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TOWARDS A SHIFT OF VALUES IN RAIL INFRASTRUCTURE PROJECT EVALUATION

SUSTAINABLE INTERVENTIONS IN RAIL INFRASTRUCTURE ASSETS

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ABSTRACT

The rail industry, despite its iconic value and status as a key economic infrastructure, faces significant challenges today: An ageing, historically underinvested system has had to accommodate an unprecedented increase in demand with limited financial resources at its disposal. Now, following the Covid pandemic the same historically underinvested infrastructure has had to address the reality of an unprecedented reduction. In order to meet these polarised challenges, brought sharply into focus by its imminent restructuring (initiated by the recent White Paper) it needs more than ever, to harness the positive socio-economic impact of its interventions on its key resource: its human potential.

In this work the author argues that the value of enhanced skill, knowledge and expertise derived from projects should be recognised and incorporated into more meaningful evaluations of project viability and sustainability. The argument draws on the notions of sustainability, the nature of the asset base and a more comprehensive whole life evaluation to inform and make this case. It has been supported through the use of surveys and interviews, within the context of case studies, in order to represent the nature of the relationship between participation in projects and the enhancement of expertise. The findings describe both a strong relationship (80% agreement and strong agreement) between project participation and expertise enhancement as well as providing indications of some of its key qualities. Adding support to the assertion that there is a necessary and contributory causal relationship between project participation and the enhancement of the expertise of the participants. The Interviews, based on grounded theory, also provide further insights through the identification and distillation of themes which emerge as integral to this process and are consistent with the concepts drawn out from the notion of a sustainable intervention in rail assets.

Supported by these findings the author concludes that the value derived from harnessing the potential of its key resource in this way needs greater recognition and to be incorporated into a more comprehensive calibration of project value. A more comprehensive form of ~~whole life~~ evaluation, which made greater accommodation of externalities, while at the same time recognising that rather than being an external attribute of asset value, the enhancement of skill, knowledge and expertise is, in fact, intrinsic to it. A recognition requiring a significant shift of emphasis in the realm of project evaluation and governance in order to ensure its rightful place in the effective incorporation and deployment of asset value

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BCR: Benefit Cost Ratio

BMS: Building Management System

BOS: Bristol Online Survey

BTP: Brittish Transport Police

HLOS: High Level Output Specification'

IIA: Initial Industry Advice

KPIs: Key Performance Indicators

NCC: Nottingham City Council

NCoC: Nottingham County Council

NET: Nottingham Express Transit

OED: Oxford English Dictionary

PFI (Private finance Initiative).

RTS: Rail Technical Strategy (Note also NRTS – Network Rail RTS and ARRTS – Academic Response to the RTS)

SoFA: Statement of Funds available

SBP Strategic Business Plan

WLC: Whole Life Cost (Note also Life Cycle Costs (LCC), Life Cycle Cost Analysis (LCCA) and Life cycle (LCA)

GLOSSARY

The definitions and descriptions listed below are intended to provide a general understanding of the terms. For this reason a significant proportion of them are derived from the Oxford English Dictionary (OED). They have been supplemented where appropriate with specialist definitions where these provide an effective complement to the OED description and are jargon free. In addition these sources may be supplemented in order to provide a fuller description of the sense in which they are being used in the text.

Affordability: The quality of being affordable. The ability to bear. Used in a multifaceted way in relation to the notion of value and where true asset value resides and therefore those aspects of asset value which should be born in order to move closer to it.

Agglomeration: The action or process by which separate particles or elements collect together in a mass or group. a clustering or cluster. The economic benefits rought about by such clustering which is facilitated by railway connectivity.

Amalgamation of meaning: Amalgamation refers to the action of combining distinct elements into one uniform whole and a homogeneous union of what were previously distinct elements. The term Amalgamation of meaning is used to refer to the combining of terms which have a closely aligned meaning and where each one may be employed in the dictionary definition of another. But where a single term does not adequately communicate the intention behind its use.

Asset: An item of value owned; an item on a balance sheet representing the value of a resource. An item of property. A term frequently coupled with liability. A thing, person, quality, etc that serves as an advantage, support, or source of strength.

Asset management: The active management of assets in order to optimize return on investment.

Asset – Railway / Rail: An item of value attributed to the Railway infrastructure system.

Benefit-Cost Ratio: An economic calculation to determine the relationship between economic cost and economic benefits. Subject to the interpretation and understanding of the notion of ‘costs’ and ‘benefits’.

Body of Knowledge: A comprehensive collection of knowledge within a particular field. In the text referring principally to ‘Body of Knowledge ‘assembled and compiled by the Association for Project Management (APM).

Calculation: The action or process of reckoning; computation. The form in which reckoning is made; its product or result. Estimate of probability, forecast. Attempts to attribute the appropriate value.

Capability: Power or ability in general. Used in conjunction with competencies to denote the capacity to undertake a task or activity. Used in the sense of having the skill, knowledge and expertise to be capable of undertaking the task or activity. (see Competence)

Cause: The circumstances which must occur in order that the event should happen. The circumstances that are required in order for another set of circumstances to be brought about.

Cause – Contributory: One of several causes for something to occur. One of several sets of circumstances that must occur in order that another set of circumstances can be brought about. The argument that participation in a project

(programme or portfolio) is a contributory cause of the enhancement of the skill, knowledge and expertise of project participants.

Cause – Necessary: A condition on which another thing is dependent or contingent; a prerequisite. In the text this is used in relation to the argument that participation in projects (programmes or portfolios) is a necessary condition for the project participants' expertise to be enhanced.

Change: Used in conjunction with the concept of project management being the management of change. The management of change and development within a business or similar organization

Competence: Sufficiency of qualification; capacity to deal adequately with a subject. (See capability)

Contingent: Not determined by necessity in regard to action or existence. Not of the nature of necessary truth; true only under existing conditions. Contingent matter. Dependent for its occurrence or character on or upon some prior occurrence or condition.

Core: That which is at the centre of ….. Essential contemporaneous with the current reality.

Correlation: In Statistics, an interdependence of two or more variable quantities such that a change in the value of one is associated with a change in the value or the expectation of the others; The condition of being correlated; mutual relation of two or more things (implying intimate or necessary connection).

Domain: A sphere of thought or action; field, province, scope of a department of knowledge, etc.

Elements: A component part of a complex whole. A constituent portion of an immaterial whole. In the text also used in relation to the 'elements' that comprise the asset base.

Expert: A person who is expert or has gained skill from experience. A person regarded or consulted as an authority on account of special skill, training, or knowledge.

Expertise: Expert opinion or knowledge. The quality or state of being expert; skill or expertness in a particular area of study or sport. Used in the text, (principally in conjunction with skill and knowledge) also to refer to an accumulated amalgamated and assimilated proficiency in an identifiable (usually complex) area of activity which may or may not be discipline or domain specific.

Externalities: A side-effect or consequence (of an industrial or commercial activity) which affects other parties without this being reflected in the cost of the goods or services involved; a social cost or benefit. An external object; an outward feature or characteristic. Outward things in general. Something which is external to and not an intrinsic part of. Used in the text and original title also to refer to the enhancement of skill, knowledge and expertise as an essential outcome, and potential output in the (what the thesis argues is an inadequate) calibration of asset value. The notion of expertise being considered as external to asset value is juxtaposed with the argument that it is in fact intrinsic to it.

Grade Separation: Where Railway Lines cross at different levels.

Gross Domestic Product (GDP): A measurement of the quantity and quality of an economy (usually one quarter or one year). Can be used to compare an economy over a period of time or different economies simultaneously.

Growth: Used in an economic sense to refer to the' per capita' increase in goods and services produced over a period of time. But also with the inference that there may be further dimensions to human productivity than the current measure of Gross Domestic Product (GDP).

Holistic: Derived from medical (holistic medicine) and political (Smuts – Holism) discourse referring to the tendency to perceive or produce wholes. In the text this is used to convey the notion of aggregation and amalgamation rather than segregation and dissociation. To consider things from a comprehensive, rather than a specific perspective.

Infrastructure: A collective term for the subordinate parts of an undertaking; substructure, foundation; the permanent installations forming a basis for… Used in the text to refer to the national economic and also social infrastructures that underpin society. But also more specifically to refer to transport infrastructure, with a particular focus on rail infrastructure.

Internalise: To incorporate (externalities, esp. social costs resulting from a product's manufacture and use) as part of a pricing structure. Used in the text to refer to the process of incorporating what are perceived to be extraneous or external aspects of asset interventions into the central body of the assessment or evaluation of the effect of that intervention.

Intervention: The action of intervening in something in order to affect the course of its development. Used in the text to refer principally enhancements of rail assets.

Knowledge: The fact or condition of having acquired a practical understanding or command of, or competence or skill in, a particular subject, or range of subjects, through instruction, study, or practice; skill or expertise acquired in a particular subject, etc., through learning.

Measurement: The process of valuation using some form of calibration.

Mentor: To act as a mentor to (a person, team, etc.); to advise or train (someone, esp. a younger and less experienced colleague).

Naturalistic: Derived from the noton of 'Naturalistic Decision Making' where observation of decision making in real-world situations was seen to differ from theoretical expectations and those observed in laboratory settings. Used in the text to refer particularly to the accumulation of skill, knowledge and expertise in the context of a live project environment.

Output (Project) Defined / designated products that emerge from a project. Project deliverables and/or service change (BOK).

Outcome (Project) The consequences, intended or otherwise, of a course of action or activity. Used in the text particularly to contrast with defined and largely presecribed outputs.

Project: A unique transient endeavour undertaken to achieve a desired outcome (BOK).

Project Management: The theory, practice, or occupation of managing projects. The process by which projects are defined, planned, monitored, controlled and delivered so that agreed benefits are realised (BOK).

Programme: A group of related projects which may include business as usual activities that together achieve a beneficial change of a strategic nature for an organisation (BOK).

Portfolio: A grouping of an organisation's projects, programmes and related business as usual activities, taking into account resource constraints. Portfolios can be managed at an organisational, programme or functional level (BOK).

Project Lifecycle: The necessary sequence of phases that provide the structure and approach for delivering the required project outputs.

Qualitative (Cost and Benefit) Relating to quality or qualities; measuring, or measured by, the quality of something. In later use often contrasted with quantitative. In text used to refer to information which requires to be evaluated using subjective judgements and which cannot be measured by a precise numerical calibration (such as through counting a definined number of discrete items)

Quantitative (Cost and Benefit) Possessing physical quantity or spatial extension. That is, or may be, measured or assessed with respect to or on the basis of quantity; that may be expressed in terms of quantity. Relating to or concerned with quantity or its measurement; that assesses or expresses quantity. In later use frequently contrasted with qualitative.

Rail network: The interconnected arrangement of tracks and associated infrastructure on which an authorised collection of rolling stock are able to move safely.

Relationship: The state or fact of being related; the way in which two things are connected; a connection, an association. Used in the text particularly to refer to a possible relationship between the participants perception of their skill, knowledge and expertise enhancement and their participation in projects and programmes.

Skill: Capability of accomplishing something with precision and certainty; practical knowledge in combination with ability; cleverness, expertness. Also, an ability to perform a function, acquired or learnt with practice.

Skill set: A range of skills or capabilities, esp. a set of skills necessary or desirable for a person's participation in a particular field.

Sustainability: Enduring and balanced approach to economic activity, environmental responsibility and social progress. The quality of being sustainable by argument; the capacity to be upheld or defended as valid, correct, or true. The provision of conditions which will ensure the indefinite continuation of something or a set of circumstances.

System: An organized or connected group of things. A set of persons working together as parts of an interconnecting network. An amalgamated composition of elements. The investigation of complex, man-made systems in relation to the apparatus that is or might be involved in them.

System of Systems: An amalgamation of systems

Trajectory: Used figuratively in the text to denote the projected direction of ‘travel’ of the amalgamation of skill, knowledge and expertise of individuals, subject areas, domains. The direction in which this amalgamated expertise could or should be heading in order to realise its optimum potential.

Transaction: A business activity involving the provision of a service for the delivery of specified requirements.

Transformative: A transformative project is one that sets out to achieve change which can be regared as different in kind to that normally expected of a (change) project.

‘Whole Life Cost’: A comprehensive estimation of value. Meaning expanded in text

‘Whole Life Value’ Refer Whole life cost

Work-stream: Identifiable pieces of work that proceed over time usually resulting in some form of output or deliverable.

1 INTRODUCING THE CHALLENGES OF SUSTAINABLE INTERVENTIONS IN RAIL ASSETS

> *"Science may be described as the art of systematic oversimplification"*
> Karl Popper

This chapter sets out to introduce the principle ideas and lines of thought that provide the base on which this thesis has been assembled. It describes the reasoning behind the choice and assembly of these constituent parts and why they were brought together in the way they were. It seeks to provide an explanation for the coincidence of subject matter, which includes such notions as sustainability, engineering assets, skill, knowledge and expertise and measurability. While this work has involved examining such terminology and concepts it is not setting out to redefine commonly used terms. Rather, that by considering the implications of the way they are used, it is intended to shed more light on the activities that they describe.

The argument has been supported through the use of surveys and interviews, within the context of case studies, in order to represent the nature of the relationship between participation in projects and the enhancement of expertise. The findings describe both a strong relationship (80% agreement and strong agreement) between project participation and expertise enhancement as well as providing indications of some of its key qualities. Adding support to the assertion that there is a necessary and contributory causal relationship between project participation and the enhancement of the expertise of the participants. The Interviews, based on grounded theory, also provide further insights through the identification and distillation of themes which emerge as integral to this process and are consistent with the concepts drawn out from the notion of a sustainable intervention in rail assets.

The Covid pandemic has undoubtably introduced a novel dimension to the subject matter, nevertheless it is the ~~the~~ same historically underinvested infrastructure which has had to address the additional challenge of a significant reduction in passenger numbers. In order to meet these polarised challenges it needs to harness the positive impact of its interventions on its key resource, its human potential.

1.1 RAIL'S PRINCIPLE ASSETS

As a key and iconic component of transport infrastructure (Shaw, 2015 p 6), rail faces very significant opportunities and challenges.While it can be argued that the railways have taken on a significance which supercedes the aggregation of their different parts. Before the pandemic the demand for the railway had been growing exponentially, and is likely to continue to do so in the future. While the resources to meet

that demand have appeared inadequate. In order to meet these challenges the industry needs to draw as effectively as possible on all the resources available to it. In particular it needs to benefit from the vast fount of human potential in the industry, while ensuring it is not constrained by processes, models and structures that might impede its realisation. Thereby enabling it to factor in and account for the human potential that could enable the rail industry to significantly enhance its value and productivity while sustaining its ongoing evolution into the future.

This work originated from the notion of sustainability (UNCED, 1987) in the context of rail infrastructure, and the need to achieve a greater understanding of a range of concepts which appeared to be central to the topic, including: The ways in which the Rail Industry can be described as sustainable. The underlying sustainability of the asset base, 'whole life cost' and 'value' and their associated 'externalities'. Specifically the work focussed on the influence of a particular externality: 'Skill, Knowledge and Expertise' in a systems based multidisciplinary environment. From the outset, it was intended that the work should be immediately relevant to practical need and as far as possible to integrate academic evaluation into operational reality.

Over the period of the study, which was developed part time, the general topic area of skills within the rail industry, has evolved from being peripheral to gaining increasing prominence to now being increasingly mainstream. There are numerous references to 'upskilling' the workforce as a means of enhancing productivity. Almost all programmes of any size are having to address the 'skills gap' in one form or another. However, although this increasing prominence has raised the profile of the general topic area, the focus has generally been on the skills that need to be in place in order that participants can contribute meaningfully to projects and programmes. These are referred to in this work as pre-requisite skills. This work however is particularly seeking to address the accumulated, latent and potential skill, knowledge and expertise that emerges as a consequence of their engagement with asset interventions, principally in the form of projects and programmes. The author who worked in the rail industry during this period sought to influence the approach to what this work refers to as this consequential skill, knowledge and expertise, in a number of areas.

It should also be noted that throughout this work there is a reference to the terms 'Skill, Knowledge and Expertise' they have been used together in order to communicate the intended meaning more effectively. While these terms might be said to have discrete meanings which are independent of each other; it is not the purpose of this work to undertake a profound linguistic analysis on their differentiation. Rather, to provide an amalgamation of meaning which describes the qualities in question. However in order to reduce unnecessary repetition and maintain the flow of the text, the three terms are used interchangeably where it does not detract from the intended meaning. Many of the arguments set out in these introductory chapters are also presented in the paper 'Internalising Externalities in a Sustainable Rail Asset Base' (Langdon et al., 2016)

1.2 THE ISSUES RAISED AND THE SIGNIFICANCE OF LANGUAGE AND TERMINOLOGY

The subject matter of this thesis has taken into account a broad range of relevant topic areas, disciplines and domains (refer glossary) that are associated with rail infrastructure. This has been necessary in order to provide an adequate context within which to address the central questions and associated subject areas that have emerged. It also serves to clarify the interrelationships between the different subject areas and to test the integrity of their cohesion within a multidisciplinary study. It was from the review of this broad context that the research question began to emerge.

The notion of sustainability or sustainable development has, in its current usage today, accumulated significantly more implicit meaning. Any notion of 'sustainability' that goes beyond a straightforward continuation or 'sustaining' of 'business as usual' inevitably begs a number of questions. Specifically about the way in which we will be able to 'continue' our current patterns of economic activity and consumption within a vulnerable environment. And that whatever the possible solutions are, they must be socially, environmentally and economically balanced. An effective sustainable development policy therefore must establish the necessary preconditions for a benign and effective pattern of operational and commercial transactions.

It can be argued that the rail industry in general, as a provider of a low carbon transport system and Network Rail (or in the future Great British Railways), in particular, as a guardian of and conscience for rail's infrastructural assets, have a significant role to play in this. By promoting the environmental, economic and social balance that needs to be maintained within our industrial system for the foreseeable future.

Integral to any evaluation of sustainable development is the notion of 'affordability'. The extent to which the infrastructure can be supported with the resources available? To what extent can the social, economic and environmental resources expended on any enterprise continue for the foreseeable future? Key to the effectiveness of such a comprehensive evaluation of affordability is that proposed changes are carried out from a holistic, systemic perspective (Rama and Andrews, 2015) and in such a way that take into account all the costs and benefits associated with the proposed change. Also, that it applies the notion of 'whole life cost' or 'whole life value' comprehensively in order to justify any investment on an on-going basis.

Whole life evaluations manifest in many forms and the subject generates much confusion and ambiguity. There is also much debate around currently measured or quantified calculations of cost and the extent to which attempts to arrive at viable forms of quantification may provide an incomplete representation of value (Laird and Venables, 2017) (Institute for Government, 2016). Nevertheless the intention remains to provide the appropriate mechanisms to ensure that certain qualitative attributes of transport infrastructure investment can be accounted for effectively in order that any evaluation is meaningful.

Whole life evaluations incorporate externalities – factors that are not included in the financial calculation but which may be very relevant to a comprehensive assessment of cradle to grave or cradle to cradle (McDonough, 2009) notion of value. They are, therefore, crucial to an understanding of whether the investment is genuinely affordable in the longer term. Central to this notion of genuine long term affordability and the optimal allocation of resources is the extent to which the constituent parts or assets of the infrastructure require the investment of those apparently limited resources: Those that may no longer be needed, those which should have their life extended or enhanced to provide a higher level of service and those aspects of the infrastructure that are so critical that they should continue indefinitely. Notwithstanding the fact that this requires a projection forward to possible future scenarios, which will to a significant extent be determined by the short, medium and long term decisions being made today.

This leads on to the need to clarify what we are referring to when we describe the 'assets' that constitute the infrastructure. We can emphasise either: The 'elements' (see section 3.1) that perform functions. The system that they form a part of, or the 'service' that needs to be delivered. So that when talking about infrastructure services we are able to consider them from a more comprehensive vantage point, to be more conscious of the common ingredients that traverse the subdivisions within the overall infrastructural system. To establish where their 'threads of continuity' lie and what needs to be in place in order to ensure that they can be sustained. It also enables greater insight into the key ingredient which remains when the different embodiments of the means of conduction and transmission, such as, tracks, cabling, excavations, pipework and networks have evolved into other forms of infrastructural solution. To recognise the transient nature of these different solutions and how to focus on the continuum? That is to consider the correct perspective from which to view the provision of a sustainable infrastructure.

Figure 1-1: Railway Assets: The Autumn Weather Fleet during maintenance

At one level this can be seen simply as a matter of emphasis and historically both the operational and conceptual emphasis has generally been on the familiar elemental breakdown of assets (refer 1.3 below). More recently there has been a recognition of the importance of the interrelationship of those elements and their interconnections within the 'system' (Technical Strategy Leadership Group, 2012). An integrated system in contrast to autonomous segmented elements.

In parallel with this shift in emphasis towards the system – there is the opportunity to give more recognition to where the core of that infrastructural system resides. An appreciation that the infrastructural system as it manifests at any point in time can be understood effectively as the current 'test bed' or 'case study' for the current state of associated skill, expertise and knowledge. The necessary conditions for the effective provision of a constantly evolving set of contingent solutions that serve to provide society's infrastructural requirements.

Clearly there are many different types, ranges and levels of expertise, skill and knowledge enhancement being referred to here. This includes: Advanced engineering research into innovative technological solutions to complex technical challenges and the extent to which such technologies should be conceptually separate from the people that enable them. The general increase in trade / craft / engineering skills that accrue to those having to refurbish and adapt the existing infrastructural stock. As well the essential skills gained by those that have never previously experienced the world of work at

all. There were a range of terms which were relevant: Skill, knowledge, expertise, capacities, competencies and capabilities. The tripartite description of skill, knowledge and expertise was adopted initially with a view to eliminating one or other of the terms with a tighter reference to one or other. However it became apparent that the lineage of all three terms was sufficiently extensive that to use one in preference to another would be to distort the amalgamation of meaning that this work was seeking to establish. If any of the three terms has predominated in the text it has been the notion of expertise for which knowledge and skill might be regarded as essential prerequisites and because it transmits the meaning more effectively.

This work is not intended to be a linguistic analysis of the use of terminology and it is not an attempt to reassign alternative meanings to commonly understood terms. Rather it seeks to clarify the meaning, function and purpose of the assets and activities associated with rail infrastructure. It does not devote chapters to precise terminological definitions, or to redefine common usage, which would be to misdirect the purpose of the work. However, as the argument presented in this work develops it will return to the meaning and amalgamation of meaning of different terms and expressions to clarify its overall direction and intent. In addition to skill, knowledge and expertise there are a range of terms and concepts such as asset, sustainability, system, transaction and measurement which are also addressed in order to understand their significance in the context of rail investment.

1.3 FRAMING THE STUDY

Rail infrastructure covers a broad range of subjects and domains. From the complex web of rail research programmes through to the practical delivery of repetitive renewals on the rail network. The possible options for evaluation in this study were extensive. As with other key economic infrastructures, investment in rail infrastructure takes place through a complex and extended range of activities. From day to day maintenance of the fixed and moving assets through to once in a generation major enhancements. The latter being generally undertaken, within the framework of projects, programmes or portfolios (refer Glossary), depending on their size and scope. For economy of expression and convenience these have generally been shortened to projects, except where particular emphasis is needed.

Identifiable boundaries were required to contextualise the study and test a developed hypothesis through a case study. While on-going activities, such as maintenance regimes were identifiable, they are also open ended. Projects, as ‘unique transient endevours’ (Association for Project Management, 2019 p 214) offered both a distinct identity and a high level of containment. In contrast to the continuity and rule based order of regular (Dadashi et al., 2021 p 257) maintenance processes. However, some early project or programme activities in the project lifecycle, such as research, development or design

development, while being identifiable, could also be extensive and extended. The focus therefore shifted to the latter, delivery end of the project lifecycle to establish a frame of reference, within which to test a formulated hypothesis or research question for the study.

The overall study was seeking to understand more about what was meant by a sustainable intervention in rail assets. While a project offered the opportunity to bound the contextualised study, its scope needed to provide a comprehensive picture of the resources deployed and the benefit gained. A notion of value that looked beyond the limited picture of financial or monetised costs in order to encompass the costs and benefits associated with these undertakings. In particular the benefits associated with the enhancement of expertise achieved as a result of working on rail infrastructure projects.

This work goes on to argue that such a positive change which underpins the evolution of the asset base is of such importance that this 'qualitative benefit' should be recognised and valued in some meaningful way. And that this recognition can be used to gain a greater understanding of how the deployment of such resources can benefit this core asset base of the rail industry as well as other infrastructures. It also considered how this understanding may influence future investment decisions and future funding negotiations.

It was therefore from the consideration of these topics that the 'research question', which addressed the connection between a sustainable intervention in the asset base, the resultant change in expertise of the participants and its consequences, including the implications for funding settlements, began to emerge.

1.4 CHALLENGING THE HYPOTHESIS THROUGH CASE STUDIES

The Nottingham Hub pilot study was initiated in order to provide a bounded study within which to test the hypothesis within the discipline of a project boundary at the delivery end of the project lifecycle. It was followed by case studies at Nottingham and Birmingham. These consisted of the Birmingham New Street Station, the Net 2 Nottingham Tram project and the East Midlands re-signalling project. The purpose of the case studies was to establish the extent to which there was a relationship between participation in infrastructure projects and programmes and the change of level of skill, knowledge and expertise of the project participants. How the demonstration of this relationship might lead to a broader and more comprehensive recognition of rail benefits. Also to provide an indication or signpost as to how the funding base might be broadened as a result of such a recognition.

The case studies were chosen and set up on the basis that they were live rail infrastructure projects that involved a broad range of technical and managerial capabilities. The three Nottingham Projects which centred on the station were both coincident with each other and also provided a fortunate and practical

solution for research access. The combination of a Heritage refurbishment, an interface between light rail and heavy rail and an extensive resignalling project (the least visible but with the highest financial cost) provided a very effective context for the study. The Birmingham Case study included all of the characteristics associated with the Nottingham studies but was on a significantly larger scale.

Data was collected through surveys and interviews with the project participants. The examination of the data collected sought to clarify the extent to which the participants believed that their participation, as well as that of their team had resulted in the enhancement of their skill, knowledge and expertise and to gain some insight (using the grounded theory approach), into the nature of that enhancement.

1.5 QUANTIFIABILITY AND MEASURABILITY

The argument that expertise had been enhanced through participation in projects and programmes needed support. Such support frequently takes the form of quantification or measurement. And the most obvious form of measurement of this change would involve some form of monetisation. Indeed such a reversion to a generally accepted and ubiquitous unit of measurement, where appropriate, is difficult to resist.

However, given the somewhat intangible nature of the hypothesised benefit, a straightforward financial formula that could describe such a comprehensive picture, was neither available nor readily derivable. Further, it was important not to undermine the argument as a whole through the attempted deployment of an inappropriate, incomplete or blunt financial economic model. Given that the topic centred on the notion of the sustainability of the asset base, it became apparent that some form of comprehensive 'whole life evaluation' of the change would be required in order to demonstrate that its value could be recognised and sustained in the short, medium and long term.

There are many versions of whole life cost evaluations and much confusion surrounding the term. Nevertheless one of the basic common assumptions is that any such holistic, comprehensive evaluation of any asset, element or system should include externalities: Qualitative costs and benefits that are brought about as a result of that change but which do not appear as part of the central financial evaluation. Or as described by the Whole life Cost forum: 'when somebody who is not directly involved in a transaction incurs a cost or enjoys a benefit as a result of that transaction' (Whole Life Cost Forum, 2012).

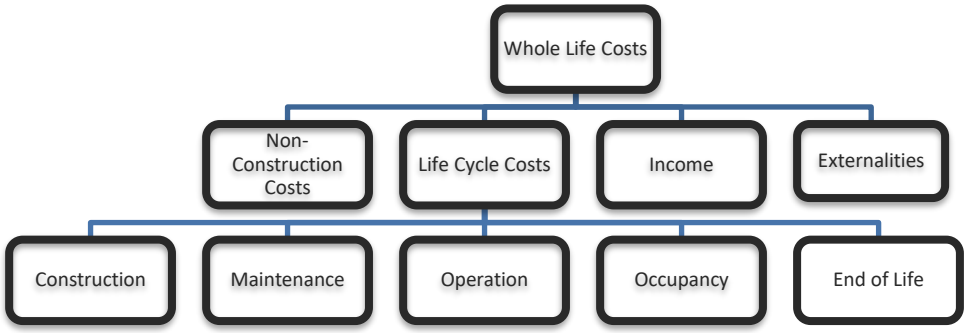


Figure 1-2: Externalities a part of a whole Life Cost Evaluation based on ISO 15686-5:2008 (BSI 2008)

The concept of 'Whole Life Cost' or 'Whole Life Value' appeared to provide indications of the way in which these calculations might be undertaken. They sought to include the comprehensive range of qualitative costs and benefits, some of which which are less obvious to attribute and are referred to as externalities. This work is arguing that among these externalities, would be the positive change in knowledge, skill and expertise of those engaged in the projects and programmes. It was expected that this would be a positive externality because it was envisaged that the change would be a positive change. But this had to be supported through contextualised case studies.

