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Using Scenario-Based Elicitation in Analysis of Uncertainty in a Transport Infrastructure Project

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Abstract

This research devised and demonstrated a method to identify the uncertainties evident in transport infrastructure planning, focussing on the early decision making stages of the project lifecycle. The core of the method used a "Cross Impact" model, anchored in complexity theory to analyse expert opinions on the future for the project. Stakeholder interviews, based around an ideal scenario, were undertaken to elicit opinions about the proposed development, focusing on the decision making steps and environment en-route to the outcome. The interviews were then coded using qualitative data analysis techniques and the emerging variables analysed using the cross impact model. The findings from this case study were that executive leadership and collaboration between Local Authorities were the most influential determinants for progress, and that the prime causes of uncertainty were the extant economic and planning policies. Since the completion of this study, structural transport governance developments have occurred in the UK that have endorsed these findings. This paper focusses on coding of the stakeholder interviews and rationalising the variables which were either present in the scenario or introduced by the stakeholders.

Keywords: Scenario Analysis; Uncertainty; Stakeholder Elicitation; Governance

1. Introduction

In transport project appraisal, a proposed development is modelled, the benefits evaluated and a recommendation is made to select the optimum design (DfT 2016; Ortuzar and Willumsen,2011). However, projects are often delayed, and the final decision to implement the project may not follow the appraisal advice. Indeed, a study of Scandinavian

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transport projects Welde et al. (2013) showed little or no correlation between the appraisal results, expressed as a Benefit Cost Ratio (BCR) and the selection of the project for implementation. This indicates that the appraisal process is not necessarily the key factor in project selection.

Wachs (1985), Marsden and Reardon (2017), and Vigar (2017) discuss the significance of the political dimension to transport decision making. Wachs (1985) in particular comments that the majority of the research has been in the technical aspect of transport assessment and that more is needed on the social and political dimension of the whole process. The goal for the research presented here, therefore, was to devise and trial a novel analytical method to provide an insight into the causes of uncertainty in a proposed transport project and to provide this insight in the entire scope of the proposed project without limiting the analysis to the quantitative assessment stage. The research gap is succinctly identified by Marsden and Reardon (2017); to identify the both the formal and informal structures of the decision making systems in terms of power and politics.

Section 2 of this paper outlines the methodology used in this research, a detailed description can be found in Sykes et al. (2018). Section 3 briefly describes the case study and the results from it and more detail on the results and a comparison with emerging changes in governance can be found in Sykes et al (2019). The major part of this paper then focusses in section 4 on one aspect of the methodology: the analysis of the stakeholder interviews to extract the elements they identify that are relevant to the development under study and the process of rationalising those elements.

2. Methodology

The methodology devised in this research was used to examine the uncertainties in a project in its initial stages, when the proposed transport development must find its niche in the current and future policy and infrastructure ecosystem. The outputs required of the analysis are a list of the components of a planning project that most contribute to the progress and to the uncertainty in the project. This must be accompanied by an understanding of how they reach their positions on this list, and therefore, the primary input must be the full list of variables governing the assessment and decision process. The task of generating that list must also be a part of the data gathering exercise as an analyst investigating the uncertainty in the project has to avoid imposing the constraints that would occur if what should, or should not, be on that list was pre-determined. This open ended data gathering requirement addresses one of the components of uncertainty; that of model completeness.

The model used to analyse the data was a cross impact model which is based in complexity theory and posits that complexity and uncertainty are synonymous with connectivity. It is expressly designed for the class of analysis described here, to identify the drivers of uncertainty in a project. The model was initially created by Gordon (1968), subsequently, Vester (2012) developed the methodology with a goal to understand the system under analysis more than just the outcome and Godet (2011), in similar work, added the use of indirect links in a causality chain. The inputs to the model are a list of relevant factors or variables, and a matrix of influences where A influences B, B Influences C, etc. The outputs are measures of Influence and Dependency which are evaluated for each element by identifying chains of causality up to five long between pairs of elements and, for each element summing the Influence (outward links) and Dependency (inward links). The strength of each link is weighted to account for the number of stakeholders making that link and also by its position in the causality chain between each pair of elements.

