more broadly. To the best of our knowledge, the term was first mentioned in the Eddington study in 2006,² and has since been used to describe major infrastructure projects or policy interventions. It is also used in the Wider Economic Impacts (WEI) appraisal section of DfT’s Transport Appraisal Guidance (TAG).³ In this chapter, we build on the Eddington study and DfT’s TAG to propose a more precise definition of the term ‘transformational impacts’, that we can use for the remainder of this study. We aim to align our definition with how the term is commonly used in the context of transport investments and with the DfT’s intended meaning in the context of this study, while being informed by the economics literature. It is important to note that the definition we propose is distinct from the definition adopted in the recent review of the Green Book.

In addition to the literature cited, we have reviewed and built on the What Works Centre for Local Economic Growth’s (WWCLEG) Transport Review (2015),⁴ the Eddington study (2006),⁵ the Handbook of Regional and Urban Economics (2015),⁶ and from three academic papers: Graham & Gibbons (2019),⁷ Ahlfeldt et al. (2015),⁸ and Redding & Rossi-Hansberg (2017).⁹

Section 2.2 starts with the Eddington study and TAG’s use of the term and sets the requirements for a suggested definition that is used throughout this report. Sections 2.3 and 2.4 highlight the relevant theoretical background in transport and urban economics and connect existing theory with the definition requirements. Sections 2.5 and 2.6 explain the various transmission mechanisms and contextual

² Eddington (2006) Eddington Transport Study, UK Department for Transport

³ DfT TAG Unit A2.1. Wider Economic Impacts Appraisal. Note that the TAG guidance does not provide an in-depth analysis of the term and does not provide a clear connection to economics literature.

⁴ What Works Centre for Local Economic Growth (2015). Transport Review

⁵ Eddington (2006) Eddington Transport Report, UK Department for Transport

⁶ Duranton, Gilles, Vernon Henderson, and William Strange, eds. Handbook of regional and urban economics. Elsevier, 2015.

⁷ Graham, Daniel J., and Stephen Gibbons. "Quantifying Wider Economic Impacts of agglomeration for transport appraisal: Existing evidence and future directions." *Economics of Transportation* 19 (2019): 100121.

⁸ Ahlfeldt, Gabriel M., et al. "The economics of density: Evidence from the Berlin Wall." *Econometrica* 83.6 (2015): 2127-2189.

⁹ Redding, Stephen J., and Esteban Rossi-Hansberg. "Quantitative spatial economics." *Annual Review of Economics* 9 (2017): 21-58.

factors that could lead to long-term, significant outcomes, and what may be considered ‘transformational’ impacts.

2.2 Definitions in literature

To the best of our knowledge, the Eddington Transport Study from 2006 is the first time the term ‘transformational’ impacts has been used to describe the types of outcomes that are now commonly associated with the term:

‘In some circumstances, projects may claim to deliver transformational economic benefits, which substantially change the geography of economic activity through the location of business and jobs.’

The Eddington study primarily uses the term in the context of economic, rather than social transformation. It emphasises the importance of Economic Impact Assessment to prioritise the most effective policies in increasing the UK’s productivity and competitiveness. It also links economic transformation to changes in the location of businesses and jobs.

In a similar vein, the DfT’s TAG suggests criteria that relate to transformational impacts when discussing the need for supplementary economic modelling:

‘For regeneration and transformational schemes, in which transport is only one of a number of interventions or the land use impacts are expected to be diffuse over the study area, it may be appropriate to undertake supplementary economic modelling.’

In this way, transformational transport schemes could be seen as those that impact an area through widespread land use change, in conjunction with other policy initiatives. However, the TAG definition does not separate transformational transport schemes from regeneration schemes. This can make defining transformational impacts challenging.

The key link between both these sources’ use of the term ‘transformational’ is the association with land use change.

In contrast, the Green Book uses a more generic definition of transformational impacts that is not limited solely to economic transformation. The Green Book Review 2020 defines transformational change as:

‘A fundamental structural change in the nature of the subject undergoing transformation. The scale of the change alone is not a defining characteristic.’

Being in practical terms virtually irreversible – in other words the removal of the intervention will not cause the system to revert to its original state.’¹⁰

¹⁰ HM Treasury Green Book Review 2020. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/937700/Green_Book_Review_final_report_241120v2.pdf

In the context of improved transport infrastructure, the concept of ‘irreversibility’ is problematic, as such infrastructure rarely gets completely removed. It is difficult to determine whether the impacts associated with a transport investment will likely be reversed if the associated infrastructure no longer exists, as we have little precedent to draw on. The only well-researched example of this nature was the rail disinvestment program of the 1950s, 60s and 70s (known colloquially as the ‘Beeching cuts’). A paper by Gibbons, Heblich and Pinchbeck (2018) found that areas impacted by the disinvestment experienced a relative decline in population and proportion of skilled workers.¹¹ However, they found no evidence that these areas ‘reverted to their original state’ as suggested in the Green Book definition. Even if rail services were not operating, the built environment had already changed as it had influenced the growth of settlements. This suggests that transport infrastructure can lead to irreversible change, largely from legacy effects on the spatial structure of economic and social activity, over a long period of time.

This definition also puts more weight to the idea that transformational impacts should lead to significant changes to local industry or population. A further definition in the Green Book Review 2020 is the following:

‘Transformational change is characterised by both tipping points (where relatively small interventions can be a catalyst for change) and leverage points (key nodes in the system where interventions are most likely to influence the system behaviour).’

The idea of tipping points, as used in the Green Book, can be linked to wider economic impacts within TAG that go beyond user benefits (explained below). These rely on either eliminating market failures (such as a bottleneck in the transport system) that have been holding back economic development or introducing positive externalities (such as knowledge spill overs), that can have knock on effects and create positive and self-perpetuating feedback loops.

In a transport investment context, leverage points can be linked to induced investment. This is where investment in transport infrastructure influences other economic agents to make additional investments, resolving a coordination failure between the different agents and in turn leading to wider economic impacts. TAG explains that improving accessibility may lead to firms changing their investment decisions about the level or location of investment, resulting in changes in employment, output, and productivity.¹²

We understand tipping points and leverage points to be closely related. Under both, the change in the transport system acts as a catalyst for economic agents to change their behaviour and induce economic growth. The difference between tipping points and leverage points becomes crucial only in the context of

¹¹ Gibbons, Stephen, Heblich, Stephan and Pinchbeck, Ted (2018) The spatial impacts of a massive rail disinvestment program: the Beeching Axe. CEP Discussion Papers (CEPDP1563). Centre for Economic Performance, London School of Economics and Political Science, London, UK.

¹² DfT TAG Unit A2.2 Appraisal of Induced Investment Impacts. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/940820/tag-a2-2-induced-investment-unit.pdf

transmission mechanisms and contextual factors. Therefore, when we refer to a ‘tipping point’ we often refer to leverage points as well.

In summary, based on TAG, the Green Book review and other literature reviewed, a transformational transport infrastructure scheme is one that has the following characteristics:

- **Land use change:** The introduction of the transport scheme results in a significant change in how land is used in an area. This can be described as a fundamental change in the nature of the area.
- **Tipping point:** The scheme provides a step change in connectivity which acts as a tipping point for agglomeration forces or other well-being enhancing investments, catalysing further economic or social impacts.
- **Additionality:** The scheme facilitates a net positive economic or social impact in an area, after accounting for displacement effects from elsewhere.

Although much of the literature we have referred to in this section only considers economic transformation, we have generalised our characteristics such that they could also apply to social transformation.

2.3 Theoretical background

Given the characteristics outlined in the previous section, we now move onto investigating the theoretical literature that underpins many of these concepts. To do this, we draw on literature covering urban economics, economic geography, transport economics, and transport appraisal.

2.3.1 User benefits and wider economic impacts

Useful starting points when considering the theory behind transformational impacts, and economic transformation in particular, are the transport appraisal concepts of user benefits and wider economic impacts. We see a link between economic transformation and wider economic impacts, as the concept of wider economic impacts provides a theoretical explanation for how economic transformation may occur following the introduction of a transport project.

For some transport infrastructure investments, appraisers may capture almost all economic impacts arising from the project by measuring the value of travel time savings, and other monetised benefits that accrue due to existing users, new users, and non-users of the transportation system, over the asset life. According to the current version of TAG, if non-transport markets are perfectly competitive and there are no market failures, transport ‘user benefits’ capture the entire welfare benefit of the investment.¹³ This is the case even though benefits may be transferred to other economic agents such as businesses, landlords and consumers through secondary markets for labour, land and products. For example, reduced travel costs may increase demand for both residential and commercial property and lead to rent increases that ultimately benefit landlords. Alternatively, reduced

¹³ “User Benefits” refer to level 1 appraisal methods

freight costs could lead to a reduction in product prices which benefits consumers. If the above assumptions (perfect competition and no market failures) are true, then appraisers only need to estimate user benefits. These user benefits are captured in 'level 1' economic benefits of transportation in the TAG guidance.¹⁴

When markets are not perfectly competitive or when other market failures exist, economic benefits that are not fully captured within user benefits may exist. The most important Wider Economic Impacts (WEIs) are gains in productivity due to agglomeration, employment effects relating to monopsony power and tax distortions, and induced investment.¹⁵ The challenge with calculating WEIs is proving additionality above user benefits, since output gains due to increased productivity or employment are already counted in user benefits.

Static agglomeration

Agglomeration effects are cost savings and productivity improvements that arise from the access to economic mass that firms and workers have. Effective density is a measure of agglomeration forces used in the literature and in TAG, where a location's economic potential decreases with distance or generalised cost to employment in all other areas of the country. Transport economic theory explains that increases in the effective density of an area lead to productivity gains above what should be expected due to lower input costs. This is due to positive externalities associated with increased density such as better matching between employers and employees, knowledge spill overs and more efficient sharing of inputs and outputs.¹⁶

Transport investment can directly lead to productivity gains by increasing connectivity and effectively bringing economic agents closer together. This can happen without a significant change in land use. TAG defines this static clustering effect as a 'level 2' impact where all economic agents in a labour market experience the same uplift in productivity whilst all agents' location remain fixed. The economic benefit resulting from this static clustering is entirely additional to those captured by user benefits.

Static agglomeration effects are additional economic benefits that are not a result of the displacement of economic activity from other areas of the UK. TAG is clear that the core appraisal of economic benefits should be at a UK level. This leaves little room for using these economic benefits unless additionality (i.e. level 2 benefits) can be proven through the transport scheme's ability to address a market failure. However, recent updates to the Green Book guidance places more emphasis on a local place-based appraisal, and as such opens the door to more extensive use of dynamic clustering and induced investment.

¹⁴ For more information on user benefits, please see DfT TAG A1-3 (2017). Available at: <https://www.gov.uk/government/publications/webtag-tag-unit-a1-3-user-and-provider-impacts-march-2017>

¹⁵ For more information on wider economic impacts, please see DfT TAG A2-1 (2019). Available at: <https://www.gov.uk/government/publications/webtag-tag-unit-a2-1-wider-economic-impacts-may-2018>

¹⁶ For information on the economics foundation of urban agglomeration benefits, please see Duranton & Puga (2004) 'Micro-foundations of Urban Agglomeration Economies.'

Dynamic agglomeration and induced investment

Transport investment projects may impact the location decision of economic agents and may lead to the *spatial redistribution* of economic activity. A new transport scheme may open up new markets for the area, increasing the demand for land. For example, new businesses may decide to relocate closer to the stations to maximise their long-term profit despite increasing land prices, while other businesses may decide to leave as they are able to maximise their profit in areas with lower land prices. This relocation of economic activity may result in new economic clusters around the new scheme which induce further agglomeration benefits in the local area, even beyond level 2 benefits enjoyed by the whole labour market. While some areas may gain due to dynamic clustering, some areas may lose economic activity due to the displacement of firms and residents. Therefore, the net growth aspect of any dynamic clustering has to be justified.