This, therefore, presented the need both to argue for the inclusion of expertise enhancement as an externality in the 'whole life cost calculation'. While also recognising that far from being external to a whole life evaluation of asset value, expertise enhancement appears as being, intrinsic to it. A significant juxtaposition that is present, along with others, throughout this work.

1.6 THE SHIFT OF EMPHASIS AND APPLICATION

The value of expertise as an intrinsic component in the evaluation of asset interventions suggested the need to reprioritise its importance in the evaluation process. A shift of emphasis that would offer the opportunity for projects to re-prioritise the relationship between physical and intellectual output. Rather than treating expertise enhancement as incidental to decisions about investment; it would become a prominent factor in decision making. Thus the centre of gravity would shift: Away from a constrained focus on the outputs of the project. Towards the outcome of enhanced skill, knowledge and expertise that would be achieved through their delivery. Indeed, in order to achieve such a refocussed outcome, expertise enhancement could be reprioritised as a designated output as well as an incidental outcome of projects. This would happen on several different levels: That of the: Individual participant, the team, the project, the programme and the portfolio. It would also need to be considered from the perspective

of the subject / domain area within which the participants were operating in order that the potential for the enhancement of domain knowledge was factored into the evaluation of interventions in the asset base. These could be significantly more strategic in approach. For example it could be possible to target the perceived expansion of subject matter or domain knowledge alongside the infrastructural output requirements of a particular project. This work is arguing such a shift of emphasis and perspective has the potential to result in improvements to both.

Taking into account the factors outlined above, a hypothesis was therefore framed as: A sustainable intervention in the rail infrastructure asset base which effectively demonstrates a meaningful form of whole life value will include externalities. Among these externalities will be a positive change in the knowledge, skill and expertise of those participating in the interventions, a significant proportion of which are carried out through projects. The enhancement of skill, knowledge and expertise underpins and is integral to the sustainable evolution of the infrastructure asset base. Therefore, this externality also needs to be recognised as intrinsic to any meaningful understanding of the value of any intervention in the railway infrastructure asset base.

1.7 THESIS STRUCTURE AND CONTENT

The thesis is comprised of eight chapters. The first four chapters set out the basic case and hypothesis with reference to some associated literature. Chapters 5 and 6 support the basic case through case studies. Chapter 7 addresses lessons learnt, indications of movement or change and suggests possible ways forward and methods of implementation. The final chapter draws overall conclusions and reiterates the contribution to knowledge and understanding.

The first chapter sets out to provide a basic context for the thesis and describes the principle components that will be central to the argument and how it will be supported through case studies. How an enhanced understanding of the notion of a sustainable intervention in railway assets leads to a shift of emphasis and modification of our assessment of value.

The Second Chapter considers this from the perspective of notions of sustainability or sustainable development. While recognising the association of environmental sustainability with engineering infrastructure, it argues that addressing the subject from a particular socio-economic perspective is particularly relevant to the maintenance and enhancement of railway assets.

The Third Chapter considers the subject from the perspective of the nature of railway assets, the constituent parts of the physical asset base and the aggregated system that they form a part of. It also considers the extent of the system boundaries and the possibility of their flexing to accommodate a broader infrastructural system.

The Fourth Chapter considers an approach that could provide a more effective description of value in relation to railway infrastructure investment. It describes the effectiveness of attempts at quantification and measurement through whole life evaluation but recognises their limitations. It goes on to consider the importance and value of expertise for Railway Infrastructure and argues that while it needs to be recognised as an externality in any calculation, it is intrinsic to any calculation of asset value.

The Fifth Chapter describes the Pilot Study at the Nottingham Hub, an exemplary rail infrastructure construction project which sets out to test the argument and hypothesis described in the previous chapters. It outlines the background to the refurbishment and configuration of the station, including interfaces with the Nottingham Tram and East Midlands Resignalling project, themselves the subject of case studies in Chapter 6. Chapter 5 also sets out the detail for the design and implementation of the surveys and interviews which were the means to contextualise and test the arguments and hypotheses. It draws initial conclusions while providing the basis for the more developed data gathering and analysis in the following Chapter.

The Sixth Chapter describes the case studies at Birmingham New Street, the Nottingham NET2 tram extension project and the Nottingham (East Midlands) Re-signalling project. Incorporating the lessons learnt from the pilot study, the case studies describe the survey and interview process and outcomes, including the emergent themes and draws conclusions from these to set up the final chapters.

Chapter 7 takes the conclusions from the previous chapter and considers the implications of the results and the themes that have emerged from the Interviews. It uses these conclusions to signpost or indicate a way forward and describes how the ideas presented have already gained some traction within the organisation and wider industry. It also suggests possible mechanisms for their future application within project, programme, portfolio management and organisational governance generally.

Chapter 8 draws some final conclusions that have emerged from the work and reiterates the contribution to knowledge and understanding. It considers the nature and implications of the shift of emphasis towards expertise enhancement when evaluating potential project benefits. Putting the work in the context of the Pandemic and imminent restructuring of the rail industry, it also summarises some of the significant lessons that were learnt from the research as well as potential developments for the future.

2 SUSTAINABILITY – A WORKING BALANCE.

This chapter considers our understanding of the notion of sustainability and its different dimensions. In particular, the tripartite distinction between social, economic and environmental sustainability. It briefly considers its predominant association with the environment and the management of natural resources. It then goes on to consider its socio-economic aspect and how a particular form of economic thinking was able to provide a degree of realignment. In particular in relation to the management of and engagement with human resources. It considers how not only environmentalists but also economists have been able to influence national and supra-national policy frameworks and how this is relevant to rail infrastructure.

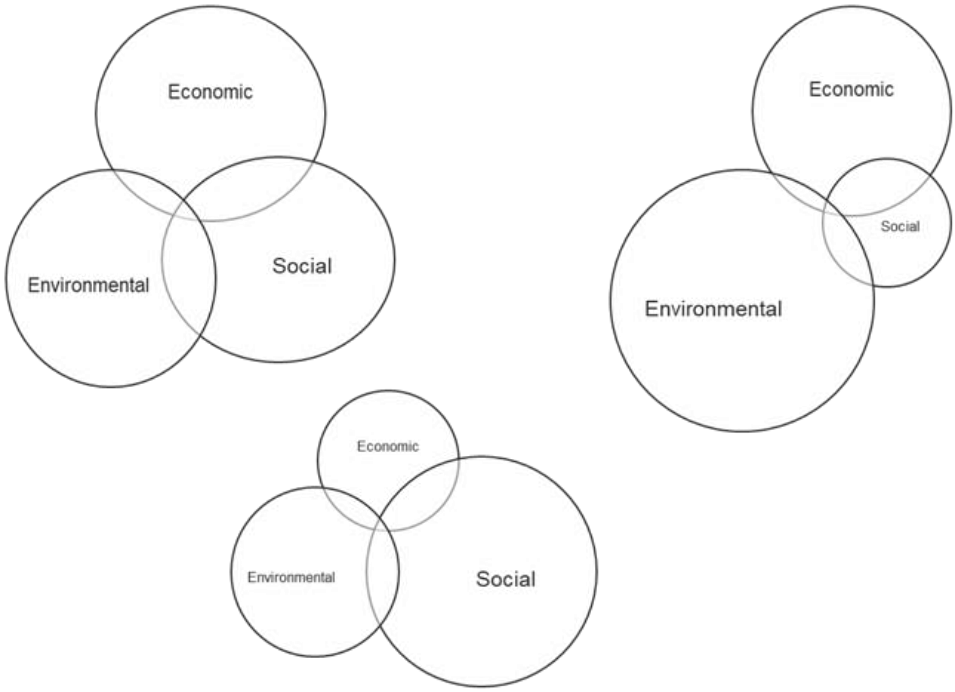


Figure 2-1: Potential shifts of emphasis between the tripartite aspects of sustainability (extract from Langdon et al 2016)

2.1 A TRIPARTITE BALANCE

The notions of ‘sustainability’ and ‘sustainable development’ are still relatively new and evolving concepts which carry significant implicit meaning while at the same time being subject to innumerable definitions and interpretations.

The United Nations report written by the World Commission on Environment and Development (WCED, 1987) describes the nature of the social, economic and environmental equilibrium required for all development activities. Most commonly associated with the Norwegian Prime Minister Gro Harlem Bruntland, it defines sustainable development as: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UNCED, 1987). Indeed, since this report, the position has deteriorated and the projections have worsened significantly in the interveneing thirty years with the ‘5 ‘Reasons for Concern’ highlighted by the Intergovernmental Panel on Climate Changes 2018 report (Byrne and Lund, 2019). The Bruntland report had sought to take a comprehensive view of sustainable development encompassing what are often referred to as the three legs of environmental, social and economic sustainability. This tripartite view has also been reflected in other descriptions or interpretations of the topic. For example, the BSI’s “enduring and balanced approach to economic activity, environmental responsibility and social progress” (ISO, 2008)

The publication of some early classics provided an environmental emphasis to this tripartite concept. These included, Rachel Carson’s ‘Silent Spring’ (Carson, 1962) which described the disastrous effects of the extensive use of pesticides on the environment and has often been associated with the initiation of the environmental movement. Or Lovelock’s ‘Gaia’ (Lovelock, 1982) which described the planet as a finely balanced ecological system with a range of subtly evolved interdependencies which needed to be kept in balance if the health and integrity of the planet is to be maintained. Both authors directed their attention towards the environmental impacts of damaging human development. This focus together with the array of arguments that accompanied them were consistent with the view that without a habitable environment neither economic nor social structures can function effectively. They brought attention to bear on the abuse of the environment at a time when little notice was being paid to the implications of human activities on its intricate checks and balances. Indeed the emphasis on the environmental dimension has increasingly come to be regarded as the ‘sine qua non’ for the other aspects of sustainability. Without a physical environment, it is argued there can be no society or economy. Such a conceptual hierarchy is exemplified in subsequent sustainability ‘models’ which have presented environment as the all-encompassing aspect. (Giddings et al., 2002 p192).

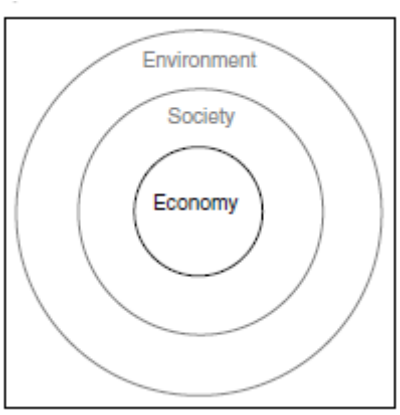


Figure 2-2: Figure 2. Diagram from Giddings, Hopwood, O'Brien Paper depicting the Nested model of sustainable development– with the economy dependent on society and both dependent on the environment.

Of course it can be argued that this tripartite compartmentalisation of sustainable development into economic, social and environmental divisions is itself a contrivance. Indeed It does not neccessarily need to be confined to these three descriptors and other potential pillars, such as 'Institutional' (Graymore et al., 2009) or Cultural/Human' (Hawkes, 2001) have been put forward as a supplement to them.

However it should be noted that these are conceptual compartments and as such should not be asked to do more than they are equipped to do. While it appears as self evident that it is necessary to have an environment within which social and human interaction can occur that is not the same as saying that one conceptually pre-dates any other. It can be argued that as anthropomorphic concepts they have equal status. At whatever point it is possible to conceive of the notion of an environment it is also possible to conceive of the notion of a society or even the notion of an economic transaction. It could be argued that these and other similar concepts such as 'Institutional' or 'Cultural' are in fact mutually interdependent, symbiotic concepts and simply provide different perspectives rather than having hierarchical or existential qualities. That is not to say that the environmental challenge should not predominate as an existential threat; but rather that trying to over refine a conceptual model in which it figures alongside others can be misleading.

Essentially, the purpose of such models is to prompt or restore a self-sustaining systemic balance (Dietz and Neumayer, 2007) to a whole system, within which the subdivisions shift and flex in order to establish their optimum configuration. Whether one dimension is more important than another is of less significance than the fact that the system and any interventions in that system move towards a benign sustainable equilibrium. So, if an 'economic' or 'social' rather than an 'environmental' intervention serve as catalysts to achieve that objective then this purpose is achieved.

Therefore, as concepts, or conceits, such notions as environment, economy and society are equally effective notions that have the equivalent existential qualities as concepts and should be treated as such. They are there to perform a function in providing useful perspectives from which to view the systemic challenge associated with Sustainable Development in order to prompt potential routes to the necessary interventions that can engage with the associated challenges. In this they can serve an effective purpose, however they should not be expected to do more than that.

While noting its limitations, the tripartite division has generally proved to be effective in providing generally accepted and recognisable categories within which to organise the associated activities and channels of thought. A structure that has contributed to the evolution of a commonly recognised concept of sustainable development that we have today. Indeed it was from a particular tributary of economic thinking that sustainable development received a significant nudge that generated a significant change of emphasis and some powerful advocacy.

2.2 A SOCIO-ECONOMIC OPPORTUNITY

Given the effect of the socio-economic forces that motivate and guide human activity; it was not surprising that it was from the field of economics that two of the most powerful and effective advocates of sustainable development have emerged.

Schumacher's 'Small is Beautiful' (Schumacher, 1973) drew together the social, economic and environmental dimensions of human activity from an economic perspective. By pointing out the ways in which industrial consumption patterns were undermining natural resources by mistaking 'capital' for 'income' (Broersma et al., 2015) Schumacher made a powerful economic case for environmental protection and conservation. He also challenged economic orthodoxies by pointing out how current economic theory, in its quest for efficiencies at the expense of human dignity, undermined the multidimensional value of work as a lifelong process of self-improvement This notion of self improvement and continuous and continuing learning in the workplace was a significant theme to emerge from the case studies and also plays a prominent part in the ways in which (7.2 and 7.3) the argument contained in this work are gaining further traction.

Unfortunately the realities of post industrial Europe did not neccessarily lend themselves to the realisation of such creative evolution through extended and extensive learning. Economic orthodoxies and efficiencies of scale that accompanied the Industrial Revolution meant that mechanised repetition was often considered more effective and efficient in the production process. The recognition and appreciation of depth and breadth of skill, knowledge and expertise became significantly tempered by the need to harness all resources, human or otherwise, for the delivery of labour saving' tasks. Activities that could repond effectively to the economies of scale brought into stark relief by the innovations of mass, mechanised production (Allen, 2009).

Of course the existence of mechanised industrial production in some areas of commercial activity did not preclude the accumulation, application and modification of skill, knowledge and expertise. Indeed it was an essential pre-requisite for the number of technological innovations and their commercial exploitation that occurred during this period. However the same economic logic meant that the human interface with the production process should be minimised and mechanised in order to facilitate the process of apparently efficient mass production. A view that, to some degree, persists today with the view that efficient use of human resource in projects entails minimising its interaction with the workstream or project (ref 7.4.4 and 7.4.5). Once the initial innovations had been initiated and their future evolution supported, there was little value to be derived from the creative potential of the human resources that would be needed to maintain the production process.

This minimising of human interaction with the production process could be contrasted with the extensive, complex, yet practically applied process of iterative learning which was effectively demonstrated in the apprenticeship system that had evolved from the late middle ages (Lane, 1996). The recognition and evaluation of this challenging passage through the stages of applied domain knowledge was formalised

by the various craft guilds which applied a range of benchmarks ranging from Novice to Master as demarcations (Hoffman et al., 1995). This was an extended and extensive learning process and the passage through the stages needed to be recorded and benchmarked in order that an individual's capability at any point in time could be assessed and monitored.

These contrasting approaches to the nature of work and the engagement of human resource potential to undertake it, provided an appropriate backdrop for such a significant economic intervention in the area of sustainable development. Schumacher considered that work should not be about the mechanisation of industrial production. If human potential was to be realised, the working environment needed to accommodate the human instinct to develop and create solutions to problems. That is, to recognise opportunities that arose in the course of well targeted endeavour and that engagement in such activities enabled a greater insight into the true nature of work. An essential human aspiration, which included affording respect to those undertaking it.

Scale also plays an important part in Schumacher's thinking: That in order to optimise a genuine economic opportunity it was important to understand the appropriate scope and scale of the endeavour. It was therefore necessary to appreciate the full extent of the system that was involved and accordingly to apply the right level of resource to realise its potential and to scale the system solution appropriately. This implied that the system needed to be understood or evaluated from the correct perspective. Also that mechanistic processes of measurement were not applied inappropriately. In 'Guide for the Perplexed', Schumacher referred to this type of inappropriate thinking as 'Scientism' (Schumacher, 1995), in that it sought to reduce all meaningful knowledge to that which can be validated by Scientific falsifiability. In addition economics was circumscribed by rules, constraints and what many regarded as inappropriate mathematical models and sought to present economic theory as scientific fact without justification. Scepticism about the ubiquitous application of scientific method had also been voiced by such disparate thinkers in the disciplines of science philosophy and Economics, including Popper and Hayek (Magee, 1985) (Popper and Hudson, 1963). More recently Mariana Mazzucato continues this sceptical approach to the inappropriate application of 'scientific analysis' to economic evaluation in her attempt to recognise, define and evaluate 'productive work'. A comprehensive ascription of value has always 'involved malleable socio-economic arguments' and that these in turn are ultimately dependent on a particular political perspective rather than misapplied scientific analysis. (Mazzucato, 2013) And in the 2020 Reith Lectures the ex Govenor of the Bank of England Mark Carney, recognising the limitations of economic analysis, described to the tendency among economics to claim scientific validity as 'Physics Envy' (Carney, 2020).

The significance of appropriate calibrations for quantitative and qualitative evaluations were consistent themes to emerge from the case studies

Thirty years later another Economist, Nicholas Stern, was to lend further economic support to the urgency of the case for environmental sustainability; this time in a more urgent guise of climate change mitigation and adaptation. He emphasised that the critical nature of these issues had become an

essential prerequisite for economic as well as environmental thinking. (Stern, 2006). By describing and quantifying albeit imperfectly, the 'economic cost' of environmental inertia he made explicit the way in which economic thinking could be brought to bear as a catalyst for environmental change. Stern certainly recognised the urgency of the task. 'We have the time and knowledge to act but only if we act internationally, strongly and urgently' (Stern, 2008). Again, the environmental case for sustainable development was supported by an informed and comprehensive understanding of economic thinking.

While Schumacher had been able to make the connection between the misuse of our natural resources or assets and the misuse of human potential. Stern's work brought the message sharply up to date, with its focus both on the severe implications of the environmental impacts of economic inertia as on the severity of the economic impacts of environmental inertia. Once again the language of economics was harnessed for the enactment of sustainable development. The shift of emphasis towards socio-economic sustainability also had the effect of increasing the environmental focus as well.

Other economists have subsequently sought to address these continuing questions. Much of the discussion has centred in on the notion of Capital and what are described as the particular and different forms of Captial. This notion was introduced into economic dialogue by Gary Becker in 1992 (Becker, 1962) He also sought to portray human potential in economic language, surprisingly seeking support in this endeavour from Adam Smiths notion of 'a capital fixed and realised' in the individual . Subsequently, notions of natural capital have been categorised under different headings and described in different ways. Forum for the Future (Forum for the Future, 2020) refer to Natural, Human, Social, Manufactured and Financial. Godfrey (Godfrey, 2014) refers to Institutional, Social, Human, Organisational and Physical. Both include the notion of Human Capital in their different compartmentations of capital and both invest in this notion some common threads, which include 'skills' and 'knowledge' and the idea of a potential value that is available to be realised.

Neumayer and Dietz (Dietz and Neumayer, 2007) also refer to different forms of capital: Produced, Natural, Human and Social as a part of the broader discussion of the Notion of Weak or Strong Sustainability in the System of Integrated Environmental and Economic Accounting (SEEA).

Weak or Strong Sustainability were concepts introduced to refer to the substitutability of the forms of Capital and specifically whether Natural Capital can be substituted by other forms of capital when calculating the sustainability of different interventions. Advocates of Strong Sustainability argue that as a non-renewable resource Natural Capital should be inviolable and unsubstitutable. Whereas the proponents of weak sustainability argue that substitution is possible if adequate mitigations are put in place. This work, in its advocacy of the skill, knowledge and expertise most closely associated with Human Capital, presents a position where this particular juxtaposition between 'weak' and 'strong' would become less significant the greater the level of expertise brought to bear on whichever question it was addressing. An exhaustive evaluation of the conceptual and practical issues associated with the question informed by the skill, knowledge and expertise of those undertaking the evaluation would provide the best available opportunity to ascribe an appropriate attribution of value to these

interpretations of these different forms of Capital. Therefore, it can be argued that the move towards the ascendency of skill knowledge and expertise and its manifestation in the notion of Human Capital would de facto result in the prioritisation of a comprehensive understanding of the critical issues at stake. And as a result questions such as which conceptualisation should be prioritised over others will fall into their appropriate and substantiated place. In other words, the engagement of the skill, knowledge and expertise of people is the sine qua non of any possible sustainable solution. In the same way that the logical, ecological or chronological primacy of natural capital is undermined if those who can work towards the appropriate attribution of value and enforcement of that evaluation are not adequately engaged or prioritised in the enterprise. Similarly this work is arguing, in the context of rail investment, that the effective deployment, of skill, knowledge and expertise, (conceptualised within the notion of human capital) would result in the most effective attribution of value for such investment because such an effective deployment would subsume any alternative more incremental, compartmentalised and sub-optimal attributions of value. It could even be argued that the prioritised deployment of Human Capital is not only a necessary condition to achieve optimal sustainable interventions in rail assets but could even be considered as a sufficient condition to do so.

Economists such as Mazzucato have argued for the placing of value in its most appropriate location. That is to say, with those who work to create it and that it is the responsibility of governments to put in place the appropriate conditions for those efforts to be optimised (Mazzucato, 2013). The notion of re-locating value from inappropriate to more appropriate location is also demonstrated by Diane Coyles critique of GDP and her advocacy of a different approach to economic measurement (Coyle et al., 2017). Key to this new approach would be the measurement of six types of economic assets: Physical, Net Financial Capital, Natural Capital, Intangible Assets, Human Capital, social and Institutional Capital. With Human Capital refering to the familiar notion of skills in the form of accumulated, adaptable skills.

Of particular interest here, is how these early founders of and subsequent contributors to, the movement, made the explicit and implicit linkage between the environment, society and the commercial medium in which they operated and how factors which might appear to be outside or external to a conventional understanding of a system of economic transactions and economic orthodoxy were nevertheless deemed to be a crucial part of that interrelationship.

2.3 THE PURPOSE, VALUE AND NATURE OF WORK

If we regard genuinely productive work and the learning process that accompanies it, as an essential part of the human condition (Yeoman, 2014). We can also argue that a self-motivated, self-improving and self-sustaining workforce will contribute with greater energy, enthusiasm and capacity to individual, local, national and regional output**.** This would seem to suggest the existence of some forms of

interrelationships or interdependencies between individual self-fulfilment genuine productivity and sustainable economic growth. It could also be argued that methods, mechanisms and processes are used to structure Human Work can facilitate or impede this process.

Three of the Seventeen Sustainable Development Goals (SDGs) (United Nations, 2007) explicitly refer to these key ingredients of socio economic infrastructure. However benign forms of human work can be said to be a key prerequisite for all of them. Notwithstanding the need for effective integration of the different goals (Lim et al., 2018); 'Decent work, employment creation, social protection, rights at work and social dialogue represent integral elements of the new 2030 Agenda for Sustainable Development. Furthermore, crucial aspects of decent work are broadly rooted in the targets of many of the other 16 goals'.(United Nations, 2007 topics / employment). Not least goal number 9, 'Industry, Innovation and Infrastructurre'.

There is then the opportunity that if harnessed correctly this human potential can contribute significantly to the solutions required for our social, economic and environmental challenges and opportunities. To provide some form of insight or perspective on the prerequisites for sustainable development. This is increasingly relevant today in our need to gain a greater understanding of the nature of work and the associated working environments through an evaluation of: The type of work available, the motivation for work, the way people work and the resulting effect on skills, expertise and knowledge.

The extensive scope of infrastructure provision and its incorporation of the associated capabilities to realise that provision would be an appropriate environment to achieve this (Spencer and Budd, 2015) (National Infrastructure Commission, 2016). There have been a broad range of studies that consider the economic, environmental or social provision of transport infrastructure (H M Treasury, 2015c). They refer to the social benefits of providing greater transport links, the benefits of investment on growth, or the 'wider economic' benefits of transport infrastructure investment. They generally address the benefits gained by those who receive the provision and the improvement to their circumstances; often described as user benfits. This work is presenting the case, however, that there is also an underappreciated opportunity to also take significantly greater account of the multi-faceted benefits that accrue to those working on and delivering the work-streams associated with Infrastucture projects. And to apply that recognition more directly when establishing project viability

2.4 SUSTAINABILITY IN THE CONTEXT OF TRANSPORT INFRASTRUCTURE

Apart from improved transport links and agglomeration benefits for passengers, businesses and freight users, 'Sustainable Development' can serve as a catalyst for a range of associated benefits at local, regional and national level in a number of ways. These include; business for local supply chains, regeneration that provides new infrastructure for area development and through the job market by creating jobs with a comprehensive range of skill requirements. The opportunity for transport infrastructure in general and rail infrastructure in particular to accommodate such an evolution sustainably is described implicitly and explicitly in a range of policies, strategies and position papers.

The pursuit of these benefits at European, national, regional and local level is reflected in the corresponding different levels of governance. This includes the European Commissions' 'White Paper on Transport. – (Road map towards a competitive and resource efficient transport system. (European Commission, 2001). The White Paper set out the basis on which European transport policy needs to be directed. "Transport is fundamental to our economy and society. Mobility is vital for the internal market and the quality of life of citizens as they enjoy their freedom to travel. Transport enables economic growth and job creation: it must be sustainable in the light of the new challenges we face." (European Commission, 2001). Recognising its shortfall, it points to the need for effective international cooperation in order to achieve its objectives.

The White Paper nevertheless sees transport policy as a significant catalyst for socio-economic improvements across the European regions, while providing a solution to many of the apparently intractable environmental challenges faced in the move forward into the next stage of European development, in whatever form that takes.

While, the reference to 'sustainable' in the white paper appears principally directed towards the environmental aspect of sustainable development, it nevertheless makes clear the direct connection with infrastructure and economic growth. However it points out that while the influence of transport infrastructure investment is essentially positive it has to be achieved in a way that minimises the negative effect on the environment (European Commission. Directorate General for and Transport, 2011 p 5)

Again the European paper noted the potential positive impact on economic growth and social benefit. It focused on the need to minimise the Environmental costs of pollution - the avoidance of the negative - as it moves towards the 'internalisation of external costs'. However the paper makes less reference to the opportunities to enhance the positives, In order that their significance is taken into account it is important that these 'positive externalities' should be given appropriate weighting in terms of their potential influence on policy which would ensure that they would have the intended effect on their wider spheres of influence. However many of these benefits are not immediately quantifiable and are therefore external to the calculation of monetary value. For example the building of a new station or interchange

can serve as a catalyst for the regeneration of an area as well as promoting more sustainable behaviour through means such as modal shift to cycling and car sharing (European Commission, 2001).

In addition, the white Paper pointed out that such investment offers an opportunity to enhance the economic robustness and competitiveness of European Operators by increasing the quantity and quality of long term career and employment opportunities. An aspiration that would be achieved through the improved training, certification and working conditions. (European Commission, 2001 p21). It moves on to emphasise the importance of research, development and innovation and how demonstration projects will promote further adoption by the market and in its search for an efficient and user friendly system it puts considerable emphasis on the notion of 'key technologies'. (European Commission. Directorate General for and Transport, 2011) .

Such a systemic relationship provides the opportunity to achieve a cohesive demonstration of 'technological' or 'technical solutions', the expertise needed to bring them about and the consequent overall benefit that can be achieved as a result. The equating of technical and technological and the separation of these activities from other outputs and activities are constant modes of description or themes in many of the domains associated with transport infrastructure. However, this hard conceptual separation can lead to a misconception of the relationship between the technologies and the multidimensional technical capabilities that need to be brought to bear in order to bring about their realisation. That they are in some sense disconnected rather than being intrinsically linked. While such an approach places this concept of a 'technology' within a systems context; such a separation or isolation of technologies from the skill, knowledge and expertise of those responsible for its creation can contribute to a range of Category errors. Particularly in the way that it suggests a difference in kind between the technical solutions and the people who brought them about. This is considered further in 3.2 below.