By positioning each element in a 2D space, Vester (2012) categorises them by their location as shown in Fig. 1. Elements in zone 1 are the most influential and crucial to initiating the system, those in zone 2 are highly influential and also highly dependent and therefore these are held to be the critical variables and the drivers of uncertainty in the system. Zones 3 and 4 contain the indicators of system outputs while zones 5 and 7 contain the sluggish indicators, and the weak control levers respectively. Zone 6 holds those elements which are least important. Finally, the neutral zone in the middle contains the controls which regulate the system. Hence by examining the location of elements in this space, roles can be assigned to them.

One weakness in the use of a cross impact model is the reliance on focus groups or a single workshop to generate both the lists of these elements of the system and the influences between them. This leads to issues of groupthink, or of the potential dominance of one of the team members as identified by Booker and McNamara (2004). Indeed, recognising the different views of multiple stakeholders in a transport project is held to be one aspect of identifying uncertainty Scolobig and Lilliestam, (2016). Therefore, in this research, the model was extended to account for the

causality perceived by individual stakeholders by interviewing them and holding their data independently. This extension bought more complexity to the derivation of the elements as the understanding of the elements could vary between stakeholders and hence a review stage was essential to ensure elements were made consistent between stakeholders. It is this review stage which forms the key theme of this paper.

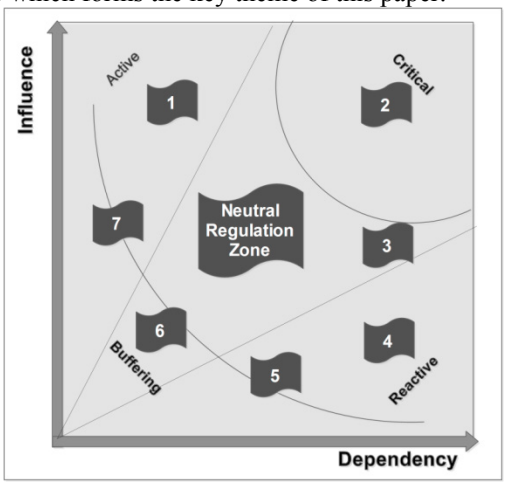

Fig. 1. Influence Dependence Space (After Vester (2012))

The data collection method used elicitation from multiple stakeholders, based on a backcast scenario. Each stakeholder was interviewed, independently to avoid bias and each recorded interview analysed using Qualitative Data Analysis techniques, (Miles et al., 2014; Packer, 2011).The integrated methodology developed for this research linked a backcast scenario with qualitative data analysis of multiple stakeholder reactions to the backcast scenario which were analysed with the cross impact method to determine the drivers of uncertainty.

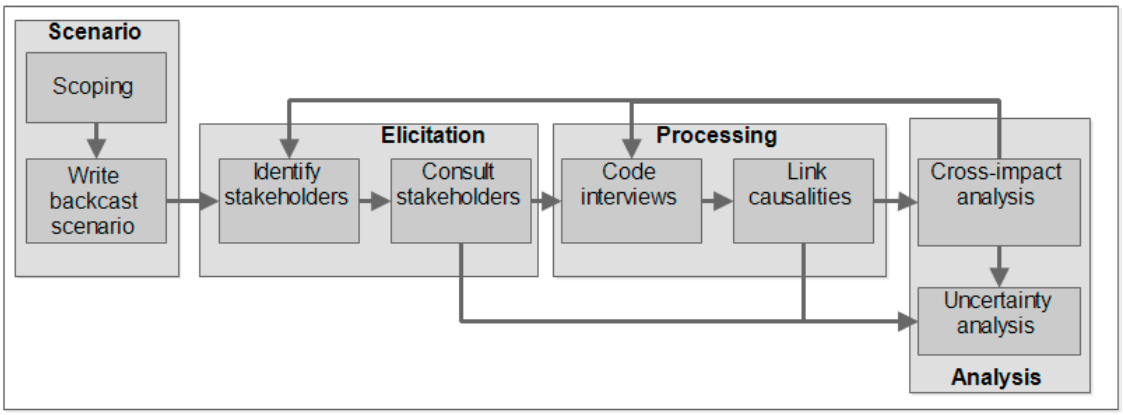

Fig. 2. Methodology Overview

This novel approach is shown conceptually in Fig. 2 with an overview of the four main steps of the integrated method:

- **Scenario**: The problem in the case study was scoped and the normative back-cast scenario was prepared through consultation with stakeholders who shared a similar, aspirational, view of the ideal outcome.
- **Elicitation** A further set of stakeholders was identified who were involved in the project or knowledgeable about the subject. They did not necessarily share the same views as the stakeholders chosen to write the scenario. Open ended, one-to one interviews were conducted to elicit their views of the route to the outcome described in the scenario with emphasis on what could happen, what would happen and what factors influenced those events.

