Economic Performance Impacts of Road Enhancements

Lessons Learned Report

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2 Introduction

2.1 The purpose of this Lessons Learned report[1]

The purpose of this Lessons Learned report is to provide future researchers and analysts examining the economic performance impacts of road enhancements with a succinct and honest record of the challenges encountered and the lessons learned from this study. This is now seen as good practice in any government-funded project because it provides a useful input to designing and delivering future studies – both within government and via contractors to government.

As the EPIRE study was large and highly complex, both in terms of ambition and delivery challenges, a report of this type is particularly important in order to help future studies to be designed and delivered as smoothly as possible. One noteworthy feature of EPIRE was that it encountered a range of very time-consuming challenges that had not been anticipated. This led to delays in completing the work, but it also stimulated the development of what should be useful solutions to use in the future, including the use of 'events timeline analysis' that had not been specified in the EPIRE scoping report published in 2019[2] but that proved to be very informative.

Note: when considering future work in this area the reader is recommended to read both the final reports on the EPIRE study and the prior (detailed) EPIRE methods scoping report.

2.2 Terms of reference

This report addresses the following Terms of Reference, as set out in the project specification.

2.2.1 Lessons Learnt

- What were the strengths and limitations of the adopted approach?
- Were there any major practical issues (e.g. data, modelling, etc.) encountered during the project? Were these able to be overcome, and how?

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[1] Ipsos would like to acknowledge the advice and useful suggestions provided by the expert advisors to this study, Goerge Barret and Tom Worsley, together with invaluable inputs from the project Steering Group. A special thanks to Matthew Clark at DfT for advice and ideas throughout this project that were critically important to its success in generating useful finding and insights.

[2] Economic Performance Impacts of Road Enhancements (EPIRE) Preparatory Work – Final Report

- Were certain types (e.g. size, new road vs enhancement of existing road etc.) of schemes more difficult to evaluate than others?
- To what extent was the study able to achieve its aims? What evidence gaps are still outstanding? How might this research be developed further in the future?

2.2.2 Practical Application of Methods to Evaluation

- How might the evaluation methodology chosen for this project be replicated in future road scheme evaluation at both a scheme and portfolio level?
- How might the evaluation methodology be replicated or adapted as part of National Highways (formerly Highways England) and DfT evaluation approaches?
- What resources (funding, skills, data, etc.) would be required to achieve this?
- What monitoring data should be collected following road scheme implementation, in order to track economic impact for future schemes?
- What baseline data should be gathered for complex infrastructure schemes to enable an effective evaluation of the economic impacts?
- What time periods beyond scheme implementation are most appropriate for data collection to track progress towards and realisation of economic impact?

All these questions are answered in the concluding section.

2.3 Structure of the report

The report commences (in Section Two) by placing the EPIRE study in context, summarising its aims and objectives, the assumptions made on economic benefits drivers and their strengths and limitations. There is a particular focus on the approach to aggregation and partition in the econometric work, and the use of a logic model. This section concludes by considering the anticipated limitations of the study and their alignment with broader DfT activities. It also addresses the potential implications of structural changes in road use that may limit the value of historical analyses in future decision-making and investment planning.

Section Three covers the technical aspects of the econometric work. This considers the limitations encountered in accessing scheme documentation, mapping challenges, the construction and use of accessibility measures, computing requirements, handling systemic differences between areas, the use of events timeline analysis recent advances in econometric theory and concludes with a set of implications for future econometric work in this area.

Section Four covers the use of scheme case studies and the lessons learned from that side of the work. It considers scheme selection, the use of business surveys and the capture of stakeholder views (with a particular emphasis on an experiment in collecting evidence on supply chains conducted as part of this study) and the lessons learned from engagement with Local

Authorities and Local Enterprise Partnerships (LEPs), noting that the latter were absorbed into Local Authorities during the later stages of the study.

Section Five then considers the analytical implications for future work in this area. It covers a productivity dissipation aspect we identified (mainly from the use of the new events timeline analysis and potential explanations, the implications for future investment appraisals and spending and the implications for other studies of transport and economic impacts. It also addresses the lessons for use of logic models to link *ex ante* appraisal and *ex post* evaluation (a long-term DfT ambition)

The concluding section (Section Six) answers the questions set in the Terms of Reference. It covers the issues of what should be repeated and updated in analysis and what could, with hindsight have been done differently in the analysis. It then turns to the key administrative implications for government regarding the handling and archiving scheme information, future appraisal guidance and some implications for monitoring and evaluation (M&E) guidance.

3 The EPIRE study in context

3.1 Aims and objectives

The aim of the EPIRE project was to assess what impacts road enhancements (National Highways, Local Major and Local Growth Fund projects) have had on local economic performance by extracting as much as possible from existing data and filling evidence gaps, in so doing, informing future evaluation strategies and methods.

The Invitation to Tender outlined the following key questions the project aimed to address:

- What has been the impact of road enhancements on local economic performance?
- How do impacts differ in different contexts?
- How do different features of a scheme affect its impact?

These questions were developed further via designing a theory of change describing how road enhancements would be expected to lead to impacts on local and subregional economies in collaboration with the DfT and National Highways. This led to the definition of a set of specific hypotheses to be tested, as follows. Note: due to changes in the availability of claimant statistics resulting from the introduction of Universal Credit, it was not possible to explore the impacts of the programme on long-term unemployment. Additionally, no usable data could be obtained on land use. These hypotheses have been greyed out in the following table.

Table 3.1: Key research questions

Impacts on firms	
1	Enhanced connectivity and/or downstream development induced by road enhancements increases firm formation in nearby areas
2	Enhanced connectivity and/or downstream development induced by road enhancements encourages firms to locate/relocate to nearby areas
3	Enhanced connectivity and/or downstream development induced by road enhancements increases the productivity of firms located in nearby areas
4	Increased local productivity is driven by the relocation of more productive firms to nearby areas and/or exit of less productive firms (i.e. displacement)
5	Increased local productivity is driven by improvements in the efficiency of incumbent (spatially stable) firms
6	Increased local productivity is driven by increases in economic density (i.e. agglomeration effects)
7	Enhanced connectivity and/or downstream development induced by road enhancements facilitate the expansion of firms in nearby areas (turnover and jobs)
8	Enhanced connectivity and/or downstream development induced by road enhancements facilitate expansions in trade (imports and exports)
9	Enhanced connectivity and/or downstream development induced by road enhancements stimulate capital investment
10	For hypotheses 1-9, the effects of road enhancements vary across sectors of the economy, and the productivity and degree of urbanisation of the sub-region
Impacts on the labour market/workers	
11	Enhanced connectivity and/or downstream development induced by road enhancements stimulates population growth in nearby areas
12	Enhanced connectivity and/or downstream development induced by road enhancements alters the composition of local skills supply
13	Enhanced connectivity and/or downstream development induced by road enhancements increases the wages of the working population
14	For hypothesis 13, the effects of road enhancements vary across occupational groups
15	For hypothesis 13, wage gains are experienced by incumbent workers
16	For hypothesis 13, wage gains are experienced by incoming workers
17	Enhanced connectivity and/or downstream development induced by road enhancements reduces the number of unemployed claimants in nearby areas
18	Enhanced connectivity and/or downstream development induced by road enhancements reduces the no. of long-term unemployed claimants in nearby areas
19	Enhanced connectivity and/or downstream development induced by road enhancements increases economic activity rates of local workers
Impacts on land and property markets	
20	Enhanced connectivity and/or downstream development induced by road enhancements increases commercial and/or industrial rental values in nearby areas
21	Enhanced connectivity and/or downstream development induced by road enhancements stimulates the development of additional commercial and industrial floorspace in nearby areas
22	Enhanced connectivity and/or downstream development induced by road enhancements increases house prices and residential development in nearby areas
23	Enhanced connectivity and/or downstream development induced by road enhancements leads to changes in land use

3.2 Assumptions on economic benefits drivers made in the EPIRE Scoping Study – strengths and limitations

EPIRE, by intention, focusses on proximity-based economic impacts. These are of course extremely important and high-profile types of impact and there is a substantial body of evidence on the importance of agglomeration effects relevant to understanding the impacts of road enhancements.

However, an aspect flagged in initial discussions with the project Steering Group and also via subsequent consultations with LEP CEOs (summarised later in this report), is that there are also more 'systemic' network-level effects that contribute to economic performance via being better connected to the entire road system (and via that overall transport network).[3] This aspect is particularly important for extended business supply chains – which can be key to business performance.

As a result, and in recognition of the importance of network-level effects, the case study work was approached with a clear emphasis on these more systemic aspects, including the use of experimental questions in a business survey on three of the case studies on the geographical sources and destinations of physical goods supply chains.

Subsequent consultations with LEPs supported this perspective. The LEPs perceived there to be too strong a focus on proximity-based effects over the network-level effects via which businesses operate and upon which they rely. The LEPs also stressed that (in their view) current road scheme investment appraisal methods pay insufficient attention to how de-congesting a link in one location can generate advantages in a range of very distant locations via reducing congestion in extended supply chains. This point made by the LEPs is not necessarily accurate however as network effects are addressed, especially for the SRN.[4]

However, the general point does highlight the advantages of complementing an analysis of proximity-based effects with network-level effects in future work in order to provide a more balanced assessment of economic impacts. This is the main reason why the EPIRE case study work experimented with collecting evidence on supply chain dependencies via a business

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[3] See for example, Laird, J.J.; Nellthorp, J.; Mackie, P.J. (2005) Network Effects and Total Economic Impact in Transport Appraisal. Transport Policy, 12 (6), pp.537-544.

[4] Current traffic modelling methods consider, in some detail, the relationships between each scheme(s) traffic flow characteristics not just in relation to local and more spatially extended geographies but also in terms of network-level effects, treated as the complex set of traffic flows between the location being considered and all UK regions (treated as zones) at a less granular level. Hence, this provides a useful balanced assessment that considers all relevant spatial connectivity aspects. See for example the assessment of the Lower Thames Crossing: TR010032-001345-7.7 Combined Modelling and Appraisal Report - Appendix B - Transport Model Package.pdf

survey (a decision made prior to the discussions with LEPs) - discussed later in this report. Although the situation is improving now due to advances in the use of AI and machine learning applied to large datasets, supply chain systems have been hard to obtain data on.

Consequently, for future analyses it would be useful to add a consideration of network-level effects to the proximity effects addressed in the EPIRE study. Estimates of improvements in economic efficiency and growth arising from system level improvements in connectivity would require a different econometric strategy to the one adopted in the study – examining the relationship between changes in the aggregate quality of road infrastructure and economic indicators at a regional or national level.

3.3 Approach to aggregation and partition

As the work progressed it became clear that, with hindsight, a greater partition of the econometric analysis into different types of local economy beyond urban, rural and semi-urban might have been useful. In particular, differences in the structure of the local economy in terms of industry mix might have been useful. This is because the economic impacts are influenced by the types of business present, or who may re-locate to take advantage of improved road connectivity. In effect, the 'average effects' identified in the econometric analysis could have been unpacked a little more to have been less 'average. However, this ideally requires a well-researched agreed taxonomy to apply (which the Theory-of-Change/logic model aspect of the EPIRE study has made an effort to contribute to for future use) – see below.

3.4 Use of a logic model – advantages and future potential

EPIRE's use of a Theory-of-Change/logic model framework is important not just in providing a clear depiction and structure for the analysis, but also in providing a framework for more general use in a range of studies. It would be particularly useful if DfT encouraged or even required researchers and contractors to feed-back their findings to 'evolve' this Theory-of-Change/logic model. This would reduce the risk of missing important insights and maximise collective learning moving forward.