Its advocacy of transport infrastructure as a catalyst for growth and the incorporation of a systems based approach includes the opportunity to realise the economic benefits through a broader systemic integration of human resource potential. Something that might be described as 'a system beyond the system'.(INCOSE, 2021)

Given that the financing of these initiatives are obviously key to their success, the White Paper addresses financial mechanisms to incorporate the externalised transaction costs into the Internalised transaction costs: To make the 'externalities' an intrinsic part of the calculation. Although, the white paper focuses on carbon and the opportunity to mitigate environmental pollution the principle would be equally applicable to socio-economic externalities. And while the references to sustainability tend to appear to equate to environmental costs, the implication of the line of argument can also suggest the inverse: The internalisation of external benefits. Despite referring to skills training, quality jobs and career development, there is no explicit reference to the potential valuation of expertise enhancement as an externality or as an internalised benefit.

2.5 SUSTAINABILITY IN THE NATIONAL CONTEXT

This broader perspective that was reflected in the European White Paper has also been developing within National boundaries. Previous models used to justify investment were based on user benefit in terms of travel time saved, service frequency and capacity increases etc.

Published two years before the Stern Review (Stern, 2008); The Eddington Report (Eddington, 2006) broadened the perspective on the relationship between transport and economic success. The report described the linkage between 'a high performing transport system' and 'sustained economic prosperity'. It also made reference to Stern and the responsibility of rail to contribute to the reduction of carbon emissions. A year later there followed the department for transport discussion paper: 'Towards a sustainable transport system: supporting economic growth in a low carbon world' (Department for Transport, 2007). The paper sought to address the Stern and Eddington Reports and to prompt a debate as to how they could be translated into policy. How transport policy and strategy could positively influence both economic growth and climate change without compromising either. The report identified policy objectives that would facilitate this process. Specifically by maximising connectivity, capacity and performance while addressing climate change and by ensuring that health, safety and wellbeing were enhanced alongside equality of opportunity. In both these published reports there was an incremental shift of economic emphasis from treating transport as a 'passive' provision to being an active stimulus for growth.

2.6 PRIORITISING INVESTMENT TO SUPPORT THE ECONOMY

This gradual shift of emphasis regarding transport as a passive provision to being an active compliment to sustainable development was continued in Network Rail's joint discussion paper (Network Rail, 2010) which addressed the question of rail investment. It advocated shifting the focus of the benefits that were derived from rail investment, from the user to the wider economy. Arguing that such decision making should adopt an approach which 'prioritises the maximisation of economic growth'

In order to achieve this re-prioritisation the 2010 paper proposes the idea of a new appraisal model which would run in parallel with the traditional transport appraisal models with its 'wider economic benefits bolt on'. Instead of asking the question posed in the Green Book: "How do we best spend the

tax proceeds of economic growth to increase total welfare?" It suggested that a more productive question to ask would be: "How do we best generate the private sector economic growth that will generate tax proceeds?"

In advocating such a revised approach the paper pointed out that the current appraisal model, founded on the 'Green Book' (H.M. Treasury, 2011) set out a range of criteria to determine the acceptability of projects or programmes which are seeking to implement government objectives. It questioned whether or not there may be better ways to meet these objectives and the extent to which the available resources are being applied to best advantage. The two methodologies would be seen as quite distinct. The 'Real Economic appraisal', it argued, would become the fundamental driver with the more passive 'Benefit-Cost-Ratio' of the welfare approach forming a 'safety net'. 'Using a welfare BCR (Benefit/Cost Ratio) as a minimum threshold within an approach that seeks to maximise economic returns would in effect act as a backstop; a minimum guarantee that, even if the economic gains being targeted by a project or programme were not fully delivered, society as a whole was in a welfare sense better off as a result' (Network Rail, 2010).

This is an important distinction. It moves from a position where public service justification for investment decisions relating to infrastructure provision is achieved through an 'external' social contribution or 'bolt-on' benefit. To a position where they are being incorporated as an active driver for investment decision making. Thereby seeking to ensure that potential socio-economic benefit will be bound up in or integrated into the drive for growth. Generally described in terms of Gross Domestic Product (GDP), growth is 'a measure of the size and health of its economy. The total value of goods and services produced over a specific time (Bank of England, 2018).

It can be argued that implicit in this attempt to take a more comprehensive view of investment is a reinterpretation of the notion of growth that looks beyond a one dimensional, GDP measure to a broader more comprehensive and ultimately sustainable interpretation (Acemoglu, 2012). An interpretation which does not treat the types of socio-economic benefits that we have been considering as being external to the process – ie externalities. Rather it seeks to integrate these supposed externalities into a core transaction together with all the other associated costs and benefits. To internalise them. This distinction between the benefit-cost ratio as a minimum threshold and the greater targeted gains from projects that are envisaged in the Network Rail paper, has implications for the nature of the 'total welfare' that the Green Book was seeking to increase. The paper argues that this total welfare Increase' could be better served by the latter approach rather than the former. Thereby implying a re-assessment of the relationship of this 'total welfare' approach to the 'whole life evaluation of economic benefits that would be applied. Such an approach would need to take into account the breadth and depth of their effect on government objectives.

This would have implications for the 'whole system' approach that is implicit in a system engineering approach to asset management (Technical Strategy Leadership Group, 2012). It would also need to take into account the relationship with the Governments aspiration to incorporate social, economic and

environmental criteria into the way that the 'growth is generated through fiscal policy and regulation' in a way that would make it comprehensively sustainable. In short: to consider the breadth depth and extent of the system that is being envisaged. The paper also recognised the importance of 'coordinating' previously disconnected policy areas: in particular; transport, regeneration and housing Interventions.

Network Rail's 2010 paper was prompted by the need to address the, then, current fiscal deficit. Nevertheless, it presents the opportunity for rail, as a key infrastructure, (together with housing and regeneration) to be a catalyst for sustained and sustainable economic growth. The latest transport investment strategy (Department for Transport, 2017), reflecting the Industrial Strategy Green Paper (H M Government, 2017) also includes housing as one of its key components. This suggests that by aiming high as an economic catalyst, infrastructure investment will achieve significantly more benefits than just aspiring to a consequential minimum welfare provision. It should be noted that the emphasis subsequently shifted towards the use of the 5 case model methodology which seeks to evaluate schemes according to strategic, economic, commercial, financial and management objectives. Chapter 7 describes how this approach was adopted and applied in the business case for the Digital Rail Programme.

The 2010 paper also cites the Jubilee Line extension, the northern hub and the Greater Manchester Transport Fund as examples of how these broader benefits and 'real economic impacts' could be achieved. The latter, using this approach to evaluate potential schemes in several ways, including their impact on: "…jobs, productivity and therefore economic output' as well as 'considering the interventions on worklessness" (Network Rail, 2010). Clearly this approach encapsulated many of the core principles of sustainable development through the application of an appropriate methodology or 'prioritisation metric' where costs to the Greater Manchester Transport Fund (GMTF) were assessed on a whole life basis.

This broader more comprehensive view of rail investment represented by the 2010 paper was further developed and emphasised the following year in the first 'George Bradshaw Address' (Haythornthwaite, 2011) by the Network Rail Chair, Rick Haythorntwaite. Describing the place of the railways in the UK, Haythornethwaite saw the opportunity for the industry to act as a catalyst for a significant culture shift. The address was unusually wide ranging and drew together a surprising number of social, economic and Environmental strands.

Drawing attention to what he perceives to be a social fragmentation and disconnection as well as an unsustainable dependency on fossil fuels and lack of indusrial direction. Haythornthwaite points to the nineteenth century railway construction as an example of the potential of well designed infrastructure to reprogram or 'rewire' our socio-economic future. Seeking to galvanise those in power, he pointed to the opportunity offered by the urgency of an economic crisis to act. He draws on the notion of rail infrastructure as a system of wiring that can link and bind together a fractured economy and society and that to do so requires a comprehensive engagement with those that have a stake in the infrastructure in order to achieve a post-industrial knowledge based shift rather than a society directed from above.

In the nineteenth century, the effects of this rewiring were profound, fundamentally affecting peoples' understanding of the world they lived in. Labour became mobile, cities were connected and all were bound by the railway clock. (Gourvish, 1980). It can certainly be argued that the opportunities available today could be equally significant if the potential of those that contribute to the system is realised in a way which is at least as expansive as it was two centuries ago.

This perspective not only recognises Rail as, itself, a key economic infrastructure but also points the way towards its closer alignment with the social infrastructural system as well. This notion of a 'rewiring' process appears particularly appropriate, in relation to the systemic inter-connections across previously segmented elemental demarcations and is discussed further in the following chapters. It also emerges as a consistent theme and condensed theme in the case studies (Figs 6.1 and 7.1).

The scope and scale of these potential interconnections between Rail Infrastructure, social cohesion, environmental integrity and by implication the consolidation of a knowledge based economy continues to be of considerable significance. It could also be inferred that this new approach to infrastructure investment and the potential systemic 'rewiring' suggests an opportunity to realign the 'wiring' in a revised infrastructural configuration. A revised configuration that would put greater emphasis on the 'knowledge' base necessary to achieve it.

Indeed the opportunity to use such crises as catalysts for action could be equally applicable today in relation to the Covid Pandemic as it was in relation to the 2011 economic recession. This is enhanced at the current time by the Williams-Shapps review (Williams Shapps, 2021), the latest of a series of reports which have sought to address the huge potential as well as the counter productive and disfuntional complexity of the rail industry. In the 2019 George Bradshaw address Keith Williams, as a precursor to the 2021 review refers to the gap between the rail industry and passenger perception of its service delivery. An observation reflecting Haythornetwaites, about public and passenger inclusion, seeing them as an intrinsic part of the system. He also makes reference to the enthusiasm, knowledge and potential of those working in the industry while lamenting the capability to serve the customer or passenger needs. While it is necessary to draw attention to the importance of the passenger as apart of the system. It is equally important to respect the importance and quality of the Engineering substructure on which it depends. This work would argue that a railway which priorities the evolution of the skill, knowledge and expertise of the people who operate the railway in all its dimensions will by default maintain the integrity of that whole system.

This recognition of the value of systemic interconnections and systems thinking has been gaining prominence in a range of related organisations and their publications (see section 3.2). This was reflected in the National Infrastructure Commission's frames of reference for its ongoing assessment and reassessment of national infrastructure provision: The National Infrastructure Assessment noted the importance of not tackling the different economic infrastructure sectors (Transport, Digital and communications, Energy, Water and Drainage, Flood defences, Waste') separately

(National Infrastructure Commission, 2017 p10) as well as in the National needs assessment (National Infrastructure Commission, 2016). However there was also a significant recognition of the importance of working towards an alignment between engineering capabilities and the necessary social awareness that would ensure their responsible implementation. In his Inaugural address as president of the Institute of Civil Engineers, John Armitt addressed this question. He called on those engineering disciplines to demonstrate their broader relevance to society and not shy away from challenging the reasons for the design and construction of all forms of engineered infrastructure. To not avoid the 'Why' question when answering the 'What' and the 'How' questions. *(Armitt, 2015)*

A significant shift of emphasis, which brings into relief the view that those responsible for the provision of engineering design and implementation need also to have some perspective on the extent of their contribution to society. However this could go further and should not simply be about the form and robustness of the design. Whether the solutions should be designed and built for a twenty, thirty, fifty,seventy or one hundred whole lifespan .It should also be about the fundamental societal value of undertaking the work and the potential value that might be generated from its realsisation.Not just the benefits accruing to the material economic and social infrastructural provision But also the benefits that would accrue to the evolution of the domain specific knowledge infrastructures and their interface with other domain specific knowledge infrastructures. And the potential benefits that would accrue to the evolution of human capital as a result.

2.7 THE EVOLUTION OF EXPERTISE IN THE RAIL INDUSTRY

The provision of national infrastructure is a technically, socially and politically complex series of activities. As in other industries, the rail industry undertakes those interventions deemed necessary to maintain and enhance its assets principally through projects and programmes. These changes usually involve some form of modification to the elements and systems that make up the asset base. The extensive projects and programmes which deliver these changes require a broad range of capabilities, competencies, skill, knowledge and expertise. In particular those that fall within the domain of rail engineering and the associated engineering and construction disciplines that design and deliver the provision deemed necessary at any point in time within thecontext of an appropriate strategic and policy framework

The capabilities that are required to undertake this provision include detailed domain knowledge as well as the ability to engage with a broad range of stakeholders in a complex, dynamic environment. The national infrastructure commission briefing document cited in the previous section referred to ecomomic infrastructures and their systemic linkages and that these defined its scope of activities. The treasury

guidance document:'Valuing Infrastructure Spend – Supplementary Guidance to the Green Book' (H M Treasury, 2015c p3) also made reference to the economic infrastructures but also pointed out that while it was developed for economic infrastructures it would also be applicable to the social infrastructures (eg: schools, prisons, courts, hospitals and more extensive regeneration projects) as well.

The overall engineering enterprise and the delivery of the required asset base provides a rich multidimensional context for the enhancement of the broad range of disciplines and domains which contribute to these complex system solutions.

Underlying the physical asset base is the intellectual asset base of which it is formed and on which it depends. The effectiveness, value and robustness of this intellectual asset base or infrastructure is dependent on its continuing evolution. An evolution which in turn is dependent on a process of knowledge accumulation, iteration and dissemination, combining the integration of formal instruction and informal learning that comes about as a consequence of participating in projects. Of course a consequent expertise enhancement for one project may well contribute towards the pre-requisite skill requirements for another. And so the cycle continues.

[5]However unless this consequential enhancement is recognised as a viable project output and benefit it becomes a dissipated outcome rather than a targeted output of project delivery. Its value and benefit, therefore not taken sufficiently into account when evaluating potential benefits for subsequent projects and programmes, thereby maintaining a disconnection, not only between projects and programmes but also between the preconditions for them. That is: the extended and extensive process of skill, knowledge and expertise accumulation that has evolved up to that point and without which informed progression is impossible.

Implicit throughout this process of expertise accumulation and assimilation, are the ongoing mentoring activities. Often taking place within a project environment, which provides the conditions for this type of naturalistic learning and decision making (Patterson et al., 2010) to take place. In particular to accommodate this multi-dimensional knowledge dissemination and accumulation and to facilitate its passage through the stages outlined above.

Much of the literature relating to the evolution of Knowledge, Skill and Expertise have drawn attention to the wholistic nature of the process (Wilson and Sharples, 2015b p 14). That the accumulation of expertise is not a one or two dimensional process of increasingly narrowing knowledge accumulation. As a systemic process, it cannot be meaningfully separated from the live context in which lives are lived and decisions are made. And that expertise evolves within the context of a 'tacit knowledge framework' that structures its development within different forms of organisation. (Lam, 2000).

Such an expansion of context or breadth of reference provides a significantly improved perspective for those needing to make more informed strategic decisions within their spheres of influence. Given the opportunity outlined above to address the 'Why' question it also offers the possibility of taking some level of responsibility for the direction of travel as well as the means and method of getting there. So

while engineering solutions will continue to be concerned with the 'What' and 'How' questions, those providing those solutions are also being increasingly challenged to explain the social, economic and environmental justification for their decisions. The implications of this within the context of a 'Systems' or 'System of Systems' approach is particularly relevant for all forms of infrastructure: '….An important thing to note is that a SoS approach is not only concerned with the physical infrastructure, such as dams, roads and pipeline, but also with social, financial and political infrastructure….'. (MengChu et al., 2015 Ch 2 p39) The Systems and Systems of Systems approach will be discussed further in the next chapter.

2.8 CONCLUDING DISCUSSION

This chapter has considerd the tripartite notion of sustainability in the context of engineering infrastructure which has naturally tended to focus on its environmental aspects. While acknowledging the conceptual limitations of the tripartite model and the further conceptual limitations of other models which have sought to refine its representation even further. There has been an understandable tendency to focus and be associated with the misuse of natural resources and consequent environmental impact. It can, however, be argued that it is particularly through an improved application of human resource potential that there is a significant opportunity to realise the greatest value invested in the entire asset base through astutely targeted interventions.

It has considered how a shift of emphasis towards this dimension of socio-economic sustainability would re-emphasise the value of human resource potential as an intrinsic part of a systemic approach to sustainable development, therby also enhancing its environmental aspect as well.

It has gone on to consider the effect of certain economic thinking on the movements' origins and its relevant contributions in this context. Central to this was an acknowledgment of the intrinsic value of human endeavour and the need for this to be acknowledged and harnessed to provide a more suitable environment for its realisation.

It further considered: The ways in which industrial strategies offer the potential to adapt to this modified approach to enable the delivery of industrial outputs. The role of those engaged in the delivery of projects and the need to be more conscious of the 'whole' endeavour, the whole system to which they contribute and why this broader context matters. And further, how this revised perspective provides greater insight into and greater recognition of the multifaceted spectrum of skill, knowledge and expertise that are essential prerequisite for the delivery of a rail infrastructure projects.

It went on to describe how this type of approach is aligned with and easily accommodated by the strategic thinking that has been emerging from the rail industry in general and infrastructure-provider in

particular. As a provider of a sustainable transport system and guardian of and ‘conscience’ for rail’s infrastructural assets, this offers a good opportunity to demonstrate how these sustainable development principles can be applied in the context of a benign infrastructural system. And that the delivery of infrastructure generally and rail infrastructure in particular can recognise and accommodate this shift of emphasis towards the socio-economic benefits in general and towards one socio-economic benefit in particular.

Such potential rewiring of a key mode of a key economic infrastructure offers the opportunity to shift the emphasis towards the potential of its prime resource: The skill, knowledge and expertise of its people. The management of these systemic changes would be aligned to the trajectory of evolving capabilities and could in turn be aligned to and implemented through, interventions that frequently took the form of projects.

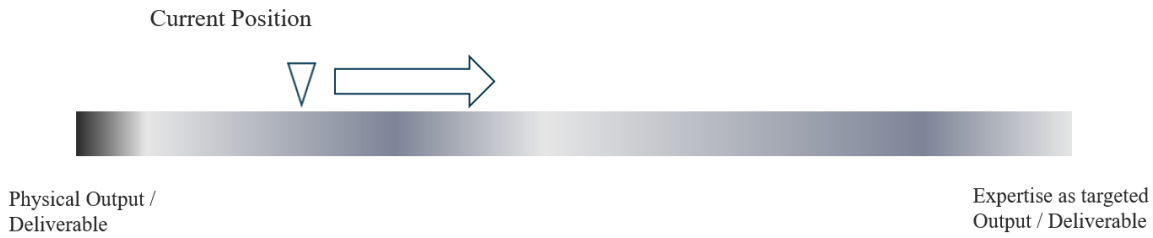


Figure 2-3: Proposed shift of focus along the deliverables – expertise spectrum

The next section considers the context in which these changes would take place: The asset base of the rail industry, its constituent parts and how they align to a systemic whole that is enabled by the evolving capabilities of its people.

3 A SUSTAINABLE RAIL ASSET BASE

This chapter considers the degree of alignment between the ‘rewired’ knowledge/skill/expertise infrastructure and the arrangement of the physical asset base. How they are viewed. Whether the emphasis should be on the functioning of the elements, the system they form a part of, or the service that needs to be delivered and the way in which these are prioritised in a broader social, economic and environmental context. It also addresses the extent to which infrastructure as a whole, transport generally and rail in particular, have the potential to accommodate this shift towards a re-emphasis on the expertise that is a necessary constituent of that infrastructural system.

3.1 THE ELEMENTAL ASSET BASE

The generally recognised subdivision of asset types in the industry are comprised of: track, signalling, structures, buildings, electrical power, telecoms, earthworks, level crossings, drainage, fleet. These subdivisions take place along carefully considered lines that have evolved over time (Network Rail, 2011) .

The image below of Birmingham New Street station provides a graphic example of the complexity and interconnectedness.of the different railway assets. In this image alone we have examples of track, signalling, structures, buildings, electrical power, telecoms, and drainage.

Figure 3-1: A range of rails physical assets on display at Birminham New Street station

A brief summary of the asset types are listed below:

Track: ‘supports the weight of trains and provides a guided path for them to run between locations’. This consists of fixed plain line and movable rails (switches and crossings) which enable trains to move from one plain line track to another. The components that constitute the track consist of: rail, sleepers, fastenings, ballast, formation and drainage.

The image below provides a graphic representation of the permanent way and describes a core railway asset: Plainline track. This is a deceptive impression of straightforward uniformity and simplicity. However there are several complex and sophisticated engineering disciplines and interfaces implicit in the successful installation in this section of track and its interaction with rolling stock. These include: The essential drainage system and its connection to the broader drainage infrastructure of the local area. The underlying formation of the ground and supporting structure for the track. The Ballast which provides an effective interface between the formation and the sleepers and running rail. The intricacy, subtlety and complexity both within and between these engineered systems require continuous focus, application and ongoing research and development.

Figure 3-2: A section of Plain Track viewed from the cab.

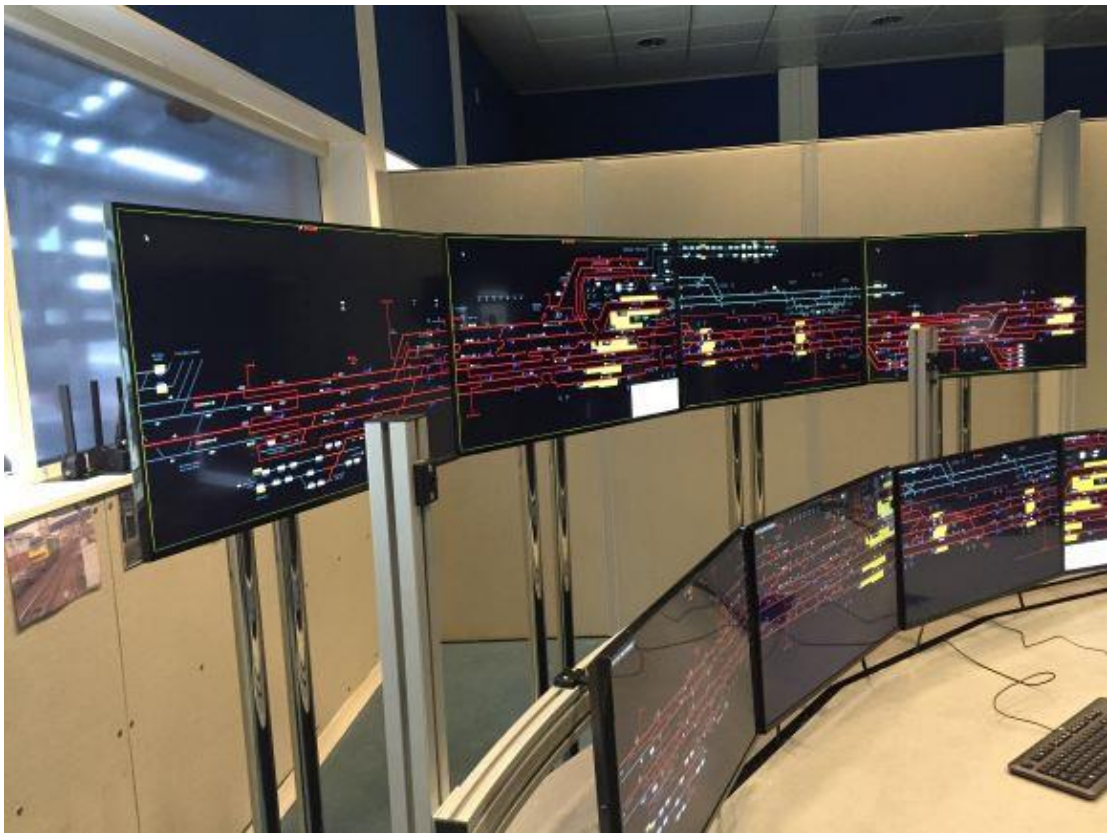


Figure 3-3: A display of route information at a Rail Operating Centre

Signalling: The management and control of the safe movement of trains is fully dependent on the signalling system. There are a range of technical solutions, originally evolved from the eighteenth century, which follow the 'Block Section Principle'. The block signalling principle ensures that no more than one train can occupy a designated 'section' of track at any moment in time. Note: The Digital Rail programme and the associated signalling systems are working towards a safe and carefully managed evolution away from this long established principle. The signalling assets are comprised of: Signallers Control Systems, Interlockings, Communication systems, Equipment Housings, Points, Signals, Train detection, Level Crossings and Other components. These are coordinated and controlled from the relatively new Railway Operating centres, as illustrated in Figure 3-3.

Structures Asset groups: This group is ordered functionally and provide the structural/ constructional support and protection for the passage of the railway. They consist of: Underbridges, Overbridges, Major Structures, Tunnels and Minor Assets.

Electrical power: The electrical power needed to operate the 40% of the overall railway system that is electrified. The power is divided into Traction power and non-Traction power. Traction power includes mechanisms to distribute power from the national grid around the network and contact systems for distributing power to trains. The traction power supply is comprised of: 25,000 volt overhead line power, 660/750 volt DC conductor rail, 1500 volt DC electrification (very small proportion). Non-traction power

distributes power to lineside signalling and other components that require lighting or heating. The Non-Traction Assets are comprised of: Signalling power supply, Electric point heaters, Conductor rail heating and Non-traction HV and LV distribution systems.

Buildings: Provide shelter, accommodation or access to the broad range of Customers and stakeholders on the railway. They consist of: Stations, Light Maintenance Depots, Maintenance Delivery units, National Delivery Service and Lineside Buildings.

Telecomms: Railway telecommunications systems provide for: Safe train movement authorisation, direct railway operation and information for customers. They consist of: transmission systems, trunk cabling, telephone exchanges, high speed bearer networks, safety critical voice communications, CCTV, safety information, and security systems.

Earthworks: These comprise cuttings, embankments or natural slopes that are located on either side of the permanent way.

Drainage: Comprised of all the components which collect surface and groundwater which is either heading towards or emerges from the railway system. These are comprised of: Earthworks Drainage, Track Drainage, Tunnels drainage, Structures drainage, Stations /depots/other buildings' drainage

Level Crossings: Exist where the permanent way intersects with a road or path at the same level. They are comprised of a range of components which include, lights, barriers, decking, alarms, interlocking, approach locking and telephones. They are being phased out in favour of grade separation where practicable.

Fleet: These are the road and rail vehicles which are engaged in the maintenance and renewal of the infrastructure. They are categorised by the following functions: incident response, monitoring/recording/testing, general maintenance support, maintaining/ renewing, intervention and materials delivery.

3.2 THE SYSTEM THAT COMPRISES THE ASSET BASE

These subdivisions outlined in the previous section are necessary to describe and understand the scope of particular infrastructural elements. However it is important to see the elements within context of the whole system, of which they form a part. A system perspective which offers a number of potential benefits. In particular, an increased understanding of the interconnections between the different elements in order to be able to focus interventions where they will have maximum impact. (Walden et al., 2015) (Technical Strategy Leadership Group, 2012).

The assets described above together with its organisations, operations and stakeholders constitute the rail sector whole system. '…..it is the railway's people, processes and systems. The railway has many thousands of assets owned operated and maintained by a range of organisations, each with their own business objectives, priorities, timescales, policies and incentives' (Technical Strategy Leadership Group, 2012 p:68). Acknowledging the complexity and scale of the 'whole system' challenge the Rail Technical Strategy (RTS) went on to describe its aspiration to Make improvements to Safety, reliability, maintainability and safety through enhanced operational planning, improve asset management and the use of an industry wide conceptual framework (Technical Strategy Leadership Group, 2012 p 9)

The RTS argued that such an approach has the potential to bring to light elements and subsystems that are not performing optimally within their current context. This may, for example, be because technologies and / or management systems have moved on, thereby leaving opportunities for other systemic configurations to be developed or rewired in order to achieve an improved performance. For example the alignment of customer systems such as ticket sales and customer information with the location of the rolling stock within an intelligent infrastructural system. An integrated whole network, rather than a range of separate and disaggregated sub-systems.

Such a broadening perspective also offers the opportunity to look beyond the immediate rail or transport system that they are associated with. To consider the way that they interact with related infrastructural systems. For example the relationship between rail power and the broader energy supply network. An aspiration to optimise the application of traction power and storage on the railway would necessitate an understanding of its potential relationship to the national grid. This led to a considered assessment of the opportunities for potential investment and the importation of expertise from global investors and electricity network operators. This aligned with Network Rails intention to seek private investment and to test its competitiveness in the market. Interestingly this would also have been an opportunity to further evaluate the alignments for the deployment of inter-infrastructural expertise (Network Rail, 2016). A process which is likely to gain increasing momentum given the direction of travel signposted in the recently published White Paper (Williams Shapps, 2021). Given that, benign energy production and storage are enormous national and supra-national challenges, there are opportunities for the transport infrastructural system in combination with the energy infrastructural system to coordinate the generation, use and storage of power. This could include using the rail network as a distribution system and rail car parks as a supplementary storage system.