- **Processing**: The elements of the scenario were identified and the causality links between them coded in the cross impact model with data held separately for each stakeholder interviewed.
- **Analysis**: The Cross-Impact analysis was then undertaken and the results analysed based on the Influence-Dependency graph augmented with the notes from stakeholder interviews and examination of the causality links, illustrated by the forward arrows in Fig. 2.

The final stage included (a) a review of the selection of the stakeholders to ensure all relevant points of view are covered and (b) a review of the evolving coding scheme to rationalise the elements of the scenario as described by the stakeholders followed by repetition of the analysis with the updates to the variable and selection of stakeholders. These reviews are illustrated by the feedback arrows in Fig. 2.

3. Case Study

The case study used to test the methodology was based in the Leamside Line, a disused railway in the North East of England with multiple reports commissioned to examine the feasibility of re-opening it, (AECOM, 2010; Network Rail, 2010; ATOC 2009; AECOM, 2007; Network Rail 2007; AECOM, 2006). Within these documents, there are wide ranging diverse recommendations for the mode of use and benefits of re-opening the Leamside Line. The modes of use are variously described as a local line to boost urban agglomeration, a strategic national line, or a dedicated freight route to free capacity on the nearby main line. The diverse, and yet unimplemented plans for the Leamside Line demonstrate significant uncertainty in future plans for the development.

The scenario developed for the case study described the Leamside Line in 2035 having been re-opened and in use as a suburban line with an associated sustainable development anchored on the pre-existing village of Fencehouses, it is also the basis of a “last mile” delivery network working with the Tyne and Wear Metro. Eleven stakeholders were drawn from the planning departments of the adjacent local authority areas, consultants in transport planning, strategy and accessibility, and experts in sustainability from local authority and activist backgrounds. Interviews were conducted in 2013-4 and a review of stakeholders was carried out as a part of the SECURE (SElf Conserving URban Environments) project Bell, (2013) A review of the elicited elements was then carried out by the project team.

The findings of the analysis were that the prime influences in undertaking the project were the ability of the local authorities to collaborate in a development that crosses their boundaries and the presence of political leadership and executive authority. The key drivers of uncertainty were the perceived utility of the re-opened line, and the decisions of government with respect to economic policy. It is noteworthy, that since the elicitation exercise, structural governance developments have occurred in the UK that have endorsed these findings. In 2016, the UK infrastructure commission was created with a goal to invest more in UK infrastructure HM Treasury (2016), potentially changing the influences and dependencies on growth and on government spending as well as making more funding available for UK infrastructure, including transport. With regards to transport governance, legislation in 2016, UK Govt. (2016), provided for the creation of integrated transport authorities and executive, mayoral leadership specifically to resolve problems of inter-region co-operation and decision hiatus. Sykes et al. (2019) further discusses the results of the case study.

4. Elicitation Interviews Coding

The remainder of this paper will describe the process of coding the variables discussed in the interviews undertaken in the elicitation exercise and discuss the issues arising from this, and how they were addressed.

Coding is the process of identifying segments of text or media which are relevant to the subject - such as a theme, concept, or physical object. The goal of a coding scheme is to identify the relevant elements (or variables) in the project and to describe them such that they are coded consistently and without bias across different data sources and media. Lewins and Silver (2008) describe coding schema as either inductive**,** where the list of entities develops as interviews are coded, or deductive where the list is pre-determined before coding starts. Completeness of coding is assessed by examination of the number of variables to determine if a plateau has been reached, i.e. no new variables, or very few new variables are being introduced with each new interview, (Miles et al., 2014; Packer, 2011).

In this research, the coding scheme was initially deductive for the physical elements of the scenario given that the topics of the interview were prescribed. However, the development of the coding scheme necessarily became inductive

as the interviews progressed. The interview technique was intended to be open-ended and there was no prior knowledge of each individual's opinions, nor any desire to constrain their responses to a fixed set of variables. Indeed, the ability to widen that set of variables depending on responses was vital to the ultimate goal; to identify the drivers of uncertainty surrounding the project.