In EPIRE, two logic model evolution pathways were established. An econometrics-focussed version, for which an updated version was generated (discussed towards the end of the econometrics report) and a more complex and nuanced version developed as part of the case study work. The latter version increased the level of detail on housing and property supply aspects as these relate to labour supply with consequent growth and productivity impact aspects.

The case study version of the logic model, which is designed to help to compare and contrast different case studies (in effect, allowing specific case study logic models to be specified within an over-arching generic framework intended for comparative analysis), is far more complex because the evidence and insights need not be restricted to data available for the econometric analysis. Hence, this allowed innovation and supply chain related aspects to be addressed in addition to incorporating housing and property supply aspects.

3.5 Anticipated and unanticipated limitations of the study

Data availability and use limitations were anticipated and were encountered. As noted above, due to changes in the availability of claimant statistics resulting from the introduction of Universal Credit, it was not possible to explore the impacts of the programme on long-term unemployment. Additionally, no usable data could be obtained on land use. However, the practical challenges covered in more detail in Section Three, below, regarding handling of very large and complex datasets, with long-duration computing times had not been adequately anticipated. We also experienced very long ONS Secure Research Service (SRS) approval, data ingesting and results checking delays due to a combination of COVID related factors and other SRS workload and capacity constraints that proved to be problematic.

3.6 Alignment with broader DfT activities

EPIRE is one of several DfT studies and activities intended to contribute to the aim of more closely linking *ex ante* appraisal and *ex post* evaluation for road schemes. This aspect should be at front of mind in any future work in this area, particularly regarding efforts to continue to develop the Theory of Change/logic model work-strand. The greater the emphasis placed on collectively advancing the two strands of logic model (the econometrics version and the more complex case study version) the more useful the contribution to more closely linking *ex ante* appraisal and *ex post* evaluation. By framing future findings in logic model terms, it is easier for those involved in the investment appraisal process to identify any findings of relevance to investment planning and business cases.

Of course, the extent to which future investment appraisal considers potential economic impacts separately from the use of generalised value of time (VoT) savings is a key consideration. For clarity, the EPIRE study refers to economic impacts in a broader and more functionally ‘unpacked’ sense than VoT and other aspects. EPIRE examines the ‘how’ and ‘why’ functional relationships that road enhancements can set in motion, including the more indirect influences on decision-making and behaviours that shape benefits realisation in practice. VoT seeks to capture an average economic impact value in a more direct manner. Both perspectives are useful and have their advantages and disadvantages (an issue we return to in the Conclusions).

For some schemes it may only be considered proportionate to assess the most robust impacts (set out in DfT's Transport Analysis Guidance) in order to demonstrate alignment with the schemes objectives and Value for Money of the investment. However, the full range of economic benefits may not fully be assessed, in those situations, the availability of the EPIRE logic models and empirical findings may help to improve understanding of the potential economic impacts.

3.7 Potential implications of structural changes in road use that may limit the value of historical analyses

Because the project took an unexpectedly long time to complete, in combination with the experience of moving from the COVID to post-COVID eras, the issue of potential structural changes that could limit the analytical relevance of this type of historical study became a

potential front-of-mind concern. In response, the Ipsos team developed a prototype set of hypotheses via which to test for any emerging structural changes (these hypotheses can be found in the accompanying Technical Resource Document). This is a useful output from the study to build-upon and use. Aspects such a hybrid working and its implications for road use are key issues covered by this framework.

However, it should also be noted that there is evidence that by 2023, some of the disruption to historic patterns of transport usage had begun to unwind with many indicators (such as traffic volumes and rail usage) approaching pre-pandemic levels. As such, there are questions as to whether any permanent changes in transport behaviour are sufficiently significant to invalidate the findings of the econometric analysis – only future experience will determine this.

4 Technical challenges

Through the production of the econometric report, a variety of technical challenges were faced by the evaluation team. These are described below with accompanying steps taken to address the issues, and potential improvements for future work.

4.1 Scheme documentation limitations

The evaluation team faced significant challenges due to gaps in the scheme documentation across various road schemes. The data available was often fragmented, covering only certain time periods or specific aspects of the projects. The DfT and National Highways were only able to provide information if it had been retained and there was some variability in the documentation available for each scheme. Business case documentation was not available for 18 originally selected schemes and for others only an appraisal summary table was available. Where appraisals or ex-post evaluations were not available, judgements had to be made on the objectives and expected impacts of the scheme based on the available information. It was challenging to identify the budget allocations of road components of larger schemes that included more than one investment and the expected magnitude and type of their anticipated benefits.

A variety of public sources were used to fill gaps wherever possible and public scheme announcements and articles were able to fill some basic details. However, these were no replacement for detailed scheme documentation and as a result 18 schemes were removed from the analysis.

It is recommended that documentation be kept where possible, however this issue was not significant enough to prevent analysis.

4.2 Mapping challenges

The process of accurately mapping road schemes to the existing road network was labour-intensive and prone to errors. The documentation available for many schemes was outdated or lacked sufficient detail, making it difficult to align them precisely with the current road network. This manual mapping process required extensive cross-referencing and validation, consuming significant time and resources.

In order to address this issue, we utilised Geographic Information Systems (GIS) tools to manually map the road schemes. The process began by digitizing the available project documentation and overlaying it onto current road network maps within the GIS software. Where GIS files were unavailable, descriptions of schemes were used to manually pinpoint on the network. The team cross-referenced information from various sources, including local authority records and historical maps, to resolve discrepancies and ensure accurate mapping.

It is recommended that DfT and National Highways keep electronic GIS files or the OS ITN road link IDs for the schemes it funds. This would considerably streamline the preparation process that would be required for future evaluations.

4.3 Obtaining data sources for accessibility modelling

There were significant data requirements to construct the accessibility measures necessary for this type of analysis. Data for this study was obtained from the DfT, Ordnance Survey and Trafficmaster for the purposes outline in the table below.

Whilst there were no significant barriers to obtaining the required data, besides the data processing agreements, it did take time to gather all the relevant data for the years of interest. In the end we were able to undertake the accessibility modelling exercise starting in the year 2011 which enabled us to explore schemes completed between then and 2020.

Table 4.1: Datasets used for generating Accessibility Indices

Dataset	Description and role in study
Trafficmaster Speed Data	The DfT has also supplied observations of traffic speeds provided by Trafficmaster, which gave observed traffic speeds in both directions based on GPS signals for 2011 to 2020. This data does not provide complete coverage of road links and speeds on some links are unobserved. Where speeds were unobserved, measures were taken to impute data as described in the accessibility measure section. The data includes average speeds for the AM peak in each direction. Where speeds were not observed, the average for that road classification (e.g. Motorway, A Road or B Road) was provided. In addition, a number of road links in the network file were not present in the speed data file. 2011 was treated as the base year for the accessibility analysis.
Road Network	The DfT provided road network files for 2011, 2014, 2016 and 2020 (the Ordnance Survey ITN / OS MasterMap Highways Layer). The road network was reconstructed for each year from 2011 using a manual process. The 2011 road network was used as the 'baseline' network, and restricted to Motorways, A-roads, and B-roads to reduce the complexity of calculating optimal journey times. A new network file was created for each successive year, that only included any new road links or redesigned junctions associated with the road improvement schemes completed in the relevant year. This approach was adopted to remove the influence of any parallel changes to the design of the network resulting from schemes that were not included in the portfolio of schemes being explored.
Business Register and Employment Survey (BRES)	Employment counts for LSOAs in the baseline year of the 2011 index were obtained from the BRES. The BRES includes details of the number of employees working in each LSOA. This version of the BRES does not include firms that were registered for PAYE only.

4.4 Computing requirements

The successful implementation of the accessibility modelling component of the evaluation showed that replication of established accessibility modelling approaches are feasible on a larger scale within the constraints of data availability, and to enable analysis of subgroups. The following sets of Origin/Destination matrices (estimating the time needed to travel by road between every pair of LSOAs, using the QNEAT3 optimal routing plug-in to QGIS) needed to be generated:

- Annual origin/destination matrices that separately capture the effects of National Highways and Local Major Schemes
- Annual origin/destination matrices that separately capture the effects of new road links and improvements to existing links.

This involved considerable demands on computing power and time to generate the matrices as set out. In all, the exercise was repeated for each year between 2011 and 2020 and this process took more than two weeks in pure processing time. The limited availability of computing power was a constraint on how quickly this step could be completed and it was further complicated where issues with the underlying data inputs into the process had issues that could not be identified until after a matrix had been generated and therefore requiring a redo.

Where possible, future work could make use of cloud computing to configure virtual machines powerful enough to handle the complex computations necessary within a reasonable timeframe.

The evaluation approach was designed in a way to provide the most robust assessment of impact possible within the limitations of current methods, and as such we proposed undertaking the analysis in multiple configurations (for example using straight line distances between areas vs using distances by the road network in the calculation of the accessibility indices or removing firms that moved location after scheme completion from the sample vs keeping them in). Ultimately this resulted in over 2000 models completed.

Whilst the running of these models in principle does not take excessive amounts of time, clearance from the ONS SRS is difficult with files this large. Building on this study, it is recommended that future work seek to only obtain clearance for selected models where appropriate. In this case it was necessary to obtain all results to allow for the effective comparison of models but going forward this may not need to be repeated and updates for key models could be targeted.

4.5 Systematic differences between areas

There were inherent differences between areas at varying distances from road schemes, such as economic activity levels, demographic profiles, and infrastructure quality. These differences could confound the results if not properly accounted for, leading to misleading conclusions about the impact of road improvements.

To address this issue the following steps were taken:

- Fixed Effects Models: The team utilized fixed effects models to control for unobserved heterogeneity between areas. Fixed effects models account for time-invariant characteristics of each area by including area-specific intercepts in the regression analysis.

- Variable Trends: The team allowed for variable trends over time by including interaction terms between time and area-specific characteristics. This helped capture the differential impact of road improvements across different areas.

- Difference-in-Differences (DiD) Approaches: The team employed DiD approaches to isolate the specific impacts of the road schemes. DiD compares the pre-treatment and post-treatment differences in outcomes between treatment and control groups, helping to control for confounding factors.

4.6 Use of event study analysis

The primary distance decay model, also known as a 'two-way fixed effects' model, is widely used in applied economic research, however recent advances in econometric theory have shown that these types of models can produce (and on occasions severely) biased results in staggered designs. These risks are highest where the effects of programmes are heterogeneous (i.e. impacts vary across groups of firms) or where effects are dynamic (i.e. impacts vary over time). A variety of solutions to these problems have been proposed using an alternative staggered difference-in-difference (DiD) approach [5] as was applied for this study.

This involves the application of the standard (two period) difference-in-difference estimator for each cohort of firms and every post-treatment period (with the group of untreated areas - yet to be treated area - forming the control group for these analyses). The estimated effect of the programme is established by taking a weighted average of these treatment effects[6].

The group-specific treatment effects can be averaged to present an overall treatment effect. The expression for the group specific treatment effects is:

$$ATT(g,t) = E\left[\left(\frac{G_g}{E[G_g]} - \frac{\frac{p_g(X)C}{1-p_g(X)}}{E\left[\frac{p_g(X)C}{1-p_g(X)}\right]}\right)Y_t - Y_{g-1}\right]$$

Where the weights, p , are propensity scores, G is a binary variable that is equal to one for areas first treated in year g, and C is a binary variable equal to one for areas in the counterfactual group. The equation above gives the treatment effect at time t for the group of areas treated at time g, and it is computed by comparing changes in outcomes for group g between periods $g-1$ to that of a control group of yet to be treated areas (C).