Similarly the telecoms systems, which are already in place on the network have the potential to significantly expand their sphere of influence. This has the potential to affect the operational functioning of the network through digital train control and signalling (The Digital Rail Programme, 2016). But it will also have further far reaching social and economic consequences for the way people undertake their working day. Moving from one working environment to another has the potential to be an increasingly productive process, if adequately facilitated with the correct provision. The process of transportation is no longer an entirely separate activity from the work which is undertaken within those environments and the working day will be increasingly dependent on the provision available within our travelling

environment. This in turn will be dependent on the connectivity within that environment being perceived as being an integral part of the overall socio-economic infrastructural provision. [SA2]Network Rail Telecomms (NRT) initiated a business case using the 5 case model (ref 4.4) to achieve additional funding for investment in enhanced infrastructural solutions to achieve 'wholesale commercial connectivity opportunities', including connectivity for both passengers and those adjacent to the railway who could benefit from it. NRT also looked into the viability of raising funding for increasing the extent and level of interconnection of rail telecoms infrastructure with the broader external telecoms network.(Network Rail Telecoms, 2018 p 9&43)

These interconnections and potential interconnections take place within the context of rail infrastructure, a critical component of transport infrastructure, itself a key economic infrastructure. (H M Treasury, 2015c) Which together with energy, waste, water and telecoms underpin the social infrastructural systems; comprising health, education and finance.(H M Treasury, 2015b). A complex and involved set of interlacing systems which neccessitates of an extensive, comprehensive and evolving set of skill, knowledge and expertise to sustain it. A mutually interdependent ecosystem where the former is ineviatably compromised by a shortfall in the latter.

The rail technical strategy recognises the potential risks of a skills shortage and notes that people must be 'equipped with the necessary skills to cope with new technologies and techniques'. Also recognising that the whole system approach which the strategy advocates suggests that 'people need to understand and adapt to new working practices'. While this strategy was very forward thinking in its advocacy of a whole systems approach and its recognition of the importance of lifelong learning, a theme that emerged from the case studies and reflected in the form of Contextualised Continuous improvement 7.2.2). It still appears to make a conceptual separation between the system and the people who implement the system. Between the technologies that are constituent parts of the system and the people in their capacity as 'drivers and enablers' (Technical Strategy Leadership Group, 2012). However, this description of people as drivers and enablers can suggest that people are not perceived to be intrinsic to the constituent parts of that system but rather are external and disconnected from it. This was also reflected in the emergent theme of Integration and linkage (7.2.5).

Of course the provision of a separate section or compartment for 'People' is a standard convention that is applied in many policy and strategy frameworks. Particularly those that address technical components and systems. It is seen as a convenient organising framework for the analysis and description of the subject matter – simply a linguistic framework or convention. However such conventions have consequences; one of which is to introduce a disconnection between the system and the essential microclimate for its sustained provision. It implies that those who are intrinsically embedded in the developing systems that constitute the asset base are somehow extrinsic to it, simply drivers and enablers.

This is problematic because it runs the risk that the assets, elements and systems that are delivered in projects and programmes can be interpreted as being conceptually prioritised over the expertise that

led to their creation. This inevitably leads to the position where the delivery of assets or interventions in the asset base are agnostic to, or take insufficient account of, the evolution of the expertise that was intrinsically bound up in their realisation. This work would argue that this misconception contributes significantly to the disconnection between the evolution and delivery of projects and programmes and the skill, knowledge and expertise on which that sustained evolution depends. .

Invariably skills gaps and skill shortages are a manifestations of this disconnection. A disconnection which would be less likely to occur if this critical precondition for programme development were fully incorporated into the system. There have been extensive warnings about this from a broad range of interested parties (Logistics and Transport Focus, 2021) and there have been extensive attempts to industrialise the learning process, including through such mechanisms as 'Skills Factories' which set out to align industrial requirement with academic provision. So that Engineering Graduates can be 'ready for industry' (Maheso et al., 2019). However this begs the question about what industry is ready for. Whether its requirements are sufficiently responsive to the anticipated domain trajectory or are they demanding more granular precision and industrial awareness at the expense of the unfettered evolution of expertise. And by doing so constraining both its own evolution as well as that of those being trained to contribute to its outputs and outcomes. This disconnection has a number of negative consequences including the retardation of project development. This in turn influences and is influenced by the trajectory and development of different domains, their interaction with other related domains and their potential expansion beyond their current boundaries. Thereby reducing the opportunity and fluency for flexing, expanding or rewiring the system beyond rail, transport or other economic infrastructures and their relationship with the social infrastructures as well. This is in contrast to the process whereby the assets become increasingly integrated as the 'rewiring' process evolves and characteristics that currently define the assets within their current context are transformed as innovative approaches to systems and sub-systems begin to challenge their original elemental identity.

3.3 INFRASTRUCTURE REWIRED. FLEXING THE SYSTEM BOUNDARIES

Implicit in this systemic 'rewiring' is the potential for the greater integration of the 'economic' and social infrastructural systems. This could include the extension of domain integrities necessary to provide a sufficiently comprehensive perspective of the infrastructural provision that is required. Such an infrastructural provision requires the co-existence and juxtaposition of a range of disciplines that traverse a broad spectrum of capabilities: sciences and humanities, technological and non-technological, quantitative and qualitative. It might be inferred from this that while core domain integrities of the different disciplines need to be respected. Overly rigid and unresponsive boundaries between infrastructural disciplines can significantly undermine the potential solutions that they seek to provide. (Ottino, 2004)

Similarly, the linkage between the economic and social infrastructural systems have the potential to become increasingly explicit. The treasury's supplementary guidance to the green book points to the many areas of overlap between of economic infrastructures and several of the social infrastructures (H.M. Treasury, 2015 1.2). The supplementary guidance also goes on to consider a range of the aspects of infrastructure investment which offer potential benefit and which need to be recognised and where possible valued. It takes into account the implication of network effects, whereby the value of a good or service vary according to the extent to which it is used. One of these network effects is referred to as a 'scale effect' where there is an opportunity to manage large scale programmes in such a way as to enhance the sum of their individual 'impacts' (H.M. Treasury, 2015 p3 - ftnt3). The opportunity to recognise and capitalise on the scale effects, where the integrated whole is greater than the sum of the parts, will be considered further in Chapter 4.

This change in perspective, brought about by the scale effect, can be achieved at a number of levels: Firstly in terms of the specific infrastructural types and the assets of which it is comprised, such as those outlined in 3.1 in relation to Rail. Secondly in terms of the broader infrastructural categories that encompass the infrastructural types, such as Transport or Energy. Thirdly through the inclusion of the broader infrastructural system, comprised of the broader grouping of economic infrastructures. For example transport and energy. And finally in the context of a broader grouping of the socio-economic infrastructures. An example of which would be transport and housing. The effective functioning and informed integration of these elements and systems at these different levels requires a further reconfiguration, expansion and realignment of our understanding of the overall infrastructural system in order to accommodate such a revised perspective.

Underlying the evolution of these dynamic system configurations are their underlying capabilities. These are, to a significant extent, contingent upon the requirements of projects which are seeking to satisfy current practical infrastructural needs. Which, in turn are dependent on funding and investment cycles which, inevitably, must prioritise practical infrastructural need. There are also therefore a range of technical, regulatory and organisational requirements which can act as a constraint, necessary or otherwise, on the sustained evolution of the requisite knowledge infrastructure. It can be argued that if such an expertise eco-system is to continue evolving effectively it needs to be prioritised so that it can be aligned to an optimum direction of travel or expertise trajectory. Such a trajectory would focus on the anticipated evolution of domain knowledge and would emerge from the process of iteration between an evolving strategy and the skill, knowledge and expertise required to achieve it. A process which could feed back into and significantly influence not only the strategic outcomes but also the tactical outputs of projects and programmes.

The accumulation of expertise and the evolution of domain knowledge is too often taken for granted and is treated as an incidental outcome that emerges during the delivery of renewed and enhanced infrastructure. The focus, therefore tends to remain disproportionately on the delivery of the physical outputs in preference to the sustainability of these preconditions for their delivery.

The implications of this disproportionate emphasis on the relatively short term delivery of the former has resulted in a shortfall in the latter. This has been principally understood in the form of what are commonly referred to as ‘skills gaps’. A shortfall in capabilities required to deliver, even, the immediate physical outputs of projects. These challenges have been noted and are being addressed within the sector (Transport, 2016a) and more generally across all the infrastructures (H.M. Treasury, 2015). Indeed, The National Infrastructure Plan for Skills highlights the need to take a systemic, rather than an elemental view of skills planning. Referring to the need to improve strategic thinking for inter sector labour mobility, it draws attention to the tendency to segmentalise skills planning and training in a way which undermines the overall potential for beneficial cross referencing.
(H M Treasury, 2015b p 6-7) While this is a positive development it focusses on the skills required to be a participant in a project and to contribute to the outputs. It does not combine this observation with the recognition of the consequential benefits of project participation.The provision of, what this work refers to as, pre-requisite skills is obviously central to the provision of any set of capabilities for any type of deliverable. However, the notion of a ‘skills gap’ can be misleading, implying that there is a complete and fully understood whole, from which a piece is missing. A gap which just has to be filled in with a known set of component parts. Indeed it seems that neither of these assumptions can necessarily be made. This is especially the case on innovative or transformative or open projects (Briner, 1990 p 94-95) where, not only are the outcome and outputs uncertain; but also the capabilities required to, firstly define and then deliver them are also undefined. This lack of clarity can be a significant positive from the perspective of learning and creativity. However it does not have the same disciplines as a closed project which constrains project scope to defined limits in order to ensure the effective delivery of its defined constituent parts.

However, even on more standard roll-out projects or programmes there may be room for productive expansion of both the scope of the deliverables and the capabilities required to achieve them. This is sometimes represented / described as lessons learnt (Association for Project Management, 2012 p 143) and is incorporated in the lessons learnt process at the post completion phase during the project review. Generally, however, this process tends to focus on whether or not agreed success criteria have been met. Indeed project management involved with infrastructure delivery neccesitates placing limitations and definition on project outputs and the capabilities required to deliver them. While this is a necessary requirement for the delivery of defined components within a defined timeframe, it is less helpful when exploring the viability, potential expansion and future trajectory of the capabilities that will determine the evolution and future shape of component parts whose form is yet to be determined. The National Skills Academy for Rail (NSAR) has engaged intensively with many of the important aspects of pre-requisite skills provision, including through ‘skills gaps and learning pathways’ (Holmes, 2021), leadership opportunities, apprenticeships and the extensive opportunities from digital data. Inevitably such measures to address the need for up-skilling implies a response to and anticipation of, expertise trajectory set by others. This suggests an opportunity to supplement these by exploring the viability, potential expansion and future trajectory of the capabilities that will determine the evolution and future shape of component parts whose form is yet to be determined.

This work is arguing that the emphasis should shift from the provision of components to the enhancement of the expertise that enables their provision. An explicit recognition that the former is contingent upon the continuing evolution of the latter. It can be further argued that there also needs to be a gradual refocussing onto these core preconditions for all forms of infrastructural provision. How the evolving expertise, skill and knowledge that underpins the physical asset provision of transport infrastructure also can play a part in underpinning the evolution of the physical asset provision of other related infrastructures and potentially their whole life evaluation (Kirkwood et al., 2016) . And also how provision for the evolution of the key economic infrastructures has the potential to be related to other economic and social infrastructures. Thereby ensuring that the pathways between physical and intellectual systems will become recognised as being explicitly rather than implicitly interdependent.

The viability of this asset configuration, at any given time, and its integration into such a comprehensively 're-wired system' is to a significant extent determined by those who have the perspective to be able to propose new potential realignments through a robust approach to research, development and innovation. This 'rewiring' involves projecting forward to new configurations which are better able to offer systemic performance improvements, which may require a reinterpretation of the nature and performance of the assets. It therefore involves the underlying reality that the elements, the elemental breakdown and the way the system presents at any point in time are simply the current 'test bed' for the current knowledge / skill and expertise base of those who have contributed towards the way it manifests at that point in time, which, in turn, inevitably evolve over time to assume new configurations. This work seeks to draw attention to the potential inherent in such re-wiring. To consider what form it might take and to gain a greater understanding of the extent to which it could be achieved through the investment process of rail initiated projects and programmes at a national, regional and local level as it aligns with policy objectives.

This move towards systems thinking is supported in the Rail Technical Strategy as well as in the Network Rail Technical Strategy (NRTS) and the Academic response to the Technical Strategy (ARRTS). The strategies seek to ".. embed whole systems thinking across the organisation and the wider industry by embracing the whole systems life cycle management approach" (Network Rail, 2013c p 23)

The Academic Response to the Rail Technical Strategy (ARRTS) also engages with the opportunities for systems thinking and adopts an expansive approach to many of the technical and technological options. It recognises the potential of being open to opportunities that may be tangential to the principal focus of the research .This includes suggesting research as a sector of the rail industry, thereby accommodating the closer relationship between the two
(RRUK, 2014 p6) However, the underlying presuppositions about the relationship between research, projects and the evolution of expertise that emerges from the latter remains essentially the same.

Thus while the RTS, NRTS and ARRTS all addressed the importance of and need for a systemic approach. None appear to be proposing an extension of the system that would reprioritise, re-categorise or recalibrate the relationship between projects, programmes and the associated evolution and enhancement of expertise that is being put forward in this work. Implicit in such a reconfiguration or realignment would be its integration into the knowledge base of an extended infrastructural system. A systemic rewiring that extends and interconnects the range of operational, commercial and academic disciplines that sit at various points along the quantitative qualitative spectrum. A knowledge infrastructure that is needed to devise, design maintain and develop, not only the physical asset base but also the intellectual asset base on which it is built. This work is arguing for a shift of emphasis which ensures that any interventions intended to enhance the former are directed and targeted in such a way as to ensure the enhancement of the latter.

3.4 INVESTMENT IN THE INFRASTRUCTURE

In parallel with this enhanced, symbiotic relationship between the physical and intellectual infrastructure, investment decisions would need to take greater account of a more comprehensive evaluation of potential benefits. However, the quantification of these are often elusive. Not least because they involve fine-tuned judgements, for which the current methods of quantification are too coarsely calibrated. Nevertheless such decisions are required and are de facto being made in the broader context of an infrastructure provider's responsibility and remit. Such a shift of emphasis, as described above, would give greater recognition to this multi-dimensional context when evaluating the viability of projects.

The mechanisms used to develop policy and strategy for the planning, delivery and maintenance of the operational railway are set up in order provide the appropriate scrutiny. Checks and balances are in place to ensure that investment funds are being properly allocated. This carefully governed and scrutinised investment process involves the following:

- The infrastructure provider putting forward their preferred strategic approach to investment through the Initial Industry Advice (IIA).

- The response from Government in the form of a 'High Level Output Specification' (HLOS) and Statement of Funds available (SoFA) from the department for transport. These set out the requirements of the Secretary of State for Transport (DfT). What the department wants to be achieved during the following 5 year control period. They are set out formally for the Office of Rail and Road (ORR) and they constitute the requirements for which Network Rail develops its Strategic Business Plan (SBP)

- Following extensive negotiation and iteration with the DfT Network Rail produces the Strategic Business Plan (SBP) which sets out the way in which the infrastructure provider will carry out what the

Department for Transport wants to be achieved during the control period. A strategy which inevitably sets out to deliver a range of benefits that would be positioned at varying points along the quantitative/qualitative spectrum.

- The High level policy and strategy that emerges from these decisions provide the benchmark against which such qualitative and quantitative judgements about the case for investment are made. While these evaluations may receive some quantitative support from the Benefit Cost Ratio (BCR) calculation or similar evaluation mechanisms, many decisions ultimately rely on fine-tuned qualitative judgements based on experience, perspective and understanding, which may manifest in the form of skill, knowledge and expertise.

3.5 UNDERSTANDING THE POTENTIAL BENEFITS

The release of allocated funding for the execution of projects and programmes is carried out via an 'Authority paper'. This sets out the justification for the release of funds at various stages or gateways along the programme lifecycle, usually defined by the GRIP (Governance for Railway Investment Projects) stages. It begins with GRIP Stage 1: Output Definition and continues through to GRIP Stage 2: Project Feasibility and then through the remaining 6 stages of Option Selection, Single Option Development, Detailed Design, Construction, Test and Commission, Scheme Handback to GRIP stage 8 Project Close out (Network Rail, 2018).

Release of funding at the different stages is dependent on fulfilling a broad range of criteria which include a requirement for applicants to describe the perceived benefits of the potential project or programme. These potential benefits are described in the authority paper and are divided into four types or Quadrants (previously referred to as 'Tiers') (Network Rail, 2013b):
Quadrant 1: Quantifiable reduction in Costs.
Quadrant 2: Quantifiable Increases in Productivity.
Quadrant 3: Qualitative benefits that accrue to the Infrastructure Provider
Quadrant 4: Qualitative benefits that accrue to the Rail industry generally.
The template for the authority paper provides an opportunity for all benefits to be listed, described and where possible, measured. The Quadrant 1 & 2 benefits are regarded as quantifiable and they are measured by being monetizable or potentially monetisable. The Quadrant 3 & 4 benefits are regarded as qualitative and are evaluated against other criteria such as safety and reputational benefit. Quadrant 3 & 4 benefits are generally recognised as being unquantifiable, although some such as safety or verifiable public spending could potentially be calculated.

Not surprisingly given the overriding focus on cost, it is the first two quadrants or tiers that receive the most attention. The breakdown of entries under the categories for 2011-2012 (see Fig 3.4) show that of the 254 entries only 30 had any sort of quadrant 3&4 benefit entries against them.

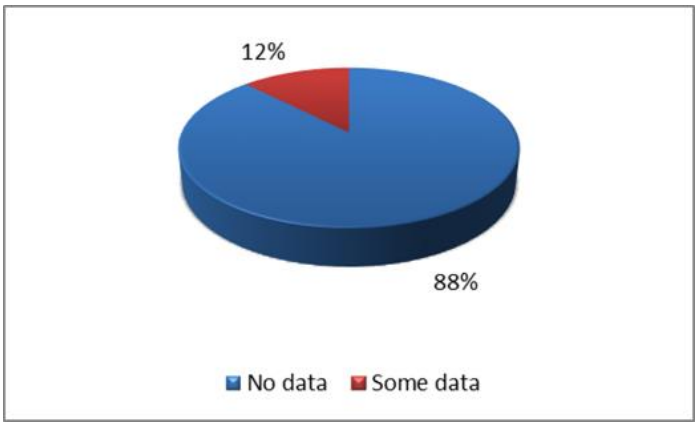


Figure 3-4: Showing the small proportion of Quadrant 3&4 benefits described on Authrity papers when compared with Quadrant 1&2 benefits

The authority papers had extensive and detailed entries for Quadrant 1 and to a lesser extent Quadrant 2 sections. The scarcity of data for Quadrant 3 and 4 reflected the predictable focus on quantifiable monetised cost, as well as the implicit difficulty in attributing value to those qualitative elements.

This could be said to represent an opportunity for projects and programmes to enhance the recording of (and subsequently validate) the qualitative non-monetised benefits, and what could be described as externalities that accrue as a result of undertaking projects. And this could include the relationship between participation in projects and programmes and a positive enhancement of skill, knowledge and expertise, which could be included as significant Quadrant 3 & 4 benefit. Benefits that would accrue not only to to the infrastructure provider and the rail industry but also to transport and other infrastructures.

The demonstration of some form of relationship between investment in projects and programmes, which serve as the vehicles for railway investment and the enhancement of skill, knowledge and expertise has the potential to offer a range of potential applications and opportunities:

- It could point to a significantly accelerated return on investment which would run ahead of the ‘material’ outputs of the project or programme therby making it inherently affordable.

- It could explicitly reinforce the linkage between the formation or evolution of the physical infrastructure and the pre-requisite knowledge infrastructure, which would be a necessary condition for its realisation.

- It could point the way towards an improved recognition of the importance of a coherent systemic resourcing strategy that incorporated the expertise trajectory of the different domains within a project, programme or portfolio. A strategy that looked beyond the filling of 'skills gaps' towards the opportunities that would emerge from a more extended vision of the implementation of domain knowledge.

Studies on the nature and evolution of Knowledge, Skill and Expertise have drawn attention to the holistic nature of the process (Farrington-Darby and Wilson, 2006).That the accumulation of expertise is not a one or two dimensional process of increasingly narrowing knowledge accumulation. It cannot be meaningfully separated from the live context in which decision making takes place and that expertise evolves within the context of a tacit knowledge framework that structures its development. This aligned with the theme of Contextualised Continuous Improvement that emerged from the case studies.

As described in Chapter 1 the terms 'skill',' knowledge' and 'expertise' have been used together to achieve an amalgamation of meaning that seeks to both encompass and extend beyond the notion of basic capabilities and competencies. In particular this work uses the term expertise to describe those intensive and extensive abilities which are identifiable and can be ascribed either to individuals or subject areas and recognisable domains. Therefore when referring to an 'expertise trajectory' we are addressing both: The anticipated enhancement of the breadth and depth of an individual's domain knowledge, as well as the enhancement of the breadth and depth of the context within which that domain knowledge is set. This work has been using the terms domain in the conventional sense to refer to the breadth and depth of a particular field of thought, activity or interest and has been referring to domain trajectory as the anticipated development and evolution of that field.

The initiation of projects and programmes are driven by a range of practical, logistical, commercial and political factors and are undertaken when it is practicable to do so within the constraints of the funding cycle. This requires an alignment between operational need and availability of funding, the latter often proving to be a significant challenge in recent years. This disjunction between need and opportunity can be exacerbated by the shortfall in the resourcing of the capabilities to undertake projects because they are in short supply. This can makes it a reactive and costly process. Requiring that projects and programmes are undertaken or intiated when they can be done rather than at the optimal point in time. Both in terms of the operational output requirement and in terms of the pre-requisite skills that enable them to be undertaken.

This work would argue that a narrow focus on project outputs can undermine the essential preconditions to sustain their ongoing delivery. While the pre-requisite skill, knowledge and expertise to initiate the project receives the necessary attention during project planning to ensure that it is resourced to proceed. The consequent skill, knowledge and expertise that is achieved on an individual, team, project or programme basis tends to receive much less attention. Risk assessments and resource planning are understandably focussed on ensuring the achievement of the immediate project or programme deliverables rather than these consequent benefits to expertise that emerge as a consequence of their delivery.

Similarly, the understandably tight focus on project outputs may ensure the achievement of the short term project or programme objectives; it does not address, directly, the ongoing management of the evolution of the capabilities that are required to sustain them into an evolving future. Indeed it can be argued that the management of the development of capabilities can be left to reside with those who have significantly less influence on the direction in which those capabilities could or should develop. So while there is an inevitable result of the requirement to respond to and cater for short / medium term perceived client or project requirements there is arguably an equally important requirement to set the trajectory for the development of the domain or subject area.

Outcome led client requirements and performance specifications have served to mitigate this by not prescribing solutions but rather by specifying the performance that is expected of the solution. This can be an opportunity for suppliers seeking to meet the specifications to demonstrate their expertise through the solutions they provide to perceived requirements thereby allowing the skill, knowledge and expertise that has evolved within their specialist domains to be applied to solve these perceived challenges.

However the questions for which the solutions are being provided are governed by the perception of the problem. If this perception is limited in perspective there can be a tendency to provide constrained solutions to constrained challenges. This has the double disadvantage that it not only provides limited solutions to a limited perception of needs in terms of immediate output requirements. It also creates an overly restricted perspective from which to manage the skills, knowledge and expertise 'palette' into the future.

However, an expansion of perspective achieved through a sustained shift of emphasis towards the enhancement of skill, knowledge and expertise would increase the quality of both perceived requirements and perceived solutions. This could be achieved by putting greater emphasis on the direction of travel for both individual and the collective expertise of the domains within which they operate. Indeed the development and evolution of such domain trajectories have the potential to realise a number of benefits. These include:

- Providing clear guidance for the contingent requirements of individual projects and programmes in the light of the evolution of domain knowledge.
- Providing a strategic objective for domain knowledge which is independent of the funding cycle and towards which operational and academic requirements can co-exist and maintain forward momentum.
- Providing an immediately realisable ongoing benefit which can be exported, where appropriate, to other related infrastructures.

A more integrated supply chain, early contractor involvement and better procurement methods and contracts may provide greater continuity and risk distribution. Thus these major vehicles for infrastructure investment that take the form of projects, programmes and portfolios could provide an opportunity to take a more responsible, cohesive and strategic role in these contexts. In particular to provide the pre-conditions for the development and evolution of skill, knowledge and expertise at a number of levels. They would also have a significant influence on the evolution of domain knowledge.

Thereby taking a more active role in the alignment of projects and programmes to the strategic and policy objectives of the areas in which they operate.

This more comprehensive approach could be integrated into other methods of knowledge accumulation. It could mediate between more institutionalised learning with academic institutions on the one hand and the lessons of operational reality on the other. It would also be compatible with apprenticeship style mentoring ('sitting by Nellie') accommodating the transmission of hard won expertise. For example, from those close to leaving the industry at their retirement to those whose perspective needed widening and deepening as they gained experience, thereby enhancing competences and capabilities. The question of 'retirement' and ways in which the management of expertise could be aligned with it could be the subject of a separate study.

Such an approach could be undertaken in the locality in which the work was being undertaken and could be managed in alignment with the local authority who would have an interest in improving local skills, competencies and capabilities. Chapters 5 & 6 describe the requirement for the case study projects to engage with the 'Employer Hubs' where the local authorities set out certain requirements for the projects to recruit locally. In certain circumstances, there may also be scope and opportunity for them to seek to influence more directly the nature of the capabilities that are delivered.

3.6 CONCLUDING DISCUSSION

This chapter has considered the different notions and manifestations of railway assets and the way in which the segmented assets also need to be perceived in terms of the systems which they are a part of. How there are opportunities to to have a more productive approach towards both natural and human resources. How this can be aligned to European, national, regional, local and company governance as well as how the move towards an enhanced infrastructural system should seek to optimise its 'core asset base'. Also, how such a system-based re-evaluation both poses challenges and offers opportunities. Not least in relation to the form that this evolution should take in order to meet the environmental, economic and social needs of the society that it serves.

A particularly challenging aspect of this is their 'affordability' in relation to the resources that are made available to meet the identified need. And further that such an assessment of the physical asset base should be more directly linked to an investment strategy adjusted to the recognition of its underlying value and structure: That is, value derived from the associated renewal and enhancement of the knowledge / expertise / skill infrastructural system on which it depends.

It has considered how an atomised focus on elements can detract from an integrated understanding of the system. How a systemic understanding of the components of rail and other infrastructures can be

achieved at a number of levels. Levels that flex the boundaries between the notions of ‘economic’ and ‘social’ infrastructures as well as between ‘physical’ and ‘intellectual’ infrastructures.

Of course at one level, the fact that the core asset base resides in the knowledge base of the industry is self-evident and true of any domain, set of domains or system. However in order for that knowledge base to evolve it must be incubated within conditions that accommodate and promote its evolution. Of particular significance here, however, is the extent to which such a ‘systemic re-wiring’ process challenges the boundaries of those disciplines and domains and introduces new interrelationships between the component parts, these, in turn becoming subject to ongoing re-evaluation.

The work has also considered how projects, as the principle vehicles for the implementation of rail infrastructure investment could provide an opportunity to benefit from this ongoing iteration and integration. And how the enhancement of skill, knowledge and expertise, as a particular consequential outcome and potential output of projects, could be mobilised to greater effect for the enhanced delivery of physical infrastructural requirements.

This revised perspective would enable a more accurate attribution of value to the asset base. Such an attribution of value would be key to determining the way the asset base needs to evolve and develop in order to maintain and enhance that evolution. Thereby gaining a greater understanding of the nature of the interventions that would be required in order to optimise the direction of that evolution in a genuinely sustainable way. To address, not only what that infrastructure should be but also why it is needed.

In the next chapter we consider the possible approaches that can be used to achieve this.

4 A COMPREHENSIVE AND SUSTAINABLE EVALUATION

Notwithstanding the reality of funding constriants and investment cycles, investment decisions in any context are rarely evaluated soley on single bottom line accounting principles (Taïbi et al., 2020). Key to the effectiveness and integrity of any evaluation process which seeks to determine the genuine affordability of potential interventions in the asset base is that they are carried out on a holistic basis. That the evaluation encompasses all the costs and benefits associated with the proposed change. That it applies the notion of 'whole life cost' or 'whole life value' comprehensively in order to justify any investment decision on an ongoing basis.