Interviews were recorded using a smartphone app and subsequently transcribed. The interviewer also took notes in the form of causal diagram snippets to indicate direction of influence. These recordings and notes were coded using NVivo QSR (2014) software to identify noun phrases in the transcribed interviews or elements in the interviewer notes (Fig. 3).

Links between variables were formed by searching the transcripts for link words and phrases between adjacent variables. For example: "*disconnected highway network*" ***because*** *"… Co Durham villages…*" and "*Not located on good nodes and links*" ***therefore*** *"they use private cars*". Similarly links were identified in the causal diagram snippets from the lines drawn by the interviewer between each variable. More subtle references to causality were derived from the conversation, for example: "*... references to quite short distance lightweight [freight] movements – it's something we have talked about but it's quite a big policy shift"* was interpreted as an influence between transport and planning policy and the operation of last mile delivery services. Similarly, the dialog "*Sunderland are already struggling in terms of being a poor relation to Newcastle so it's just a fear amongst certain council members that the Leamside line could further devalue Sunderland's position…"* was coded as an influence from the relationship between the local authorities to the business case to re-open the Leamside Line.

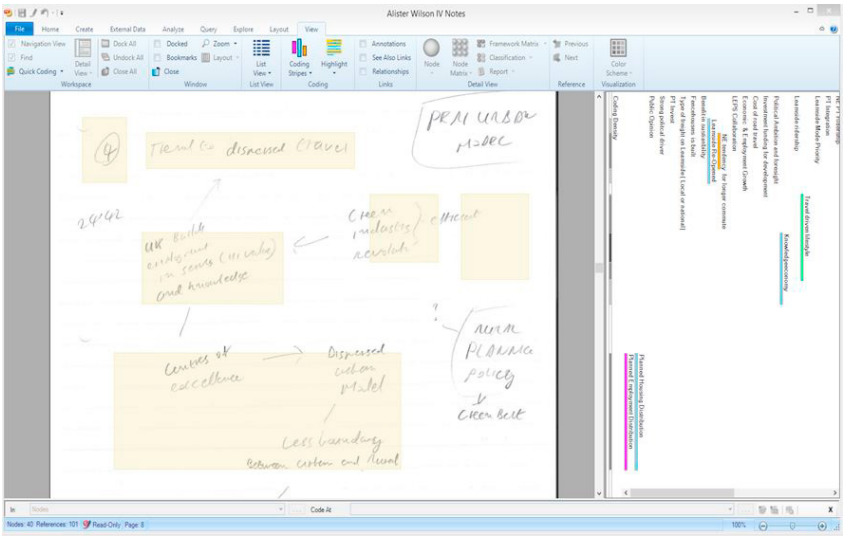

Fig. 3. Interview Coding

During coding, some observations were made by the research team:

- The stakeholder may not agree with the concept described in the scenario and their comments focussed on the shortcomings in the concept and not on how the path to it may either succeed or fail. The interviewer was then drawn into switching from the "what if" questions to the "why not" questions, albeit with the same causality goal.
- The scenario is multi-faceted, which complicated the elicitation. However, if the scenario and interview had been constrained to be too narrow, stakeholders would not have had the opportunity to investigate the causality in the wider context and the analysis would be artificially limited.
- Stakeholder views on causality varied. One view may be that A influences B, another that B influences A. However the cross impact method does not impose a single direction and if there is ambiguity in the stakeholders' perceptions of how the decision process functions, then this will be reflected in the raised uncertainty attributed to those elements of the scenario, which is indeed the purpose of the analysis.

At the end of the coding exercise, 99 variables had been created. An exercise was then carried out to rationalise them using cluster analysis and by critical re-examination. The cluster analysis was undertaken by calculating a measure of similarity based on the number of common links made by each variable in comparison with the other variables. The resulting dendogram is shown in Fig. 4.