[5] See Chaisemartin and D'Haltfoeuille (2022) Two Way Fixed Effects And Difference-in-Differences with Heterogenous Treatment Effects: A Survey.
[6] See Callaway and Sant'Anna (2019) Difference-in-Differences with Multiple Time Periods

The chosen DiD estimator for staggered treatment effects was implemented in STATA using the user-written command ‘csdid’. Given the potential drawbacks of the two-way fixed effects models, these results are considered the most robust. However, there was as yet no implementation of this approach for multiple treatment variables, as presented in the by distance band results, nor was there an implementation for continuous treatment variables as required for the accessibility index approach described below.

Application of this method enabled the event study type analysis described in the econometric report. These figures add greater detail to the estimated effects and show how these vary over time from scheme completion.

Whilst this method was feasible, practical and successfully implemented in this study, future studies may benefit further if an extension to this method is created that allows for continuous treatment variables thus allowing accessibility indices to be analysed in the same manner.

4.7 Distance decay modelling as a proxy for accessibility modelling

One of the key takeaways of the econometric modelling undertaken in this study has been the appropriateness of the standard distance decay approach as a proxy for accessibility modelling. Whilst our preferred approach remains the accessibility modelling (given it is this that theoretically motivates the achievement of impact), the distance decay approach proved able to provide similar results with far less time and data processing required. Where possible, we suggest an accessibility modelling approach should be applied given that effects are typically more conservative in this approach and theoretically more robust, but the distance decay modelling can provide quick results that are similar enough to imply robustness.

4.8 Summary

The above technical challenges and the implementation of the models as described in the econometric report suggest that:

- There would be benefits in scheme documentation being held by sponsors (e.g. DfT or NH) for longer. This would enable more schemes to potentially be included in analysis and classified more accurately.
- The collection and storing of GIS files on the locations of road schemes would significantly reduce the amount of time required to map the relevant schemes before analysis.
- Options for utilising cloud computing could be explored alongside distributed computing frameworks to reduce the time required to produce the origin/destination matrices required. The methods adopted in this study could be used to impute missing data and set speeds to enable the methods to provide robust assessments of impact.
- Future adaptations of the staggered difference-in-difference may enable the modelling of multiple ’treatments’ and/or continuous treatment variables and therefore allow for accessibility modelling results to be used in the regression analysis and decomposition of effects by type of scheme. The events study analysis provides rich information on the timing

and persistence of impacts which would further benefit from combination with accessibility modelling results.

- Future projects of this type should apply accessibility modelling approaches where possible given the additional robustness these models provide. However, this study does show that distance decay modelling is a good proxy for more robust modelling and may be appropriate where timescales are short. Overall, the econometric approach undertaken here should be replicated, following similar steps.

5 Use of scheme case studies

This section of the report covers the use of scheme case studies and the main lessons learned.

5.1 Selection

The original intention was for the selection of scheme case studies to be informed by the econometrics findings in order to provide an opportunity to unpack and explain the results in specific places and economic contexts. However, the delays to the econometrics workstream meant that case study selection had to proceed in parallel to the econometrics work. Although not ideal, this sequencing mismatch did not prove to be particularly problematic.

Consequently, a diverse selection of ten was made, in discussion with DfT, in an effort to capture scheme and location contexts likely to be useful in explaining economic impacts. Full details can be found in the case studies report. For this Lessons Learned report we highlight some key aspects and issues. The aim was to cover sea port and airport proximity (Immingham and Manchester respectively), established high-tech innovation driven local economies (Cambridge), a more aspiring case of that type which (unplanned) leveraged a road enhancement to attract the new Met Office supercomputer facility (Exeter), three places along a extended road improvement spine/axis (A1(M) and A1 linking Newark-on-Trent – Grantham – Peterborough), a tunnel (Hindhead), an M25 road widening junction improvements (Dartford) and a bridge facilitated by PFI (Mersey Gateway).

The intention was that this breadth of situations would be useful in allowing a range of aspects to be explored, including (as a final phase) examining aspects highlighted in the econometric findings (which we cover in Section Five).

5.2 Stakeholder views

Before considering stakeholders' views from a lessons learned perspective, we consider the practical aspects of conducting consultations and carrying out survey work relating to the economic impacts of road enhancements. In general, businesses were willing to be consulted via interviews, but this did require significant efforts to follow-up, and many declined or did not respond to requests for interviews (though this is not unusual) . In some cases, there was a positive initial response to the interview request, but the firm was unable to find an appropriate person with the knowledge and time available to take part in an interview. This was most likely because the issues being covered required a high-level managerial staff member who is therefore very busy (again not unusual). The telephone CATI survey with the experimental supply chain questions was effective, and yielded an adequate response for Cambridge and Manchester, but not so for Exeter.

Looking to the future as regards business engagement, it would be worth DfT reflecting the key findings from the EPIRE study in the published guidance and advice on questions asked for survey work (in regard to close proximity, extended proximity and network-level effects, logistics-driven benefits not necessarily reflected in productivity performance, supply chain links, planning consent and strategic fit aspects in particular).

Engagement with Local Authorities faced the challenge of finding the most appropriate person or group of officers to consult who had the necessary knowledge of both road transport and local economic performance impacts. Consequently, those consultations worked best when two officers in different roles were available. However, in some cases local authorities were cooperative but struggled to identify a relevant officer if the scheme(s) to be discussed were not recent. Record keeping, including the documented recording of experiences for future analyses tend to be weak given hard-pressed staff time and very tight local authority budgets. The resulting reliance on tacit knowledge makes it hard to consult over case studies that were completed several years ago (especially when the staff involved have retired or moved to other jobs).

As regards local government stakeholder views, the overall conclusion is that Local Authorities view road enhancements very favourably in terms of their enabling role in delivering local economic growth and prosperity ambitions, but, are well-aware of the following key considerations.

Firstly, the complexities of local-level interactions between causes and effects that determine how road enhancements generate economic performance impacts, and why this sometimes does not happen. Planning consent concerns, and particularly the potential for traffic congestion driven by success in attracting new investments enabled by road enhancements are front of mind issues.

Secondly, the importance of applying a broad and comprehensive perspective on how road enhancements drive economic impacts via the combined consequences of close-proximity, extended proximity and network-level effects. As immediately above, planning consent concerns arise from the interactions between these three geographical domains.

Thirdly, and in recognition of the two points above, there is currently a disjuncture between local-level strategic thinking on delivering economic growth enabled by road enhancements and current practices in ex ante appraisal. Network-level effects, extended-proximity effects and close-proximity effects are all modelled (with great sophistication) by DfT ex ante. This modelling examines how a specific road scheme, or bundle of schemes, will not only impact on local journey time savings but also via far more general extended proximity and network-level journey time savings.

Yet, some local authority officers working on economic development contend that they would prefer broader regional and national level to be considered in scheme specific businesses cases (even though they currently are in terms of DfT's sophisticated traffic modelling). Given such statements, there is clearly an information asymmetry both within Local Authorities, and, possibly, between Local Authorities and DfT. It would therefore be useful for DfT to consider the best way of removing such information asymmetries in order to produce a more joined-up and better coordinated policy framework via which Whitehall can liaise with Local Authorities. The mission-driven mind-set, and supporting approaches, currently being articulated to deliver national economic growth provides a logical and timely opportunity to reduce these information asymmetries and improve strategic coordination. One practical suggestion for DfT to consider

would be to present the findings from the EPIRE study at a forum of Local Authority officers and to discuss the implications for supporting national economic growth via investment in new and better roads. The work done via EPIRE on a detailed strategic logic model complements and supports such a dialogue.

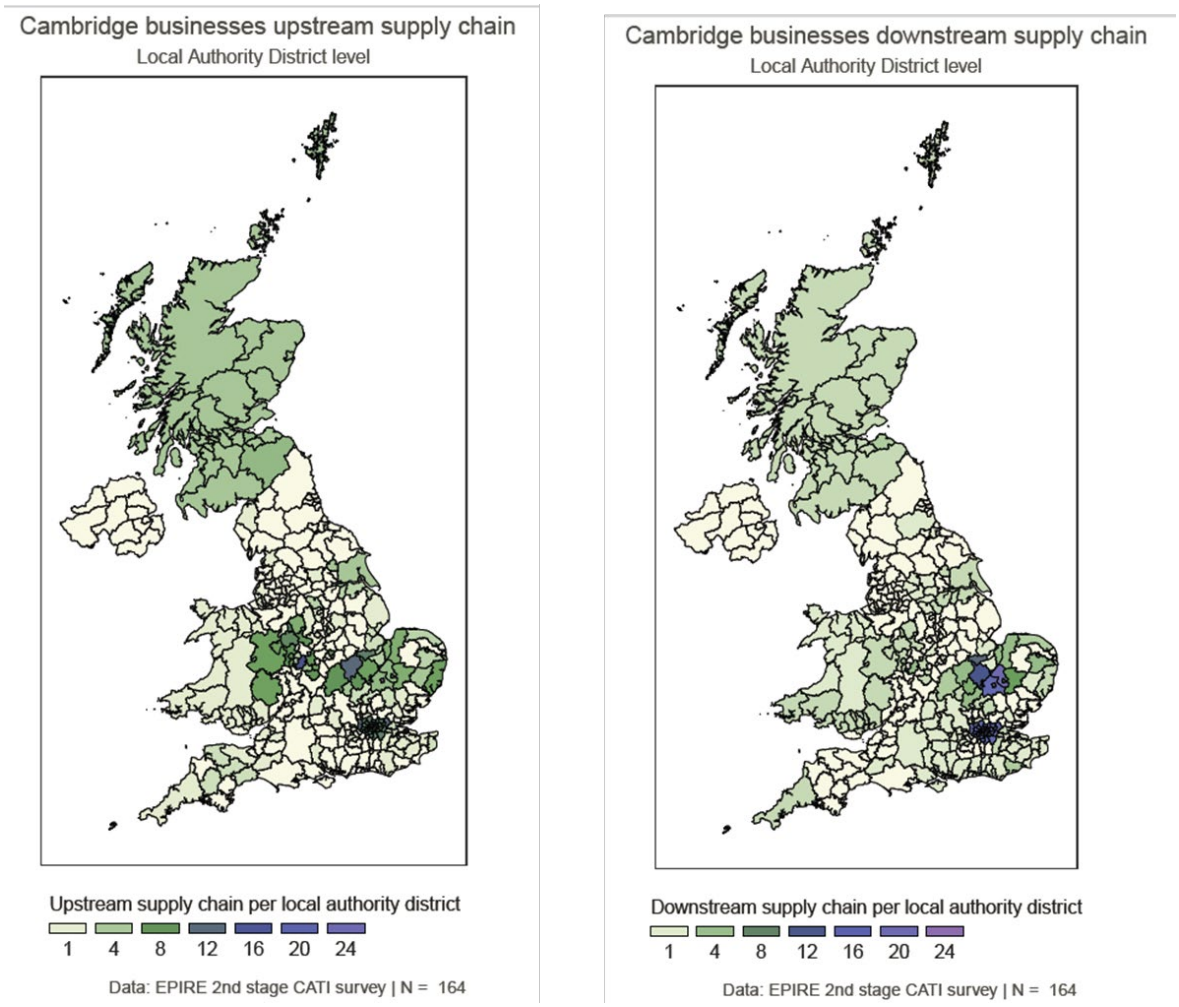
However, there is a more general point to consider here. This is that whilst the *ex-ante* traffic modelling considers the full local to national span of traffic patterns potentially impacted by a new scheme, current TAG guidance encourages a more localised perspective on economic impacts. As a result, there is a disjuncture between the ways in which new schemes can potentially contribute to collectively important network-level effects and how more place-specific benefits are articulated. It would be useful for DfT to consider whether the EPIRE study's proposed strategic logic model (in its more detailed case study level formulation) could be built upon to develop a more holistic articulation of extended-proximity and network-level economic impacts.