This whole life evaluation process includes externalities (Fig 4.1): Economic and social costs and benefits, which may go unreported and may not be quantified, but nevertheless have a significant influence on investment decisions. Indeed, it can be argued that an 'optimal investment strategy' requires that all relevant non-financial costs and benefits are fully taken into account Of particular significance here is one of those parts of the calculation that do not lend themselves to quantification or measurement within the parameters of the methods of evaluation that we currently have available. This chapter considers the importance of including an intrinsic component of sustainable asset value: Expertise enhancement into a holistic assessment of potential interventions in the asset base.

4.1 WHOLE LIFE COSTS

The idea of a cost calculation for asset value which extended beyond Capital Costs can be traced back to the 1960s (Kirkwood et al., 2016) with the advents of terotechnology. This was followed in the next decade with the 'cost in use' calculation and then in the late seventys with 'Life Cycle Costing' and the associated notion of Life Cycle Assessment. The notion of Whole life Costs which extends the calculation beyond commercial appeared in the late 90's. While aspiring to be a formalised and structured methodology, Whole life cost evaluation is an imprecise science. The terms 'Whole Life Costs'(WLC), Life Cycle Costs (LCC), and Life cycle Assessment (LCA) are frequently used interchangeably. For reference this work will use ISO 15686-5: 2017(British Standards Institute, 2017) to describe the notion of whole life costs.

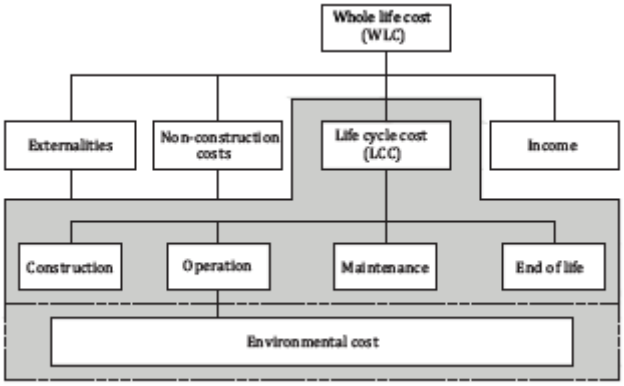


Figure 4-1: The concept of Externalities as a constituent part of a Whole Life Cost evaluation based on ISO 15686-5:2008 (BSI 2017)

Figure 4-2).

This inclusion of 'externalities' in the evaluation process provides a degree of recognition that there are qualitative factors that are not generally included in the core quantitative financial calculation. But which are nevertheless important contributors to any meaningful understanding of the costs and benefits associated with that transaction.

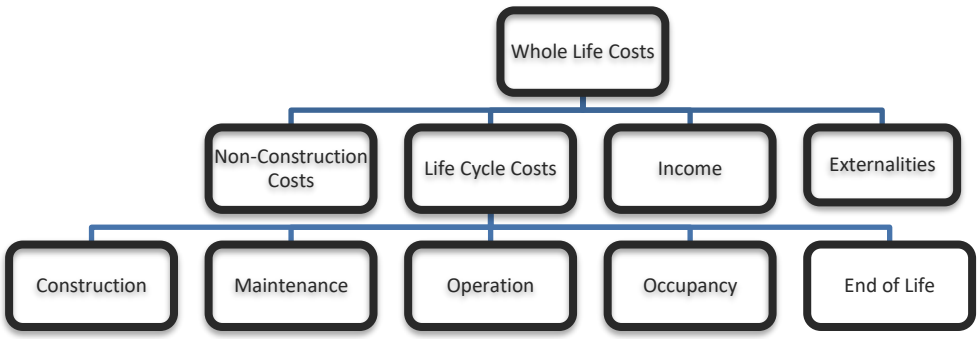


Figure 4-2: The concept of Externalities as a constituent part of a Whole Life Cost evaluation based on ISO 15686-5:2008 (BSI 2008) and ISO 15686-5:2008 (BSI 2017)

The use of the term 'Whole Life Cost' is often compared with the with the notion of 'Whole Life Value' (IET, 2008) (Waterman, 2004). This implies that the notion of cost in the concept of a 'whole life cost' is too constrained and that the notion of value provides a more comprehensive description of the assessment, calculation or evaluation that takes place. While recognising that whole life value may be a more representative description of the whole life evaluation process; this work will, nevertheless, continue with the use of whole life cost. Firstly because the notion of value is implicit in the ISO definition of costs and benefits. Secondly because it is more readily recognised in accountancy terminology and has a range of standards associated with it, thereby providing a more stable point of reference.

Such an evaluation seeks to indicate the most effective and efficient allocation of resources by taking all the relevant factors that might affect the true value of the infrastructure asset base. A central purpose of which is to establish the extent to which the different elements, processes and systems which form the constituent parts of the infrastructure require investment. And further to gain greater clarity about the ways in which that investment should be prioritised.

This assessment of the 'whole ('cradle to grave' or 'cradle to cradle') life' (McDonough, 2009) of the assets needs to incorporate the associated costs and benefits that would accrue as a result of any proposed change. Without this comprehensive assessment of long term benefit it is likely that the positive and negative consequences of short term costs and capital outlay would be likely to take precedence in any investment decision-making process – particularly in times of financial constraint. The evaluation of different options needs to be carried out using an effective means of comparison between the different options.

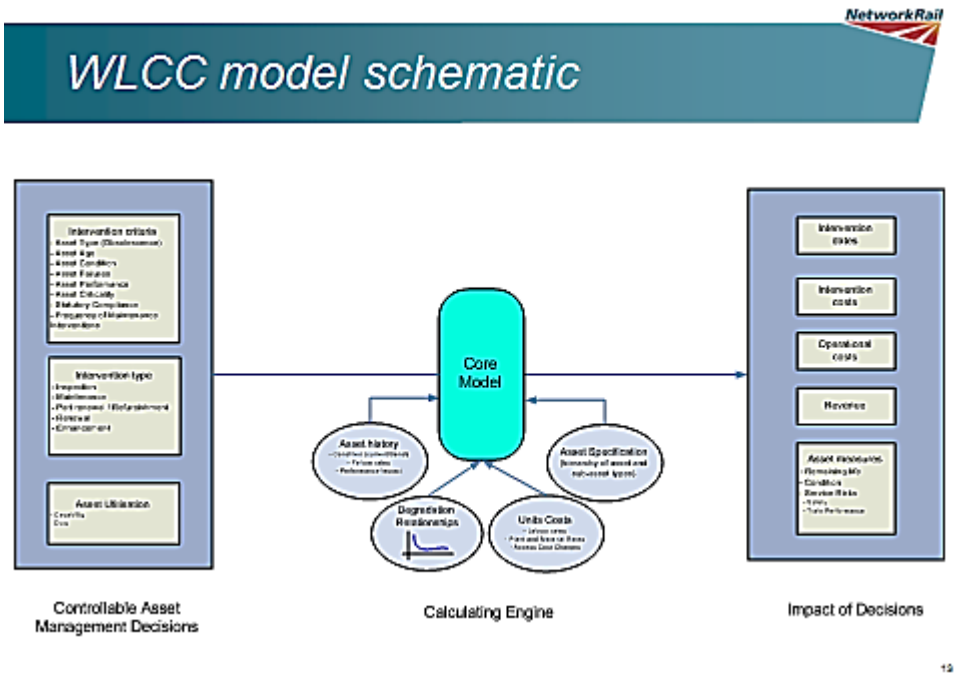
The calibration of value through monetisation offers several benefits including: Reducing the cost or benefit down to a common currency that can be compared with a broad range of comparators thereby reducing the likelihood of subjectivity in the assessment. The use of a monetary comparison can also enhance the credibility of the choices on offer.

However this approach presents the difficulty of arriving at a meaningful monetary value for a non financial transaction, as well as applying a future discount rate. Such a use of monetisation can also have the negative effect of devaluing those costs and benefits which cannot be convincingly reduced down to this 'Lowest Common Denominator'. So, In focussing attention on expertise as an externality in any form of whole life cost evaluation, this work is seeking to draw attention to what could be regarded as a 'Highest Common Multiple' in the calculation of asset value in any asset intervention.

4.2 THE NATURE OF THE CALCULATION

The development of a comprehensive whole life cost model was intiated (Skinner et al., 2011) in 2010 and continued (Rama and Andrews, 2015) in the ongoing work between the University of Nottingham and Network Rail as part of a programme being undertaken with the University

It addresses the minimum whole life and lifecycle cost concept via a modelling hierarchy at three levels. The core model calculates optimum points for asset intervention based on the type and criteria for intervention. This is moderated by the history, degradation relationships, unit costs and specification.



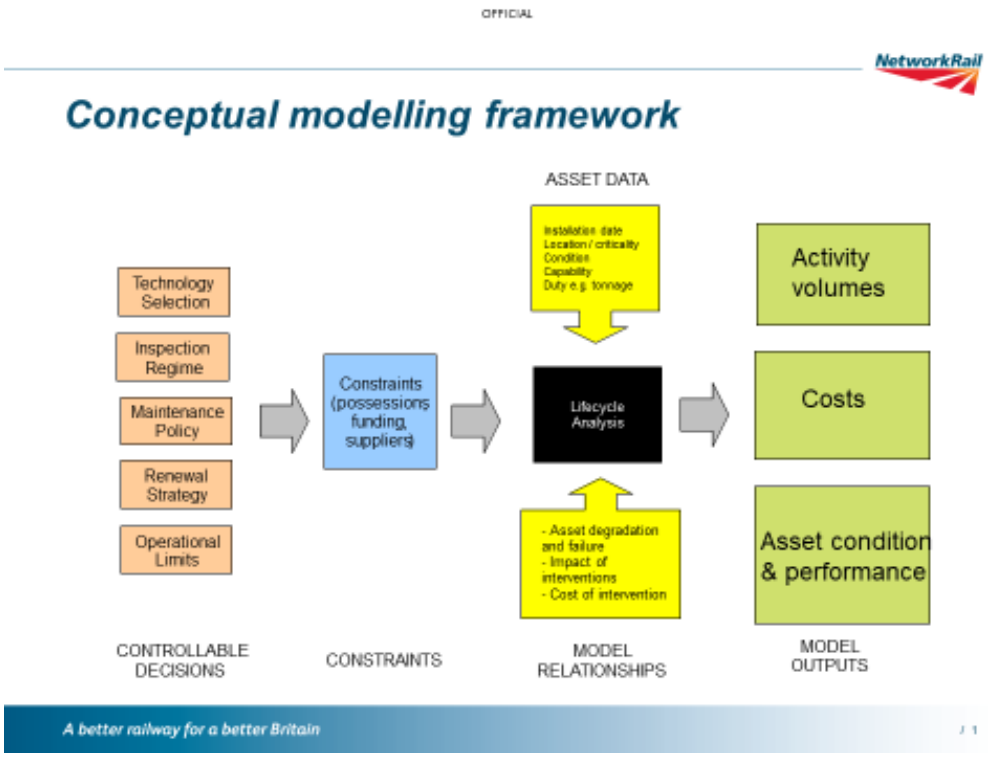


Figure 4-3: Network Rail Whole Life Cost Model – Schematic and Modeling framework

It seeks to optimise the replacement points and intervals between them by assessing the risk, maintenance and renewal costs of different approaches. The model addresses: life-cycle costs, non-construction income and potential income while seeking to establish the optimum method and point of intervention. Once these are determined, they are formally sanctioned through the investment process. The model also addresses the life cycle of the assets as well as taking into account potential income and non-construction costs. However, it does not currently include externalities within its scope.

While this whole life cost model and its evolving iterations have developed entirely separately from this work the lead responsible for its evolution has developed a paper or 'discussion note' (Kirwan, 2020) to address the opportunity presented by the development of a 'Value Framework'. Emphasising the complex nature of Railway infrastructure and 'its large number of human interfaces' and looking to move on from other decision frameworks with their tendency to 'compartmentalise decisions' Kirwan has proposed a framework mechanism to achieve a more comprehensive evaluation of potential interventions in the railway system. Such a framework based on Reliability, Availability and Mainitainability (RAMS) would incorporate Environmental, Economic and Social Sustainability criteria, with the latter including 'the effect of operations, activities and decisions on people'. Such an approach could have the potential to provide a possible mechanism where the more explicit recognition of the value of expertise enhancement could be further developed, calibrated, located and explicitly incorporated into an evaluation mechanism that could go a significant way towards achieving the shift of emphasis advocated in this work. Referring to possible benefits from rail investment that went beyond the financially focussed Tier or Quadrant 1 and 2 benefits (ref 3.5 and 7.3.1 Quadrant 3 and 4 benefits) Kirwan commented that the Intellectual Capital (methods and competences) generated from project

participation and continuity can produce better outputs and efficiencies for projects, providing its value is maintained through project continuity.

4.3 THE NATURE OF THE TRANSACTION – THE SIGNIFICANCE OF EXTERNALITIES

The externalised transactions that may be either explicit or implicit in these 'calculations' have the potential to be key contributors to a comprehensive representation of sustainable value. 'Externalities' are defined in different ways. The Organisation for Economic Cooperation and development (OECD) glossary of terms describes them as 'situations when the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided' (Organisation For Economic Co-Operation and Development, 2000) and as 'changes in the condition or circumstances of institutional units caused by the economic actions of other units without the consent of the former'.

The ISO definition describes how LCC calculations will arrive at decisions on the basis of market efficiency. However they do not fully recognise 'the wider implications that economic decisions have on society' (ISO, 2008 p: 22). The definition also refers to the opportunity to identify future risk and reward and that externalities should be 'identified in the analysis'. It goes on to point out that both negative and positive externalities can be addressed by government through taxes, on the one hand and subsidies on the other. Most definitions of externalities refer to the cost or benefit that accrues to a third party in the transaction being undertaken.

Notwithstanding the implicit overarching transaction that takes place between society which requires the investment and the government who sanction it on society's behalf. The transactions that takes place in Infrastructure investment are essentially between the Infrastructure owner who seeks to achieve a positive change to the infrastructure and the organisations deemed competent and capable to undertake them. With the project or programme often used as the vehicle to undertake the change. This will be referred to as the principal or primary transaction.

Apart from the costs and benefits accruing to the principle parties to the transaction, there are also external costs and benefits which accrue to third parties who have no direct relationship with the primary transaction. This is particularly the case for infrastructure investment. For example, on the positive side, the environmental benefits of shifting the modal balance from road to rail can reduce levels of pollution and carbon emmissions. This benefits not only lineside neighbours but can also have significant wide ranging regional and national impacts. Whereas on the negative side, the third party impacts of the disruption of an engineering infrastructure project can also extend beyond the immediate project

environs, causing road congestion and blockages over a significant area. In both positive and negative examples, the third parties appear as passive recipients of these effects. They are not directly involved in the project and are not immediate parties to the transactions which brought it about.

However, as far as the individual project participants are concerned, although they may be actively engaged in the project and are directly associated with the principal parties to the transaction through their participation in the project. They can also, individually, be said to be affected by certain externalities that accrue as a result of their participation in the project. So, in that sense they can be regarded as third parties.

Through their engagement in the project, many of the project participants will benefit from a positive change in their individual circumstances, including in their leve lof experience. However, there is no direct transactional recognition of any costs and benefits accruing to the individual project participants as a result of their change of circumstances: In particular the change in skill, knowledge and expertise that comes about as a consequence of their participation in the project.

Further, because this consequential change in expertise may not be recognised as an externality there is no compensation or subsidy available for the positive benefit that emerges from the transaction. A double disadvantage because this programme benefit is neither internalised in the transaction nor treated as an externality to attract a subsidy (GLAEconomics, 2006).

Given the significance of the wider economic and social benefits in the evaluation of investment cases for interventions in engineering infrastructure, it seems clearly preferable if the wider economic and societal benefits that are claimed for engineering / infrastructure can be given due recognition. The greater the understanding of the relationship between the intervention and the suggested benefits; the greater the likelihood that it will be correctly acknowledged and accommodated either internally within some form of transaction, or externally where it can attract the appropriate subsidy. This work is arguing that the enhancement of skill, knowledge and expertise should be recognised as a positive externality. This would constitute an important step towards the recognition of its intrinsic value, even though it was not included in the immediate costs and benefits of the transaction.

There are three requirements to achieve this:
- Firstly that it is possible to establish that a relationship exists between participation in projects and programmes and an uplift or enhancement of expertise.
- Secondly that this relationship is consequential. That is, the uplift in expertise is recognised as being brought about as a consequence of that participation. And that it would be reasonable to infer from this that participation in the project or programme contributed directly to the uplift in expertise. And further that with reference to the concepts of necessary, sufficient and contributory causes (Mumford, 2013) it could be possible to argue that participation in projects or programmes is both a necessary and contributory cause of the uplift in expertise. (The notion of causation carries significant implications. Further work could be undertaken in this area)

- And finally that this consequential change is recognised as a benefit and can be accommodated within some form of comprehensive evaluation, including a whole life cost calculation, as a viable positive externality.

4.4 THE GENERAL RECOURSE TO QUANTIFICATION AND MEASUREMENT VIA MULTI-CRITERIA ANALYSIS

There are a range of 'Multicriteria' (Communities and Local Government, 2009) (Dodgson et al., 2009) methods of analysis that seek to provide objectivity to different types of externalities and the perceived effect that they have (via mechanisms such as the Green Book and the Department for Transport '5 Case model'). However the socio-economic wider benefits that appraisal methodologies (adjustments for social benefit /'dis-benefit') are very specific. They are described as: Agglomeration benefits, increased competition as a result of better transport, increased outputs in imperfectly competitive markets and improvements in labour supply. Because there are benefits that do not fall into these categories, this work would argue that they need to be widened to include an uplift in expertise brought about through the process of infrastructure enhancement.

The assumption that the validation of the optimum solution resides in some form of quantification or measurement is present in most forms of evaluation of different investment options. Indeed the process of appraisal calculation in business cases presupposes the ability to provide some form of quantification of cost and benefit that can justify the decision to invest. This is usually undertaken via a cost - benefit ratio calculation. However, as described in 3.5 above, the justification or rationale for policy and strategic decision making is rarely based on this form of quantification alone but also includes a range of qualitative judgements. These qualitative judgements may be informed by a range of factors that cannot be easily represented in the evaluation mechanisms that are available to those making the decisions. Hence the attempts to mitigate this involves the use of different forms of multi-criteria analysis (Communities and Local Government, 2009).

The 5 case model (H.M. Treasury, 2011) provides an insight into the process here through the application of five different perspectives on a proposal for investment: Strategic, Economic, Finanacial, Commercial and Management. The Strategic Case offers the opportunity to lay out a balanced qualitative and quantitative argument for change. The Supplementary Guidance on using the 5 Case Model describes the strategic case as: 'A case for change that provides holistic fit with other parts of the organisation and public sector' as well as demonstrating 'that the spending proposal provides business synergy and strategic fit and is predicated on a robust and evidenced case for change' (H M Treasury, 2015a p 8, 11). Clearly this offers a sufficiently holistic scope for such an inclusion, however the strategic direction must be tempered by the Economic, Financial, Management and Commercial cases. On the

face of it, the economic case should support a comprehensive and robust case for change in that it could 'demonstrate that the spending proposal optimises public value to the UK as a whole'. However, as is often the case much depends on definitions and understanding of terms and what we understand the optimisation of that public value to be. Where significant cost constraints exist it is not surprising that the economic, financial and commercial cases exert a significant influence on the balance of the 5 case model. Acknowledging the limitations in appraisal methodology and the broad and extended impacts of transport improvement initiatives, particularly large projects and programmes (Laird and Venables, 2017), there have been several attempts to address these limitations through refinements to appraisal.

However, given the implicit policy endorsement that monetisation brings, there is an understandable if disproportionate focus on the financially quantifiable. Such an emphasis can lead to the under-representation and consequent under evaluation of socially qualifiable benefits. However it can be argued that this would be significantly moderated by an increasing focus on the the consequent qualitative benefits that would be more readily represented in a multi-disciplinary, system based perspective. This would increase the likelihood of the more 'holistic fit' aspired to in the proposed revisions to appraisal methodologies. Of course, if these were to become more demonstrably quantifiable, they would have the potential to supplement the calculation of quantitative value, without compromising the financial integrity of the investment calculation. However, as noted above, while there are clearly benefits in providing 'quantified' support for a business case, the nature of the calibration would be critical here. A crude monetary calculation that failed to capture the relevant nuance inherent within the qualitative values that needed to be represented would be counter-productive.

Currently the 'Wider Economic Impacts' of projects are deemed to fall within either: User benefits, productivity effects or investment and employment effects, subsequently revised to Induced Investment, Employment Effects and Productivity from Agglomeration Economics (Transport, 2016b). Reference is made both to job creation (Employment Effects) and the colocation of skills (Agglomeration Economics). However these do not capture the inherent benefits of expertise enhancement that accrue to those participating in projects and that is gained as a result of that participation.

There are a broad range and number of qualitative factors that must necessarily be incorporated into investment decisions in the rail context. These can include the use of local materials, local labour and local employment opportunities. Indeed, it can be argued that the consequential change in expertise in the workforce that is achieved through this approach to investment, represents a good example of such a benefit. The more these qualitative benefits can be incorporated into a core calculation the more they provide support for and would be integral to, a sustainable investment strategy and its 'whole life costed' justification. It can be further argued that such a benefit could be internalised as an intrinsic part of a systemic 're-wiring' (described in the previous section). This is something which would both broaden and deepen the system wide interconnections that would in turn be integral to a system wide informed recognition of value and benefit. Although, as discussed above, the nature of the revised calculation that enabled this internalisation would be critical here.

The evolution of the consequential 'Knowledge Infrastructure' which is integral to the asset base would therefore be intrinsically, linked to any comprehensively whole life 'costed' investment decision, which in turn would have the potential to become one of the principle drivers for future renewals and enhancements of the asset base. The demonstration of this linkage and the shift of emphasis towards it, would also offer the opportunity to broaden the negotiation for funding settlements. It would not only supplement the clear manifestation of the positive contribution that rail and rail infrastructure provision makes across the broader economy. It would point towards a far more comprehensive and holistic 'calculation' or evaluation that would give due recognition to the constituent fabric that weaves its way through the different manifestations of rail infrastructure: The skill, knowledge and expertise of its people.

4.5 THE CASE FOR INCLUDING SKILL, KNOWLEDGE AND EXPERTISE IN THE 'CALCULATION'

This work has argued for a shift of emphasis towards the threads of continuity that underlies the provision of Sustainable infrastructure. A revised perspective which would give due recognition to the underlying basis of that provision.

Any assumption that the level of skills, training, knowledge and expertise will be increased or enhanced as a result of the 'sustainable interventions' that we describe above implies the need to understand more about what we are referring to. And to understand how to benchmark them during the process of expertise accumulation and enhancement both formally and informally. Clearly the expertise, skill and knowledge we are referring to could range from specialised and complex research in a particular engineering domain to those competencies necessary to make a basic contribution to an engineering or construction project.

The terms knowledge, skill and expertise are perceived to have discreet meanings or definitions and the dictionary definitions frequently cross refer to each other (see Glossary). As described in 1.2 and 3.4. It is not within the scope of this work to analyse these linguistic distinctions in depth. Nevertheless some appreciation of the difference is worthwhile because it provides some context for the amalgamation of meaning that this work has sought to convey.

Studies about the nature of knowledge and how it is accumulated and assimilated are extensive and are the subject matter of a broad range of epistomological theories within the field of philosophy. However the literature on the nature of expertise has less of a philosophical backdrop. It does however have significant implications across a broad range of disciplines; in particular Human Factors and Ergonomics (Wilson and Sharples, 2015a)

‘The Nature of Expertise: A Review’ (Farrington-Darby and Wilson, 2006) provides a comprehensive perspective: “…. we have seen much increased interest in expertise as a cultural and social phenomenon, discussed in political debate and as a central concern for organisations”. The paper examines the different approaches to and understanding of the notion of expertise, as well as suggesting a move towards a more ‘naturalistic’ approach. It goes on to refer to two particular models of Expertise evaluation which serve to calibrate different stages in the accumulation of ‘Sustainable Knowledge Competencies’. Firstly the Dreyfus and Dreyfus (1986) skill acquisition model which describes the stages of Expertise accumulation as: Novice, Advanced, Beginner, Competent, Proficient and Expert (Dreyfus and Dreyfus, 1980b). Secondly the Craft Skills classification suggested by Hoffman and Hoffman: Naivette, Novice, Initiate, Apprentice, Journeyman, Expert and Master (Hoffman et al., 1995). These classifications helped to form the categories for the evaluation of expertise in the questionnaire used in the case studies.

The accumulation and amalgamation of expertise via a natural on the job learning process over an extensive period of time inevitably requires the constructive juxtaposition of the practical and the theoretical, the mechanistic and the manual as well as the formal and informal. These approaches to knowledge accumulation and enhancement are reminiscent of the apprenticeship process that has evolved from the Middle Ages. With the assimilation of expertise involving a progression through different stages of development and the accumulation of ‘situated practical experience’. This process also leads to a more holistic perspective of their domain and facilitates the transition from analytical towards intuitive thinking. Therby enabling an understanding of the whole rather than the constituent parts. (Farrington-Darby and Wilson, 2006 p 29)

While the gradations being proposed, serve as a practical benchmark for different levels of expertise, the paper points to the need to understand ‘how someone becomes an expert’ and in relation to Hoffman: A greater insight on the process of movement between the stages. While this work does not purport to contain anything like depth of an Ergonomics study it has referred to the human factors perspective in order to understand more about the process of Knowledge / Skill / Expertise accumulation and its evaluation. This enhanced understanding is set within the context of the case studies (Chapters 5 & 6) in order to gain greater insight into the process of achieving this change in level of expertise during an intervention in the infrastructure.

Noting a general decline in opportunities to accumulate and develop expertise in the workplace, accentuated by the reduction of apprenticeships [“sitting by Nellie”] the Wilson – Darby paper makes the observation that an expert is often seen as someone who has developed sufficient mastery over their domain that they can exercise discretion over which rules to follow and which to waive in the pursuit of their intended outcome. It contrasts this approach with more mechanistic interpretation of expertise exemplified by robotics and raises the question about the need to decide where along this spectrum, apparently limited resources should be applied in order to accomplish technically complex tasks. These are questions that relate to the nature of work and the potential value of not reducing down human participation in tasks to mechanistic repetition (see 2.2 and 2.3).

It favours a move towards a more ‘naturalistic’ approach to the measurement of expertise accumulation which would seem to be most appropriate for a live, complex, multi-dimensional project environment: “…people at work have a vast variety of roles, multiple goals and means and require the integration of social, cognitive and physical skills” (Farrington-Darby and Wilson, 2006) The supplementary accumulation of front line contextual skills would also support the capabilities required to address the complex systemic challenges described in the previous chapter. In particular, this would include the integration of the theoretical and the operational, many of which would lend themselves to a naturalistic process of learning on the job (“Sitting by Nellie”) from the more experienced to the less experienced practitioners.

These perceived incidental benefits figure in numerous policy documents and are often seen as a bi-product of ’sustainable investment’ Much of the literature and references applied in this context refer to the potential for a ‘skills uplift’, to be achieved in different ways. Rick Haythorntwaites (Haythornthwaite, 2011) assumption about a ‘bottom up post industrial knowledge based economy’ was also reflected in the government response to the’ Low Carbon Construction Innovation and Growth team Report’ where Chapter 6 is focussed on capacity and Skills.

In addressing the carbon challenge and whole life carbon emmissions the report points towards the need both for continuing skill accumulation as well as the redirection of current expertise in different ways. It also points towards the need for integrated inter-disciplinary thinking that should replace overly segmented disciplinary boundaries. (H M Government, 2011b p 53)

The accretion and evolution of this ‘knowledge/skill/expertise Infrastructure’, which forms an intrinsic part of the physical asset infrastructure has de facto been evolving with the railways as it has with other infrastructural systems. However a method of incorporating it into a calculation of asset value has remained elusive.

In principle, the elemental asset base and its systemic interconnections into the broader infrastructural system, could, at any point in time be valued according to the latent expertise contained within it and that any change or intervention in the asset base via a project or programme would need to factor in the consequent change or modification of this parallel infrastructural system. An intellectual twin residing alongside the digital twin and both informing the inception, design, construction and deployment of physical infrastructural solutions.

Projects and programmes could provide the focus or catalyst for these changes in levels of expertise. They could accommodate the evaluation of this process within a working environment that provided a ‘Naturalistic context’. That is, within an active working environment, where an enhanced amalgamation of skill, knowledge and expertise are assimilated into an existing amalgamation that predated the project.

Projects and programmes therefore could be said to offer the spatio-temporal boundary within which to begin to evaluate such a change of skill, knowledge and expertise. They also offer the opportunity to

understand from the participants what they perceived were the ingredients / characteristics of project participation that would enable this process of expertise enhancement to take place.