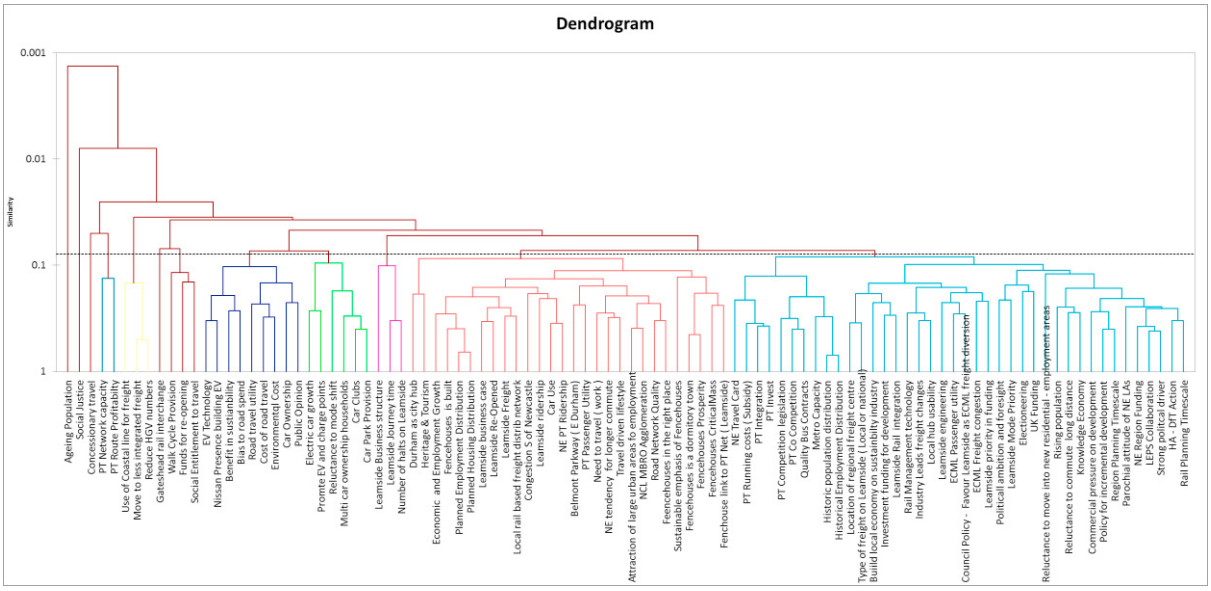

Fig. 4. Clustered Variables

In examination of the variables. The following observations were made where links were adjacent in the cluster analysis:

- The two variables "*Historical Employment Distribution*" and "*Historical Population Distribution*" refer to the pre-existing land use patterns. They have a high degree of similarity in their links and were hence merged to a single "*Historical Demographics*" variable.
- The two variables "*Planned Employment Distribution*" and "*Planned Housing Distribution*" have a high degree of similarity in the dendrogram both refer to current planning policy and both are commonly co-coded in the interview transcripts. Two more variables "*Policy for Incremental Development*" and "*Regional Planning Timescales"* also are similar; one refers to the style of development and the other to the existence of local structure plans that are infrequently updated as well as the inertia in the planning system. As these four all refer to one common concept, they were merged into a single "*Local Authority Planning Policy"* variable.
- The "*Leamside Journey Time*" and the "*Number of Halts on the Leamside*" variables are related through simple journey times and also share common links . As attractors of passengers to the Leamside Line, they were merged to a single "*Leamside Passenger Utility*" variable.

These merges demonstrate how a broad concept can be described by multiple facets of its detail, but in examining causality, it is the broad concept that is the active variable and the different facets of it are similar when examined in terms of the links they make.

In other comparisons where links were similar and variables were close in the cluster analysis:

- The "*Leamside Business Case*" and the "*Leamside Re-opened*" variables are adjacent in the cluster analysis, but here, one is the business case made to justify the other and the presence of a strong business case for a transport development does not necessarily imply the decision will be made to fund it. These two variables were therefore kept distinct.
- In the Public Transport category of variables, the "*PT Running Costs (Subsidy*)" and "*PT Investment*" variables are similarly linked, but while one refers to ongoing cost of existing facilities, the other refers to capital investment. Hence these two variables were also kept distinct.

- Similarly, while the two variables representing employment and housing planning are already merged into the "*Planning Policy*" variable, they are also adjacent to the "*Fencehouses is Built*" variable in the dendrogram. Here, the former two refer to a process, the latter to an action and hence the "*Fencehouses is Built*" variable was maintained as an independent variable despite its similarity in linking to the two planning variables.

These decisions in rationalising the variables demonstrate that while variables may have similar influences and be adjacent in the cluster analysis, they represent different concepts and should be kept separate.