Business stakeholder views usefully emphasised the business reality that road enhancements make very important contributions to competitiveness in ways that do not necessarily get reflected in productivity data. The key insight provided by these consultations was that more reliable freight transport logistics help to maintain business-to-business customer satisfaction and generally assists supply chain logistics efficiencies. There are also benefits from being able to free up factory floorspace used for inventories for more profitable uses (and indeed output increases not requiring new floorspace additions). Consequently, it would be useful if future DfT studies captured such impacts as a separate impact pathway from business productivity performance per se.

5.3 Use of business surveys and experimental supply chain identification

The EPIRE budget allowed for three CATI business surveys to be carried out. The Cambridge A14 Huntingdon scheme, Exeter M5 junction improvement and Manchester Airport Relief Road (A5/A555) were selected for the business surveys. These surveys performed well in general and provided useful standard data of the type often collected to evaluate road scheme impacts. Details can be found in the Case Studies Report. One set of results are presented below to stress the utility of that exploratory work in demonstrating the importance of network-level effects for freight supply chains.

Figure 5.1: Supply chain connectivity maps for Cambridge



Source: Ipsos business survey

One new and noteworthy feature of the business surveys was the experimental inclusion of questions on the geographical sources and destinations of incoming and outgoing goods (i.e., upstream and downstream supply chain linkages). We had little sense of how business would respond to these questions, but wanted to test whether any such data could be collected – mainly to inform future studies. As discussed above in relation to network-level effects, supply chain linkages can be key to business location (re-location) and productivity performance. This means that businesses can benefit from distant as well as closer road enhancements if their supply chain is made more reliable as a result.

More reliable freight logistics due to road enhancements mean that business inventory levels can be reduced in order to decrease inventory carrying costs (a financial burden) and the use of floorspace required to store the inventories (floorspace that if freed-up can be used for more productive value-adding activities). This is a particular issue for input inventories (materials, stores and fuel) for which ‘stockout’ shocks will disrupt production and lower productivity. Goods on hand for sale inventories similarly act as a buffer that allows faster reactions to increased orders that the production process may struggle to respond to (depending on the length of the production period and assessments of upstream supply chain responsiveness). The greater the uncertainty, and hence risks to production efficiency, due to road congestion the greater the

need for inventories as a hedge against uncertainty. Consequently, inventory levels will reflect freight transport reliability, and can be used as a measure of economic benefits for businesses (we discuss these aspects in more detail later on in this report, however it is worth noting that TAG does include an appraisal of freight transport reliability).[7]

This experimental effort to collect supply chain data points to the importance of adding this aspect to the remit for future studies of this type (although delivering this would require significant new methodological design work). One interesting finding was that there tended to be a broad association between the geographical sources and destinations of these 'first order' supply chain links. As supply chains can be complex systems rather than linear 'chains' per se, sophisticated business relationship tracing methods are required to grasp the overall structure of supply chain relationships,[8] 'First order'; links are the initial 'entry points' into these more complex supply chain systems. A geographical source or destination in this context refers to the geographical place where the inputs came from and went on to after value-adding activity. This was captured via asking for the postcode, town name or other geographical location details of the top three tangible goods inputs and outputs for that facility. The finding that there was a broad association between geographical sources and destinations of these 'first order' supply chain links may be an artefact of the sample or other limitations, but is worth investigating in future work, not least because it is an unexpected finding.

'Beyond first order' supply chain relationships are particularly relevant to understanding import and export performance and road enhancements. The EPIRE econometric analysis did not identify any *direct* trade performance impacts. However, reliance on imports and export activities tends to be reflected in more indirect supply chain relationships. For example, imported inputs arriving by air freight or by sea and undergoing one or more value-adding stages before being transported by road to the location of interest. Consequently, any road enhancements in the parts of the road network used in that context will generate benefits indirectly (investments and benefits need not be co-located geographically). This is an important aspect of network-level effects, especially for freight transport reliability.

Interestingly, with LEP assistance, an online version of the questions used in the CATI business survey was tried out in order to determine whether supply chain data could be collected at greater scale via that route. It turned out that firms were unwilling to participate in such an online data collection process as they viewed the information as too sensitive to share and found it hard to see the benefits for them of developing a better collective understanding of supply chain

[7] In any future investigation it will be necessary to control for other factors than transport that drive inventory levels.

[8] HMG's inter-departmental GSCIP work on international supply chain tracing noted in the following footnote uses sophisticated 'knowledge graph' tools to handle highly complex supply chain systems, often extending to at least several tiers into supply chain systems rather than just the initial (first order) relationships. The US national security community uses similar tools to trace complex international supply chains.

systems, as distinct from their own firm's confidential assessments of supply chain vulnerabilities.

It is worth noting that, more recently, industry-driven initiatives to map supply chain systems are taking place (e.g., for offshore wind) and that non-generative AI and machine learning based services able to map supply chain systems are now entering the market, albeit currently with a greater focus on international than domestic supply chain systems. For instance, the US firm Altana AI specialises in complex supply chain mapping, and is one of a number of firms providing data for the UK's inter-departmental *Global Supply Chains Intelligence Programme* (GSCIP)[9]As these tools avoid using the generative AI approaches currently in vogue they are not prone to what is referred to as 'hallucinations', but they can still generate 'false positive' supply chain links from pattern recognition algorithms. The incidence of 'false negative', i.e., missed supply chain links is far lower when AI/machine learning tools are used compared to manual supply chain tracing (which traditionally relies on 'cascading' email and phone-based consultations with businesses and is therefore expensive to carry out and takes several months).

For this reason, the use of these tools is treated as 'semi-automated', with analysts using them in an iterative manner that allows for false positives to be identified and excluded from supply chain maps. Whilst this semi-automated approach is well-suited to the forensic nature of security intelligence work organised around the intelligence cycle (in which senior officials request specific intelligence to be gathered, cross-checked, analysed and disseminated) it is less well-suited to more routine big data uses in national statistics. This is one reason why the ONS is collaborating with data scientists in the Turing Institute in efforts to overcome such analytical and robustness challenges, notably those faced using financial payments data to trace domestic UK supply chains Consequently, opportunities to access supply chain data may increase in the future.

5.4 LA/LEP engagement

Local Enterprise Partnerships (LEPs) existed at the start of the EPIRE study but had been absorbed into Local Authorities by its conclusion (due to government review of their function and future). As LEPs were established to act as the voice of local/regional businesses it was

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[9] see Evaluation of the Global Supply Chains Intelligence Pilot (GSCIP) by Ipsos - GOV.UK for an Ipsos evaluation of the pilot phase. GSCIP is aware of departmental interest in domestic supply chain mapping. In addition, the ONS is progressing its own experimental use of financial payments data to map supply chains, see: Industry-to-industry payment flows, UK - Office for National Statistics. The ONS plans to publish spatial supply chain data (which they refer to as inter-regional trade data) but this is a long-term aim and unlikely to be sufficiently granular for use by DfT. Consequently, access to more granular anonymised financial payments data for use by DfT in supply chain mapping would need to be discussed with the ONS in the context of within government uses (perhaps delivered via the secure GSCIP platform).

logical to seek to build a collaborative relationship with them as part of the study. This collaboration was kicked-off by forming a working group of interested LEP CEOs (14 initially) with whom issues of collective interest relating to roads and economic performance were discussed. These discussions were very useful in informing the work on the detailed case study-oriented Theory of Change/logic model, in particular by highlighting how including supply chain connectivity has causal links to innovation capability and performance – in turn of course a powerful driver of GVA, employment, GVA per worker and investment attraction.

One feature of LEP engagement on the road enhancements-economic performance issue was that LEPs tended to be reluctant to engage in discussions of the transport infrastructure side and deferred to LA colleagues (beyond basic recognition of the importance of roads for local performance). This means that the absorption of LEPs into LAs is unlikely to limit the ability to continue this type of collaborative discussion in the future. The new Business Board Network (BBN) that has replaced the LEP Network has expressed an interest in coordinating any future collaborative activities in this area of investigation – which may be of use to other teams in the future.

5.5 Insights into business productivity effects – the importance of Total Factor Productivity

The EPIRE analysis has focused on labour productivity impacts (in the form of GVA per worker). However, for business competitiveness, Total Factor Productivity (TFP), sometimes also referred to as Multi-Factor Productivity (MFP), can be very important, especially for capital intensive industries.[10] This is because TFP uses an estimate of businesses' capital stocks, and often labour input quality to provide a more complete picture of productivity performance. This is important because increased mechanisation through new and improved capital equipment can increase labour productivity, but at the expense of increased fixed capital costs.

Farming (a road access dependent sector) provides a clear example of this aspect. Defra data indicates that whilst labour productivity has been rising, TFP growth has been far lower and declined by 5.1 per cent between 2022 and 2023. Increased farm mechanisation substitutes capital for labour inputs and seeds, fuel, fertilisers and other production inputs can be expensive to source.[11] The volume measures used by Defra indicate that output has declined slightly but that the inputs required to produce the outputs have increased.

The ONS has published new experimental estimates of TFP using data from the Annual Business Survey for the period 1998 to 2019 that confirm the existence of a general industrial

[10] For useful ONS definitions of MFP/TFP see: https://www.ons.gov.uk/economy/economicoutputandproductivity/publicservicesproductivity/methodologies/howtocompareandinterpretonsproductivitymeasures

[11] See: Total Factor Productivity of the United Kingdom agricultural industry in 2023 - GOV.UK

productivity puzzle in the form of declining annual TFP growth over that period.[12] Consequently, both the Defra and ONS estimates point to the importance of improving understanding of UK TFP performance (especially important for the government's economic growth agenda at a general level, and also the importance of improving understanding of how roads (and transport in general) shape TFP performance.

As the EPIRE study progressed, and in particular once the events timeline analysis of local economic impacts results were produced, some additional thought was put into the challenge of understanding productivity impacts, and whether examining labour productivity impacts alone would provide a sufficient basis for future analyses. In particular, and in recognition of the use of business consultations in the case studies, we started to consider the specific issue of how improved freight transport reliability generates productivity gains.

This aspect of the work was informed by the published work on low inventory – high throughput rate 'lean production' in the manufacturing sector. [13] It was also informed by the prior government policy work of one of the team members who had taken part in a series of Department of Trade and Industry (DTI) factory visits and industry consultations carried out to inform an HMG White Paper in the 1990s.[14] That work addressed evidence gaps in the academic work available on aerospace manufacturing supply chain productivity at that time (covering aspects that firms were reluctant to share with academic researchers).

Those factory visits emphasised the importance of floorspace utilisation as a direct and indirect factor in how efficient production processes are, and are hence relevant to productivity performance. Factory floorspace can be time consuming and costly to increase (especially if planning consent is required), and may require plant re-location if floorspace cannot be increased at the existing site. Consequently, floorspace utilisation can be key to understanding changes in turnover and (where known) GVA and also productivity performance. As factory floorspace availability is a key constraint (and significant overhead cost), anything that releases floorspace from less to more productive uses can contribute to productivity growth.