Induced investment may also lead to the *dynamic clustering* of economic activity. A new transport scheme may impact the location choice and behaviour of economic agents and they would invest more in areas around the scheme. This chain of events acts together with the agglomeration led clustering potentially inducing benefits beyond level 2.

New transport infrastructure does not necessarily lead to increased economic activity. Areas directly benefitting from increased connectivity may grow to the detriment of other areas losing as economic agents decide to relocate. International empirical evidence is growing, and the results so far suggest that radial highways may decentralise population¹⁷ and service sector activity, radial railways decentralise industrial activity and ring roads decentralise both service and industrial activity.¹⁸ A recent paper finds that after the opening of the Jubilee Line Extension in London, net growth in employment was close to zero as most of the growth experienced within walking distance to stations coincided with further off areas losing employment.¹⁹

2.3.2 Tipping points and self-perpetuating growth

The economic framework that has informed the TAG units on wider economic impacts is generally silent on non-linear effects from transport improvements. There are also only a limited number of theories in urban and transport economics that explore how change happens across time. Gilles Duranton is one of the few urban and transport economists to have written on this topic, developing a paper on tipping points and self-perpetuating growth.

His economic framework in which he explains the self-perpetual nature of dynamic clustering can be seen in Figure 1.²⁰ Using his theory, we are able to see how a large change in the transport system may push the economic size of an area

¹⁷ Baum-Snow, N., 2007. Did highways cause suburbanization? Q. J. Econ. 122 (2), 775–805.

¹⁸ Baum-Snow, N., Brandt, L., Henderson, J.V., Turner, M.A., Zhang, Q., 2017. Roads, railroads, and decentralization of Chinese cities. Rev. Econ. Stat. 99 (3), 435–448.

¹⁹ Pogonyi, Csaba G., Daniel J. Graham, and Jose M. Carbo. 'Metros, agglomeration and displacement. Evidence from London.' Regional Science and Urban Economics (2021): 103681.

²⁰ Duranton (2011), California Dreamin': The Feeble Case for Cluster Policies

above a threshold (tipping point – point ‘W’ in Figure 1). This may lead to self-perpetuating growth due to agglomeration benefits leading to increased employment and productivity. Moreover, it also explains that this growth does not necessarily last for long as there are costs associated with increasing density and eventually a new equilibrium is reached without further growth (point ‘Z’).

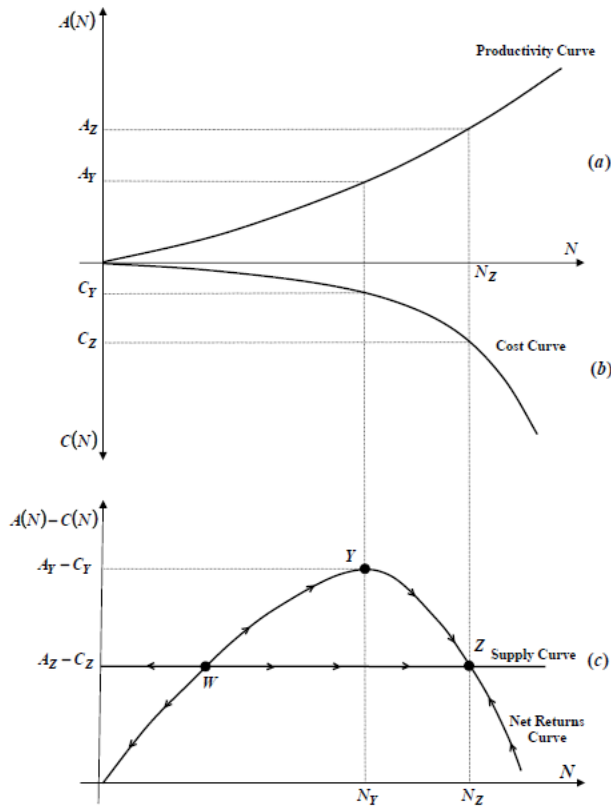


Figure 1 Self-perpetuating growth graph in Duranton (2011)²¹

The top graph consists of two curves, the first of which is marginal productivity of a particular activity graphed against the local employment size of that activity. The upward slope reflects the assumption of increasing local returns to productivity given an increase in employment size. The second curve is the marginal cost of production plotted against employment size (it is below the x-axis to reflect the fact that costs are negative). These costs increase as the employment size increases due to increased competition for land and associated rising rents, with an increasingly steep slope justified by an assumption that the area in question is limited in size.

The lower graph also contains two curves. The first is the difference between the productivity curve and the cost curve and represents the net marginal return at various levels of employment. This rises initially on the assumption that the productivity return to employment initially outpaces the rise in costs. The curve reaches a peak and then starts to fall as the marginal costs overtake the marginal gains. The second curve represents the supply of labour, which is flat based on the assumption that there is an infinite supply of labour at a fixed price. This creates

²¹ Duranton (2011), ‘California Dreamin’: The Feeble Case for Cluster Policies’

two equilibria, where the lower (W) is an unstable equilibrium point. If employment size is below this level, then the net returns are too low, and no cluster will be formed. If employment is above this level, then net returns are above labour cost and firms will be incentivised to increase employment. The second equilibrium point (Z) is stable and occurs when the returns to employment falls and the costs rise until they again coincide. At this point, firms will not be incentivised to expand further. Building new transport infrastructure and thus increasing the supply of labour and decreasing its cost pushes the supply curve downwards. This leads to higher incentives to cluster and increases the size of the labour market.

Point Y is where the cluster is most efficient and where the productivity benefits from clustering outweigh the costs from increasing competition for land. That firms will continue to expand beyond this point is a form of coordination failure, with welfare benefits set to be gains were they to cooperate. For example, when this point has been reached, firms could agree to create a new cluster from scratch by investing enough to get over the lower equilibrium point.

Venables et al (2014)²² provides an alternative theory which may explain changes in the retail sector through attractiveness and variety. Venables argues that the externalities associated with agglomeration and clustering within business districts and cities has an equivalent in the retail sector. After the introduction of transport infrastructure which allows easier access to a retail development, the increase in customers leads to higher profits. This in turn leads to higher rents, higher land prices, and the investment and development of new retail plots. This expands the variety of shops and the attractiveness of the retail space to customers, thus attracting more customers and setting off a positive feedback loop. Increasing levels of variety and specialisms are introduced, increasing the attractiveness of the area. As with the Duranton model, there is an initial tipping point of variety (economic density) which transport investment overcomes, and then a period of self-perpetuating growth. This analysis is arguably valid even in a rapidly digitalising world, where pandemics exacerbate the incentive to meet only digitally. The evidence so far suggests that while the importance of face-to-face retail may reduce, growing incomes in high value-added sectors and thus increasing spending on the face-to-face sector may counterweight a substantial part of the decline.²³

We can imagine a similar dynamic occurring with housing in a residential area. A transport scheme provides a step-change in the level of connectivity for the area, for example by making it possible to commute to and from a local employment centre. Improved transport infrastructure leads to an area becoming attractive to commuters, which can prompt a latent demand which is explained above. This leads to a tipping point since increasing the number of commuters leads to justified demands for more infrastructure, which in turn increases the demand even further. Commuters move to the area, thus increasing both residential and

²² Venables, Anthony, James J. Laird, and Henry G. Overman (2014), 'Transport investment and economic performance: Implications for project appraisal.' : 1-79.

²³ Economic Futures Research of the Central Activity Zone, GLA and Arup (2021), Available at: <https://www.london.gov.uk/business-and-economy-publications/central-activities-zone-caz-economic-futures-research>

commercial rents and property prices. Higher levels of spending by high-income residents induce further investment in the area thus increasing the attractiveness of the area and the variety of local amenities available, allowing for increased specialisation. This in turn leads to further attractiveness to other residents and potentially businesses (planning policy permitting). Again, this feedback loop is defined by removing a constraint and/or achieving a step-change and thus reaching a tipping point that the transport infrastructure enabled.

2.3.3 Sectoral redistribution and land use change

Increasing effective density and the redistribution of economic activity after the introduction of a change in the transport system may also lead to certain sectors entering the market and other sectors exiting, ultimately leading to a change in land use.

Firms choose their locations to maximise their profits, factoring in a number of elements including labour force availability, proximity to markets and suppliers, availability of land, tax regimes and incentives, and others. In many cases, it may be beneficial for firms to locate to an area where they are able to enjoy higher agglomeration externalities stemming from the co-location of firms, population, and relevant institutions. Dynamic clustering offers higher levels of agglomeration externalities; however, the literature is not clear on what types of new sectors and land uses may arise.

There are two competing or complementary theories of agglomeration externalities. On the one hand, Marshallian externalities ('MAR' – Marshall-Arrow-Romer²⁴) emphasise the importance of knowledge spillovers arising from similar firms co-locating and learning from each other leading to increasing productivity. On the other hand, the theory of Jacobs' externalities²⁵ emphasises positive externalities which arise from different industries co-locating. She argues that economic diversity in an area leads to the cross-fertilisation of ideas and thus increases productivity. Note that neither of these two theories are able to provide a clear picture on what type of new sectors may arise due to dynamic clustering.

2.3.4 Social transformation and wellbeing

Much of the literature has evidently focused on the economic impact of transport investment as this has been more of a priority for policy makers in recent decades. Nevertheless, there has been a renewed focus on the link between transport and well-being, and the role transport can play in transforming an area socially as well as economically.

Transport can contribute to wellbeing through enhancing connectivity and impacting the social and economic connection of firms and individuals. Based on

²⁴ Glaeser, Edward L., et al. 'Growth in cities.' *Journal of political economy* 100.6 (1992): 1126-1152.

²⁵ Jacobs, Jane. 'Strategies for helping cities.' *The American Economic Review* 59.4 (1969): 652-656.

our analysis, a change in transport connectivity can impact wellbeing mainly through the following three social benefits:

1. Better access to services
2. Better access to employment / work opportunities
3. Enhanced social interactions

Better access to services means that transport makes it possible to access a wide range of services including health services, shops, education, and leisure activities. There is a high correlation between transport disadvantage and wellbeing, with those with poor transport connectivity having a lower level of subjective wellbeing.²⁶ In fact, longer commutes such as between 60 and 90 minutes have the biggest negative impact on wellbeing, while shorter travel times improve wellbeing.²⁷ Better access also affects stress and wellbeing as it alleviates total traffic and reduces commuting time. This is especially relevant for vulnerable groups and those reliant on public transport.²⁸

Transport also increases access to work opportunities, which can contribute to reduced unemployment, which in turn increases the wellbeing of individuals. Also, studies found that better access to transport increases the likelihood of job seekers obtaining paid employment.

Enhanced social interactions can be achieved by higher levels of population movement, connecting people with others, enabling relationship-building, social inclusion and addressing loneliness.

Transport noise and air pollution can also cause stress and other negative health impacts dependent on people's proximity to transport schemes, as air and noise pollution can be prevalent in areas close to schemes.

Wellbeing and associated metrics

As with the use of the term transformation in the context of transport investments, the term wellbeing has not had a very precise definition in the context of transport improvements.

There are multiple ways of defining wellbeing, as it is dependent on multiple factors. It has been defined as people's 'emotional and psychological state as well as the ability to function socially, cope well with difficulties, develop potential, work productively and creatively, build strong and positive relationships with others and contribute to the community.'²⁹ The What Works Wellbeing Centre

²⁶ NatCen (2019) Transport and Inequality: An evidence review for the DfT.

²⁷ ONS (2014) cited in DfT (2019) Transport, health, and wellbeing. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/847884/Transport_health_and_wellbeing.pdf

²⁸ DfT (2019) Transport, health, and wellbeing. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/847884/Transport_health_and_wellbeing.pdf

²⁹ Government office for Science (2008) cited in DfT (2019) Transport, health, and wellbeing. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/847884/Transport_health_and_wellbeing.pdf

include 10 broad dimensions in its wellbeing definition: (i) the natural environment; (ii) personal wellbeing; (iii) our relationships; (iv) health; (v) what we do; (vi) where we live; (vii) personal finance; (viii) the economy; (ix) education; and (x) skills and governance.³⁰

The quantification of such measures will always be challenging. The Office for National Statistics (ONS) regularly publishes data on the population's personal well-being. They ask people to evaluate 'on a scale of 0 to 10 how satisfied they are with their life overall, whether they feel they have meaning and purpose in their life, and about their emotions during a particular period'³¹. They use a consistent methodology³² using the Annual Population Survey for high quality quarterly data and the smaller sample Opinions and Lifestyle Survey³³ for weekly figures.