Of course, this demonstrable internalisation of such externalised benefits into a meaningful recognition or calculation of asset value presents both challenges and opportunities. These include:
- The demonstration of some form of linkage between intervention and change in level of expertise.
- The calibration or benchmarking of the levels of expertise at any point in time in order to gain a greater understanding of the degree and process of transition between one level and another.
- The recognition of the value of and potential for some form of 'expertise trajectory' and the need for a greater emphasis on it.
- Finally the recognition that this trajectory would positively influence and be positively influenced by participation in projects and programmes.

4.6 CONCLUDING DISCUSSION

This chapter has considered the significance of whole life costs in a comprehensive evaluation of true asset value as well as the significance of externalities in such a multicriteria analysis. It has explained the argument for the inclusion of the critical externality of Skill, Knowledge and expertise in any meaningful investment 'calculation'. Together with the previous three chapters it has described the basis on which a holistic evaluation of affordable and sustainable investment decisions within the rail industry would include externalised benefits. And that one of these key externalised benefits would be a positive change in Knowledge / Skill / Expertise. It has outlined the argument for the recognition of this particular manifestation of the notion of human capital while recognising that despite having to be presented as being 'external' to the transaction, it is in fact, fundamental to it. It has further argued that the aspiration to reconfigure the nations infrastructural wiring would be aligned with a systems based approach that further integrates engineering disciplines within the context of a broader economic and social infrastructural system. And that such a move to 'internalise' such 'externalities' would be compatible with policy making at a number of levels

In order to ensure that these societal requirements are aligned to technical possibilities and economic reality they need to be under constant and evolving scrutiny, particularly in a challenging environment, where work patterns have to adapt quickly to stark financial constraints and reduced investment options. Indeed it is the way in which this expertise, skill, knowledge and systemic thinking is managed directed and targeted that will determine the 'sustainability' or otherwise of an infrastructural system which sets out to serve our economic, social and environmental needs. Although challenging, this also represents an opportunity to consider different project options much more explicitly in relation to their potential to enhance expertise of those participating in them. The optioneering process which systematically balances costs and benefits would need to incorporate this into their, now, more comprehensive calibrations.

It can be argued therefore that in a very real sense the ‘Sustainability’ or otherwise of the infrastructural provision and any associated intervention refers not just to the ‘sustainability of the components or elements of which it is comprised, or even the ‘system’ which they form part of. But to the evolution in knowledge, expertise and skills that has brought them about. Necessary attributes that are intrinsic to them and without which neither elements nor systems would exist.

The benefits that flow from this process contribute directly to the quality of rail infrastructure and its continuing evolution. It can also be argued that this process represents an intrinsic benefit to the wider economy by adding to an ever increasing range and depth of capabilities and labour productivity. So the argument for the recognition of the enhancement of expertise as an externality in the evaluation of rail investment is, paradoxically dependent on the recognition that, far from being external, it is in fact intrinsic to rail asset value.

Informed by the perspectives presented in the preceding chapters the Pilot and Case Studies in Nottingham and Birmingham provided a suitable context within which to test the assembled argument and hypothesis. As large scale major station interventions they provided four projects which were representative of the challenges presented to those undertaking such significant interventions in the rail asset base.

5 PILOT STUDY – NOTTINGHAM HUB

Figure 5-1: View of Nottingham Station with the recently installed tram bridge oversailing the platforms

The argument and hypothesis, outlined in chapters 1-4 needed to be evaluated in an appropriate context. This chapter goes on to describe the pilot study at Nottingham Station, which provided the appropriate environment for doing so through surveys and interviews. The use of the delivery stage of live project environments were considered to be the most effective way to achieve this. Coincidentally Nottingham station was about to embark on an extensive refurbishment. The Nottingham Hub project therefore provided the initial focus as the pilot study for the subsequent case studies. There were also two other major autonomous projects associated with the Nottingham Hub Project: the NET2 tram project and the East Midlands Re-signalling Project. Figure 5.1 shows a very explicit interface between the Hub and NET2 projects with the oversailing of the platforms at Nottingham station by the Tram Bridge. These three Nottingham projects together with the Birmingham New Street refurbishment (which was significantly larger than any of the Nottingham projects) constituted the four Case studies which provided the appropriate context to test the assertion that expertise was enhanced through participation in projects.

5.1 METHODOLOGY FOR THE PILOT STUDY

The Pilot study, in providing context for the hypothesis had had to take into account a range of considerations: What the scope of the study would be. The type and extent of data that would be collected. The method of collecting the data. The type of data on the quantitative/qualitative spectrum/continuum and the appropriate method of calibrating the responses. Huberman refers to the Case being 'a phenomenon of some sort occurring in a bounded context' (Huberman, 1994). The phenomenon here would be the hypothesised uplift in skill, knowledge and expertise. The bounded context would the project within which that uplift did or did not occur.

The Pilot study had both quantitative and qualitative characteristics. The quantitative aspect resided in the extent to which it would be possible to calibrate the level of agreement with the survey and interview questions. This was balanced by the fact that this evaluation or self-evaluation of the respondents would inevitably be subjective and self-referential. It would be this qualitative judgement, reflected in the opinions of the respondents that would form the basis of the calibration of an interval method of measurement (Walliman, 2011).

This juxtaposition between quantitative and qualitative research models aligns to a considerable extent with the distinction between fixed and flexible research design approaches. Where a fixed research design model is associated with the quantification of a fully understood entity. (Robson, 2011). Whereas a flexible design approach would be appropriate for the dynamic organisation of data to formulate a hypothesis as the data is accumulated and analysed. While the subjective nature of the data to be collected, tended to shift the balance towards the qualitative or 'flexible' approach. This was, nevertheless mediated by the fact that there were identifiable gradations or calibrations of levels of expertise that could, be evaluated. This suggested the case studies would benefit from a multi strategy approach.

In addition to evaluating the strength of agreement with the survey and interview questions which provided a form of calibration with which to gauge the level of agreement that expertise had been enhanced. There was also the opportunity to gain a greater understanding of those aspects of project participation which provided a suitable environment to achieve that expertise incubation and enhancement. In order to gain most from the interview responses and benefit from the opportunity for more extended dialogue it was considered important not to impose a pre-conceived framework or structure over the data that emerged from the surveys and interviews. The approach adopted was based on Grounded theory. (Robson, 2011 p 474-494)and involved the use of thematic or category coding of the interview data. Then the further reduction down of the catrgories to overarching themes that cut across the different case studies. The detailed approach to surveys and interviews is discussed and developed in 5.3, 5.4. The learning from the pilot study was incorporated into and modified the approach for the case studies (These are described in 6.5). As the findings from the case studies emerged the nature and degree of alignment with the conceptual framework presented in the previous chapters are outlined and discussed. Finally the overall themes,referred to in this work as 'Cross cutting'

were further condensed down to a series of overarching ‘themes’ and these are described in 7.2. These condensed themes provided a further insight into the qualities of projects which they considered as principal factors in the enhancement of skill, expertise and knowledge for the participants and their teams. And that they achieved alignment with both: the theoretical conceptual framework and hypothesis outlined in the previous chapters and current and future measures and initiatives described in the concluding chapters.

The data in question would be the informed opinions of the participants which would need to be evaluated in some way. While there may be some methods of calibrating enhancement of expertise through such means as progression onto similar projects, recorded participation, experience gained, recognition of achievements etc. These can be quite blunt measures and do not account fully for the multidimensional nature of skill, knowledge and expertise. So while there may be some ways to quantify certain indications of expertise enhancement through these forms of measurement; there are other aspects which remain significantly more elusive.

The pilot study at the Nottingham Hub project and subsequent case studies at Nottingham and Birmingham were selected because they were representative of typical large scale engineering construction projects. Their scope had been defined previously and they were being implemented in order to realise defined practical deliverables. By using an ongoing rail construction project, the pilot study represented an already pre-formed environment within which to gain an understanding from the project participants the extent to which they believed their experience had been enhanced as a result of that participation and therefore the extent to which their views supported or challenged the argument and hypothesis.

5.2 PILOT STUDY CONTEXT

This section describes the background and context to the Nottingham Hub project.

5.2.1 Historical Background

As ‘One of the last great city stations’ (English Heritage - John Minnis, 2005) to be built at the beginning of the last century, Nottingham Station was an original hybrid – demonstrating the mix of American and British approaches to station design . Its Architect, Albert Lambert, worked under the direction of Charles Trubshaw, architect for the Midland Railway Company. The design combined the American approach and focus on achieving a spacious, elegant concourse with extensive and sometimes elaborate, platform buildings, with their associated facilities, which were characteristic of British stations.

Figure 5-2: Nottingham Station Porte-Cochere during Construction

Originally located at the point of intersection between the different modes of road, rail and canal; the Nottingham station was part of a programme of station redevelopment. This had been initiated by the Midland Railway Company and was partly in response to the Grand Central Railway which had commissioned an imposing design at the Nottingham Victoria station, also by Lambert.

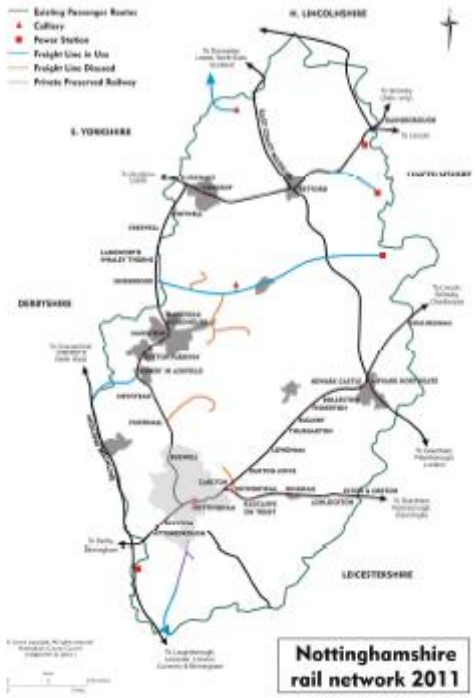


Figure 12: Nottinghamshire rail network
Source: Nottinghamshire County Council

Figure 5-3 Nottingham Station within the context of the Rail Network - Nottinghamshire Local Transport Plan 2011-2026 p41

Figure 5-4: Map showing Nottingham Station in its street context (Streetcheck)

Straddling the tracks on Carrington Road (Fig 3) the main station building (Network Rail / Building Design Partnership, 2007) is separated from Lambert's terracotta baroque frontage by the porte-cochere (Fig 5.2) . The building is set at ninety degrees to the East Midland mainline which runs underneath. Figure 5.3 depicts Nottingham Staion in the context of the rail network. The booking hall is lit from above by a rooflight and from the side by lunettes, its centrepiece is characterised by its elaborate Burmantofts' tiling design which is glazed below the dado level.

Figure 5-5: Nottingham Station Booking Hall and Roof.

The platform buildings are equally elaborate, albeit on a smaller scale, and contain several features including the tiled fireplace in the refreshment rooms.

Trubshaw's response to the American influence placed in context Britain's role in the development of innovative rail infrastructure. In fact things had moved on since the mid nineteenth century when the UK had been clearly seen as leading engineering innovation. By the end of the nineteenth century this centre of gravity had shifted towards the United States. Trubshaw was one of many engineers dispatched across the Atlantic to learn from their approach to station design. Clearly the application of expertise associated with the ground-breaking and innovative period of design and construction that

characterised the development of the railways in Britain in the middle of the century had not been sustained at the same level.

Figure 5-6: Refurbished Terracotta Façade of Nottingham Station with temporary corner bracing

The business case for the project was based on the needs of the three principle stakeholders: Network Rail, Nottingham City Council and East Midland Trains. Its key drivers were the anticipated benefits to be realised from:

- Moving people from road to rail (facilitated by the construction of the multi storey car park).
- Using the enlarged Interchange as a means to integrate transport modes and to interconnect the north and south of the city with all the economic benefits that would entail.
- The increase in revenue from the facilities. It was estimated that the Benefit Cost Ratio (BCR) for the project would also be positive.

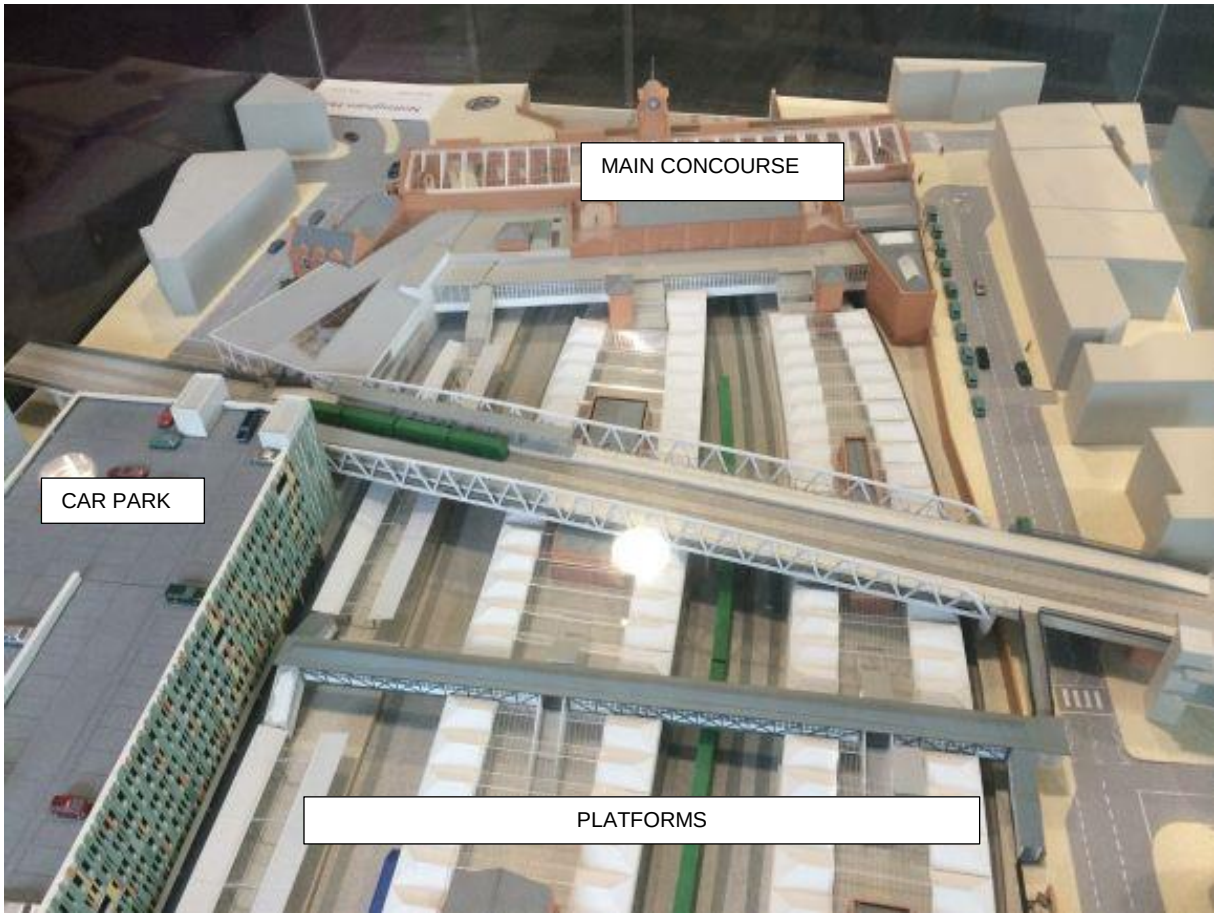


Figure 5-7: The final model of the Nottingham Hub Project, retained for public dispalay at Nottingham Station.

Scope

The project, which involved the refurbishment and adaptation of the existing station buildings and the construction of a new southern concourse was divided into 3 components carried out in conjunction with the redesign of the signalling and works to the permanent way. These are represented in the final model – (Fig 5-6)

1. Multi-storey Car Park: A new build construction, designed to combine short and long stay car parking which substantially increased the capacity of the latter. (Network Rail / Building Design Partnership, 2008)

2. Main and south concourses:

    - Enclosure and refurbishment of the Porte Cochere to create concourse and retail space
    - The refurbishment of the iconic Booking Hall.
    - The relocation of the ticket Office.
    - The refurbishment and redecoration of the Dispersal Bridge.
    - The Construction of New south concourse extension and associated links.
    - Relocation of signalling
    - External works to South Concourse
    - Works to the Brittish Transport Police (BTP) building

3. Platforms:

   - Refurbishment of platform buildings
   - Refurbishment of existing canopies
   - New glazing to existing station canopy
   - New canopy to Platform 6
   - New surfacing, ‘Tactiles’ and ‘Copers’ to platforms 3&6
   - Renovation of access to the dispersal bridge.

Figure 5-8: Car Park in backgrounf with NET2 overbrige in foreground during the process of installation over the station

The project programme duration of 130 weeks was planned to run between 01 10 2011 and 28 03 14. However it significantly overran.

The overbridge represented in the model (Fig 5-7) was a visually prominent part of the redevelopment and its installation was a considerable feat of Engineering and logistics. However, although installed during this programme period it was not part of the Hub project but came within the scope of the NET2 project.

5.2.2 Project Context

]Located within walking distance of the Cricket Ground, Football Grounds, City centre, Broadmarsh and Nottingham Arena (Network Rail / Building Design Partnership, 2008) the station is described as ‘a key building in the city of Nottingham’. The station was clearly envisaged as a ‘central transport hub’ given the nearby tram, bus, canal and cycle lanes. It was also seen as a catalyst for the development and evolution of sustainable communities by moving people from car use, integrating neighbouring areas and reducing congestion thereby actively supporting local policy statements.

The Sustainability strategy (City of Nottingham, 2009) took into account a range of national, regional and local policy and strategy documents including: ‘Securing the Future’ (H M Government, 2011a), the planning policy statements and Nottingham Local plan (Nottingham City Council, 2005). The Hub development was to be seen within the context of developments to other stations in the area, such as Beeston and East Midlands Parkway, as well as the associated resignalling project. It was envisaged as being part of an extensive modal interchange and was intended to be a part of the planned regeneration of the Southside and Eastside regeneration zones. (Nottingham CC, 2005 p 73)

The new station complex would facilitate access for all by minimising level changes and using the most effective forms of vertical transport, where necessary and appropriate, for the new design. It was envisaged that the feeling of security and well-being of passengers would be enhanced by extensive closed circuit television (CCTV) and a sophisticated controls system that would monitor the station environment. The project also included the selective re-glazing of the platform canopies (5.8) which significantly improved the level of light and general atmosphere.

Figure 5-9: The reglazing of the platform canopies showing temporary cabling and containment.

It was also intended that the project would free up small amounts of development land which could be combined with larger plots outside the site curtilage thereby generating greater value from the whole development. Employment would not be adversely affected and could be enhanced if job opportunities generated by both the station and the larger development were realised. The 'Employer Hub' (now superceded by 'Nottingham Jobs') initiated by Nottingham City Council was incorporated into the Alliance contract requirements in order to promote job opportunities with local people and was monitored throughout the project.

5.2.3 Stakeholders, Alliance Composition and Procurement

The Nottingham Hub project was a 'Tripartite Alliance' (Network Rail, 2013a) between Network Rail, East Midland Trains and Vinci and included a Memorandum of Understanding between East Midland Trains and Network Rail as well as two joint target cost contracts between East Midland Trains and Network Rail and between Network Rail and Vinci. The management structure was based on a joint project board and an integrated project team (see Figure 5-10).

Initially envisaged as being procured via a traditional contract route it became one of the first projects to adopt an alliancing model. The main principles of which included a joint management approach based on collective responsibility and the appropriate sharing of risk, the majority of which would be owned by the alliance. Working on the basis of open book and target costs it incorporated a no blame culture in order to facilitate a commitment to avoiding disputes wherever possible.

The anticipated outturn cost benefit of this form of procurement was anticipated to be up to £3m as a result of the integrated methods of working. Part of this benefit would be achieved through a significant reduction in programme duration.

5.2.4 Site Logistics

Figure 5-11 and Figure 5-12 give an indication of levels of attendance, the composition of the workforce and the nature of their disciplines and capabilities.

Between 16th March 2012 and 7th May 2014 2,429 individuals were inducted on to the site. (Taylor Woodrow, 2012) (See Figs 5-9 and 5-10).

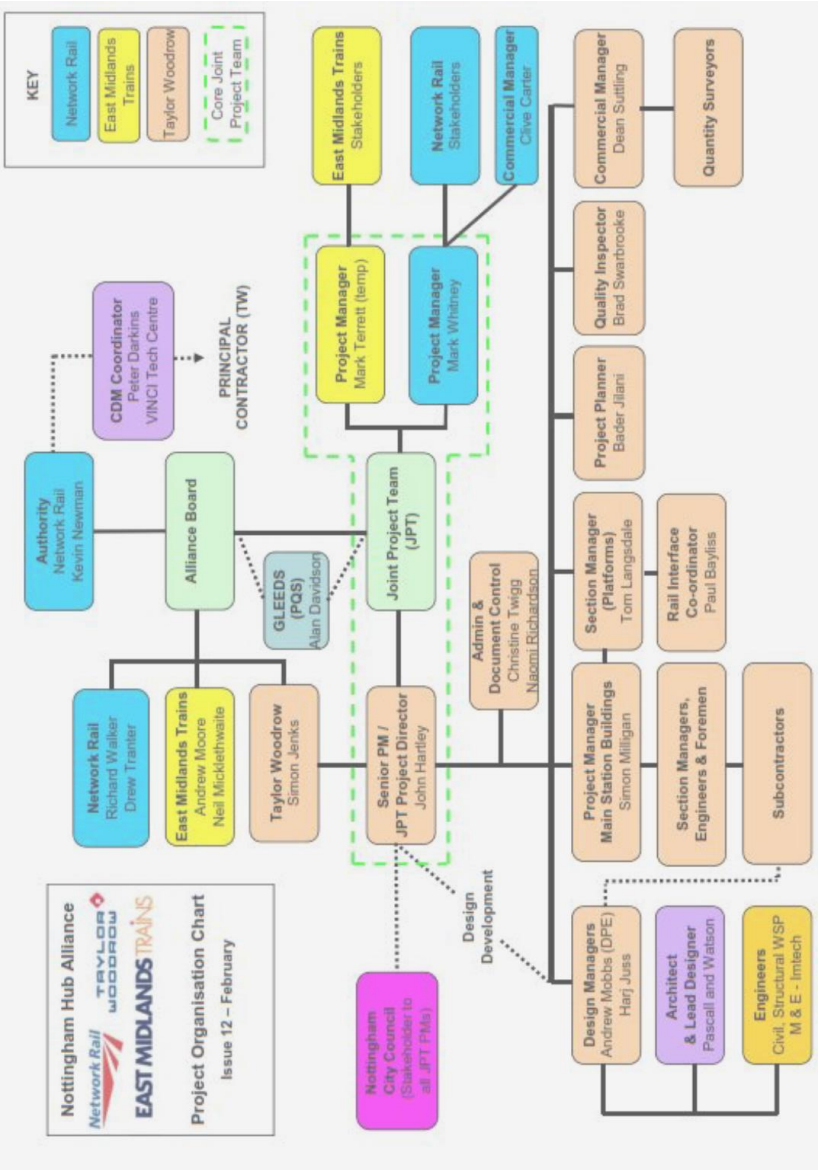


Figure 5-10 Alliance Organisation Chart for the Nottingham Hub Proje

Average Daily attendance:

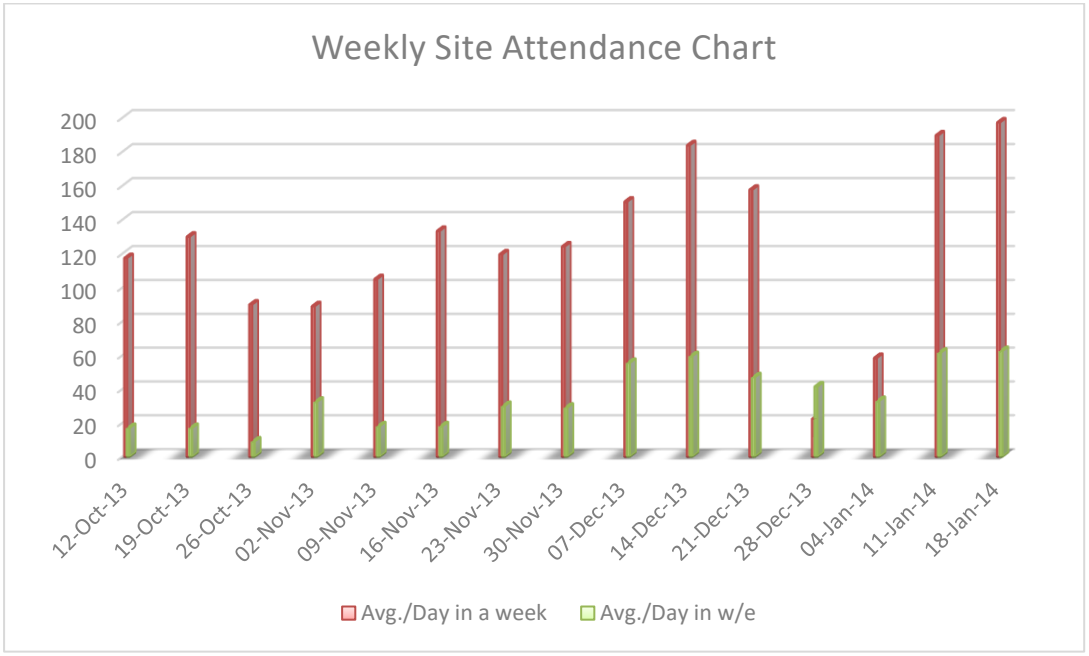


Figure 5-11: Weekly Site Atendance Chart (5.3)

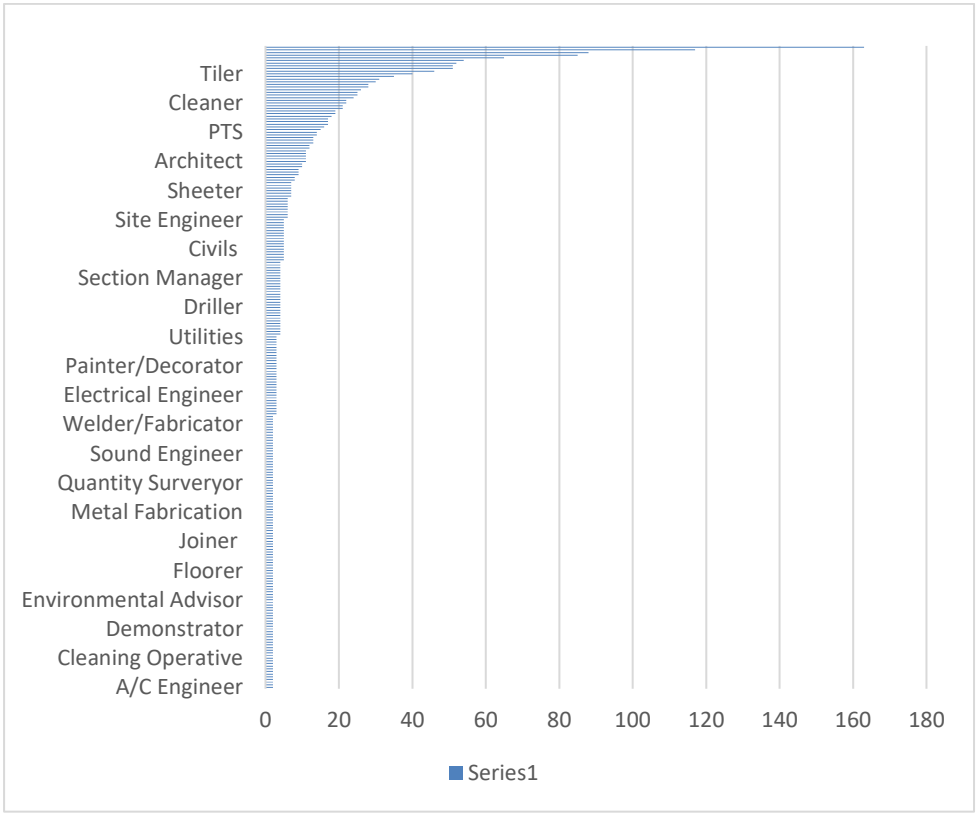


Figure 5-12: Pivot Table Indicating Site Inductions by Discipline. (5.4) Survey Design and distribution

As described above, the most appropriate method to begin to clarify the relationship between project participation and expertise enhancement was considered to be a combination of quantitative and qualitative data accumulation and analysis (Walliman, 2011) through surveys and interviews. And that these should take place through a bounded case study or studies. It was envisaged that the pilot study would point the way towards further developments and refinements of the approach that occurred during this iterative process of data collection and analysis. The extent of these are described in Chapter 6.

The intention was to develop the survey as homogeneously as possible in order that it could be used more broadly and was not specific to the Nottingham Hub. So while the Hub project may have provided the context within which the questionnaire was shaped. It was important that it was designed in a way that it could be transferred to other types of projects and their associated disciplines. The Survey was by its nature self-referential therefore the responses were likely to be influenced by the limitations of self- perception, however it was hoped that the anonymity of the survey would encourage straightforward and honest responses.