However, this would be experienced as an increase in the rate of return to capital (by enabling a greater level of output to be produced with the same level of capital inputs) without necessarily

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[12] See Estimates of total factor productivity from the Annual Business Survey, Great Britain: 1998 to 2019 - Office for National Statistics

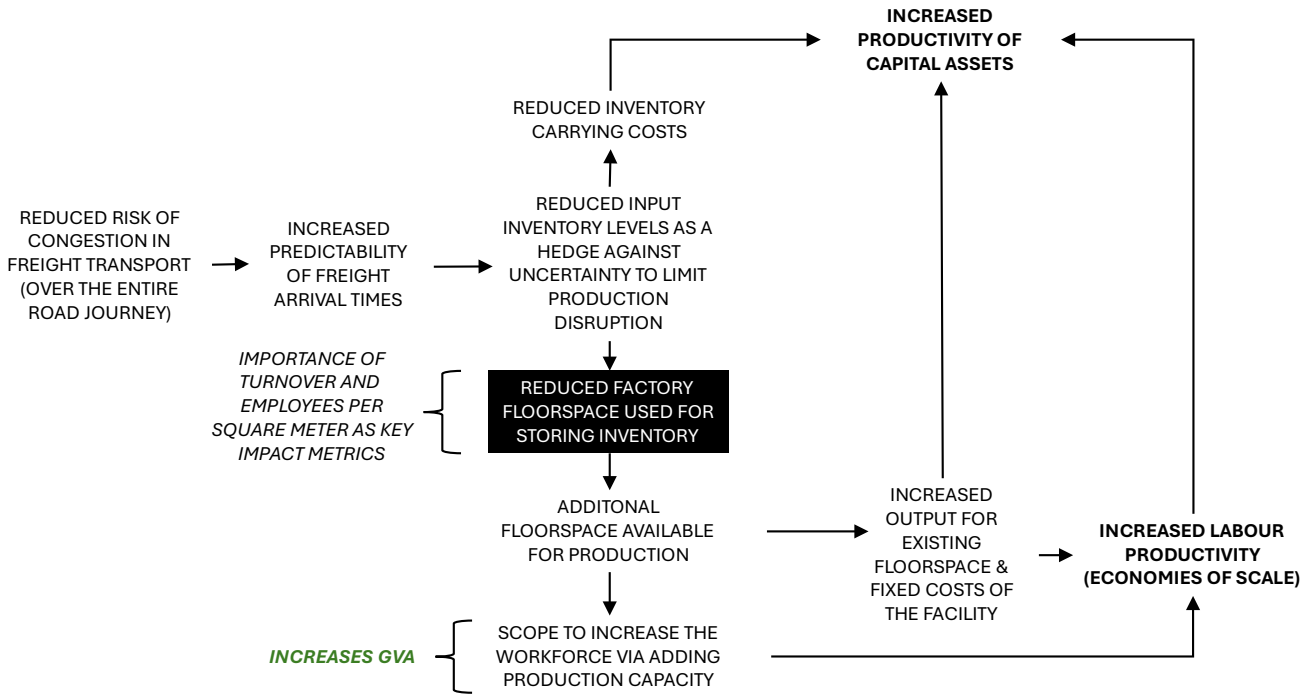
[13] See: Womak, J. P., Jones, D. T., Roos, D. (1990) *The Machine that Changed the World*. Simon and Schuster.

[14] This was research to inform the 1996 White Paper on Competitiveness, the third in a series. The absence of peer-reviewed academic research on some key productivity concerns led the Treasury to request a series of factory visits to assess the situation at that time. However, sensitivity and editorial issues limited coverage of these aspects in the published document.

implying an increase in GVA per worker unless (a) there are increasing returns to scale or (b) if the additional floorspace facilitates transformations in the organisation of production.

The key argument here is that a reduction in business inventory levels driven by increased freight arrival reliability can lead to factory capacity increases that boost GVA and potentially the productivity of capital assets by freeing-up valuable factory floorspace, see Figure 4.1, below for a depiction of this impact pathway.

Figure 5.2: Depiction of factory logistics-based impacts



Source: Ipsos

As this diagram makes clear, lower input inventory levels can free up factory floorspace for more productive uses, resulting in an increase in turnover and GVA, and potentially GVA per worker, due to economies of scale. It is likely that most effects of this type will be reflected in an increased Total Factor Productivity. Visitors to factories are often struck by the proportion of floorspace used for storing input inventories (to reduce the risks of production disruption) and sometimes, completed goods awaiting onward shipment.

This can therefore be an important benefits pathway for manufacturing businesses because it is harder, more costly and more expensive to add new factory floorspace in order to add more production capacity than to convert existing floorspace from storing inventories (a cost) to use as new production capacity (a benefit). The Valuation Office Agency (VOA) publishes granular business floorspace data at the administrative area level, which allows for useful timeline

tracking (this is a different presentation of the data than used in the econometrics work).[15] As the currently published data breaks down business floorspace into the following categories it provides a useful (and to our understanding under-used) basis for including this aspect in future analyses:

- Industrial floorspace;
- Retail floorspace;
- Office floorspace, and;
- All other business floorspace.

At this point however, there are some technical aspects of the VOA's business floorspace classification that limit their use in assessing (and to an extent forecasting beyond a current baseline) the GVA and employment impacts of road enhancements. These limitations were revealed when Ipsos requested and obtained the VOA concordance with SIC categories in order to link VOA business floorspace data with ONS GVA and employment data in the case studies workstream. This classification was developed and used in the COVID-19 pandemic to calculate support for local authorities in administering the COVID-19 Additional Relief Fund (CARF), which provided support for those businesses affected by the pandemic but that were ineligible for existing support linked to business rates[16] As it was necessary to link the business floorspace data to SIC classified data for that purpose, Ipsos were able to carry out some exploratory work aimed at estimating GVA and employment trends relative to business floorspace (thus generating 'economic density' estimates (discussed further below).

These limitations are that the VOA business floorspace data:

- Splits office floorspace between the main 'office' category, which in fact only contains headquarters and other offices (including computer centres) and the 'Other' sector via an offices sub-sector. This means that a considerable amount of office floorspace is hidden in the 'Other' floorspace category.
- Generally uses the 'Other' floorspace category to cover a very wide range of activities such as education, hotels, government buildings, car parks, various retail establishments (e.g. car showrooms), transport facilities and utilities. The result is that the Other category is treated as a residual grouping that combines many SIC categories in such a way that the analytical utility when linked with GVA and employment data is very limited.

[15] For details see Annex C in: https://www.gov.uk/government/statistics/non-domestic-rating-stock-of-properties-including-business-floorspace-2023

[16] COVID-19 Additional Relief Fund (CARF): local authority guidance - GOV.UK

As a result, the exploratory work carried out for the case studies focussed on the Retail and Industrial floorspace categories in order to minimise presenting misleading data.

Future use of such floorspace data will help analysts to understand how road enhancements have helped to shape changes in business activity (especially when linked to GVA and employment changes as economic 'density' measures). Given this potential, it would be useful for DfT to start a discussion with the VOA over whether: (a) industrial floorspace could be dis-aggregated a little to identify any changes in industry mix (aggregating spatially if necessary to avoid breaching disclosure constraints), (b) the 'other' floorspace category could be handled differently for the reasons summarised above and (c) office floorspace could be treated more accurately by also covering offices currently placed in the Other category, and (d) the Other category could be unpacked to align better with the major, but very different, GVA and employment SIC categories that it currently contains (education, health, public administration and defence etc).

These factors point to the importance of some potentially complex effects that must be considered in future studies, and also highlight the relevance of using Turnover (and if possible) GVA per square meter and related factory floorspace related metrics as diagnostic data in this context. Most importantly, as regards future studies, this aspect highlights the importance of considering effects on the productivity of other factors of production beyond labour – which are of course particularly important for the competitiveness of capital-intensive firms and sectors.

The final phase of business interviews responding to the econometrics findings was used to gather more information on, and insights into, this link between freight transport reliability and factory performance.

The focus outlined above also has the advantage of directing more attention to the more detailed causal pathways via which road enhancements generate economic impacts. This is important because the statistical associations identified do not always provide a complete explanation of what is driving the underlying hidden relationships reflected in the data – for instance the specific ways in which agglomeration effects, access to labour and other factors create economic benefits at the firm or plant level. In any case, agglomeration effects can, from a theoretical perspective, combine a spatially specific aspect based on proximity (knowledge spillovers, social capital that improves trust and reciprocity in the business community etc) and aspects that get picked up statistically as agglomeration benefits but that are not necessarily spatially specific – notably supply chain related effects.

The supply chain aspect is important because knowledge also flows along supply chains, hence localised supply chains contribute to agglomeration effects, *but* if these are replaced by more spatially extended supply chains businesses still benefit from knowledge spillovers. This aspect is strongest when international high-tech supply chains are involved because the firms in those supply chains can benefit far more from the knowledge and IP spillovers that flow along those supply chains than from local agglomeration effects.

We advise that care be taken to avoid applying the agglomeration concept too broadly, such as in the notion of 'long-distance' agglomeration effects. A 'purist' approach to agglomeration recognises that spatial proximity creates a wide range of spillover based economic benefits, including strengthened trust and reciprocity in business-to-business relationships ('social capital') as well as labour supply advantages (easier to move jobs without moving home etc). Large cities, and successful knowledge-based smaller urban concentrations such as the clusters of high-tech firms (and 'serial entrepreneurs') in and around Cambridge[17] are well-known examples of agglomeration-driven competitive advantages. These aspects of agglomeration effects rest on a high density in businesses, relevant R&D performing organisations, skilled labour and their housing etc.

These concentrations of economic (and especially innovative activities) are anecdotally assumed to produce more favourable investment risk-taking conditions resulting from in higher rates of start-up company formations, higher five-year start-up survival rates and a high proportion of start-ups growing above 20 percent per annum for three consecutive years (all aspects that the ONS Business Demography data can shed light on if geographical variations are adjusted for different sectoral mixes).[18]

Road enhancements assist and facilitate these causal relationships, but the causal relationships do not depend on road transport as they are far broader in scope.

Given the potential for what are currently treated as agglomeration effects to capture other beneficial causal relationships that do not necessarily depend on close proximity, as summarised above, analytical robustness is best achieved by avoiding over-using the agglomeration concept in future studies and restricting it to close proximity and/or economic density aspects. Otherwise, there is a risk that 'long-distance' agglomeration effects are actually capturing extended supply chain driven effects (as spillovers, including social capital benefits flow along supply chains too).

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[17] See for example: https://www.sqw.co.uk/application/files/6016/2126/4622/Viewpoint_-_The_Cambridge_Phenomenon.pdf

[18] See, https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/datasets/businessdemographyreferencetable. Note: for a small fee the ONS are able to provide bespoke business demography data that provides a broad SIC breakdown of the data by geography (requiring data requests to trade-off geographical and sector granularity in order to avoid breaching business confidentiality constraints).

6 Analytical implications for future work

This section briefly discusses the key policy relevant findings from a lessons learned perspective.

6.1 Temporary effects on labour productivity

The finding that stands out from the events timeline analysis is that whilst the positive effects of new road infrastructure on GVA per worker appear to be temporary, this reflects a broader range of economic impacts via which contributions to economic growth take place. Specifically, improvements in GVA per worker appear to decay over a timeline of two to three years. This coincides with the period over which the initial gains in traffic speeds resulting from road improvements fall back to pre-improvement speeds (likely due to higher volumes of traffic).

- A plausible explanation of these patterns is that the prospect of higher returns leads to additional demand for locations in proximity to areas with improved road connectivity. However, as this additional demand absorbs the additional road network capacity created by the improvement, the productivity gains associated with the location are progressively lost.

- As such, investments in the road network appear to have a permanent increase on the level of economic activity within local economies but only a temporary effect on the efficiency of local firms (with any residual productivity gains captured by landowners via higher asset prices or rents, rather than by firms and workers via profits and wages).

- This analysis does not account for the possibility that roads may have on the productivity of other factors of production (for example, by allowing floorspace to be reallocated from less productive to more productive activities – e.g. from storage to production). Improvements in economic efficiency arising from 'network level' improvements are also not quantified by the type of analysis adopted in the study.