More recently, the Wellbeing Guidance for Appraisal: Supplementary Green Book Guidance³⁴ explains where, when and how wellbeing concepts, measurement and estimation may contribute to the project appraisals. The guidance outlines a range of different methodologies available for monetising or valuing wellbeing impacts, from state preference surveys, revealed preference surveys, to the wellbeing valuation approach, where high quality subjective wellbeing data can also be used to value outcomes.

Evaluating wellbeing is challenging, as it is dependent on multiple factors and interdependencies. There is no standardised approach or methodology on how to measure wellbeing, as this often would depend on the scheme and project objective. In some cases, wellbeing is monetised, while in others a range of different wellbeing metrics are used, metrics which usually have been developed alongside stakeholders.³⁵ These can include change in employment, income, stress, loneliness, and anxiety, as well as other physical and mental health disorders. In this context, these aspects have been used to understand transport's impact on wellbeing. Another option is to look at a single measure of wellbeing which captures all wellbeing outcomes.³⁵

Even if a standardised and consistent measure of wellbeing exists, it would be challenging to evaluate the net impact of transportation as wellbeing effects tend

³⁰ What Works Wellbeing (2018) What is wellbeing? Available at:
<https://whatworkswellbeing.org/about-wellbeing/what-is-wellbeing/>

³¹
<https://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/bulletins/personalwellbeingint heukquarterly/april2011toseptember2020>

³²
<https://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/methodologies/personalwellbe ingintheukqmi>

³³
<https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandwellbeing/ datasets/coronavirusandthesocialimpactsongreatbritaindata>

³⁴ HM Treasury, 2021, Wellbeing Guidance for Appraisal: Supplementary Green Book Guidance. Available at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005388/Wellbeing_guidance_for_appraisal_-_supplementary_Green_Book_guidance.pdf

³⁵ What Works Wellbeing (2018) Wellbeing in Policy Analysis. Available at:
<https://www.whatworkswellbeing.org/wp-content/uploads/2018/03/Overview-incorporating-wellbeing-in-policy-analysis-vMarch2018.pdf>

to be secondary or tertiary impacts and thus additionality would be a major concern: a successful and transformational transport scheme creates new and higher value-added jobs and provides better access to key services. Analysis would show that over time the wellbeing of the population increases; however, it would be very difficult to disentangle whether this is due directly to the transport scheme, or to new housing developments, new firms and sectors moving in or to increased levels of public services.

2.4 Summary of literature on transformational impacts

Based on the use of the term transformational in the literature, and the theory around key concepts linked to transformation, we consider a transport scheme is likely to be transformational if it has one or more of the following characteristics.

The transport scheme leads to a change in connectivity in the area such that a tipping point is reached. The existence of the tipping point is the unique feature of what may be considered a transformational impact, as described by Duranton. It is challenging to provide a clear empirical definition for a tipping point. In our view, a sharp discontinuity in connectivity may be a definition that can be used in practice, or it could be seen in outcome metrics such as passenger number. For instance, a statistically significant change in accessibility, and a similar change in total local employment and sectoral/land use change between the pre-opening and post-opening period for a scheme may be considered as a tipping point. Or alternatively, it may be outturn passenger growth being higher than what was envisaged in the original appraisal, and beyond what can be explained by standard drivers of patronage.

The transport scheme acts as a leverage point to induce other investment in the local area, which eventually also leads to a significant change in effective density. It is important to note that in most cases we expect effective density to increase, and this leads to positive agglomeration benefits. However, the literature has started to examine cases of new transport schemes impacting areas negatively due to the displacement of economic activity

In cases where changes in connectivity and effective density reach a tipping point, a dynamic clustering of economic activity occurs. This self-perpetuating growth involves the redistribution of firms and population in space, potentially moving closer to the transport scheme and inducing high levels of agglomeration benefits.

This leads to our third characteristic relating to a significant land use change in the area. Due to localisation and/or urbanisation externalities, new sectors may enter the local labour market while others may exit, leading to a sectoral redistribution. This impact could be net zero on the total labour market level as while certain local areas may lose, others may benefit.

This new demand for using land differently, exacerbated by population and firm movement in space, leads to significant changes in land use. We suggest a broad definition for land use change: new types of usage within the same broad land use category are considered to be land use changes (such as higher value-added office sector usage for office use or more expensive housing units in residential use).

Land use change also means that the built environment in the area changes significantly, making the change irreversible. Empirically we suggest examining how sectoral employment shares change after the transport scheme, and how a significant change favouring one or many key sectors suggests a transformational change.

The above process culminates in level 3 agglomeration benefits which are additional to user and static clustering benefits. Benefits may comprise increased local employment and productivity, new homes and land value uplift.

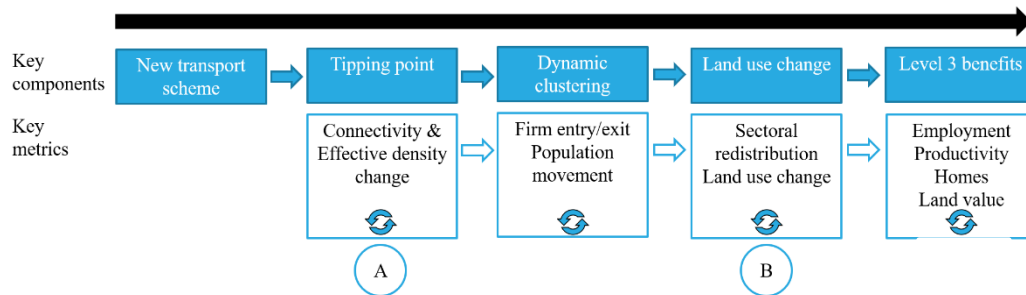


Figure 2: Overview of our proposed definition of transformational impact

For the case studies, we suggest defining the impact of a scheme which may be considered as ‘transformational’, if:

- A. There is empirical evidence of a significant increase in the following metrics: The change in the transportation system leads to an increase in connectivity and / or effective density, which manifests itself in a significantly increased usage of the transport network.
- B. The scheme leads to dynamic clustering and / or land use change which can be empirically identified by a significant change in sectoral employment shares or land use shares.
- C. The scheme leads to increases in at least one of the following four metrics: employment, productivity per worker/firm, number of homes and/or land and property values.

This definition can be applied to both small and large projects (though the geographic scope of changes is likely to vary). Please note that for stage 2 this definition may need to be revised for instance to set condition A **or** B **or** C as the transformational threshold, (rather than require all three).

2.5 Transmission mechanisms

There are two important definitions which need to be clearly defined for the purpose of the case study exercise. ‘Transmission mechanisms’ refer to the type of impact that may be considered ‘transformational’ that the transport scheme induces, particularly the land use change that it leads to. ‘Contextual factors’ provide the context in which impacts that may be considered ‘transformational’ are happening, of which the success or failure of the project depends on.

Transport infrastructure may deliver several outcomes, depending on the transmission mechanism behind it. These mechanisms might be entirely separate effects, or they may occur simultaneously and lead to different outcomes:

- **Residential impacts:** After a change in the transport system the location experiences a tipping point in connectivity and effective density, leading to a significant movement of population. The location becomes a more effective dormitory for an employment centre ('commuter town'), leading to changes in housing. This process leads to a change in land use which favours residential and retailing activities. Empirically this impact can be identified by a significant increase in residential land use and in the number of new homes.
- **Labour demand impacts:** The change in the transport system triggers a tipping point in effective density and connectivity which leads to the formation of a more effective employment centre. Better connection to a supply of labour and skills, leads to changes in employment and productivity predominantly. This process leads to a change in land use which favours office, retailing and community service activities. This impact can be identified empirically by an increase in business services and retail employment shares and a change in land use which favours these activities, potentially increasing the overall productivity of the area.
- **Consumer demand impacts:** Changes in the transport system leads to a tipping point in the connectivity and effective density of a location so it may specialise in retail and leisure activities. The better connection of firms to customers leads to changes in employment and productivity (either as GVA/worker or a measure of firm productivity). This process favours retailing, leisure and tourism, and other community service activities in the land use mix. The empirical identification involves a significant increase in the share of retail activities in the employment mix.
- **Industrial and freight impacts:** A significant change in the transport system triggers a tipping point in connectivity and connects a location to a wider market, increasing effective density. This location becomes an industrial hub and a larger employment centre, leading to changes in business activity and investment. Land use change predominantly favours industry and commerce activities, which empirically can be identified by a significant increase in manufacturing, construction and other industrial sectoral shares.

2.6 Contextual factors

We use the term contextual factors to refer to the wider context that surrounds a transport investment, such as characteristics of the local area, characteristics of the transport investment itself, or complementary investments or policies. In particular, we are interested in contextual factors that may interact with a transport investment to determine whether it is a success or not (or transformational or not). We have been unable to find substantive literature on this specific topic, but

through a high-level review³⁶ of historic transport schemes, we have identified a range of potential contextual factors that may work with (or against) a transport investment to determine its success.

Table 1 below shows our initial list of contextual factors and our rationale for their inclusion. We split these contextual factors into two types – those that relate to the characteristics of an area at the time the transport scheme was introduced to an area, and those that relate to activities and actions that took place alongside the transport investment.

Table 1: Initial list of contextual factors

Contextual factor	Rationale for inclusion
Characteristics of the area at time of investment	
Business cycle - When in a business cycle a scheme opened	Whether a scheme opens during a period of economic expansion or economic contraction is unlikely to determine whether a scheme is ultimately transformational, when considering a long time horizon (or at least, we have been unable to find an economic rationale for why it would). But this factor might explain poor outcomes over a 5-10 year horizon following scheme opening. The great recession after the 2008 financial crisis has also been anecdotally identified as a factor for why HS1 may have not delivered on some of its expected outcomes.
Quality of existing transport access - Whether the scheme improved transport in an area where transport accessibility / connectivity was already good	This relates to the idea that there are diminishing marginal returns to transport improvements, and more importantly (for the context of this study) diminishing wider economic benefits to transport improvements. So, schemes are more likely to be transformational where they take place in areas with poor existing connectivity.
Housing - Whether the scheme served a location, where either that location or other areas connected to that location, had severe housing constraints. Could be generalised to capture the context below.	This context relates to the idea that to achieve a transformative outcome, there needs to be latent demand. So, if transport access to an area is improved with the aim of unlocking housing development, that is only likely to succeed if the area has housing shortages, or other nearby areas have housing shortages. Without the transport investment, there is a coordination failure that prevents the housing (and associated) development from progressing. The scheme also enables greater effective employment density in an area than it would otherwise be able to accommodate, allowing for greater agglomeration effects.
Commercial development - Whether the scheme served a	Similar to the above, this contextual factor relates to the idea of there being latent demand for commercial developments

³⁶ Venables, Anthony, James J. Laird, and Henry G. Overman. 'Transport investment and economic performance: Implications for project appraisal.' (2014): 1-79