The gradations used were developed for the survey with reference to literature on expertise development. In particular the works on expertise elicitation by Hoffman (Hoffman et al., 1995) and Dreyfus and Dreyfus (Dreyfus and Dreyfus, 1980a). Both works refer to scales of development in order to calibrate different stages of expertise evolution. Hoffman's 'Guild terminology for development' uses a more direct reference to this system: Naivette, Novice, Initiate, Apprentice, Journeyman, Expert and Master. Dreyfus refers to: Novice, Competence, proficiency, Expertise and Mastery. While Hofmann's reference is more direct. Both owe their origins to the original medieval guild classifications. Drawing on these, the survey, developed for the pilot study uses a list of five developmental categories: Novice, Beginner, Competent, Proficient and Expert. The survey provides a brief guide and synopsis of the criteria for selecting each one (See Appendix 1). It was important to ensure that the categories and choices offered in the survey were extensive enough to cover the broad range of potential participants. It also needed to take into account a very extensive spectrum of capabilities and qualifications, ranging from highly qualified, experienced engineers to those that had never worked.

In addition to level and type of qualification, the survey was asking for information related to the participants' levels of experience: Their age, the length of time they had spent on the project and the extent of their time in the rail and/or construction industry. The steady accumulation of experience and the development of the associated capabilities are critical ingredients in the effective enhancement of expertise. This is particularly so in both the rail and construction industries where the gestation period is particularly long and in relation to the construction industry where its cyclical nature has been particularly damaging to continuous learning. While the direct effects on apprenticeships and training may not be significant (Brunello, 2009) the effect on overall skill, knowledge and expertise accumulation, of the potential workforce, from personal experience, was significant. This process led to significant loss of knowledge and experience during downturns (Building Better Healthcare, 2015) as well as a consequent 'skills and experience gap' when the inevitable upturn occurred.

The survey divides into five sections:

A. Explanation: The survey is introduced by an explanation of its purpose and by emphasising its voluntary nature.

B. Position on the Skill/Knowledge/Expertise developmental spectrum: The second section asks the participants to assess their level of expertise/knowledge/skill level in the area they are working in. It asks them to compare the level they perceived themselves to be at when they started the project with the level they perceive themselves to be at on the date they undertake the survey.

C. Influence of the Project/Programme on the development described in previous section: It asks the respondents to affirm or negate on the 5 level scale (referred to above) the extent to which their level of expertise has been changed by working on the project also to affirm or negate the extent to which their 'green skills' had been similarly increased.

D. Background information: seeks to capture the background of the respondents in terms of: Gender, Age, Years working in the construction and rail industries and formal qualifications. These formed the basis of the overlays illustrated in section 5.5.

E. Individual comments: by the participants relating to the evolution of their skill, knowledge and expertise on the project.

A common approach that met the stringent requirements of both the University and Network rail was eventually agreed for surveys and interviews in alignment with the Ethics Approval process. Initially the Questionnaire was issued in Hard Copy format (See Appendix 1). It was agreed that it would be distributed by the project management team at appropriate points in the programme. Compactness and brevity were important given programme pressures and therefore it was restricted to one side of A4. The pace and number of returns of the hard copy survey from the project proved to be limited and slow with 29 returned surveys.

Following the Pilot Study, the distribution was changed to on-line survey approach for the remaining case studies. Following an extensive screening process to find an online survey mechanism that was acceptable to the two organisations; the Bristol On-line Surveys (BOS) system was selected. This was introduced at the end of the pilot studies but became the sole means of distribution for the case studies in both Birmingham and the two Nottingham case studies. The online version can be found at: https://nottingham.onlinesurveys.ac.uk/sustainable-interventions-in-rail-assets-copy-4 (Appendix 2)

It became apparent during the course of the pilot study that the distribution, support and means of communication were very important factors in its initiation and implementation. Towards its end the opportunity arose to undertake a second case study at the major refurbishment and redevelopment of Birmingham New Street. This was a significantly larger project than Nottingham Hub and therefore correspondingly expanded the perspective of the study. The NET 2 light rail project also added another dimension to the notion of the rail asset base and this together with the East Midlands Resignalling Project, broadened the scope of the information that would be collected.

Figure 5-13: Nottingham Station Facade. The Station spans the tracks on Carrington St

5.4 INTERVIEW DESIGN & IMPLEMENTATION

Interview Design:

In addition to the surveys, a series of interviews were arranged with the more senior members of the project team in order to supplement the information provided by the surveys. They would also contribute to a greater understanding of the background to and reasons for the responses they provided. The possibility of interviewing all the survey respondents was considered but this would have prejudiced the anonymity of the participants and would have been logistically challenging. The possibility of following up with the interviewees post project completion was also considered. But again the importance of security and anonymity requirements precluded this.

As described above (5.1) the options considered for the types of interviews were: Open, Structured and Semi-structured (Walliman, 2011). A closed approach would have provided a tight structure but little flexibility. An open approach would have been very flexible but would have substantially reduced its

consistency and the ability to compare case studies. Given the nature of the project, the interviewees and the subject under consideration it was decided that semi-structured interviews would be the most appropriate approach. This was because it would be able to pose… 'defined questions while leaving time for further development of those answers including more open ended questions' (Walliman, 2011:p 193). It was also important to be aware of the effect of the researcher on the nature of the interview and assimilation of data (Mac Donald et al., 2020 p 34)

It was intended that the interviews would provide support for and build on the surveys by drawing out the attributes of the projects which the participants considered had contributed to the enhancement of their expertise. The surveys had been intended to provide a calibrated (albeit self-evaluated) estimate of the extent of the change of expertise that the project participants believed they had undergone as a result of that participation. The interviews also sought to gain a greater understanding of some of the more complex relationships that lay behind those changes. To explore some of the different dimensions of skill, knowledge and expertise and the extent to which they manifested themselves on the project. The range of topics that were considered for further exploration included:

- The extent of the relationship or co-relation between project participation and the perceived enhancement. of expertise generally as well as what could be described as an original domain or core technical area?
- The extent to which their expertise had evolved because its centre of gravity had shifted (eg from Engineering towards management)
- Whether there was a perceived enhancement of what can be described as 'green skills' (eg: Technical skills relating to the installation of energy saving equipment) in relation to core skills? Also, the extent of the distinction between expertise enhancement in a 'core' area and enhancement in what are understood as 'green' or sustainable skills. The extent to which this was this a useful or meaningful distinction.
- The relationship between project participation and all round educational enhancement.
- Whether the expertise enhancement, if demonstrated was compartmentalised or holistic.
- The extent to which the expertise enhancement leads to transferable skills.
- The opportunity for and effect of 'naturalistic' learning.
- The relation between age and the perception of expertise change.
- The relationship between qualification and the perception of expertise change.
- The relationship between length of time on the project and perceived enhancement of expertise.
- The relationship between the length of time working in rail and/or Construction projects and the perceived enhancement of skills/expertise.

The questions were developed with reference to the survey questions and the range of topics described above. Some sought to address expertise enhancement generally, others its different manifestations in relation to sustainability or Green Skills and the latter questions considered the more strategic expertise associated with what could be described as the public good. Questions 1and 2 were addressing the participants role, work domain and expected expertise. Questions 5 and 6 were addressing the extent to which expertise was enhanced. Questions 3, 4, 7 and 8 were addressing the perception and possible

distinction of sustainable/green skills. Questions 9 and 10 were addressing training and ongoing learning. And questions 11, 12 and 13 were considering the broader policy questions and the extent to which they influenced the projects. Following the Pilot study the questions were regrouped more formally by themes (6.2.2)

The questions and the initial order they were asked in are listed below:

- Q1: please describe briefly the area/field in which you work
- Q2: broadly outline the range and depth of :a: qualifications b: competencies / skill / knowledge /expertise expected of those in your management line, particularly those that report directly to you.
- Q3 do you consider that those workstreams on your project/programm/portfolio can be described as 'sustainable' – (ie: demonstrating 'an enduring and balanced approach to economic activity, environmental responsibility and social progress'. (linked to Q4))
- Q4. Briefly describe the focus/emphasis of the sustainability effort, as you see it, on the project.
- q5. Do you consider that the level of competency skill / knowledge / expertise of your team is actively enhanced as a result of working on the project.
- Q6. Do you consider that the level of competency skill / knowledge / expertise of your team can be demonstrated / measured? If so how?
- Q7.are you able to distinguish between the change in / enhancement of basic / core skillsets and their 'sustainable' component. (linked to Q8)
- Q8 do you think there is a meaningful distinction between core skillsets and sustainable skillsets.
- Q9. Do you consider that the basic/core skills would be increased/enhanced if day to day workstreams were combined with on the job training. (linked to Q10)
- Q10. Do you consider that the sustainable component of core skill-sets would be increased if day to day workstreams were combined with on the job training.
- Q11. When evaluating the business case for the project, to what extent did the non-quantifiable benefits influence the decision to undertake the project.
- Q12. What do you percieve those non-quantifiable benefits to be?
- Q13 to what extent do you consider that you would achieve a more effective evaluation of a potential project if greater account of these externalised benefits were taken into account at the outset.

As described above the Interviews were undertaken in accordance with the principles of Grounded theory (5.1). It was intended that Interviews would be undertaken and recorded and some very limited contemporaneous notes taken, where necessary, in order to maintain pace and facilitate communication. The participants were selected in discussion with the senior manager to provide a representative cross section of the more senior management team.

- Recordings to be reviewed the requisite number of times in order to identify repeating themes (categories) emerging from each question for each interviewee.
- Themes (categories) that gained prominence in the response to each question across the different interviewees were noted against each question.

- Then as other case studies were undertaken themes which repeated across the case studies would be further condensed down to what are described as ‘supra-themes’ and noted against each question across the four case studies
- Themes which oversailed the individual questions would be captured in what are described as ‘cross-cutting themes’
- Finally the Cross-Cutting themes would be further condensed down as far as possible in order to encapsulate the overriding themes or focus of the study.

During the course of the Pilot study, it became apparent that, although many of these areas that were reflected in the study were of great interest, it would have been impossible to engage with the full implications of the issues they raised within the bounds of this work. For example the distinction between job specific training and all round educational benefit, core skills and green skills or to understand the full extent of the transferability of the skills that were considered to have been enhanced. This is discussed further in the next chapter and in the lessons learnt postscript at the end of Chapter 7.

5.5 SURVEY RESULTS.

With the Caveat, noted above in 5.3.1, of using a self-referential process there were a number of questions raised which needed to be addressed during the survey, interview, data accumulation and analysis process. This was intended to achieve a greater understanding of the relationship or co-relationship that might exist between the project participants and the extent to which they perceived their level of expertise to be enhanced. It needed to take into account the varying attributes of: Age, rail and construction experience, qualifications and time on the project. While the surveys provided structure and clarity they also allowed sufficient freedom for individual perspectives on their situation. For example, there was no precise description of core skills. This left the opportunity for the participants to interpret this central set of skills, knowledge and expertise in a way that acknowledged the dynamic reality of their career/competence/capability development. That is to say it allowed respondents the opportunity to acknowledge their original training but also to recognise that their capabilities and specialisms had evolved since their original training. An evolution which could have had a significant effect on what they would have described as their core skills as their career had developed. Because the project was centred around engineering infrastructure many of the respondents original specialisms were in engineering or construction related disciplines. So, for example, a respondent may have originally trained as a civil engineer but had subsequently evolved into a programme management role. A significant proportion of those surveyed and almost all the interviewees were currently in management roles.

The surveys were initially distributed and collated by hand through hard copy A4 forms by the project management team. As described in 5.3.2 the disadvantages and constraints of this approach were lessons to be taken forward into the case Studies. All of the case studies subsequently used the Bristol Online Survey (BOS) on line survey method, later renamed as ‘Online surveys’.

A range of options for the presentation of the results was considered and the use of conventional Office software was chosen for its ease of access and translatability and it was eventually decided to present the results on Microsoft Excell pivot tables. A range of different pivot table and pivot chart formats were considered before a final approach was arrived at and it was considered that a greyscale palette would be the most appropriate. It also aligned with the ongoing process of journal article submission which required them to be made in black and white. These are illustrated in figures 22-26 below.

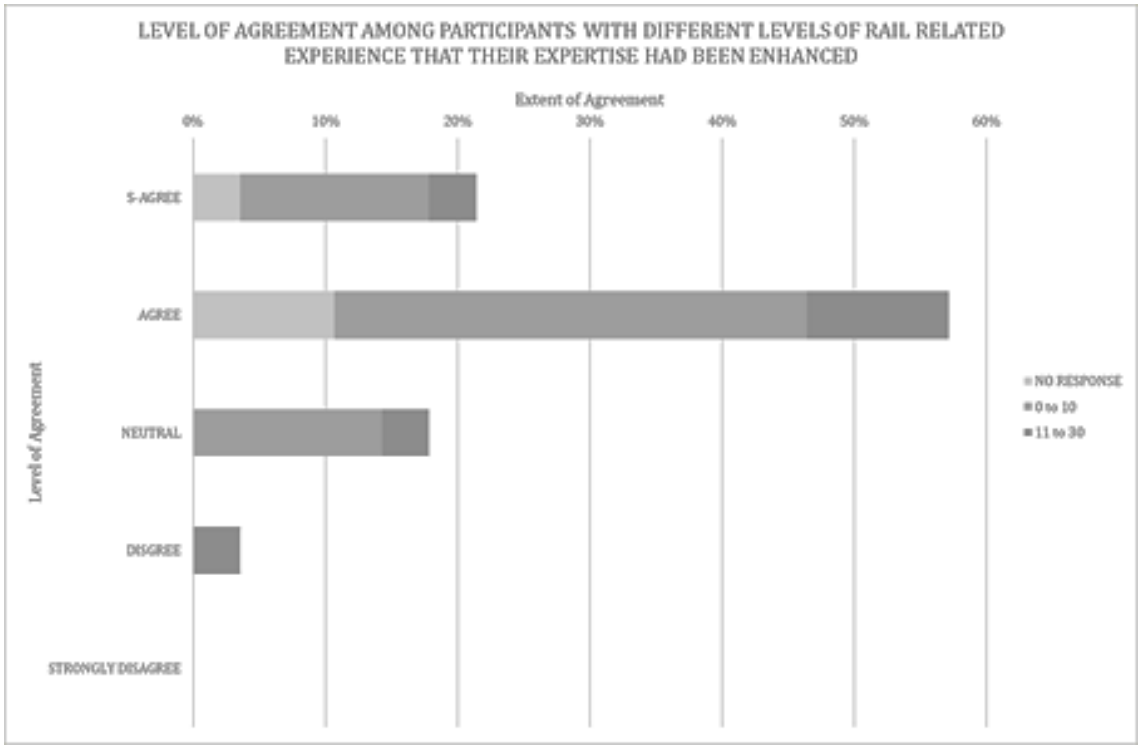


Figure 5-14: Greyscale Horizontal Gantt chart representation of the Level of Agreement that expertise had been enhanced overlaid by levels of Rail Related experience of the participants.

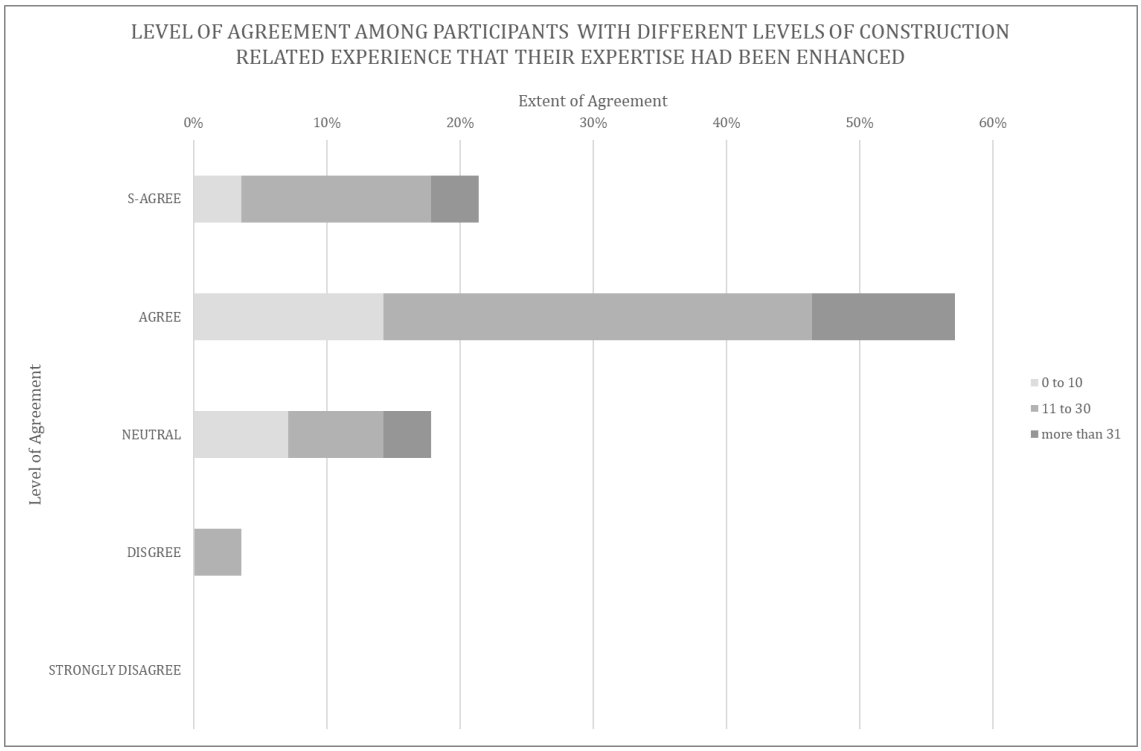


Figure 5-15: Greyscale Horizontal Gantt chart representation of the Level of Agreement that expertise had been enhanced overlaid by levels of Construction Related experience of the participants.

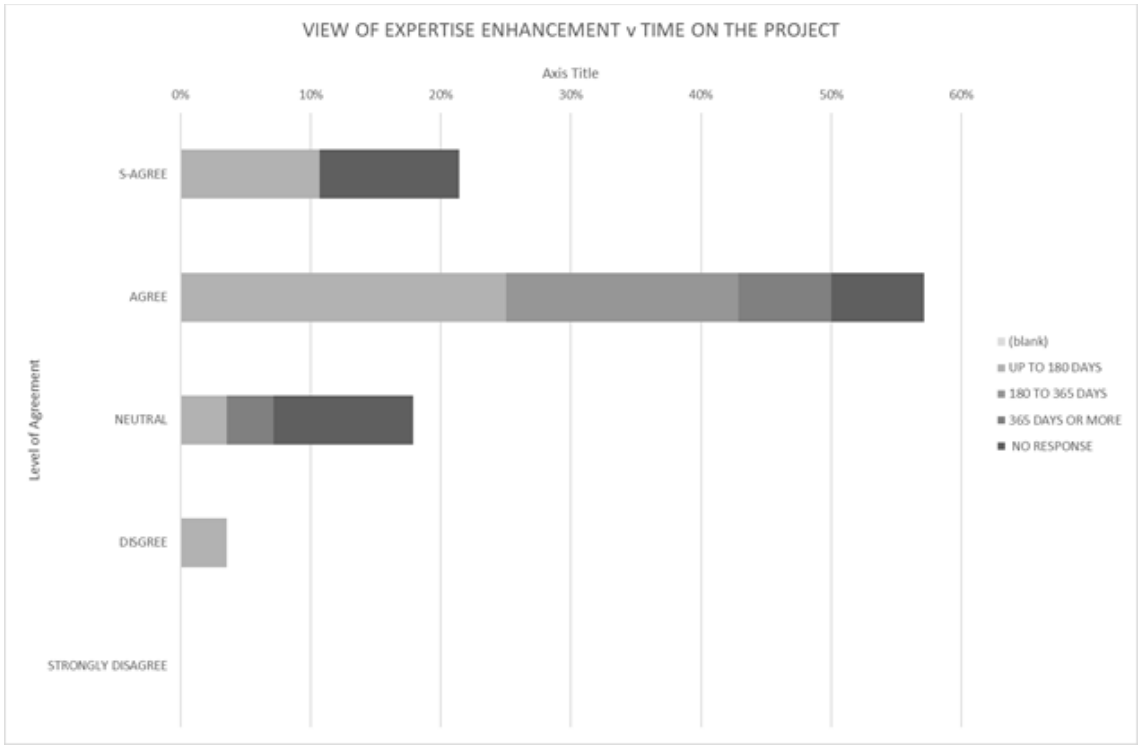


Figure 5-16: Greyscale Horizontal Gantt chart representation of the Level of Agreement that expertise had been enhanced overlaid by the Participants length of time on the project.

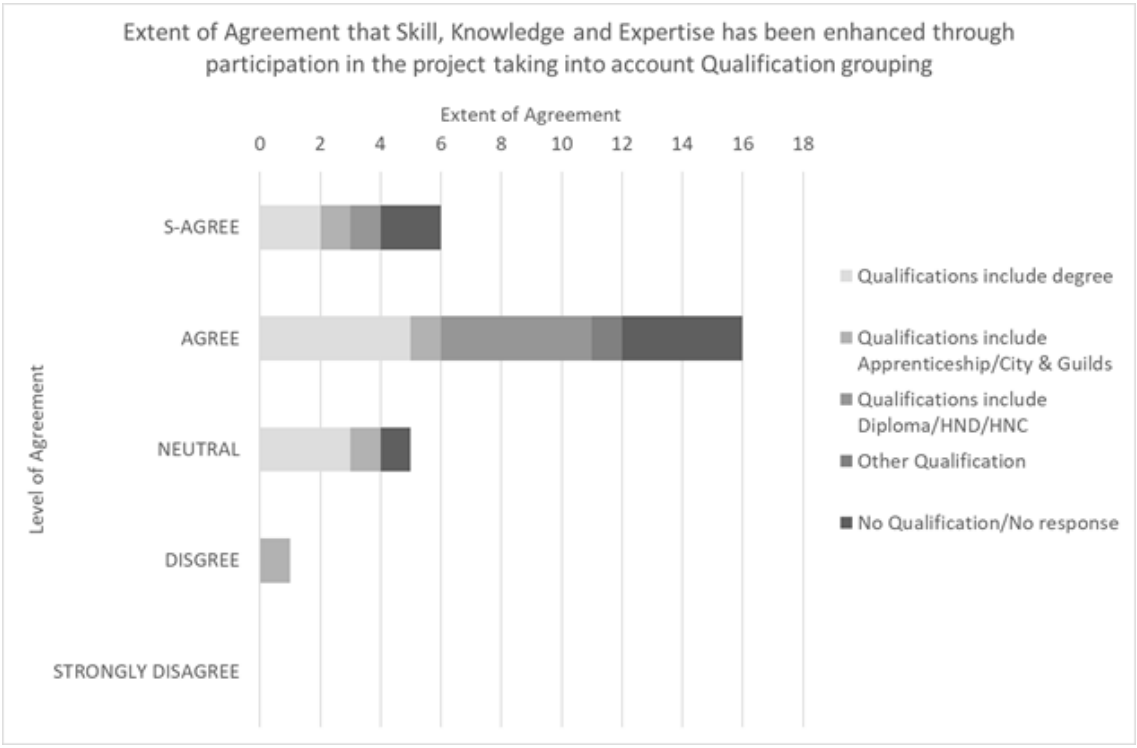


Figure 5-17: Greyscale Horizontal Gantt chart representation of the Level of Agreement that expertise had been enhanced overlaid by the qualifications of the participants.

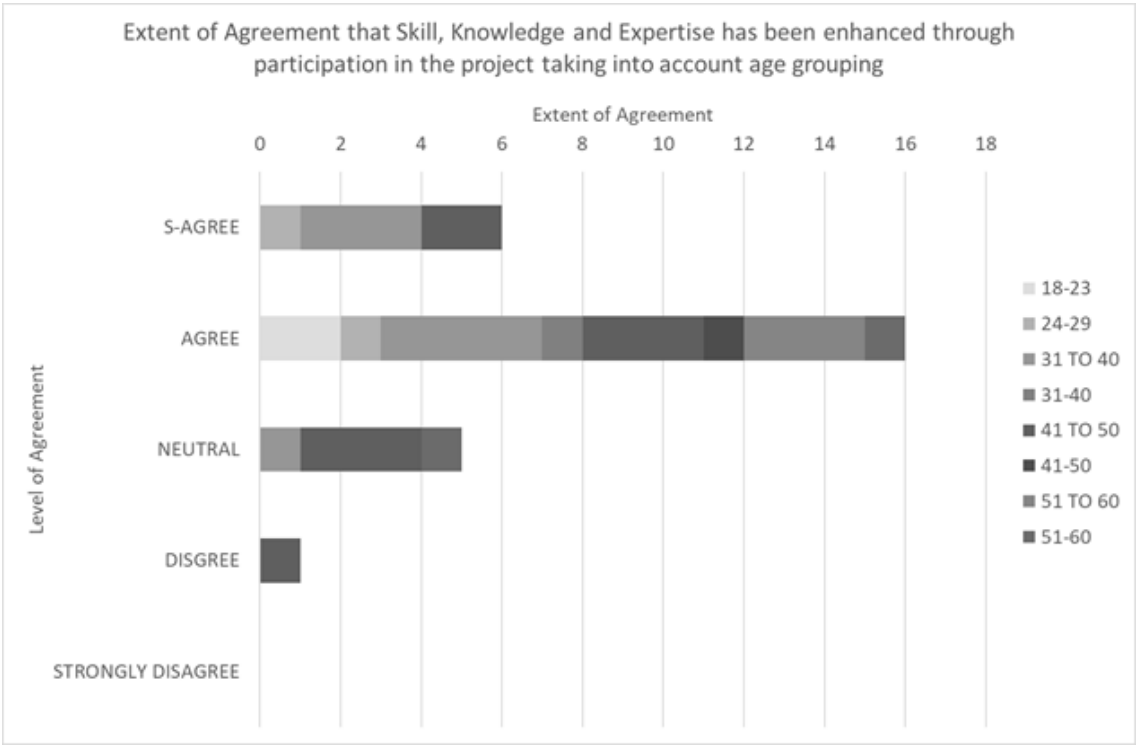


Figure 5-18: Greyscale Horizontal Gantt chart representation of the Level of Agreement that expertise had been enhanced overlaid by Age of the participants.

The different representations of the survey results presented above describe a consistent alignment between participation in projects and programmes and the participants' perception that their expertise had been enhanced as a result of doing so. This appeared to be consistent across the overlays of age, time on the project, qualification and experience in rail / construction.

It became apparent that although the surveys were perceived to be more quantitative and binary in nature; they, nevertheless relied on the subjective judgements of the participants. And that any apparent distinction between quantitative surveys and qualitative interviews would be misleading. While the surveys provided discreet calibration in the form of boxes that could be ticked and counted. The decision to attribute the particular levels of attainment were largly a matter of the subjective judgement and self evaluation of the participants. Notwithstanding this, there was a consistently reported uplift of the levels of enhancement from whatever the originally self-attributed level had been.

5.6 INTERVIEW RESULTS

The Interviews were carried out on site at the Nottingham Hub just after the main deadline for project completion. The immediate focus of the project practical completion deadline had recently passed and the site was not as highly focussed as it had been in the weeks leading up to this significant milestone. However all the participants, selected on their seniority, availability and domain relevance, were still extremely busy and so it was necessary to organise and run the interviews at a business-like pace. While this was useful in keeping the answers concise, there was a risk that it could have contrained or curtailed the interview and consequent discussion. However this concern did not materialise, indeed several of the interviewees were interested in exploring several of the subject areas extensively and the interview time extended accordingly.

The topics or categories which emerged from the interviews were transcribed into a spreadsheet and indicative values were ascribed to the type of response (positive-negative) that emerged from the direct answers to the questions or the subsequent discussion. These categories were listed and tabulated and summarised in Figure 5_1

The interviews were intended to achieve the following: Firstly to test the extent to which there was some form of relationship between expertise enhancement and project participation. Secondly to gain a greater understanding of the factors which the participants believed were instrumental in achieving that enhancement. Thirdly, to consider any patterns and themes that emerged in order to understand more about the nature of that perceived enhancement. And finally, to consider how these themes might point the way and be effectively harnessed in order to support this shift of emphasis towards the engagement of expertise as a project output. This is developed further in Chapter 7.

As with the survey / questionnaire it was important to be aware of the self-referential nature of the interviews. Also, given the nature of the study, of the potential for the interviewees to lean towards

uncontentious responses to the question. However this concern was significantly mitigated by the strength and clarity of the responses suggesting that they were informed and credible. The interviewees gave the impression of being fairly 'battle hardened' and not given to either, hyperbole or being reluctant to share their opinions. Also that they were more than prepared to challenge the status quo if they felt it was necessary to do so and that they would be as direct as they needed to be in order to communicate their views.