The study suggests the following directions for further research. Firstly, there may be value in seeking to estimate the 'network' level impacts of investments in road infrastructure using alternative methodologies, as well as explore alternative measures of productivity and pathways to impact (such as via the innovation capability of local economies). However, the findings also indicate that further research into the role of the planning system in constraining the extent to which the full potential impacts of road infrastructure improvements (and how better co-ordination of transport and planning policy might be achieved) could also be valuable.

Given that the productivity boost and dissipation aspects only became clear when an events timeline analysis was used (as described above) **one key lesson is that all future studies able to carry out such a sophisticated econometric analysis do so at the outset**. Prioritising that analysis would then provide greater scope for investigating causal explanations

via the comparative testing of a broad range of hypotheses (as initially defined in Table 9.1 in the econometrics report).

6.2 Implications for future investment appraisals, spending and related work

The main lesson for future investment appraisals and spending plans for transport infrastructure is that any assumed economic benefits will require a nuanced treatment that recognises the relevance and importance of more complex first, second and potentially third-order effects than may previously have been assumed to come into play. As noted above, these are best treated as local socio-economic ecosystem effects. Road enhancements can, potentially (as a speculative conjecture), play a key 'catalytic' role in stimulating and supporting these ecosystem level effects via virtuous circles of cumulative improvements.

6.3 Use of logic models to link *ex ante* appraisal and *ex post* evaluation

Given that the econometric analysis revealed a range of more nuanced impacts (sector, type of scheme) future logic model evolution will need to reflect these differences and will therefore need to be more complex. One practical solution noted in the econometrics report would be for DfT to develop an interactive online version of the more complex version of the EPIRE logic model that allows the user to specify the type of scheme and sector(s) of interest and, in so doing, generating the relevant set of key expected causal impact pathways. Such an interactive logic model could be of use in informing future business cases (where those aspects are addressed). This would help to overcome the 'average effects for the average place' challenge (once the necessary additional data on different contextual factors and their consequences for economic performance impacts is included). Indeed, an interactive tool of this type could also be used to highlight potential barriers and impediments to benefits realisation post-investment.[19]

6.4 Dynamic overshoot and related transient effects

One technical challenge faced in understanding events analysis results is that, from a theoretical perspective, two distinct sets of processes may be at work. Firstly, the familiar market adjustments to a (in this case positive) shock to the system – as addressed in the hypotheses created to explain productivity performance. Secondly, what is referred to in engineering/systems dynamics as 'dynamic overshoot': this is the transient phenomena caused by how a system responds to a major change in input strength. When dynamic overshoot

[19] Of course, there are non-trivial data availability constraints to populating such a model, hence the importance of adopting standard scheme impact M&E methods for use by all local authorities.

occurs, the system temporarily exhibits stronger performance that then subsides to a new equilibrium state.[20]

Dynamic overshoot is potentially relevant to the EPIRE study, albeit highly speculative in nature, because it is possible that something similar is taking place when a scheme opens and starts to generate economic impacts. The distinction between dynamic overshoot and more familiar market adjustments is that the dynamic overshoot effects may exaggerate apparent initial economic impacts and hence distort the measurement of subsequent market adjustments.

As dynamic overshoot in the economic impacts of transport improvements is not, as far as we are aware, well-researched and addressed in the peer-reviewed academic literature, at this stage it should only be highlighted as an issue that may require investigation in future research. Such research would need to focus on how, and why, better transport connectivity can cause an apparent boost to the behaviour of key economic variables (especially GVA and GVA/worker) that reflects a mix of real but transient impacts and, potentially, accounting adjustments that impact on the variables being tracked over time.

6.5 Portfolio versus individual scheme differences from an evaluation perspective

One key question for officials is: how we can use the study to enhance our ex-post evaluation of individual schemes?

This is a difficult question to answer, in part because achieving statistical significance using complex and noisy data requires diverse scheme contexts and extended timelines to be considered to identify economic impacts. As the events timeline analysis demonstrates, statistical significance is limited by restrictions in the number of schemes with long-enough post-opening timelines to help to increase statistical significance. However, extending the econometric analysis further back in time exacerbates data availability challenges and also creates problems for using the results of such a historical analysis to inform future decisions given changing socio-economic circumstances (the economy in the 1980s was different than that in the 2024).

These challenges have important implications for evaluating individual schemes because, at the local level, it can be difficult to attribute economic impacts to the road enhancement schemes as so many other factors come into play. This means that capturing ‘on the ground’ perceptions of

[20] This process is evident when rocket engines are started, and the rocket visibly moves whilst tethered to its launch pad before settling into a new position – at which point launch takes place. Premature launch before dynamic overshoot re-equilibrates risks collision with the gantry. Dynamic overshoot was clearest for NASA’s Space Shuttle because the rocket engines were not aligned fully with the vehicle’s vertical axis. Interestingly, dynamic overshoot was not modelled or predicted by NASA, or its prime contractors, during system design. Consequently, engineering work was needed to address the problem, eventually resulting in the need for a significant payload reduction below the modelled mass.

cause-effect relationships does not have the benefit, in particular, of access to the analytically sophisticated econometric work that identifies events timeline aspects (until that work is published).

This means that the evaluation of individual schemes is subject to the 'stochastic' serendipitous aspects of economic impacts, notably any major lumpy investments in, or the re-location of, new facilities (e.g., the Met Office Supercomputer in Exeter). Such effects, whilst noteworthy, do little to inform our understanding of general patterns in impacts and the causal relationships being examined in this study. The general patterns analysed on the econometrics 'blend in' such 'stochastic' serendipitous aspects as part of the average effects.

In response to this challenge, the scheme case studies report has developed a set of complementary suggestions and exploratory solutions:

Firstly, use of the following three-tier classification of spatial effects:

- **Close proximity effects** are defined in spatial terms as those observed up to 35km for schemes. Close proximity effects align with, and is informed by, the study's econometric analysis component which found economic impacts up to 20km from schemes within a radius of analysis of 30km (an extra 5km has been added to avoid too close a spatial cut-off in future work given potential future changes in road uses and associated economic benefits).
- **Extended proximity effects** are defined in travel time terms using a radius of 2 hours travel time. Extended proximity effects have been informed by the case study workstream and recognise that for some major local business clusters the nature and value of the overall economic activities and resident population within that travel radius (the broader 'economic hinterland') is an important factor in attracting investment and in exploiting economies of scale – especially for large retail businesses and regional airports etc.
- **Network-level effects,** the 'whole road network' based benefits discussed elsewhere in this report.

This three-tier classification is intended to inform discrete scheme *ex post* evaluations in the future by encouraging a broader and more realistically scoped assessment of how road enhancements contribute to economic performance improvements.

The case studies report contains a set of testable hypotheses (for use with mixed methods evidence) based on considering some key combinations of these close proximity, extended proximity and network-level effects, as follows:

- Combined close and extended proximity effects;
- Close proximity and network-level effects, and;
- Extended proximity and network-level effects.

More complex combinations (combined close proximity, extended proximity and network-level effects) are best handled as findings from ex post evaluations in order to avoid an overly complicated set of hypotheses. Note: this set of hypotheses has been designed to make it easier for future studies to relate econometric and discrete scheme evaluations.

In order to encourage scientific rigour, this framework includes a weak and strong null hypothesis:

- Weak null hypothesis: economic performance is facilitated by, but not dependent on, proximity and/or network-level effects.
- Strong null hypothesis: economic performance has no reliance on proximity and/or network-level effects.

These hypotheses based on combinations of close proximity, extended proximity and network-level effects can also be used to develop a *Qualitative Comparative Analysis* (QCA) style characterisation of individual scheme impact characteristics (patterns that can be 'heat mapped' to facilitate comparisons). This QCA framework can, in future studies, assist in the comparative analysis of individual schemes, and therefore facilitates drawing comparative *ex post* evaluation conclusions from diverse scheme contexts.

Additional aspects of the proposed approach to individual scheme *ex post* evaluations are the use of the more complex theory of change and logical model developed via the case studies workstream to:

- Frame the scrutiny of key causal relationships that may be involved in generating economic performance impacts for individual schemes – covering both intensive (within a fixed Functional Economic Area) and extensive margin aspects (via an expanded Functional Economic Area).
- Develop a scheme classification framework based on any dominating causal impact pathways both ex ante and ex post (a classification that can also be used to segment future econometric analyses).

6.6 Additional considerations for future studies

Given the importance of the complex local factors of a 'strategic fit' nature that shape the economic performance impacts of road enhancements, portfolio-level analysis using econometric methods is best equipped to identify general patterns for ex post evaluation purposes. At the discrete scheme level, there are a myriad of other factors outside of the 'span of control' of local authorities and businesses that determine the nature and extent of the economic impacts actually achieved. From an analytical perspective, these are effectively stochastic events (both positive and negative) that determine outcomes. The econometric work screens out these stochastic aspects, in so doing identifying general patterns. However, these general patterns can only be identified as 'weak signals' in the data that are affected by diversity across samples and the number of years for which the analysis can be carried out. Thus, there

is an overall return on investment in road enhancements in terms of economic performance impacts but, on the basis of the evidence currently available, this is dissipated by a set of market-adjustment (and potentially other) effects that require further investigation.

For individual schemes, the case study analysis indicates that these stochastic factors, in the form of unexpected events, tend to dominate outcomes (positive and negative). These are often caused by broader strategic fit rather than road-specific factors – in both a positive and negative sense. This includes un-anticipated new investments facilitated but only in part by the road enhancements and benefits that did not eventuate because other expected enabling developments did not happen. Hence, at a general level, this aspect limits the potential to use the technical (modelled) tools informed by *ex post* evaluations to appraise individual schemes as regards potential economic impacts.

The main caveat to note however is that the EPIRE Scoping Report that informed this study noted that an evaluation method known as a Synthetic Control Group (SCG) approach could be used. A SCG evaluation method is useful when there are no comparable cases via which to assess whether treated and untreated cases with similar characteristics reveal statistically significant differences in performance. A SCG approach analyses and combines diverse cases in order to construct a match with a 'fictional' comparator case based on combining relevant aspects of real diverse cases in order to create the closest fictional match possible. This comparison allows for a statistical analysis that can identify any difference between cases benefitting from government support in comparison to those that did not (i.e., a real case compared with a synthetic comparator).

The scoping report highlighted the potential to use an SCG analysis to support a case studies analysis. As things turned out, the unexpected lead times and multiple technical challenges faced in delivering the econometric analysis limited the ability to carry out an SCG assessment to inform the case studies so this was not carried out.

However, the study also identified a useful reverse relationship between case studies and the future potential to apply SCG methods. Prior to this study, we did not have access to the type of analytically based categorisation framework and initial large-scope econometrics findings (as generated by this study) that could be used in combination in an SCG assessment. Both strands of analysis are required because the average effects identified by the econometrics are not sufficient to inform an SCG approach without calibration against the complex contextual factors that influence the impacts actually achieved. All schemes need to be classified in a manner that is suitable for a SCG analysis and is: (a) not restricted to the variables covered in the econometric work to date, and (b) not based solely close proximity effects in a distance-decay manner – there are broader extended proximity and network-level effects to cover (as noted elsewhere in this Lessons Learned report).

For example, the econometrics analysis did not consider business floorspace characteristics from an economic density perspective: how road enhancements can impact on GVA per square meter and square meters per FTE employee (two key measures) at the intensive margin and

increases in GVA and employment associated with increases in business floorspace at the extensive margin.

The case studies analysis explored this spatial economic density perspective, in so doing highlighting the potential to incorporate this aspect in future econometric analyses. Potentially, adding this dimension (along with other aspects) could assist in delivering an SCG analysis. It would reduce the risk of comparing economic performance impacts without capturing any spatial density aspects: cases in which GVA and employment increased because more business floorspace was created versus cases in which these benefits were achieved with no increases in floorspace.