<p>location where there were development constraints</p>	<p>(warehousing, retail space, office space, etc.) that can only be realised through improved transport links.</p>
<p>Regeneration potential - Whether the scheme served an area considered to be unsafe or have poor visual amenity, which the scheme aimed to reverse</p>	<p>This contextual factor is designed to identify areas with high regeneration potential. Some of the literature theorises that areas can fall into low-level traps - that making an investment to improve an area would encourage more investment, but each economic agent is relying on the other because of the first mover disadvantage. This contextual factor considers whether government investment in transport can facilitate that process by taking the first step.</p>
<p>Underutilised skills - Whether the scheme served an area where there was a skilled population, but low levels of productivity and employment</p>	<p>This links to the coordination failure, where investment in the requisite skills does not take place because the relevant jobs do not currently exist locally, and firms are not investing in particular areas because people do not have the requisite skills they're looking for. By improving the transport provision, firms can be given wider access to the labour market and people wider access to employment - which creates a tipping point that makes such investments worthwhile.</p>
<p>Associated activities and actions alongside transport investment</p>	
<p>Benefits realisation - Whether the implementation of the scheme was associated with a clear benefits realisation strategy, or a local development strategy.</p>	<p>This factor is somewhat a process consideration rather than a context consideration. But, it is possible that (a) necessary condition for achieving a transformative outcome is the presence of a clear strategy for how such an outcome is going to be achieved.</p>
<p>Unlocking development - Whether the scheme took place alongside the release of land, the relaxation of planning rules, or the co-development of land</p>	<p>This factor is associated with the two contextual factors presented earlier relating to there being latent demand for housing or commercial development. The distinction we make here is that this contextual factor requires an action to take place alongside the transport investment, e.g. release of land, relaxation of development rules, complementary investments. This factor may be crucial in explaining the success of places like Canary Wharf and Stratford where planning rules were less stringent compared to such historical neighbourhoods like the West End.</p>
<p>Regeneration programme – Whether the scheme was part of a wider regeneration programme</p>	<p>This factor is linked to the regeneration potential context described above but relates to specific actions that have taken place to facilitate the regeneration process rather than relying solely on transport improvements to act as an enabler.</p>
<p>Skills investment - Whether the scheme took</p>	<p>This contextual factor relates to specific actions that have taken place to facilitate the upskilling of residents in an area, as way of</p>

place alongside investment in human capital	ensuring residents of an area have the skills required for newly accessible jobs.
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3 Evidence

3.1 Overview of the chapter

This chapter provides an overview of the literature on ex-post evaluations of transport schemes. The papers reviewed were chosen based on literature suggested by the DfT, our academic panel, and desk-based research.

Instead of providing a list of findings from each paper, we have aimed to connect the findings to our proposed definition of transformational impacts described in chapter 2. The Appendix provides a detailed summary for all modes.

3.2 Impact on key metrics

Our literature review focuses on identifying relevant literature for four key metrics: employment, productivity or wages, population or homes, and property or land value. Table 2 below provides an overview of our findings broken down by key outcome metrics. We identified five main modes of transport which are relevant for the project: inter-urban rail, high-speed rail, railway stations (as a separate investment additional to an inter-urban rail improvement), urban rail, and road. The international literature is especially rich for road schemes; however, since there have been few large road improvements in the United Kingdom in recent decades, domestic papers are rare. There is also ample international evidence on inter-urban rail, but mostly for the opening of new lines; the impact of rail improvements has been rarely studied. The evidence base on high-speed rail and urban rail is increasing as states are investing heavily in these modes and are interested in their impacts. There is also a growing literature looking at the impact of new railway stations, though primarily focusing on property price impacts.

Table 2: Mode-specific impacts on key outcome metrics

	Inter-urban rail	High-speed rail	Railway stations	Urban rail	Road
Employment	Mixed results: positive effects in growing sectors and economies but may be influenced by displacement.	Mixed results based on mostly Spanish evidence	Limited evidence which suggests no significant changes	Generally positive but evidence of displacement	Positive results: employment gains and increased firm entry

Productivity / wage	Limited evidence	Positive results both in Spain and Germany	No evidence found	Generally positive but evidence of displacement	Positive results: wage and productivity gains
Population / homes	Limited evidence	Limited evidence	Significant positive results for housing and population	Limited evidence	Evidence for changes in population movements for areas with existing population growth
Land value	Positive results but depends on contextual factors.	Limited evidence	Mixed results: impact on property values depends on contextual factors	Positive impact but this varies with local and investment characteristics	Limited evidence

An important concern for all empirical evidence is that it is unclear how much of the observed growth is due to net overall growth and how much of it is merely the result of redistribution. One area may reap benefits, while another experiences a loss so even though studies identify positive economic outcomes around the scheme, this cannot be identified as pure economic growth.

3.3 Inter-urban rail

Evidence for inter-urban rail shows that such schemes are likely to increase land values and provide a boost to population in areas with already growing population. For employment, we found mixed results where increasing employment is observed, but it is unclear whether this is net growth or the outcome of spatial displacement from elsewhere. In terms of property and land value, rail projects tend to have a positive effect on property prices, although the size of the effect varies considerably. It appears that the impact is stronger in areas where public transport is prevalent but does not provide competing alternatives. Even though certain contextual factors may prove to be more important than others, it is important to acknowledge that an existing vibrant economy appears to underlie potentially transformative national impacts brought by inter-urban rail.

Table 3 Inter-urban rail: contextual factors across transmission mechanisms

Inter-urban rail

Residential impact	There is little evidence for the residential impact mechanism. Population movement is based on a long-term decision and such long-run effects are hard to identify in empirical research.
Labour demand impact	<p>There is evidence of labour demand impacts in areas close to rail schemes.</p> <p>Rail can increase dynamic clustering in areas close to stations, resulting in land use change. This is the most apparent in the local areas' existing sectors, as employment growth is the strongest in sectors of the same kind. Employment growth is also prevalent in industries that benefit from connections to big cities, such as professional services and accommodation, food, and tourism. This implies that commercial development is important as it addresses latent demand.</p> <p>Complementary regeneration initiatives, such as housing or other commercial development, also appear to support labour impacts emphasising that rail schemes may address the issue of latent demand.</p> <p>The business cycle appears to be one of the most important contextual factors when considering impacts from inter-urban rail as areas benefit the most where there is already a rise in economic growth and where there are complementary regeneration initiatives.</p>
Consumer demand	<p>There is some evidence that retail and leisure activities increase in areas close to the station to capitalise on an increase of customers. This may be due to complementary transport methods, that can contribute to an increase in footfall close to rail schemes.</p> <p>This suggests that commercial development is an important contextual factor, as it addresses latent demand.</p>
Industrial and freight impact	We found no evidence for industrial and freight impacts.

3.4 High-speed rail

Evidence on the impact of high-speed rail is limited; therefore, all results must be taken with caution. Several studies which considered the impact of the expansion of the Spanish high-speed rail network found no significant impact on employment; however, they found a significant increase in productivity. Increasing productivity is supported by a high-quality ex-post evaluation which reviewed a German high-speed opening. All the studies reviewed concentrate on the whole local labour market and most of them show positive economic impacts; however, it is unclear whether these can be considered transformational as evidence is lacking on contextual factors and sectoral or land use change impacts.

Table 4 High-speed rail: contextual factors across transmission mechanisms

High-speed rail	
Residential impact	The limited existing evidence does not show residential impacts of high-speed rail. In theory, a new HSR connection leads to a decrease in commuting costs to the economic centre, so it might attract new residents to locations on the line if it offers lower housing and living costs and higher benefits. Therefore, key contextual factors to consider when testing residential impacts are the housing conditions, related constraints and decisions for unlocking development. The quality of existing transport access is also relevant, as it contributes to the general living costs, and to transport costs and benefits.
Labour demand impact	Factors critical for HSR investment to enable regional economic growth may be pre-existing economic performance and growth trajectory, and quality of existing intraregional transport services are at the root of varying impact found in HSR ex-post studies. This suggests the importance of the business cycle and quality of existing transport access contextual factors.
Consumer demand	We found no evidence for consumer demand impacts related to high speed rail projects.
Industrial and freight impact	We found no evidence for industrial and freight impacts.

3.5 Railway stations

Overall, there is good evidence to suggest that railway stations can create long-term, significant change through positive impacts on population, housing, and property value, however these effects depend on several contextual factors. New railway stations induce population and housing growth in the vicinity of the new station and increase rail use for travel to work. There are mixed results on the impact of stations on property values, with some studies citing large positive effects and others not finding significant results. Evidence suggests that the reason for this is that these effects depend considerably on location, modal split, and the attitudes of the population to public transport.

Table 5 Railway stations: contextual factors across transmission mechanisms

Railway stations	
Residential impact	There is strong evidence for residential impacts occurring close to stations, but its extent depends on various factors, including the type of station implemented, the location of the station (local vs. major station), local development strategies (e.g. housing regeneration schemes) and the population's reliance on the railway system. This suggests the importance of housing and unlocking development contextual factors and regeneration programme in some cases.

Labour demand impact	Evidence suggests that new railway stations may induce labour demand impacts as they often lead to increased office use. Unlocking development is a particularly relevant contextual factor, as we found that new station openings are often accompanied with significant changes in land development rules. Quality of existing transport access may also be important as we found evidence that stations lead to significant changes in travel to work behaviour in the 0-500m zone around a new station ³⁷ .
Consumer demand	Similar to labour demand impacts, railway stations may induce consumer demand mechanisms as well and the unlocking development and quality of existing transport access factors may be the most important. However, we found no evidence for these in the literature.
Industrial and freight impact	We found no evidence for industrial and freight impacts.

3.6 Urban rail

For urban rail, the reviewed literature suggests local employment and productivity may increase. However, the results are unclear on whether this is net growth or merely displaced economic activity from elsewhere. Results suggest that an urban rail investment is not a sufficient condition for positive economic gains and complimentary policy and investment is also needed. We found urban rail stations to have a positive impact on property prices, but this impact is variable, and dependent on scheme characteristics.

Table 6 Urban rail: contextual factors across transmission mechanisms

Urban rail	
Residential impact	Evidence suggests that urban rail can induce residential impact mechanisms through increased opportunities for commuting. As most of new urban rail was built in areas with increasing population, latent demand was present for more housing. Transport can relieve housing constraints and lead to transformational impacts, so the housing contextual factor is particularly relevant here. Urban rail is also often used as a catalyst for a regeneration programme creating homes in brownfield areas; therefore, regeneration potential and programmes may be relevant here.
Labour demand impact	By allowing access to a larger job market, urban rail is able to push areas out of low-level income traps and, particularly when coupled with well-targeted regeneration programmes, can achieve significant transformational impacts.

³⁷ Blainey, S and Preston, J (2010) Gateways to prosperity? The long-term impacts of new local railway stations. Available at: <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.681.4925&rep=rep1&type=pdf>

	<p>Unlocking development is often accompanied by urban rail. Without relaxing land development rules, it would be impossible to leverage the new opportunities which were created by the rail.</p> <p>Similar to residential impacts, regeneration potential and programme may be important as urban rail is often introduced in areas with high potential but high risk of investment.</p>
Consumer demand	<p>There is plenty of evidence that light urban rail can improve business sales in retail centres by improving access. Furthermore, there is evidence that it can lead to business entry, particularly from large retail stores and high-value retail good stores. This suggests the importance of the commercial development contextual factor.</p> <p>Interestingly, evidence suggests that the impact depends on the availability of other modes of transport and other retail options.</p>
Industrial and freight impact	<p>We found no evidence for industrial and freight impacts.</p>

3.7 Road

Road schemes tend to impact positively on employment, firm entry, wages, productivity, and can lead to significant changes to population. However, productivity and wage gains are dependent on the concentration of incumbent firms and level of excess labour supply, therefore results may vary depending on contextual factors. Evidence suggests that road improvements also affect population movement through journey reassignment, dependent on background growth. Based on our review, there is limited evidence to suggest that road improvements induce long-term, significant change on their own as they tend to spatially disperse economic activity which does not necessarily lead to the significant increase in effective density needed to reach a tipping point.