In other cases, examination of the variables shows that they do represent similar concepts despite being relatively remote in the cluster analysis. For example:

- The "*Leamside Business Structure*" variable refers to the commercial structure of the Leamside Line ownership and has a sole link to the "*Leamside Line Business Case*" variable but shares no other common links with it and the two are therefore remote in the cluster analysis. These two variables were merged as one was deemed to be a single facet of the other more complex variable.
- The two variables "*Benefit in Sustainability*" and "*Build Local Economy on Sustainability Industry*" are not closely related in the cluster analysis but on superficial examination refer to similar concepts. However, on deeper examination, referring back to the interview notes and transcripts, one refers to the benefits of emissions management/air quality and the other to the economic benefits of new industry. These variables were therefore kept distinct. The "*Build Local Economy on Sustainability Industry*" variable is however similar in intent to the "*Planned Employment Distribution*" variable and these two were merged.

In the Political category of variables, the three variables "*NE Region Funding*", "*LEPS Collaboration*" and "*Strong Political Driver*" are clustered in the dendrogram and also are adjacent to the "*Parochial attitude of NE LAs*" variable. The LEP is the Local Enterprise Partnership, designed to promote collaboration between the Local Authorities in the North East of England, but the parochial nature of those authorities is illustrated by the comment from one stakeholder "*we wouldn't be happy with a service that goes out to Metro Centre and Team Valley but you can't get it from Gateshead*", and more directly from another "*we still have vast parochial problems in the North East*". Closer investigation in the interviews revealed the problem stems from council revenues where transport is seen as an expense while economic activity provides a benefit. The solution was recognised by the stakeholders: "*Manchester has a combined transport authority covering whole of the city."* in reference to that city's ability to win transport funding through co-ordinated action, but locally; "*the NE is in words only moving towards a combined transport authority*." Following examination of the interviews, the collaboration and the parochial attitude variables were viewed as opposing descriptions of a similar attribute; the tendency of Local Authorities to compete or collaborate; and were hence combined into a single "*LA Political (dis)Unity*" variable in the "*Politics*" category.

In the same category, the "*Strong Political Driver*" variable refers to the need for clear leadership for the project to happen. It has similar influence and dependency to the Local Authority collaboration, variable but the act of collaboration does not necessarily imply a leader is found and it was kept distinct from those adjacent to it in the cluster analysis. The variable "*Political Ambition and Foresight*" also referred to the leadership required to instigate and carry out a transport project; the former tended to be used to refer to institutional leadership, the latter to a project champion for a specific project. As the comments made by the stakeholders were similar, these two variables were merged to one "*Political Action Initiated*". These examples endorse the value of clustering as an analytical method whilst acknowledging its limitations and the need to verify the reasoning and hence robustness of the exercise with critical analysis.

In all cases, when variables were merged, a check was made to compare the results of the analysis *before* and *after* the merge to verify that changes were consistent with the merge that was made; the narrative surrounding the results was similar; and the merge did not make significant changes, or if it did then these were justifiable. At the end of the rationalisation stage, 68 variables remained and were used in the subsequent analysis.

5. Conclusions

The scenario presented to the stakeholders described the future goals for the proposed development under study. In this case study this scenario contained elements of traditional planning for sustainability and elements of innovation in last mile delivery technology. However, it should be noted that the most influential effects observed in the case

study were not mentioned in the scenario but instead were brought in by the stakeholders. This reinforces the decision to adopt a coding method which was initially deductive, but later inductive to encompass new factors.

The discussion in section 4 demonstrates the value of critical and systematic examination of the elements of the system as identified by the stakeholders as a vital step of the method designed and trialed in this research and how it serves to both ensure consistency between stakeholders, and to gain a better understanding of the issues involved in the project. It also demonstrates the need to examine the elements systematically, by cluster analysis based on their similarity in links, and also to examine them critically, by thorough inspection and review by the project team.

6. References

AECOM. (2006) 'Tees Tyne Connectivity Study Final Report', [Online]. Available at: www.strategyintegrationne.co.uk/displaypagedoc.asp?id=644 (Accessed: 25/09/2012).

AECOM. (2007) Leamside Final Report (V3), November 2007 in Nexus.

AECOM. (2010) 'Rail Freight Review 2010', [Online]. Available at: http://www.tyneandwearfreight.info/rail_freight/pdf/Rail Freight Review 2010.pdf. (Accessed: 25/09/2012).