These extensive versus intensive margin effects are important because planning constraints and other land uses (residential, agricultural etc) plus other infrastructure aspects (electricity supply, water, sewerage etc) can limit or allow for business floorspace expansion very differently in different places/contexts. The distinction is also useful in understanding TFP-related aspects and, potentially, for adjusting for the effects of innovation adoption and related improvements in production organisation and facility logistics.

Hence, whilst an SCG approach was not used in this study, future work can build-on the progress achieved to date by exploring the technical feasibility of using an SCG approach in future work by combining the findings from the econometrics analysis and the insights gained from the cases studies over the complexity of the causal links that need to be considered in such future work.

The case studies work carried out in this project has identified the following strategic considerations at the induvial scheme level:

- Adopting a balanced approach that considers close proximity, extended proximity and network-level effects – including potential positive and negative interactions between them. That is to say, how the localised economic impacts generated by each spatial radius can either strengthen or weaken overall economic impacts. For example, network-level (supply chain factors) and/or extended productivity effects (2-hour travel time retail catchment area driven benefits) can unintentionally increase local traffic congestion in so doing dissipating an initial close proximity-driven economic boost. As current traffic modelling methods align well with this three-tier framing, this perspective complements existing approaches. Given this, individual scheme appraisal should consider both the distinctions between close proximity, extended proximity and network-level effects and potential interactions between them – both positive and negative in consequences.

- Using the more complex EPIRE logic model to identify the main expected economic impact drivers and associated ‘strategic fit’ factors that need addressing for benefits realisation.

- Considering business floorspace characteristics from an economic density perspective against baseline conditions: specifically, how future road enhancements can impact on GVA per square meter and square meters per FTE employee (two key measures) at the intensive margin and aggregate local GVA and employment at the extensive margin. This spatialised

measurement dimension aligns well with local authorities' interests in expanding business floorspace, and maximising its economic contribution, via road enhancements.

These considerations relate more to strategic planning than technical modelling simply because these is so much uncertainty and potential for stochastic influences at the individual scheme level. However, these aspects can also be used to organise a future SCG scoping study by providing a basis for characterising all road enhancement contexts (how they differ in comparison with each other), in so doing providing a basis for the SCG work.

7 Summary of main lessons

This final concluding section brings together the main conclusions by answering the questions posed in the Terms of Reference for this report.

7.1 Lessons Learnt

What were the strengths and limitations of the adopted approach?

The main strengths of the EPIRE study are that it is provided useful data and insights into the nature and magnitude of these economic impacts. EPIRE has confirmed that there are statistically significant economic impacts from road enhancements. However, it has also highlighted the transient/dissipating nature of this aspect of economic impacts, in so doing raising some important policy issues that stand to benefit from more detailed future analysis into why the economic impacts dissipate in the ways we have uncovered.

The econometric work did highlight the ways in which economic benefits were greatest either for urban areas or more geographically remote, but less so for 'in between' smaller towns and places – this was a strength of using proximity analysis methods.

The main limitation, which was recognised at the start of the study, was that the data and econometric method used were unable to capture the complementary network-level drivers of economic impacts. That is to say, how combinations of road enhancements generate generalised 'entire road network' accessibility benefits (especially for freight). This type of benefit means that businesses and local economies benefit from geographically remote road schemes, and in a more collective manner than scheme proximity effects can capture. Although whether that aspect would explain the productivity dissipation aspect is another matter (and unlikely). However, EPIRE's case study work did demonstrate that it is possible to start to build-up new and useful data on supply chain systems relevant to road freight. – a systemic aspect that it would be useful to address in future work.

Were there any major practical issues (e.g. data, modelling etc.) encountered during the project? Were these able to be overcome, and how?

As detailed in this report, major practical challenges on a technical nature were encountered in this study. In particular, the computational requirements were significant with the computation of accessibility modelling inputs (origin/destination matrices) taking days to complete a single iteration with this step repeated for each year included in the analysis. Options were explored as part of the study but existing remote PCs were utilised given a lack of implementable options in the short term. This meant processing times were longer than could be in future studies.

Where possible, future work could make use of cloud computing to configure virtual machines powerful enough to handle the complex computations necessary within a reasonable timeframe.

In addition, over 2000 models completed within the ONS SRS. Obtaining clearance from the ONS SRS was difficult with files this large and it is recommended that future work seek to only obtain clearance for select models where appropriate. In this case it was necessary to obtain all

results in order to allow for the effective comparison of models but going forward this may not need to be repeated and updates for key models could be targeted.

Practical data issues were encountered with documentation on schemes not always readily accessible with GIS files for schemes sometimes not obtainable. These issues were overcome through desk research into schemes and manually mapping of schemes where descriptions were available.

Were certain types (e.g. size, new road v enhancement of existing road etc.) of schemes more difficult to evaluate than others?

The evaluation methodology adopted meant that no individual type of scheme was more difficult to evaluate than others. However, road schemes that did not directly improve accessibility had to be removed prior to analysis as there was no change in accessibility to exploit in modelling.

To what extent was the study able to achieve its aims? What evidence gaps are still outstanding? How might this research be developed further in the future?

The EPIRE study was able to achieve its overall aims via making significant progress in understanding the nature and magnitude of economic impacts on key variables (notably GVA, Employment and GVA per worker). It was also able to extend the scope of the analysis to consider impacts on property prices and introduced what proved to be an informative events timeline analysis using the staggard Difference-in-Difference method.

The main aspects that would warrant investigation in future studies are:

- **Extended impact timelines:** Economic impacts can, potentially, have significant time lags between scheme completion and significant investments facilitated by improved road connectivity (e.g. the ten years between M25 junction improvements in Dartford and the re-development of an old power station site to exploit SRN-based opportunities). It is therefore important that future studies allow for such long-gestation time lag effects to be captured.

- **Impact decay**: As the staggard Difference-in-Difference analysis demonstrated, initial economic impacts can dissipate. Consequently, why this happens will require further investigation in future work. These investigations could usefully cover both market-driven adjustments and other ‘data artefact’ aspects such as the ways in which aggregate data can conceal details about mixes of aspects such as GVA/per worker related to an evolving business ‘ecosystem’.

- **Impact resurgence:** However, despite an initial impact decay, as this study has highlighted via proposing hypotheses relating to impact dissipation, there is the potential for eventual long-term positive impacts over an extended time period that take advantage of the initial improvement in the economic performance of businesses and the inward relocation of businesses (via creating a more vibrant local economy that attracts subsequent rounds of investment). This reinforces the importance of examining extended impact timelines, perhaps over as long as two-decades (which would be well within the road investment asset lifetime projection timeline).

- **Network-level effects:** The econometrics component of the EPIRE study set-out to focus on scheme proximity-based economic impacts. The (complementary) importance of network-level effects driving economic impacts was noted by the project Steering Group at the outset, and, accordingly, explored – as far as possible – via the case studies (albeit in a more qualitative manner). It would be useful for future econometric work to examine network-level effects via a more generalised application of accessibility modelling and analysis. This type of analysis would need to consider how the entire portfolio of schemes over specified time periods affected the overall travel times in the road network (for freight especially). However, given the major challenges on computing power and data processing lead times such work would require the use of more specialised high-speed and large scale computing equipment.

7.1.1 Practical Application of Methods to Evaluation

How might the evaluation methodology chosen for this project be replicated in future road scheme evaluation at both a scheme and portfolio level?

The methodology used for EPIRE could, now, be more easily replicated in future studies because of the range of 'pathway clearing' challenges that have needed to be address (discussed in greater detail in the following sub-section). As a result, follow-up econometric studies replicating this approach will be much faster and more cost-effective to deliver.

However, as stressed at various points in this Lessons Learned report, it would be useful to complement a future analysis of scheme proximity-driven effects with an analysis of more systemic network-level effects. This would 'balance' the analysis to capture both rather than just one aspect of the economic impacts of road enhancements. A note of caution over any future addition of a network-level analysis is that the technical challenges in data access and access to computing power are likely to be far greater than encountered in the proximity-based work carried out in this study. In addition, the analytical value of adding a network-level analysis would be increased by drawing on the emerging financial payments-based supply chain tracing data now becoming available (noted earlier in this report).

Econometric modelling undertaken through the study has been detailed in depth and can be replicated relatively easily using the evaluation plan, econometric report and files being compiled on implementation.

As regards individual schemes, the main lesson from the EPIRE study is that the work done on a more complex Theory of Change and logic model addressing the economic impacts of road enhancements highlights the potential for categorising different types of schemes according to their context, and on that basis generating more specific hypotheses to test in evaluation studies. For example, if the local economy has started to establish an innovation capability then it will be useful to examine the extent to which road enhancements have strengthened innovation capability (perhaps via access to skilled labour). Context is key to understanding how and why road enhancements make a difference (or not).

The case study report contains a 'proof-of-principle' application of such a set of testable hypotheses based on combinations of close proximity, extended proximity and network-level

effects that is specifically intended to inform future *ex post* evaluations of individual schemes. This framework can be linked to business floorspace characteristics because retail and industrial floorspace (and associated GVA and employment densities) relate to close proximity, extended proximity and network-level affects differently). These hypotheses are intended to be used in a mixed methods manner: being tested using both quantitative and qualitative evidence in order to produce a 'rounded' assessment.

How might the evaluation methodology be replicated or adapted as part of National Highways (formerly Highways England) and DfT evaluation approaches? What resources (funding, skills, data) would be required to achieve this?

The econometric approaches require specialist skills that would need to be acquired in order to be applied as part of NH and DfT evaluation approaches. The approaches adopted would also not be appropriate for individual scheme analysis. Case study research approaches may be more relevant for evaluation activity with econometric analysis taking place at longer intervals and using a portfolio approach.

The approaches used in this study are detailed throughout the reports and in the coding files used to produce the analysis. This can be used and adapted as necessary for future research.

What monitoring data should be collected following road scheme implementation, in order to track economic impact for future schemes?

The findings from EPIRE study suggest that monitoring data post scheme opening should focus on the following aspects and issues:

- Economic data dashboards, as a general principle, it would be useful if the key variables analysed in the EPIRE study (and some additional metrics that with hindsight could have been used in this study) were replicated in a standard economic data dashboard made available to Local Authorities. As it is now possible to use satellite data to track housing and business floorspace changes, use of such data would overcome data constraints (and time lags) for that aspect of the dashboard architecture. This would provide a useful monitoring tool at the local level (to inform the Benefits Management aspect noted below) whist also providing DfT and National Highways with a consistent basis for comparing and contrasting evolving economic impacts (although causality attribution will still be challenging). In so doing, the data dashboards would provide a starting point for future studies, including future case study selection (by more easily identifying successful and less successful impact zones). The more detailed version of the economic impact logic model developed in the case study workstream should be made available, ideally as an interactive online tool, to help users interpret the economic data dashboards – and most importantly identify and actions needed to address benefits realisation shortcomings. Changes in business demography – both the dissipation of initial economic impacts and potential impact resurgence over the longer-term (ten plus years and longer) may involve both a broadening of sector activity (via trickle down effects) and subsequent business re-location and associated inward investment. It would be useful to cover business start-up and five-year survival rate data as part of this monitoring activity (the data are already collected by ONS but are not released at this

granular level due to confidentiality constraints, so that issue would need addressing within government and the data would not be released publicly at a local level).

- Strategic fit, in line with the latest Treasury Green book guidance, the ways in which realising local economic growth benefits tends to rely on other, non-road, factors such as local government strategies, the planning system, how active investment attraction is, and network-level effects at the SRN level. This would best to handles as a Benefits Management aspect of monitoring, drawing upon the more complex EPIRE logic model developed via the case study workstream. For monitoring data, this point suggests that the major broader (not road specific) change drivers be identified at the business case stage and subsequent performance tracked as part of these Benefits Management efforts. For example, if new housing availability to increase labour supply, or inward business re-locations are part of the Theory of Change then the new housing completion counts should be treated as a Strategic Fit metric. The key point is to engage more actively with a Theory of Change for why and how the road enhancement(s) will boost local economic performance that includes the key Strategic Fit impact pathways (as evidenced, mainly, via qualitative understanding at the local level).