Table 7 Road: contextual factors across transmission mechanisms

Road	
Residential impact	<p>There is evidence of residential impacts in the form of significant changes to population movements, however, often this is a result of journey reassignment rather than new journeys created and depends on background population growth.</p> <p>This suggests that latent demand for new housing is the most important contextual factor.</p>

<p>Labour demand impact</p>	<p>Road schemes have significant positive impacts on employment³⁸, firm entry, productivity³⁹ and wages⁴⁰, which links strongly to the labour demand transmission mechanism. These impacts are significant within 30km of road improvements and become more significant closer to the scheme. This is due to the nature of road improvements which tend to result in more dispersed economic growth.</p> <p>Results are dependent on the quality and accessibility of the existing road network, the type of sectors present (aggregate employment effects concentrated in producer services, transport and administrative sectors), and on the degree of urbanisation, congestion and the country in question reliance of the population and businesses on road networks.</p> <p>This suggests that the quality of existing transport access and underutilised skills factors are key for this mechanism.</p>
<p>Consumer demand</p>	<p>We found no evidence for consumer demand impacts related to new road infrastructure.</p>
<p>Industrial and freight impact</p>	<p>Evidence suggests that there is a strong causal effect of new roads on firm-level productivity and effective density⁴¹. Evidence shows that firms choose to move closer to highways, attracting economic activity in the process.</p> <p>Specifically, manufacturing firms which are close to new highways benefit most from the productivity gains related to better connectivity. This is because such firms rely most strongly on the road network to transport raw materials.</p> <p>This strongly depends on contextual factors such as the businesses cycle and the quality of existing road infrastructure. In a recession, firms are less likely to move closer to road improvements. Furthermore, if there is already high-quality road infrastructure, firms will not be incentivised to move closer, and the road improvement will produce fewer benefits.</p>

³⁸ Gibbons, S. Lyytikäinen, T and Overman, H (2019) New Road Infrastructure: The effects on firms. Available at: <https://www.sciencedirect.com/science/article/pii/S0094119019300105>

³⁹ Melo, P. Graham, D and Brage-Ardao, R (2013) The productivity of transport infrastructure investment: A meta-analysis of empirical evidence. Available at: <https://doi.org/10.1016/j.regsciurbeco.2013.05.002>

⁴⁰ Sanchis-Guarner, R, and Lyytikäinen, T (2012). Driving up Wages: The Effects of Road Improvements in Great Britain. Available at: <http://www-sre.wu.ac.at/ersa/ersaconfs/ersa12/e120821aFinal00892.pdf>

⁴¹ Holl, A. Highways and Productivity in manufacturing firms (2016). Available at: <https://doi.org/10.1016/j.jue.2016.04.002>

4 Summary and conclusions

4.1 Overview

This literature review is part of the wider research commissioned by the DfT to understand contextual factors necessary for transport investments to transform regional and national economies. The review:

- covers major theoretical analyses on the transformational impacts of transport projects;
- summarises existing transport impact evaluations in the UK and internationally where relevant; and
- proposes a definition for transformational impacts and describes their nature, based on the discourse in the literature.

4.2 Definitions of transformational impact – key findings

The first part of the literature review suggests a definition of transformational change that is in line with TAG and the literature on urban and transport economics.

We found that the term ‘transformational impact’ is mainly used in the United Kingdom (UK) and the three levels of productivity impacts used in TAG are also UK-specific. However, it has no agreed definition in the literature, which makes it challenging to connect existing theoretical and empirical evidence directly to our research.

4.3 Empirical review

The second part of the review considers the empirical literature for five modes of transportation: inter-urban rail, high-speed rail, railway stations (as a separate investment on top of an inter-urban rail improvement), urban rail, and road. We focus on four key outcomes: employment, productivity or wages, population or housing impacts, property or land value (see Table 8 for an overview).

Impacts on productivity, wages and land values are generally significant and positive for all modes, which is in line with the expectations of TAG. Impacts on population were found mostly for areas where population was already growing or moving before the intervention. Evidence on employment impacts is varied and suggests that displacement is an important part of the picture.

Overall, we found that while there is ample evidence of impacts for many modes and economic outcomes, it is rare that academic papers or institutional reviews provide an analysis of the contextual factors behind the success or failure of schemes.

Table 8 Focus of the empirical literature review

Modes covered by reviewed literature	Outcomes evaluated
Inter-urban rail	Employment
High-speed rail	Productivity or wages
Railway stations	Population or housing impacts
Urban rail	Land and property value
Road	

Table 9 presents an overview of our findings on contextual factors. Each row represents one of the transmission mechanisms, and each column one of the analysed transport modes. Based on our findings we filled each cell with those contextual factors which may be relevant for that particular transmission mechanism and for that particular mode. Where a cell is empty, it means we found no empirical evidence of relevant contextual factors. Table 9 is built on evidence from a body of literature that has to date not focused on contextual factors. We suggest revisiting Table 9 later in the project and update it based on further evidence gathered.

We find that housing and unlocking development factors are crucial for residential and labour demand transmission mechanisms, and commercial development for consumer demand. The quality of existing transport access also looks like a crucial factor and it shows the importance of existing levels of connectivity in the success of a transport project.

Table 9: Overview of findings on contextual factors

	Inter-urban rail	High-speed rail	Railway stations	Urban rail	Roads
Residential	-	Housing Unlocking development Quality of existing transport access	Housing Unlocking development Regeneration programme	Housing Unlocking development Regeneration potential & programme	Housing
Labour demand	Commercial development Regeneration programme Business cycle	Business cycle Quality of existing transport access	Unlocking development Quality of existing transport access	Unlocking development Regeneration potential & programme	Quality of existing transport access Underutilised skills
Consumer demand	Commercial development	-	Commercial development	Commercial development	-

	Inter-urban rail	High-speed rail	Railway stations	Urban rail	Roads
			Unlocking development Quality of existing transport access		
Industrial and freight	-	-	-	-	Business cycle Quality of existing transport access

Appendices

A1. Inter-urban rail

Inter-urban rail is usually defined as passenger rail service between cities across regions or countries, covering longer distances than within-city trains. It differs from high-speed rail, as it operates at lower speed, with less distance between station stops, and provides services between urban and rural areas.

Inter-urban transport facilitates connectivity for people, businesses, and trade. It lowers the costs of trade and connects employers with employees, which can have implications on urban specialisation and interactions between supply and demand of labour and services. This may enable firms in one city to specialise and develop products that can be exported to other cities, and vice versa.⁴²

The quality of the literature on transformational change following inter-urban rail schemes varies significantly by focus, quality, and results. In particular, the What Works Centre for Local Economic Growth (WWCLEG) highlights the lack of high-quality evaluations to provide evidence on employment effects.⁴³ This is especially true when looking at inter-urban rail impacts.

The literature usually follows the hypothesis that inter-urban rail schemes enable more rail trips through increased accessibility, which improves the convenience of rail travel. This generates more trips; some additional, while others captured from other modes.⁴⁴ Higher accessibility creates more attractive places to live, work or locate a business. It might incentivise businesses to move to an area from other locations as it could increase access to suppliers, employees, and consumers, overall resulting in greater productivity. Based on this, the literature suggests that labour demand impacts are the most relevant types of transformational impacts of inter-urban rail.

In general, the literature acknowledges that the level and impact of transformational change depends on the contextual factors in which inter-urban rail is located. The literature highlights that if ‘economic and investment conditions are positive, as well as the broader political and institutional conditions, then economic development might take place as a result of transport investment.’⁴⁵ Therefore, certain economic conditions must be in place before we see transformational change from rail schemes. Areas that already have a vibrant economy seem to benefit the most. This underlies the conclusion behind the

⁴² Venables, A. (2016) Expanding cities and connecting cities: appraising the effects of transport improvements

⁴³ What Works Centre for Local Economic Growth (2015). Transport evidence review. Available at: https://whatworksgrowth.org/public/files/Policy_Reviews/15-06-25_Transport_Review.pdf

⁴⁴ Department for Transport, Steer Davies Gleade, and Cambridge Econometrics (2018). New or improved rail lines – technical note. Available at: <https://www.gov.uk/government/publications/economic-impact-of-new-and-improved-rail-lines-case-studies-and-method>

⁴⁵ Banister, D. (2007) Quantification of the non-transport benefits resulting from rail investment.

Eddington Report (2006) that claimed that transport investment was the most efficient in areas with a growing transport demand.⁴⁶

It is important to note that considering inter-urban rail increases access between, rather than within cities, transformational impacts can be disproportionate across areas. This implies that an area may reap the benefits, while another may experience a loss, suggesting that displacement rather than induced economic growth is an important consideration for inter-urban rail. So even though studies are able to identify positive economic outcomes, it is unclear whether this is a result of additionality or displacement.

Findings and results vary dependent on the combination of sectors, land use, employment patterns, and other economic factors existing across cities. Unsurprisingly, all these factors vary greatly across cities. The variation across places, transport schemes, and evaluation studies, makes it challenging to extract useful insight into which contextual factors are the most important under which circumstances. Nevertheless, there are certain lessons that can be drawn from the studies as described in the subsections below, such as the importance of commercial development addressing latent demand and business cycles. Perhaps, the most important lesson is the importance of knowing the local context, which can provide useful insight into the design of schemes.

Population and employment

There is some evidence that new or improved transport services may attract people to locations close to new schemes, but the evidence also shows that this may coincide with a population growth trend already present in the area, particularly if there are complementary regeneration initiatives taking place.⁴⁷ In general, there is little significant evidence attributing residential impacts to inter-urban rail. This is likely due to population movements only being visible in the long-term. Those who are willing to move based on rail connectivity, are more likely to do so to areas with existing transport connections making empirical research on specific rail schemes hard to identify.

There are mixed results for the level of impact on employment and productivity. There are also mixed results on which contextual factors are the most important for increasing employment and productivity alongside with inter-urban rail schemes.

Usually, employment is shown to increase in areas where employment or population growth has already been occurring. Sector-specific employment is also expected to increase if there is already a strong existing sector of the same kind. For example, Falmouth in Cornwall experienced an employment growth in accommodation and food industry following the introduction of an inter-urban rail

⁴⁶ Eddington (2006) The Eddington Transport Study: Transport's role in sustaining the UK's productivity and competitiveness.

⁴⁷ Department for Transport, Steer Davies Gleade, and Cambridge Econometrics (2018). New or improved rail lines – case studies (Corby, Falmouth, Leamington Spa). Available at: <https://www.gov.uk/government/publications/economic-impact-of-new-and-improved-rail-lines-case-studies-and-method>

scheme, reflecting the role of tourism in the area.⁴⁸ A case study on the economic impacts following the new rail project in Corby in Northamptonshire from 2009, shows a slight increase in employment for retail and wholesale trade, and transport and storage sectors, which is partially attributed to the rapid employment growth across Corby that occurred at the same time. This implies that rail can address latent demand through commercial development across sectors.

Businesses that rely on employees and customers from other cities benefit more from increased inter-urban rail schemes. This may include businesses from sectors which rely on tourists or knowledge-intensive firms whose employees regularly travel to other cities. This may include retail and leisure activities, which may also experience a positive impact through complementary transport methods that can contribute to an increase in footfall, emphasising the importance of addressing latent demand through commercial development. Nevertheless, as mentioned previously it is important to acknowledge that employment impacts can be a result of displacement rather than induced economic growth.

Land value and property prices

The impact of rail schemes on the property market is relatively well-studied. The literature generally finds that land and property values increase in close proximity to rail stations and decrease as distance from stations increases. The uplift in value is due to an improvement in access that commuters may be willing to pay for, as well as the associated commercial services (such as retail) that are attracted to these areas.⁴⁹

There is a higher increase in land values compared to property values, which may be due to land's ability to promote more varied development schemes and therefore provides a less risky investment. Similarly, commercial properties (including land) exhibit higher increases in values than residential land. There is little evidence that property characteristics affect land value, which is perhaps due to the variation in properties across areas close to rail schemes (Mohammad et al., 2013).⁵⁰

The quality of existing transport access, as well as public transport use appears to be important. Positive land value impacts are more prevalent in East Asian and European cities compared to North America. One explanation has been that East Asian and European cities have a higher dependence on public transport, while North American cities are more dependent on car, implying that rail schemes impact land values more in settings where public transport is already in high use or where there are fewer competing alternatives (Mohammad et al., 2013).

⁴⁸ Department for Transport, Steer Davies Gleade, and Cambridge Econometrics (2018). New or improved rail lines – executive summary. Available at: <https://www.gov.uk/government/publications/economic-impact-of-new-and-improved-rail-lines-case-studies-and-method>

⁴⁹ Bowes and Ihlantfeldt (2001) Identifying the Impacts of Rail Transit Stations on Residential Property Values. Available at: <https://www.sciencedirect.com/science/article/abs/pii/S0094119001922144>

⁵⁰ Mohammad et al. (2013). A meta-analysis of the impact of rail projects on land and property values.