ATOC. (2009) 'Connecting Communities Expanding Access to the Rail Network', [Online]. Available at: www.atoc.org/clientfiles/.../ConnectingCommunitiesReport_S10.pdf (Accessed: 18/09/2012).

Bell, M. C. (2013) SECURE (SElf Conserving URban Environments). Available at: https://www.secure-project.org/ (Accessed: 17/05/2013).

Booker, J. M. and McNamara, L. L. (2004) 'Solving black box computation problems using expert knowledge theory and methods', Reliability Engineering and System Safety 85, pp. 331–340.

DfT (2016). 'Transport analysis guidance: WebTAG.' WebTAG. Available at https://www.gov.uk/guidance/transport-analysis-guidance-webtag. (Accessed 19/02/2017).

Godet, M. (2011) Methods of prospective: Micmac: Structural Analysis. Available at: http://en.laprospective.fr/methods-of-prospective/softwares/59-micmac.html (Accessed: 31/10/2011).

Gordon, T. J. (1968) 'Initial Experiments with the Cross-Impact Matrix Method of Forecasting', Futures, 1, (2), pp. 100-116.

HM Treasury (2016) Infrastructure at heart of Spending Review as Chancellor launches National Infrastructure Commission. Available at: https://www.gov.uk/government/news/infrastructure-at-heart-of-spending-review-as-chancellor-launches-national-infrastructure-commission

Lewins, A. and Silver, C. (2008) Using Software in Qualitative Research. SAGE.

Marsden, G. and Reardon, L. (2017) 'Questions of governance: Rethinking the study of transportation policy', Transportation Research Part A, 101, pp. 238-251.

Miles, M. B., Huberman, M. A. and Saldana, J. (2014) Qualitative Data Analysis. Sage.

Network Rail. (2007) 'Freight Route Utilisation Strategy (Archived)', [Online]. Available at: http://archive.nr.co.uk/aspx/4449.aspx (Accessed: 25/03/2018).

Network Rail. (2010) 'East Coast Main Line 2016 Capacity Review', [Online]. Available at:h ttp://www.networkrail.co.uk/browse documents/rus documents/route utilisation strategies/east coast main line/east coast main line 2016 capacity review/east coast main line 2016 capacity review.pdf (Accessed: 01/10/2012).

Ortuzar, J. D. and Willumsen, L. G. (2011) Modelling Transport (4th Edition) 4 ed London: Wiley.

Packer, M. (2011) The Science of Qualitative Research. Cambridge University Press.

QSR, I. (2014) NVivo. Available at: http://www.qsrinternational.com/products_nvivo.aspx (Accessed: 18/12/2014).

Scolobig, A. and Lilliestam, J. (2016) 'Comparing Approaches for the Integration of Stakeholder Perspectives in Environmental Decision Making', Resources, 5, (4).

Sykes, , P.,Bell, M., Dissanayake, D.. (2019). " ."Identifying the factors driving the uncertainty in a transport infrastructure project by application of structural dynamic analysis to a backcast scenario"Futures 111, pp. 26-41.

Sykes, P.,Bell, M., Dissanayake, D.. (2018). "Combined use of a backcast scenario and cross-impact matrix analysis to identify causes of uncertainty in a nascent transport infrastructure project." Transportation Research Part B: Methodological 116: 124-140.

UK Govt. (2016) Cities and Local Government Devolution Act 2016. Available at: http://www.legislation.gov.uk/ukpga/2016/1/pdfs/ukpga_20160001_en.pdf (Accessed: 25/09/2018).

Vester, F. (2012) The Art of Interconnected Thinking: Tools and concepts for a new approach to tackling complexity.2nd ed Munich: MCB.

Vigar, G. (2017) 'The four knowledges of transport planning: Enacting a more communicative, trans-disciplinary policy and decision-making', Transport Policy, 58, pp. 39-45.

Wachs, M. (1985) 'Planning, Organizations and Decision Making: A Research Agenda', Transportation Research A, 19A, (5/6), pp. 521-531.

Welde, M., Eliasson, J., Odeck, J. and Borjesson, M. (2013) 'The Use of Cost-Benefit Analyses in Norway and Sweden: A Comparison', European Transport Conference. Frankfurt, AET, pp. 1-13.