- The practical data requirements for implementing this approach are to make the best use of existing ONS and other official data to profile (as a baseline) and then track subsequent spatially identified changes in GVA, employment, turnover, GVA/worker, housing stock, business counts, Standard Industrial Classification (SIC) breakdowns of industrial activity, residential housing stock, wages, claimant counts and economic activity as addressed in the EPIRE study. Given the potential importance of network-level effects in addition to scheme proximity effects limits to the spatial granularity of the available data should not be a major concern. The pragmatic aim should be to provide the best available localised data dashboard via which to track the evolving local economy in a manner that can be used for comparative analysis (and discussion in Local Authorities). This is most easily organised spatially at the Output Area and Lower Super Output Areas level. If possible, data on factory floorspace sourced from the Valuation Office Agency (VOA) should be included to provide an aggregate picture of GVA per square meter and related metrics able to capture the extent to which output and employment are linked to more intensive use of the same aggregate floorspace or an increase in aggregate floorspace.[21] Other potential options for more granular and timely data on commercial floorspace should be explored where possible, however none were found to be suitable for this study. In addition, more timely data on housing starts at the very

[21] See: Non-domestic rating: stock of properties including business floorspace, 2020 - GOV.UK (NDR Business Floorspace Tables). These data are collected as part of business rates setting calculations. As the published data is for all businesses the possibility of obtaining a factory subset would need to be discussed with the VOA (although overall business floorspace data is still useful for the local data dashboards). Access to the microdata may also be an option to evaluate with the VOA.

local level may be available through consultations with the Housing Analysis team at the ONS as there was likely to be an unknown lag to the council tax housing stock data used in this study. This core dashboard should be augmented by a more qualitative set of evidence on the enabling and facilitating activities associated with the broader Strategic Fit aspects that can determine the overall long-term economic impacts. This should cover efforts to attract re-locating firms and new inward investment, local skills and training support, and any uses of enterprise zone, freeport or other distinctive comparative local advantages. In making this consistent evidence base available, it will be easier to compare and contrast now specific schemes, or bundles of complementary local schemes, are performing at an observational level. In so doing, future econometric analyses will be able to explore impacts for different types of local context as reflected in groupings developed using this comparative dataset. The selection of those groupings should be based on the data, identifying the main clusters of characteristics identified. If network-level accessibility is computationally feasible then this could be added to the dashboards and will be particularly useful for tracking changes in overall road network accessibility.

- Network-level accessibility tracking, it would be useful, if possible, for post opening monitoring to consider providing access to a central national dataset capturing whole of network-level accessibility effects.

What baseline data which should be gathered for complex infrastructure schemes to enable an effective evaluation of the economic impacts?

The proposed use of centrally provided (via DfT) economic data dashboards described above under monitoring arrangements (aligned with but augmenting the data used in this study) would provide a suitable basis for baseline data provision, as part of a well-organised and coordinated effort to track benefits realisation for the economic impacts of road enhancements. Business floorspace using VOA data (and ideally more relevant categories if these could be agreed with the VOA) would form an important part of this baseline data, especially when used with GVA and employment data to measure the economic density of floorspace use and as a means of distinguishing between intensive and extensive margin economic growth (and contraction) dimensions.

Business engagement can be difficult if any survey work is required (a commonly encountered challenge nowadays in evaluation studies due to ‘survey fatigue’). Consequently, it is preferable to hold interview-based consultations for both baseline and subsequent evaluation studies. Access to the proposed economic data dashboards would provide a useful input to these consultations by providing data to be discussed from an interpretation and calibration angle (what is agreed with, disagreed with and what is missing etc). It is always useful to provide something substantive for industrialists to react to in such circumstances. Similarly, the EPIRE logic model, the set of hypotheses on the productivity aspects and also (possibly) the hypotheses on potential structural changes can be used to capture feedback at both the baseline and subsequent evaluation stages – facilitating the discussion whilst also providing a useful source of more general insights.

What time periods beyond scheme implementation are most appropriate for data collection to track progress towards and realisation of economic impact?

This study indicates that the analysis of scheme impacts should extend, at the very least, for up to twenty years. This would allow the expected mix of initial impact dissipation (or in some cases sustenance), and impact resurgence via second and third order effects to be captured.

7.2 What should be repeated and updated in future analyses and what could have been done differently?

Given the ways in which the EPIRE study has acted as a large-scale 'pathway clearing' project it has been forced to discover and solve (where possible) a wide range of technical problems (as detailed in Section Three). This aspect will make it easier for subsequent large-scale studies of this type to carry out the work faster and on a more cost-effective basis. In effect, EPIRE has pushed UK spatial econometrics capability for large-scale studies of road driven economic impacts a long way down the learning/experience curve.

Hence, repeated studies can follow the same broad approach to assembling and using the data, but – importantly – should prioritise events timeline analysis and network-level aspects. This prioritising should, ideally, allow for more examination of the causal factors that may explain the events timelines. However, as discussed above, a distance decay approach may be sufficient for quick turnaround research where time is a factor (although not the preferred approach given the additional robustness of accessibility modelling approaches).

Future research may be able to obtain data on and analyse outcomes not covered in this study. Land use and long-term unemployment outcomes were not explored given data limitations, should data on these outcomes become available the approaches adopted for this study could potentially be applied to further enhance understanding of the economic impacts of road enhancements.

Finally, there is a useful lesson learned from the EPIRE study about the use of maps as part of data visualisation efforts, and a related issue concerning understanding and communicating spatial data. For econometricians well-versed in using spatially organised data, the technical definitions (such as "LSOA" – *Lower Super Output Area*) are familiar and understood. For others, these definitions may be less well understood, and therefore harder to grasp in terms of their application and interpretation 'on the ground'. Using maps to communicate the size of these spatial domains helps greatly in this respect.

Using maps to present the findings can also be very useful to effective data visualisation. At various points in this study maps of intermediate results on particular aspects of the data (where this was possible) were produced and, we understand, were seen as useful in their own right in DfT. Some of these maps can be found in the econometrics report, in particular. At DfT's request, the final version of the econometrics report will include an Annex containing some additional maps generated as part of EPIRE's 'work-in-progress'.

It would be useful if future evaluation studies using spatial econometric analysis complemented (where this is possible) the standard tabular reporting of regression results with maps in order to

communicate key findings, mainly as a means of communicating the key intermediate steps from data assembly (the inputs to the complex regressions which cannot be mapped themselves). Future studies could also, potentially, explore new ways of visualising spatial regression results for non-econometricians.

7.3 Administrative implications for government

7.3.1 Handling and archiving scheme information

The following recommendations are highlighted in this Lessons Learned report.

There would be benefits in scheme documentation being held **centrally** by sponsors (e.g. DfT or NH) for longer. This would enable more schemes to potentially be included in analysis and classified more accurately.

- The collection and storing of GIS files on the locations of road schemes would significantly reduce the amount of time required to map the relevant schemes before analysis.
- Options for utilising cloud computing could be explored alongside distributed computing frameworks to reduce the time required to produce the origin/destination matrices required. The methods adopted in this study could be used to impute missing data and set speeds to enable the methods to provide robust assessments of impact.

Future adaptations of the staggered difference-in-difference may enable the use of categorical and/or continuous treatment variables and therefore allow for accessibility modelling results to be used in the regression analysis. The events study analysis provide rich information on the timing and persistence of impacts which would further benefit from combination with accessibility modelling results.

7.3.2 Appraisal guidance

The EPIRE project's work on pushing-forward the Theory of Change/logic model depiction of key casual relationships emphasising systems inter-dependencies and feedback loops/cumulative causation could be drawn upon, where necessary, to inform future investment appraisals (for both roads and, potentially, rail). Used in this way, the logic model(s) would help to identify local economic 'ecosystem' aspects that the investments have the potential to contribute to.

It would also be useful to ensure that guidance pays adequate attention to network-level economic impacts not based on scheme proximity per se (especially improved extended supply chain aspects for freight).

7.3.3 Monitoring & Evaluation guidelines

Individual scheme case studies are an invaluable source of qualitative contextual information and insights into the 'on the ground' realities of how economic impacts are achieved – and why they sometimes fail to meet expectations. Case studies can only rarely provide a robust basis for measuring causal economic performance impacts because too many other factors are in-play that create a 'signal to noise' ratio challenge. It is only possible to identify economic

impacts via discrete case studies when the local economy is relatively simple in structure, and allows a clearly attributable impact to stand out in data (especially on the new employment created by a major investment linked to road enhancements and when they facilitate new housing developments).

This means that, as a general principle, only portfolio-level econometric analysis can identify the general patterns by in effect screening-out multiple local aspects that mask the impacts. It would therefore be useful for DfT to consider the technical feasibility of carrying out portfolio-based econometric analyses at a regional level. Whilst technical challenges exist in how/where to define regional boundaries for regional econometric studies, such work would align with the government's interest in establishing broader regional 'compacts' of local authorities in the post-LEP era.

These 'bundles' of inter-related schemes could also be used at the business case stage, thus creating a useful link between *ex ante* appraisal and *ex post* evaluations that, in some circumstances, is more likely to generate useful benefits management findings and policy learning. DfT's experience with these programmatic appraisals is that whilst useful (where examining scheme inter-dependencies is warranted) the significant additional costs are a limiting factor for their use. Consequently, a programmatic approach ex ante appraisal is not recommended outside of the special cases in which they are warranted.

Monitoring and evaluation guidance would benefit from emphasising the importances of 'timeline sensitive' local economic ecosystem inter-dependencies of the type identified in the events timeline econometric analysis. If future studies confirm that these effects are driven by a mix of first, second and third order effects (including the faster than modelled filling of the new traffic capacity due to strong local economic impacts) then these aspects will need tracking.

To stress, these effects are not a criticism of traffic modelling and forecasts per se. This is because there are multiple causal links via which a road scheme can stimulate the economic activities that, in turn, fill new traffic capacity faster than expected (as the more complex logic model summarises). By implication, the ability to estimate future traffic and the filling of new capacity requires that the broader set of economic impact considerations examined in the EPIRE study are addressed in future work.

Finally, we recommend that future M&E methods use business floorspace as an anchor variable that can be related to GVA and employment and other aspects of interest, and ideally as part of the general M&E framework to be used by local authorities in future years. As such, future M&E work could aim to be able to use existing official data (ONS and VOA combined) to be able to compare and contrast scheme contexts and road enhancement business impacts in a manner that sheds light on economic impacts without relying on portfolio-level econometric analysis in isolation. For example, plots of the year-by-year trajectories of the relationships between business floorspace (which can increase or decrease) and GVA and employment (that can also increase or decrease) provides a useful diagnostic tool. This can help us to understand where a local economy sits before a scheme is opened, and how it performs after the scheme is opened – especially over the long-term (10 to 20 years) including looking at intensive and extensive

margin effects. Whilst there is no causal attribution in such plots and associated analyses, these tools will provide an improved starting-point for examining these issues (especially as part of Local Authority Benefits Management work), with the advantage of linking with the close proximity, extended proximity and network-level effects that capture the full spectrum of the economic performance impacts of road enhancements (beyond distance-decay aspects alone). Different business floorspace categories relate differently to close proximity, extended proximity and network-level effects (e.g. the industries for which network-level supply chain connectivity matters far more than close proximity supply chain effects, provided the labour supply within reasonable commute times is available).

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