Complementary housing development can also impact property values. Rail schemes may not lead to an increase in property values where there is a simultaneous increase in housing supply, through increased development or volume of planning applications (DfT et al, 2018).⁵¹ Notably, a few studies have found that rail schemes reduce property and land values as a result of an increase in noise, pollution, and crime levels (Mohammad et al., 2013).

⁵¹ Department for Transport, Steer Davies Gleade, and Cambridge Econometrics (2018) New or improved rail lines – case studies (Corby, Falmouth, Leamington Spa). Available at: <https://www.gov.uk/government/publications/economic-impact-of-new-and-improved-rail-lines-case-studies-and-method>

Title	Author	Publication year	Type	Reporting years	Study country	Outcome variable(s)	Results
Evidence Review: Transport	What Works Centre for Local Economic Growth	2015	Evidence review	N/A	Various OECD countries	Property values, GDP, business productivity, population, crime	Overall, there is a lack of high-quality evaluations that provide insight into employment effects. However, there is evidence that rail projects tend to have a positive effect on property prices, although this depends on the distance from rail scheme.
Economic Impacts of new or improved rail lines	DfT, Steer Davies Gleade, and Cambridge Econometrics	2018	Report, including case studies: Corby, Falmouth, and Leamington Spa.	2009 - 2018	UK	Population, business units, employment, productivity	The report finds numerous key lessons, although in this context the most relevant are: <ul style="list-style-type: none"> • Rail improvements are impacted by other contextual factors, highlighting the importance of collecting good contextual and control data to identify exogenous factors that can impact rail interventions and economic impacts. • Employment effects generally vary, but sector-specific employment can increase if there is already a growing existing sector of the same kind. • Certain businesses that rely on employees and customers from other areas / cities seem to benefit.
A meta-analysis of the impact of rail projects on land and property values	Mohammad, S., Graham, D. J., Melo, P. C., and Anderson, R. J.	2013	Academic paper	1980 - 2007	US, Europe, and Asia	Property value	The main results show that a number of factors impact variations in land / property values: type of land use, type of rail service, rail system life cycle maturity, distance to stations, geographical location, accessibility to roads, data specification, methodological characteristics, as well as whether the impacted area is land or property.
Expanding cities and connecting cities: appraising the effects of transport improvements	Venables, A. J.	2016	Academic paper: theory	N/A	UK	N/A	The paper develops a framework to analyse wider benefits from inter- and intra-city transport projects than rather providing results through evaluation. Theoretically, inter-city transport schemes can improve connections for businesses so they are better able to draw on goods and services from other cities, which can enable city specialisation.

Quantification of the non-transport benefits resulting from rail investment	Banister, D.	2007	Academic paper: theory	N/A	UK	N/A	<p>The paper looks at evidence on rail investment. Some findings include:</p> <ul style="list-style-type: none"> • There is evidence for property value impacts, dependent on contextual factors, such as the location, time, catchment area, scale of investment and local economic context. • Additionality is a key concern for rail schemes • Overall, contextual factors are important across analysis and similar transport schemes will have different impacts across locations. Vibrant economies seem to benefit the most.
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Table 10 Selection of core literature reviewed

A2. High speed rail

High-speed rail (HSR) are inter-city services with an operating speed of at least 250 kilometres per hour (although in some cases, the definition includes long-existing lines upgraded for speeds of up to 200 or even 220 kilometres per hour⁵²). Most of these systems have become operational since around 1990.

In general, the literature suggests that HSR impacts the economy similarly to inter-urban rail. The potential difference is the scale of the impact: HSR projects often explicitly concentrate on connecting large urban areas and aim to induce higher levels of economic interaction between the areas. The economic argument behind this is that HSR joins distant labour markets thus inducing agglomeration benefits leading to increasing productivity and economic output. This argument closely resembles our definition of transformational change where due to a tipping point a labour market reaches a threshold density for perpetual growth leading to a significant reorganisation of economic activity manifesting in sectoral and land use changes.

Studies reviewed so far stress a significant shortage of empirical research on the wider spatial-economic impacts of high-speed rail. In particular, existing evidence focuses on individual cities, while there seem to be a scarcity of ex-post studies at the intra-regional scale. In addition, as is the case with inter-urban rail in general, the limited existing pool of evidence does not provide conclusive answers.

What little existing evidence there is on French and Spanish HSR suggests that there has been a tendency towards the spatial concentration of activities around the major cities served by high-speed rail (Paris, Lyon, Lille, Madrid, Barcelona), and towards their metropolitan integration with medium and smaller cities, through increased commuting over shorter and medium distances (within roundly one hour).

While HSR services appear to reinforce large regional cities, impacts vary for smaller cities on the routes.⁵³ For instance, Brage-Ardao et al. (2012)⁵⁴ did not find impacts on the economic growth of the provinces in the Madrid-Barcelona corridor. However, Garmendia et al. (2008)⁵⁵ did find that Ciudad Real, within 1 hour from Madrid by HSR, had transformed itself from a previously isolated small regional city to a sub-centre within a polycentric mega-city functional region, through a sizeable increase in commuting into the capital coupled with a regional university and business centre. Graham and Anupriya (2018)⁵⁶ found significant positive impacts of the Spanish HSR on several economic outcomes (listed below)

⁵² Definition by the International Union of Railways, www.uic.org

⁵³ Chia-Lin Chen, Peter Hall, (2012). The wider spatial-economic impacts of high speed trains: a comparative case study of Manchester and Lille sub-regions

⁵⁴ Ruben Brage-Ardao, Daniel Graham, Patricia Melo, (2012). Measuring the Impact of High-Speed Rail on Economic Performance: Evidence for the Madrid-Barcelona Corridor

⁵⁵ Garmendia, M., de Ureña, J.M., Ribalaygua, C., Leal, J., Coronado, J.M., (2008). Urban residential development in isolated small cities that are partially integrated in metropolitan areas by high speed train

⁵⁶ Daniel Graham, Anupriya Anupriya, (2018). Evaluating the causal economic impacts of transport investments: evidence from the Madrid-Barcelona high speed rail corridor

in provinces between Madrid and Barcelona. The positive estimates were robust to excluding Madrid and Barcelona from the treatment sample (known as incidental treatment approach).

Graham and Anupriya (2018) found evidence on positive impacts on GVA, GVA per employee and number of firms, and no significant impact on employment (the number of people employed plus employers). Therefore, the authors suggest that the observed labour productivity impacts have come about via growth in GVA or improvements in labour efficiency, rather than through employment.

The labour productivity impacts were additionally tested and confirmed using a synthetic control group approach for the provinces of Lleida and Tarragona, both within an hour by HSR of Barcelona. The authors argue that these two provinces received HSR stations due to their geographical location on the route between Madrid and Barcelona, thus their assignment to the HSR network can be considered largely exogenous to their baseline economic performance. This argument is similar to Ahlfeldt and Feddersen (2010)'s study which tested HSR impacts on two small towns on the Cologne-Frankfurt HSR route – Montabaur and Limburg. Both towns (populations of 13 and 34 thousand people respectively) 'happened to get stations following complex negotiations, despite their small size and peripherality'. According to that analysis, German counties adjacent to these two 'quasi-randomly' added stations experienced a 2.7% level shift in GDP, compared to the rest of the study area (four years after the treatment). This is in fact an impact of a similar scale as the one found by Graham and Anupriya in Spain – a statistically significant increase of 2.3% in GVA in all HSR treated provinces relative to controls, and a comparable estimate for the intermediate provinces of 2.4%.

Ahlfeldt and Feddersen (2010)⁵⁷ also tested for population impacts and did not find significant evidence that new residents were attracted to Montaburg and Limburg in the short-term. Similarly, they did not find evidence that land values increased after the HSR line had opened. This suggests that the two provinces experienced impacts through the labour market mechanism – receiving HSR stations effectively increased access to the regional markets, which improved business, customer and employee interactions, which led to an increase in productivity levels.

Chen and Hall (2012)⁵⁸ discuss factors critical for high speed rail investment to enable regional economic growth after providing a case study of high-speed rail's impact on Manchester and Lille. They suggest that the simultaneous improvement of the intraregional transport network and a high-speed rail hub strategy are both crucial to enable spill-over effects. They argue that this, the existing economic conditions and infrastructure system, seem to be at the root of varying regional impacts found for high speed rail interventions.

⁵⁷ Ahlfeldt, Gabriel M., and Arne Feddersen. 'From periphery to core: measuring agglomeration effects using high-speed rail.' *Journal of Economic Geography* 18.2 (2018): 355-390.

⁵⁸ Chen, Chia-Lin, and Peter Hall. 'The wider spatial-economic impacts of high-speed trains: a comparative case study of Manchester and Lille sub-regions.' *Journal of Transport Geography* 24 (2012): 89-110.

Table 11 Literature reviewed for high speed rail

Title	Author	Publication year	Type	Reporting years	Study country	Outcome variable(s)	Results
From periphery to core: economic adjustments to high speed rail.	Gabriel Ahlfeldt and Arne Feddersen	2010	Academic paper	1992 – 2006	Germany	Population GDP Employment Land value	<p>Results provide compelling evidence for an increase in economic activity (GDP, GDP/capita, and employment) within areas that gained in access to regional economies following with the availability of the new HSR line. No impact found for population and land values.</p> <p>The results indicate that the observed growth effects of the HSR line remained persistent as a) growth is not reversed during the subsequent years and b) there is a return to the local growth trends experienced prior to the shock. The treatment effect is robust to a range of alternative explanations provided.</p> <p>Considerable anticipation effects have been found.</p>
Measuring the impact of high-speed rail on economic performance evidence for the Madrid-Barcelona corridor	Ruben Brage-Ardao et al.	2012	Academic paper	N/A	Spain	N/A	<p>Results indicate that the Madrid-Barcelona high-speed rail corridor has not produced any positive transformational effects on the economic growth of the provinces receiving the high-speed corridor. Differences in the economic performance between these regions and those that did not receive a high-speed rail investment have not been altered by the investment, which suggests that the alleged positive effects proclaimed by the Spanish government cannot be confirmed empirically for the Madrid-Barcelona high-speed rail corridor, at least not in the short to medium term.</p>
The wider spatial-economic impacts of high-speed trains: a comparative case study of Manchester and Lille sub-regions	Chia-Lin Chen and Peter Hall	2012	Academic paper	1998-2008	UK and Spain	GVA/head Employment property values Economics structure	<p>For both regions, the arrival of HSTs did assist the development towards the knowledge economy, but the specific aspects vary. The connection with the capital did economically strengthen the regional capital, but not some sub-regions around it, especially former industrial sub-regions. It has been argued that poor intra-regional connectivity is a significant factor. "The transformation process is about much more than highspeed trains, significant as they might be."</p>
Evaluating the causal economic impacts of	Daniel Graham and	2018	Academic paper	1995 – 2014	Spain	Gross Value Added (GVA)	<p>Difference in difference analyses show positive and significant impacts from Spanish HSR on labour productivity, on the</p>

Title	Author	Publication year	Type	Reporting years	Study country	Outcome variable(s)	Results
transport investments: evidence from the Madrid–Barcelona high speed rail corridor	Anupriya Anupriya					Labour productivity, measured as average GVA per employee Total employment Number of registered companies	<p>GVA, and on the numbers of firms.</p> <p>No statistically significant impact on employment. This suggests that the observed increases in labour productivity have come about via growth in GVA or improvements in labour efficiency, rather than through numbers employed.</p> <p>The authors discuss that the growth in the number of firms could have arisen either due to a net positive impact from HSR in the Spanish economy as a whole, or due to negative spillovers as firms relocate from adjacent control provinces; but they were not able to distinguish these mechanisms in our data.</p> <p>Synthetic control analysis looked at number of firms and labour productivity. Significant and positive impacts found in both tested provinces (Lleida and Tarragona).</p>

A3. Railway stations

The literature on the impact of new railway stations is limited and has a particular focus on their impact on property values, with the majority of studies tackling the question of residential impacts. New rail stations tend to have a positive effect on property prices, although the size of the effect varies considerably.

Varied property impacts reflect willingness to pay for improved accessibility, but could also be related to improved safety, connectivity, and public realm in the local area which increasingly forms a part of station interventions. Accessibility improvements entail new or better connections, but also improvements in station design leading to better interchange opportunities and interchange with other modes (and ultimately, accessibility).

Stations provide access to a range of transport modes, therefore the investment in new stations can greatly improve accessibility for a variety of users, facilitating transformational change in their immediate vicinity.

The investment in railway stations can have implications for land use surrounding the station, with residential and commercial real estate values increasing⁵⁹. Through better accessibility, new railway stations can have both long and short run impacts on their catchment areas, through effects such as movements in population, investments in housing developments, and in rail demand.

The intensity of the impacts may depend on the type of station developed, and on the location of the railway station i.e. 'local' station versus a major station in a large city, or the country within which the scheme is implemented. It may also depend on the quality of facilities provided, with higher quality facilities creating a greater impact on surrounding properties (Debrezion et al, 2007)⁶⁰.

The literature⁶¹ describes long run increases in population, number of homes, and travel to work journeys resulting from the opening of a new station. Short run impacts of higher house prices were also recorded, suggesting that residents value proximity to rail stations, and they are willing to pay a premium. However, the impact of new stations on house prices is debated in other studies⁶² which suggest that the impact may be context dependent.

⁵⁹ Blainey, S and Preston, J (2010) Gateways to prosperity? The long-term impacts of new local railway stations. Available at:

<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.681.4925&rep=rep1&type=pdf>

⁶⁰ Debrezion, Ghebreegiabiher, Eric Pels, and Piet Rietveld. 'The impact of railway stations on residential and commercial property value: a meta-analysis.' *The Journal of Real Estate Finance and Economics* 35.2 (2007): 161-180.

⁶¹ Blainey, S and Preston, J (2010) Gateways to prosperity? The long-term impacts of new local railway stations. Available at:

<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.681.4925&rep=rep1&type=pdf>

⁶² Rietveld, P. Ommeren, J and Koster, H. (2012) The Gains of Trains: The effect of station openings on house prices. Available at: <https://papers.tinbergen.nl/10094.pdf>

Population

A comprehensive study (Blainey & Preston, 2010)⁶³ looking at the UK assessed the long and short-term impacts of new local railway stations on urban areas. It found that in the two decades following the opening of a new station, the population within 2-5km around the station increased by 8%, with the distance reflecting the tendency for new housing developments to be centred on the edge of urban areas. In addition, on average 600 additional household spaces were created over the two decades in the zone 2-5 km from the new station than in the control zones, suggesting that the residential transmission mechanism explained in chapter 3 may be at play.

Population movements also changed because of investment in new local stations. The same study found that rail use for travel to work increased by 4 percentage points more in the 0-500m zone around new stations than in the control zones, and by 2 percentage points more in the 0.5-2km zone. This suggests that the areas in question became more effective 'commuter towns' through better links to employment sites, facilitating a change in land use which favours residential uses.

Property values

The same study also examined the impact of a new station on house prices, with the opening of a new station creating a 7-10% increase in house prices in the station's postcode sector. On the other hand, a more recent academic paper (2012)⁶⁴ analysing the effect of station openings on house prices in the Netherlands found that whilst households are willing to pay a premium for living closer to public transport stations, new railway stations do not have a statistically significant impact on house prices. However, this may be because only 2.2% of trips are made by train in the Netherlands, indicating that accessibility may not be of much importance to residents. Therefore, although the impacts of better accessibility may vary depending on the study area in question and the modal split, UK residents are willing to pay more to live closer to stations, which is evidence for the residential transmission mechanism in transformational change.

⁶³ Blainey, S and Preston, J (2010) Gateways to prosperity? The long-term impacts of new local railway stations. Available at: <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.681.4925&rep=rep1&type=pdf>

⁶⁴ Rietveld, P. Ommeren, J and Koster, H. (2012) The Gains of Trains: The effect of station openings on house prices. Available at: <https://papers.tinbergen.nl/10094.pdf>

Title	Author	Publication year	Type	Reporting years	Study country	Mode	Outcome variable(s)	Results
Gateways to prosperity? The long-term impacts of new local railway stations	Simon P Blainey & John M Preston, Transportation Research Group (University of Southampton)	2010	Conference Paper	1982-2005	United Kingdom	Rail	Catchment, population, new housing developments, rail use for travelling to work, house prices.	In the short term, new local stations have impacts on house prices, causing 7-10% growths within the station's postcode sector. In the long term, new local stations have impacts on catchment, population, rail use and housing. In the two decades following the opening of a new station, the population within 2-5km around the station will increase by 8%, household spaces in the same distance will grow by 600 spaces, and rail use for travel to work by 4% within 0-500m zone, then by a further 2% in the 0.5-2km zone.
The Impact of Railway Stations on Residential and Commercial Property Value: A Meta-analysis	Ghebreegziabihir Debrezion, Eric Pels, Piet Rietveld	2007	Meta-Analysis	1965-2007	United States	Rail	Percentage change in property value per distance measure to the station - includes Commercial property value and residential property value. Other outcome variables vary across the different studies which were considered.	The impact of railway stations on property values differs across property type, but generally railway stations have a greater positive effect on commercial properties than residential properties within short distances from the station. In addition, commuter railway stations have a greater impact on property values, when compared to light or heavy railway/metro, possibly due to the higher service coverage which has a greater appeal. Commercial properties closer to stations have a higher property value when compared to residential properties in the same distance, but for every 250m closer to the station, the value is 2.3% higher for residential properties when compared with commercial properties. However, when other accessibility modes are included i.e. highways or buses, railway stations have a lower impact on property values.
The Gains of Trains: The effect of station openings on house prices	Hans Koster, Jos van Ommeren, Piet Rietveld	2012	Academic paper	1995-2007	The Netherlands	Rail	Residential property prices	A kilometre decrease in distance to the nearest station increases house prices by 3.2%, and price trends are likely correlated with changes in the distance to the nearest station. Under specification 2, 3 and 4 of the model which includes year fixed effects, the distance to station coefficient becomes statistically insignificant, suggesting that there is no impact of station openings on house prices in the Netherlands. This contrasts previous studies and this may be due to several factors, including that new stations may be relatively small and located near large stations, limiting the effects of travel time for passengers, and that station openings may have negative externalities i.e. crime, noise, unsightliness, which may offset accessibility. Finally, the third reason may be that only 2.2% of trips use trains in the Netherlands, so accessibility is not that important to residents.

Table 12 Selection of core literature reviewed

A4. Urban rail

Urban rail may take many forms, we concentrate on high-capacity light train, tram and metro services, typically built to help commuting within a functioning labour market. Urban rail schemes aim to improve connectivity and reduce transport costs for both current users and new users, who benefit from lower costs, reduced travel time and improved reliability.

Firm entry and employment

Empirical evidence for wider economic impacts of light rail found light rail investment alone is unlikely to be a sufficient catalyst for economic change without additional supportive policies⁶⁵. There is evidence that this type of investment could extend labour market catchment areas, but the effects are linked to the presence of other conditions including links to other transport modes, land use and employment location planning. It can also lead to the reorganisation or rationalisation of production, distribution and land use, which may lead to further growth.

Urban rail can improve sales in retail centres by improving access, for example in Manchester, Newcastle, and Croydon. It can also lead to business entry, for example in Strasbourg, where large retail stores and high-value retail good stores moved near the new stations. However, there can be negative effects near stations, for example Manchester, where economic activity has been displaced to other retail centres or simply nearby streets. The impact on retail is dependent on the other transport modes and shopping options that are available. For example, the existence of large car-based suburban Shopping Malls (West Edmonton Mall and Gateshead Metro Centre) can limit positive effects on CBD retail activity.

Areas of cities that are poorly connected can enjoy significant regeneration due to clustering effects, with examples of media clusters and financial clusters (Media City, Canary Wharf). However, the introduction of light rail on its own is not enough, it is dependent on complimentary land use planning, such as offices and residential accommodation, and significant additional investment in this development (DIR and Metrolink extension). The level of planning and investment for a new town of Orestad included significant private sector investment and business entry, retail investment, and additional heavy rail and transport infrastructure requirements. There was initially evidence of first mover coordination failure that was eventually overcome.

Wages and productivity

By increasing economic density through investment in urban transport infrastructure productivity gains can be stimulated⁶⁶. However, empirical evidence that urban transport investment has a causal effect on productivity has proved more challenging to identify. This is due to the complex spatial character

⁶⁵ Ferbrache, F & Knowles (2016): the wider economic impacts of light rail

⁶⁶ Venables (2016) Expanding cities and connecting cities: appraising the effects of transport improvements

of urban centres, the multitude of factors that can affect the outcome of transport investment, and issues around data and methodological challenges. Despite this, there is some evidence of causal links.

Analysis of one urban tram scheme found an overall significant decrease in employment and productivity close to new stations. This can be explained by displacement effects, with the increases in connectivity in less economically dense areas being further reduced by the reduced costs of travelling to higher density areas both for retail and employment purposes. However, a second urban tram scheme found very significant increases in both productivity and employment in the areas close to stations but turning negative further away⁶⁷. This kind of displacement is perhaps to be expected. There is also evidence that home-buyers significantly valued proximity to planned Crossrail terminals following the period after this project was announced.⁶⁸

Population and population movement

New residential developments can result from urban rail, but evidence suggests this is dependent on further business investment and other transport infrastructure⁶⁹. However, the evidence here is mixed, with examples where effects have been neutral or even negative, for example in Sunderland after the introduction of Tyne and Wear light rail metro system. Evidence from Portland suggests that residential areas near the new light rail stations became more densely populated than control areas (Ewing and Hamidi (2014)). However, evidence from the South Yorkshire Supertram suggests negative impacts when compared to control group and that perhaps this was down to lack of well-integrated transport plans or coordinated investment ((Haywood, 1999; Lawless and Gore, 1999).

Property prices near new metro stations can also increase as was the case for the Manchester Metrolink (2007, in Senior, 2009, p.91)). A meta-analysis by Mohammad, et al (2013) of the impact of rail projects found that estimated impacts on property prices varied significantly⁷⁰. However, in general these rail investments did have a positive and significant impact on property prices. Properties around commuter rail schemes experienced significant positive impact on house prices, and in general commercial properties saw a more positive impact. There were also quite significant effects relating to the econometric methods used. For example, evaluations that used panel data rather than cross sectional data predicted more positive effects on property prices.

The land value increase depends on the scale of investment, as smaller investments affect accessibility, while larger scale investments have the ability to impact the property market. This may be because larger transport investments

⁶⁷ Pogonyi. C, The Wider Economic Benefits of Transportation

⁶⁸ Combera. S, Arribas-Bela. D (2017), Waiting on the train: The anticipatory (causal) effects of Crossrail in Ealing

⁶⁹ Ferbrache, F & Knowles (2016): the wider economic impacts of light rail

⁷⁰ Mohammad, et al (2013), A meta-analysis of the impact of rail projects on land and property values

have a greater ability to lead to a reduction in road traffic congestion and increase public transport use.

A recent paper by Pogonyi et al (2021)⁷¹ suggests that high capacity urban metro systems may impact the spatial organisation of economic activity more than light rail systems. They found no evidence for net growth in employment due to displacement after the opening of the Jubilee Line Extension in London. They found that areas within walking distance of the stations experienced a sizeable increase in employment; however, this growth is counterbalanced by a small but significant decrease in employment in areas which are between 750m and 2000m from stations. Interestingly they found a significant shift in sectors as the share of business and retail services increased, whereas the share of manufacturing decreased, suggesting that transformational impacts may have happened after the opening. This claim is further supported by Gibbons & Machin (2005)⁷² who find that house prices also increased significantly after the opening of the Jubilee Line Extension.

⁷¹ Pogonyi, Csaba G., Daniel J. Graham, and Jose M. Carbo. 'Metros, agglomeration and displacement. Evidence from London.' *Regional Science and Urban Economics* (2021): 103681.

⁷² Gibbons, Stephen, and Stephen Machin. 'Valuing rail access using transport innovations.' *Journal of urban Economics* 57.1 (2005): 148-169.

Table 13 Selection of core literature reviewed

Title	Author	Publication year	Type	Reporting years	Study country	Mode	Outcome variable(s)	Results
The economic effects of density: A synthesis	Gabriel M. Ahlfeldt, Elisabetta Pietrostefani	2019	Academic paper	2000 - 2019	Worldwide	Focus: impacts of density	18 outputs including productivity, rent, inequality measures	Benefits of density exceed costs across a broad range of measures, including productivity and rent. However, the evidence varies significantly in quality.
Evaluation of wider economic impacts of light rail investment on cities	Richard D. Knowles, Fiona Ferbrache	2015	Academic	1990s to 2015	UK, Europe, North America	Light rail	Productivity, investment and property values	Light rail can have positive impacts but it varies and depends on other factors. There is evidence that it can stimulate growth by unlocking land and encouraging investment. There is also evidence that it can trigger a re-organisation of land.
If We Build, Will They Pay? Predicting Property Price Effects of Transport Innovations	Gabriel M. Ahlfeldt	2011	Academic	1995 - 2008	UK	Metro and light rail	Property prices	The DID model calculates Property prices for properties within the vicinity of new stations experience an additional 4.5% increase over 8.5 years compared to the control group. This is very similar to what his gravity model predicts.
Metros, agglomeration and displacement. Evidence from London	Csaba G. Pogonyi, Daniel J. Graham, Jose M. Carbo	2021	Academic	1998 - 2007	UK	Metro	Employment and number of establishments	They find that areas within 750 m to stations gain employment, but those 750-2000 m lose, leading to no overall growth. They find significant change in sectoral shares, favouring office and retail.

A5. Roads

Road schemes are investments into the road network that often aim to improve accessibility, safety, and the efficiency of the transport system. In the UK, road networks dominate transport infrastructure, with 68% of travel-to-work journeys made by car, and 79% of freight moved by roads in 2019⁷³. There is evidence that road networks significantly benefit individuals and firms and are generally high value for money investments⁷⁴.

Improved road connections can improve access to markets and labour through reduced transportation costs and lower travel times, and this can foster economic integration, stimulate competition, generate agglomeration economies, and produce other wider economic benefits⁷⁵.

Unlike public transport interventions such as station developments, road schemes extend over a number of locations, making it challenging to understand the geographical scale of their impact. Although road schemes may increase the accessibility of an area after opening, they do not necessarily lead to increased effective density as both evidence and theory suggests that roads lead to more dispersed economic systems⁷⁶. This is because firms often decide to locate out from dense areas due to increased road accessibility. However, this sometimes differs with large-scale road improvements such as highways, where manufacturing firms may move closer to benefit from lower transport costs.

However, evidence suggests that road schemes have positive impacts such as accessibility-induced increases in firm entry and exit, prompting changes to population, worker location, and wages, which in turn increase productivity.

Employment and Firm Entry

The studies reviewed conclude that increases in employment are dependent on contextual factors such as the presence of incumbent businesses and excess labour supply, thus there must already be underlying growth for further employment gains to take place following a transport intervention.

A study of new road schemes in the UK between the years of 1997 and 2019 (Gibbons et al. 2019)⁷⁷ found that road improvement-induced accessibility changes, increased employment and the number of new establishments with an elasticity of 0.3-0.5, with employment gains attributed to the inflow of new

⁷³ Department for Transport (2020) Transport Statistics Great Britain. Available at: <https://www.gov.uk/government/statistics/transport-statistics-great-britain-2020>

⁷⁴ Highways England (2019). Evaluation Insight Paper: Post Opening Project Evaluation of Major Schemes. Available at: <https://www.gov.uk/government/publications/post-opening-project-evaluation-of-major-schemes-evaluation-insight-paper>

⁷⁵ Gibbons, S. Lyytikäinen, T and Overman, H (2019) New Road Infrastructure: The effects on firms. Available At: <https://www.sciencedirect.com/science/article/pii/S0094119019300105>

⁷⁶ Redding, S. J. and Turner, M. A. (2015). Transportation Costs and the Spatial Organization of Economic Activity. *Handbook of Regional and Urban Economics*, 5:1339–1398.

⁷⁷ Gibbons, S. Lyytikäinen, T and Overman, H (2019) New Road Infrastructure: The effects on firms. Available At: <https://www.sciencedirect.com/science/article/pii/S0094119019300105>

establishments. In addition, accessibility improvements attracted establishments that benefit most from transport accessibility, and aggregate employment effects were concentrated in producer services, transport, and administrative sectors.

These findings suggest that through better accessibility and connections between firms and customers, the areas in question became better employment centres, creating changes in employment and productivity.

Productivity and wages

The same study also concludes that productivity gains resulting from road improvements can be attributed to the inflow of new establishments. Within 1-20km of a road improvement, the average mean accessibility change is 0.83%, and the induced output per worker and wage effects are 0.20% for firms as a result.

Another study by Sanchis-Guarner & Lyytikainen (2012)⁷⁸ looked at the effect of road improvements and found that labour market outcomes such as wages and additional hours worked are positively affected by better accessibility to work. The impacts on wages and hours worked were analysed at 10-20-30km ranges on a statistical ward-level. For those wards in the furthest band from the improvement(30km), approximately 0.26% of the growth of weekly nominal wages and 0.3% of the growth in hours worked were attributed to the changes in accessibility that stem from road improvements. These impacts increased in wards closer to the road improvements.

Further to this, a meta-analysis by P Melo, D Graham & R Brage-Ardao (2013)⁷⁹ looking at the productivity impacts of infrastructure investments found that the productivity effect was higher for roads than any other transport modes in the long run, providing further evidence for the labour demand mechanism. Additionally, the effect was strongest for the primary sector which relies more heavily on the transportation of materials, such as manufacturing and construction, as well as for countries more reliant on the road network, such as the United States.

More recent studies, such as the study by Adelheid Holl (2016)⁸⁰ which estimates the effects of highways on manufacturing firm productivity in Spain, suggest that there is a strong causal effect of new highways on manufacturing firm productivity and effective density. This increases productivity through agglomeration benefits, as firms choose to move closer to highways to reduce transport costs of materials. By moving closer to highways, firms attract economic activity to their vicinity, and the location becomes a more effective employment centre and industrial hub. The study found that a doubling of the distance to highways is associated with 1.7% reduction in firm-level productivity. These

⁷⁸ Sanchis-Guarner, R, and Lyytikainen, T (2012). Driving up Wages: The Effects of Road Improvements in Great Britain. Available at: <http://www-sre.wu.ac.at/ersa/ersaconfs/ersa12/e120821aFinal00892.pdf>

⁷⁹ Melo, P, Graham, D and Brage-Ardao, R (2013) The productivity of transport infrastructure investment: A meta-analysis of empirical evidence. Available at: <https://doi.org/10.1016/j.regsciurbeco.2013.05.002>

⁸⁰ Holl, A. Highways and Productivity in manufacturing firms (2016). Available at: <https://doi.org/10.1016/j.jue.2016.04.002>

effects differ for firms which are not based in the manufacturing sector, such as service sector firms. A study by Chandra and Thompson (2000)⁸¹ found that there were adverse effects for earnings in services within rural regions adjacent to regions that received new highways.

Based on these results, we conclude that as road accessibility is improved the location becomes a more effective employment centre for primary sector firms due to better accessibility, leading to higher inputs/outputs per worker, higher wages, and greater expenditure, in turn affecting productivity and employment in incumbent businesses. Furthermore, road accessibility boosts effective density surrounding the road improvement, leading to changes in manufacturing business activity and investment.

Population and population movement

A post-opening paper by Highways England⁸² evaluated 85 major road schemes in the UK suggested that road improvements lead to changes in travel behaviour through reassignment of journeys, suggesting better accessibility has impacts on labour and population movement.

The evaluation shows that for 76% of major road schemes, increases in traffic volumes (movement of population) were attributed to changes in background growth or reassignment of journeys from alternative routes rather than to new additional journeys from the implementation of these road schemes. This suggests that major road schemes have an influence on population and labour movement, linking with the residential impacts and highlighting the importance of contextual factors such as pre-existing background growth.

⁸¹ Chandra, A & Thompson, E. (2000) Does public infrastructure affect economic activity? Evidence from the rural interstate highway system. Available at: <https://www.sciencedirect.com/science/article/pii/S0166046200000405>

⁸² Highways England (2019). Evaluation Insight Paper: Post Opening Project Evaluation of Major Schemes. Available at: <https://www.gov.uk/government/publications/post-opening-project-evaluation-pope-of-major-schemes-evaluation-insight-paper>

Title	Author	Publication year	Type	Reporting years	Study country	Mode	Outcome variable(s)	Results
New road infrastructure: The effects on firms	Stephen Gibbons, Teemu Lyytikäinen, Henry G. Overman, Rosa Sanchis-Guarner	2019	Academic paper	1997-2009	United Kingdom	Road	Employment, number of establishments, labour productivity.	Road improvements directly increase the number of establishments and the level of employment in areas with good network access, however, increases in employment come from the new growth in establishments rather than incumbent ones. In addition to this, productivity (output/worker), G&S inputs and wages increase for incumbent establishments, thus road improvements attract establishments which benefit from accessibility and this in turn bids up wages relative to other input prices and transport costs. The paper cannot conclude whether these effects are due to new roads improving access to output markets, inputs or workers, or whether they simply reduce travel times.
Post Opening Project Evaluation of Major Schemes	Highways England	2019	Evaluation	2002-2014	United Kingdom	Road	Traffic volume, additional journeys, journey times, number of collisions, scheme costs and benefits (£), air quality, noise, biodiversity	All major schemes have either hit their target or overdelivered on their forecasted benefits for journey time savings, reducing the number and severity of collisions, environmental benefits, and biodiversity, however observed benefits were around 30% lower than total benefits, possibly due to lower expected traffic growth. On average, major schemes have presented accurate costs forecasts which improved in accuracy over time and have delivered high value for money benefits of £3 for every £1 spent. However, BCR forecasts have been shown to be overly optimistic. Major schemes have delivered their environmental sub-objectives, with good noise mitigation practices in place as well as the establishment of habitats to encourage biodiversity; however they also resulted in an increase in carbon emissions with the majority of scheme forecasts overestimating this impact.
Driving up Wages: The Effects of Road Improvements	Rosa Sanchis-Guarner, Teemu Lyytikäinen	2012	Academic paper	1998-2008	United Kingdom	Road	Wages, travel time, hours worked, Employment status	Accessibility improvements affect flexible labour market outcomes such as wages and overtime, however fixed effects such as working hours are not changed. Through better accessibility, businesses have greater access to the labour market and workers behave more competitively, working for longer and being more

in Great Britain								competitive. In addition, workers may find it more worthwhile to work for longer if their wages are more competitive, affecting overtime.
The productivity of transport infrastructure investment: A meta-analysis of empirical evidence	Patricia C. Melo, Daniel J. Graham, Ruben Brage-Ardao	2013	Meta-Analysis	1988-2008	United Kingdom	Road	Productivity	The productivity effect is higher for roads than other transport modes and higher for the primary sector, manufacturing and construction. It is higher/lower if urbanisation/congestion is not accounted for in the model, and higher if unobserved heterogeneity and spurious associations are present.
Highways and productivity in manufacturing firms	Adelheid Holl	2016	Report	1997-2007	Spain	Road	Productivity	Evidence suggests that there is a strong causal effect of new roads on firm-level productivity and effective density. This is because road improvements such as new highways cause growths in local density, positively affecting productivity via agglomeration benefits. Evidence shows that firms choose to move closer to highways, attracting economic activity in the process.