Questions 1&2

Area/field of work / expectation of qualifications, competencies (skill / knowledge /expertise):

There were a broad range of construction /engineering disciplines represented by the interviewees as well as an effective grasp of the other disciplines that were required in their teams and on the project as a whole. The range of disciplines either represented by the interviewees or that they were responsible for managing included: Project and Programme Management, Engineering, Civils, M&E, Signalling, Engineering Management, Construction, Construction Management, Commercial Management, Design Management. Four of the six participants demonstrated an awareness of an appreciation of the relationship between their current roles and the domain of their original training.
The responses were generally limited to being factual descriptions with some limited consideration of their value and potential. There was an expectation that the relevant technical, commercial and managerial capabilities were required and indeed were represented in the project team.

Questions 3&4

Sustainability of works-treams / focus of sustainability of effort:

The question invariably required clarification and explanation and there was a certain unfamiliarity in the answers to the 'sustainability topic'. Not surprisingly, given that it was an infrastructure project, the focus tended to be on the environmental aspect. There were a range of responses which reflected this. Such as: 'working with the environmental agency', 'responsible disposal of waste', the use of the Building Management System (BMS) to optimise the building's performance. There were limited references to the more socio-economic aspects of the project, which ranged from health and safety to more nuanced references to 'team management' and 'economic cycles'. This response indicated a more immediate association with Natural Capital with the reference to the notion Human Capital being realised through effective management of the team. There were no explicit references to the concepts highlighted in Chapter 2, such as the different models of Sustainability, forms of Capital, 'Sustainable Development Goals', the significance of skill enhancement in rail strategies, the value of work or whole system thinking. Indeed, the questions and the responses came across as as tangential to the principle direction of the interview. Several of the interviewees had needed prompting to identify 'sustainability' work streams which were distinct from what were perceived to be the more standard work streams. There

was a similarity here with questions 11-13 which also required prompting. This was in contrast to the discussion around skill, knowledge and expertise or training where there was a familiarity, as well as what appeared as, a natural association with the subject matter.

The subject area of sustainability and its different manifestations and conceptual alignments (Chapter 2) is obviously of enormous significance as well as being very extensive and It became apparent that there was a significant risk that an approach which sought to develop and emphasise these distinctions would substantially over-extend the study. It also provided indications of a more productive understanding of the way in which the notion of sustainability was manifesting itself – this is considered further in the next section (5.7).

Question 5

The extent of skill / knowledge / expertise enhancement achieved through project participation:

There was an almost unanimous consensus that the skill, knowledge and expertise of both the interviewees and their teams had been significantly enhanced since working on the project. One of the Participants responded clearly that it had 'definitely' enhanced the expertise of themselves and the team. Also that the complexity of the project, including the mix of new build and refurbishment had made it an 'extremely challenging refurbishment' but at the same time had provided substantial opportunities for 'personal development'. This view was reflected by those managing the construction who also considered that their perspective had been substantially enlarged although the question also prompted a criticism of the apparent disconnection between the management of the programme and constructional reality. There was a degree of nuance from one of the participants, while agreeing that 'absolutely' it had enhanced the expertise of their reports they considered that their own 'baseline' experience had not been 'significantly' enhanced given the number of station refurbishments they had undertaken in the course of gaining their considerable experiences. Although, they acknowledged that there were always 'nuances' that 'you can learn from'.

Some of the the interviewees also referred to the fact that the project was both challenging and complex on a number of levels. This left the impression that it had been a very demanding process that had tested the majority of participants beyond their comfort zone in relation to their previous experience of working on similar projects. From experience, it is not uncommon for project participants to have a more critical view of a project when they are immersed in it and are disproportionately aware of the challenges in relation to the overall achievement and its attendant benefits. However there was a consistent emphasis on the benefits of informed cohesion on a complex project aligned with the recognition that the project could provide a complex setting in which to gain a broad and informed perspective (Chapter 4)

There were certain themes which were beginning to emerge from this central question and which were to continue to emerge from the interviews in the Case Studies: The value of the complexity of the project and the perception that it provided the opportunity to increase perspective and expand horizons while offering an environment for continuous learning. There was also an impression that the task of integrating the management of the different disciplines and suppliers together in an integrated whole rather than disparate segments was an extremely challenging but also essential aspect of the evolution of the project.

Question 6:

The possibility of measuring skill / knowledge / expertise:

While there was an emphatically affirmative response as to whether expertise had been enhanced as a result of project participation, there were a broad range of attitudes to the measurement of expertise. And while there was a general consensus that measurement should be, in principle, possible, there was less agreement and clarity on how it should be achieved. There were some suggestions that the number of people passing courses including safety critical training would serve as an effective 'hard measure'. There were also suggestions around key performance indicators (KPIs). That using KPIs could provide an effective reflection of recognisable changes in related competences. The subjective assessment of performance reviews were also suggested as a means of evaluating the extent to which the enhancement of expertise could be recognised. There was also a suggestion that the quality of the delivered scheme would serve as an effective measure, although clearly this type of judgement, by its nature, would be essentially qualitative. Other possible suggestions included: Noting those tasks which could be undertaken following the interventions which could not have been undertaken prior to them, the completion of training schemes and the extent of the interdisciplinary exchange of knowledge. So while there was belief that such an enhancement should be measurable there were no obvious mechanisms put forward as to how to achieve this. This suggested that the qualities associated with expertise and expertise enhancement did not lend themselves readily to quantification. That all the forms of possible calibration were essentially too blunt.

Question 7 & 8

The distinction between the enhancement of basic/core skillsets and sustainable skillsets.

This question consistently required exemplification and clarification as to its meaning. Once this was done there was a belief that there was a legitimate distinction to be made between core and sustainable skills/expertise. The 'sustainable' component of these was again perceived to be centred on the environmental aspect of sustainable development, which, as in Questions 3 & 4, was to be expected on

an engineering infrastructure project. At this time, the construction industry was in the process of assimilitaing the implications of sustainable development and there were some energetic responses to the subject area. The responses tended to reflect an environmental focus however several did not have the conviction and familiarity that had been present in response to questions 1, 2, 5 and 6. It was also noted by the interviewees that a number of sustainability workstreams had been 'contracted out' to consultants. This added to the impression of a degree of separation of the topic from those working on the project as well as further reinforcing the impression of segmentation and lack of integration that had been noted in response to the previous two questions. It was becoming apparent that the reference to sustainability and sustainable skillsets was creating a lack of fluency with the other questions in the interview because of the respondents' lack of familiarity and perspective in relation to the subject matter. It was tending to generate responses which gave the impression of not coming from such an informed perspective as the other responses and appeared different in tone to the responses relating to their perception of general expertise enhancement. This could have led to a more granular consideration of the participants understanding of the term and its different manifestations on the project. However a detailed examination of the different dimensions of sustainability some of which have been outlined in the previous chapter), as a part of what was alreadty a multidimensional study could risk a dispersal of focus. It was also pointing towards a shift of emphasis in relation to the nature of the sustainaible enhancements of expertise that the study was seeking to address and this is further considered in the next section (5.7)

Question 9 &10

The enhancement of basic/core skills (and sustainable skills) by combining workstreams with on the job training:

There was a strong affirmation that combining day to day 'work-streams' with on-the job training would have a positive influence on the evolution and development of skill, knowledge and expertise because the interviewees were conscious of the beneficial effects of training to support their competencies and those of their team. There was a general agreement that the industry was reliant on such training that combined contextual understanding with theoretical explanation. There was also general agreement with the fact that training that took place on the job would ensure that it was relevant and tailored to the tasks in hand or 'Sitting by Nellie' (Farrington-Darby and Wilson, 2006)**.** However it was also made clear that the training needed to be tailored to project requirements. One of the participants was 'definitely' in favour of on-site training providing it was 'targetted applicable and undertaken at the right time' The broader educational benefits of training or education for its own sake was not considered sufficient justification to divert people from principle day to day tasks. Again the reference to sustainable skill sets did not appear to add anything to the notion of skills, of whatever type, being enhanced through on the job training.

Reference was made to Nottingham City Council's instigation of an employment facility which they described as a 'Jobs Hub' to facilitate employment within the Nottingham area. This initiative had gained support and there was a requirement written into the contract that the project should seek to recruit, in the first instance, from this facility. Recruiting for the project was not always possible as there were considerable technical competences and capabilities required for the majority of the roles. Neverthess it transmitted a positive message and did have some success, including the recruitment of one of the interviewees.

Question 11 &12

The nature and influence of non-quantifiable benefits on the business case for the project.

While this question also required clarification, there was a more limited but thoughtful response to the question relating to non-quantifiable benefits. Although there was a general understanding that the business case was inevitably driven by financial criteria there was also a recognition of the broader, strategic aims of the local authority. These included health, safety and wellbeing, improving the interconnectedness of the transport system, connecting the different parts of the city as well as the benefits of regeneration, such as increased employment opportunities. That it would bring an 'integrated hub' and bring 'some form of transport cohesion' There were direct references to the project connecting the north and south of the city and of it acting as a catalyst to enhance the conditions of the more deprived areas. It was also seen as an opportunity to bring 'work and work experience to local people' and that it would serve as a catalyst to bring some cohesion the transport policy in Nottingham. There was also some criticism of the degree of alignment of project planning.

Question 13

Would early recognition of externalised benefits provide more effective evaluation of potential projects:

Again, this question opened up a discussion about the strategic aims of the project and there was considerable overlap with the previous two questions. The refurbishment of the listed station was perceived to be a considerable benefit to the people of Nottingham. However there were a range of observations relating to the lack of interconnection and integration of projects over time with current projects not being aligned to future projects, such as electrification. In particular the missed opportunity of 'Renewals' not taking advantage of the opportunity to upgrade the facilities in the same way that 'Enhancements' do. (Network Rail makes a clear distinction between renewals and enhancements – the latter involving the replacement of assets on a 'like for like' basis whereas enhancements would involve the appropriate upgrading of the asset). It was also noted that the three Nottingham projects (Nottingham Hub, NET2 and The East Midlands Re-signalling Project) coincided in time rather than being planned to be within the same timeframe

There was an appreciation of the local authority's broader aspirations on a number of fronts: By rectifying what was perceived to be a previously disjointed transport policy through an interchange which brought

together different transport modes. By combining old and new construction methods and renovating an iconic listed building and by acting as a catalyst for regeneration by connecting the different parts of the city.

As with some of the earlier questions there was a perception that interconnection and where appropriate integration, was preferable to separation and disconnection. Whether that related to the integration of: different transport modes, the technical needs of the project or its managerial governance. This began to develop into a consistent theme.

During the interviews it had become clear that the distinctions between questions 11, 12 and 13 were dissipated in the interview process and that it would be preferable to combine them. The modifications to the case study as a result of the pilot study is considered further in the next chapter.

The responses to the interview questions are summarised in the spreadsheet below:

Table 5-1: Synopsis of the Interview responses

All of the six interviewees (participants 1-6) were asked the following questions:	
Question	Emergent Theme
1: Please describe briefly the area/field in which you work [Indicative Level of Affirmation/Negation: N/A]	Management Administration Civil Engineering /Engineering / Construction Project / Programme Management
2: Broadly outline the range and depth of: a: qualifications b: competencies / skill / knowledge /expertise expected of those in your management line, particularly those that report directly to you. [Indicative Level of Affirmation/Negation: N/A]	"Day-release Graduate Apprenticeship Design management Construction Construction management Project management Accountant/quantity surveyor Trades
3: Do you consider that those workstreams on your project/programme/portfolio can be described as 'sustainable' – ie: demonstrating 'an enduring and balanced approach to economic activity, environmental responsibility and social progress'. [Indicative Level of Affirmation/Negation: 4/6 Strongly Affirmative or Affirmative, 2/6 Neutral]	Limitations on attribution of term Construction / infrastructure always needed Environmental management emphasis Safety a constant Ongoing improvement Characterised by reference to KPIS /CSR
4 Briefly describe the focus/emphasis of the sustainability effort, as you see it, on the project.	Environmental metrics /Management/BSM Avoid incidents/spillages Value of intermodal interchanges Carbon footprint Minimise resources use / wastage/incidents
5. Do you consider that the level of competency skill / knowledge / expertise of your team is actively enhanced as a result of working on the project.	Has increased overall higher level skill Has increased knowledge in terms of process, increase perspective & horizons Get valuable experience Complex station project

[Indicative Level of Affirmation/Negation: 6/6 Strongly Affirmative or Affirmative]	New build with much refurb - challenging design Opportunity for personal development & promotion Good team working well together Some new angles nuances but nothing fundementally new -good for reports though Significant limitations of management rather than technical focus"
6. Do you consider that the level of competency / skill / knowledge / expertise of your team can be demonstrated / measured? If so how? Indicative Level of Affirmation/Negation: 6/6 Affirmative.	Through performance reviews Through the quality of the scheme delivered Through progress through training schemes Through qualifications gained on the job Through positive feedback - believe progrssing Through safety measures Through extent of challenge to the design Extent of interdisciplinary communication
7. Are you able to distinguish between the change in / enhancement of basic / core skillsets and their 'sustainable' component. [Indicative Level of Affirmation/Negation: 2/6 Affirmative, 4/6 Neutral]	Distinct skillsets No distinction: skills integrated together Fixed traditional views on extent of core skillset Encourage confidence in judgement not just rule-book Awareness of how to design sustainability into building Running technical models Core knowledge + extra information to be assimilated and applied
8. Do you think there is a meaningful distinction between core skillsets and sustainable skillsets. [Indicative Level of Affirmation/Negation: 4/6 Affirmative, 2/6 Neutral]	Refer Q 07 Right Skills In The Right Place No Distinction: Skills Integrated Together All In Team Have Core Skills Set Apply Common Sense
9. Do you consider that the basic/core skills would be increased if day to day workstreams were combined with on the job training. [Indicative Level of Affirmation/Negation: 6/6 Strongly Affirmative or Affirmative]	Would support on the job training More than class only What type of training Apprentice type training very positive"
10.Do you consider that the sustainable componenent of core skillsets , would be increased if day to day workstreams were combined with on the job training.	Training Making Aware of Sustainable Issues Get Basics Right Simple Things Can Make Big Difference At Very Low Cost Keep Things Simple
11. When evaluating the business case for the project, to what extent did the non-quantifiable benefits influence the decision to undertake it. [Indicative Level of Affirmation/Negation: 3/6 Affirmative, 3/6 Neutral]	Focus on cost - should be quantifiable in bc Local authority has wider perspective Connecting people from north and south of the city Regeneration-work and work experience brought to local people An integrated hub
12. What do you perceive those non-quantifiable benefits to be?	Connecting people / close to deprived area Local work experience/apprenticeships opportunity Integration of transport modes at interchange Prompt for regeneration Improvements to contractor (supplier) expertise
13. To what extent do you consider that you would achieve a more effective evaluation of a potential project if you did take these externalised benefits into account at the outset.	Great benefit to nottingham Needed more planning / perspective Business aligns to local authority requirements Difficult to evaluate

5.7 OVERALL PILOT STUDY CONCLUSIONS, POSSIBLE MODIFICATIONS AND WAY FORWARD

On a practical level, the pilot study had highlighted certain logistic organisational and methodological challenges that needed to be addressed. The reliance on a project management team working under pressure to distribute hard copy research material in a timely way was unrealistic. This prompted the search for an on line survey organisation to provide the medium and distribution mechanism for the survey. Bristol Online Surveys (BOS) were eventually chosen to underake this.

Both the hard copy and online questionnaire could be completed in 10-15 minutes. The interviews were allotted slots of about 1 hour. As semi-structured interviews the participants the opportunity to speak for as long as they needed to communicate the information they wished to communicate in response to the questions. None of the interviews were extended or curtailed to keep to a pre-imposed schedule. Some interviews were around 20 minutes and some were as long as 75 minutes, dependending on the extent to which the participants wanted to expand on their responses and also, of course, on the time they had available given the inevitable pressure of work.

Similarly the running order and structure of the interviews needed to be adjusted to the rhythm of the dialogue that had emerged during the pilot study. While essentially the same questions needed to be asked for consistency they were re-grouped in order to facilitate communication flow in order to aid the process of eliciting their understanding of and perspective on the project they were engaged in. (See 6.5). For example the four separate questions around Sustainability (3, 4, 7 and 8) and the three separate questions about non quantifiable, externalised benefits (11, 12 and 13) were tending to create hesitancy and tentativeness and interrupting the general flow of the conversation. This may have been because these areas were either delegated to consultants or had been addressed at much earlier stages of the project when the participants had less involvement and so felt somewhat disconnected from the subject areas. By running them together it was possible to build up a sense of the field of interest and facilitate the communication and knowledge elicitation process. On the other hand, the respondents were generally confident in their responses to 1, 2, 5 and 9 and these were important in maintaining the flow of the conversation as well as the recognition of its relevance.

As described in 1.4, during the course of the pilot study, potential case studies to follow on, were selected. The eventual selection consisted of: The Birmingham New Street Redevelopment project, The Net 2 Tram project and The East Midlands Re-signalling project. In addition some consideration was given to using the European Rail Development Fund (ERDF) 'INTEREG' programme, in particular, the 'Sustations' and 'Citizens' Rail projects (ERDF, 2012-15). However, although the survey responses were consistent with the other results, the research scope was confined to the four UK projects.

The answer to the central question; the extent to which there is a positive enhancement of skill, knowledge and expertise as a result of participating in the project received an emphatically affirmative response. This level of agreement with this central question was spread across the age and qualification ranges, suggesting that most of the participants considered that their expertise had been enhanced. This was consistent across seniority, qualifications and construction/rail experience.

This emphatic response to the central question emerged both from the survey responses (Figs 22-26) and the interview responses, in spite of the fact that there was a considerable depth and range of experience among the interviewees. Indeed it could have been expected that the more experienced participants believed they had less to learn from projects as time went on and therefore interpreted their experience of the project in this way. However the positive response to the question suggested the contrary and supported the clear impression that the prevalent attitude was one of 'never stopping learning' – rather than 'having seen it all before'. This aligned with the emergent theme of steadily accumulating continuous learning outlined in the initial chapters and which persisted through the case studies and emerged in the final cross-cutting condensed themes (7.2.2 and Fig 7-1).

In referring to 'Core Skills', 'Specialist area' and 'Area currently working in'' both surveys and interviews allowed for the flexibility of interpretation of what the interviewees believed their current area of expertise to be. This left the impression that those with Engineering training and qualifications believed their principle enhancement was significantly less about their engineering or construction skills and more about management skills such as stakeholder management. This suggests that the perception of the constitution of the core skill, knowledge and expertise for a programme manager whose original training was as an engineer or building contractor had evolved. It was significant that no one responding to the survey or interview felt unable to adress the question about core skills. Indeed the lack of specificity accomodated the implicit recognition that the centre of gravity of their skill, knowledge and expertise had shifted as a result of their evolving perspective.

In retrospect it may have been beneficial to have been more explicit about this divergence in order to understand more about the evolution from the original training and discipline. However, as discussed above in relation to sustainability, that type of refocussing would have opened up an extended, divergent scope and emphasis for the study. While this would have been of great interest and possible significance it would have over extended the scope. It does nevertheless provide a worthwhile direction for future research.

Another important aspect of the pilot study was the emergence of various themes, as described in section 5.6 and summarised in table 5-1 above. It was intended that these areas of interest or themes would be able to illuminate further the nature of the enhancement of skill, knowledge and expertise in the context of the study and to suggest what the preconditions might be for its incubation. In particular, the extent to which the project environment would facilitate an expansion of perspective on behalf of the project participants. For example, the findings from the pilot study suggested that this would be more likely to be achieved by ensuring an integrated, systemic pattern of working rather than a

compartmentalised, elemental one. This also appeared consistent with the observation noted in Chapter 4 that expertise tended to evolve in a broad multi-dimensional context.

While the principal interview questions and their supplementary follow ups offered the opportunity to develop these areas of interest, the interviews did not seek to choreograph the interviewees into following any particular line of response. Rather they were given room to manoeuvre as they chose within the framework of the questions and as a consequence certain themes began to emerge:

There was a recognition among several of the participants that the complexity of the project was both a challenge and an opportunity. While it enabled the honing of capabilities, the divisions of governance between technical and managerial areas could lead to unhelpful fragmentation, separation and misalignment. That different parts of the project were not always fully sighted and didn't understand the significance of other parts.

Sections 3.1 and 3.2 considered the complex nature of rail assets, their elemental complexity and how this was compounded by the need for a systemic perspective on their interrelationships. This theme also persisted in the findings from the case studies and grew in significance as a reason why projects provided the preconditions for the enhancement of expertise, emerging as a significant cross cutting theme (7.2) in the concluding chapters.

There was a recognition of the value of training undertaken on the job and while there was general support for 'Sitting by Nellie' type mentoring referred to previously, there was less support for offsite training unless it was specifically tailored to the project requirements. This seemed on the face of it to be counter to an appreciation of the general educational quality of training which served to contextualise and put into perspective the particular specialism being trained, thereby enhancing the expertise of the trainee. However given that the question was being put to active project participants with resource and time pressures it was not surprising that specific project requirements took precedence over an appreciation of general educational benefits. Unfortunately the perceived need to focus on these immediate requirements at the expense of the general context can limit the potential enhancement of perspective and therefore the potential enhancement of expertise. The importance of this contextualisation of specialist knowledge in the evolution of expertise was considered in Chapter 4.

The value of continuous learning had been highlighted in the initial chapters (2.3 and 4.5) and its different manifestations had emerged and would continue to emerge as a theme in the Case studies (6.2) and was further distilled into a cross cutting theme (7.2) . There was therefore a thematic reference forwards and backwards from the case studies, serving as a point of reference, for this and other thematic threads.

The significance of the distinction between qualitative and quantitative evaluation was also a consistent theme throughout: While it was generally acknowledged that an uplift had occurred there was no consensus on how it might be measured.

However in response to the later questions which related to the original strategic intention of the project (Q 11-13) there were a range of responses which demonstrated varying degrees of appreciation of a broader perspective which went beyond its technical accomplishments. For example the participants recognition of the value of an integrated transport hub that connected people into the city and the benefits of regeneration as part of Nottingham's civic plan.

Finally, In relation to Sustainability the emphasis was shifting from the skill, knowledge and expertise of the specific discipline associated with sustainable development towards the assertion that all forms of expertise, including those workstreams associated with sustainable development were being enhanced within the project environment. That it was an attribute which should be assigned to the process of Skill, Knowledge and Expertise accumulation and enhancement generally rather than an attribute that should be assigned to particular skillsets. There were indications, therefore, that a more productive interpretation of a sustainable expertise accumulation and enhancement within a sustainable asset base was emerging. That it was a quality of the enhancement and amalgamation of expertise achieved by engaging effectively with the industry's principle assets, in which that skill, knowledge and expertise was invested.

This was in alignment with the argument laid out in the initial chapters, which considered the different manifestations of Sustainable Development and how they related to both the notion of the asset and the notion of an effective evaluation process. It was moving it a further stage, providing further emphasis that the interventions were not sustainable because they enabled the enhancement of domains associated with sustainability but rather because the enhancement of skill, knowledge and expertise in and of itself would result in an enhancement of sustainability. The rigorous, iterative nature of the process of knowledge creation would eventually lead to more robust and ultimately more sustainable outcomes. That is not to say that every stage in that process would be a linear process of social, economic and environmental improvement and development. But that the implicit or explicit intention to prioritise or at least accommodate expertise enhancement in the assessment of value would move that process of evaluation to a better place. And that whatever the manifestations or models of Sustainability may be, its realisation would be ultimately dependent on the systematic enhancement of the expertise of the people generating the solutions.

The emergence of the themes from the Pilot Study provided degrees of alignment with the conceptual perspectives outlined in the initial chapters. The next chapter continues this process within the context of further case studies pointing forwards to the direction of travel while also referring backward to the concepts which moulded the argument.

6 CASE STUDIES – BIRMINGHAM NEW STREET, NOTTINGHAM NET 2 AND THE EAST MIDLANDS RE-SIGNALLING PROGRAMME

Chapter 5 has described how the pilot study provided support for the argument and hypothesis outlined in 1.3 and at the beginning of the previous chapter. In both surveys and interviews the participants expressed their belief that participation in projects had resulted in an enhancement of skill, knowledge and expertise. It was also apparent that the centre of gravity of this expertise had evolved and shifted. in order to realise complex technical outcome in a complex live project environment.

This led to a greater understanding of how the research which sought to demonstrate the importance and value of enhanced expertise needed to thread its way through these different domains, in order to gain a greater understanding of the extent and nature of that enhancement. Indeed, one of the challenges with such a multi-disciplinary study has been to arrive at the appropriate levels of information and points of reference in any particular area for it to be able to provide worthwhile context on the one hand while not being too immersed in specialist detail, on the other.

There were also a number of lessons to be learnt from the pilot study which prompted some iteration between the hypothesis, pilot studies, data collection, collation and evaluation. These are further described in 6.5. Towards the completion of the in Nottingham hub pilot study three further project case studies were set up. Two of these were in Nottingham and one was in Birmingham. The two further Nottingham studies were also linked to Nottingham station. The Net 2 light rail project linked to the Nottingham hub project through the interchange at the station. The East Midlands Re-signalling project, although not centred on Nottingham station, because its scope was much broader, undertook many of its work-streams within the station curtilage. The Birmingham new street project was on a considerably larger scale, both in terms of its impact on the rail network, Birmingham city centre and the surrounding area.

A common feature of all the case studies, including the Pilot Study, was the development of an employment facility and facilitator generally described as a ‘Jobs Hub’. In both Nottingham and Birmingham these were set up and managed by the local authority who required the project team to come to them as a first port of call for the selection and hiring of prospective project participants. These requirements were written into the contracts and the projects’ engagement with them was monitored throughout the project duration. This was seen as a very positive initiative on the part of the local authorities and the implications of it are considered further in the evaluations of the case studies that follow.

6.1 CASE STUDY CONTEXT AND BUSINESS CASE

This section describes the historic and geographical background to and context for the three Case Studies, as well as outlining, in broad terms, the business cases that underpinned them.

6.1.1 Birmingham Context, Business Case, Scope and Procurement

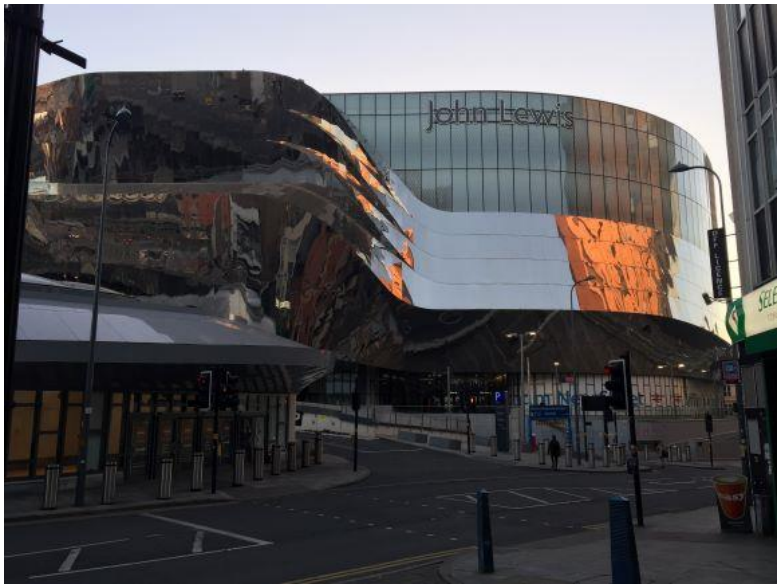


Figure 6-1: Birmingham New Street Façade

The origins of the station began in 1851, when it was used as a temporary terminus for the London and Birmingham Railway (Steer Davis Gleave, 2010c). A permanent station structure was built three years later in 1854 for the London and North western and Midland Railways. It was substantially reconfigured in 1965 to accommodate 12 double platforms and two years later was covered by the 'Pallisades' shopping centre which turned it into the UK'S largest underground station. It is located close to both the Bullring shopping centre and the International convention centre.

Birmingham station is one of the largest interchange stations in the UK serving as the most important West Midlands Hub, with rolling stock operated by; Virgin and Arriva trains. It also serves as a node to provide swift connections to the associated motorway and road network as well as the Airport via Birmingham International station

Prior to the project, the station had been regarded as being a negative influence on Birmingham's image as well as being perceived to cause congestion, safety problems and to provide a negative travelling experience for passengers (ref: Unitary Development Plan and Regional Transport Strategy). The pedestrian flow between concourse, dispersal-bridge and platforms were becoming dangerously congested as a result of constricted vertical and horizontal circulation. .

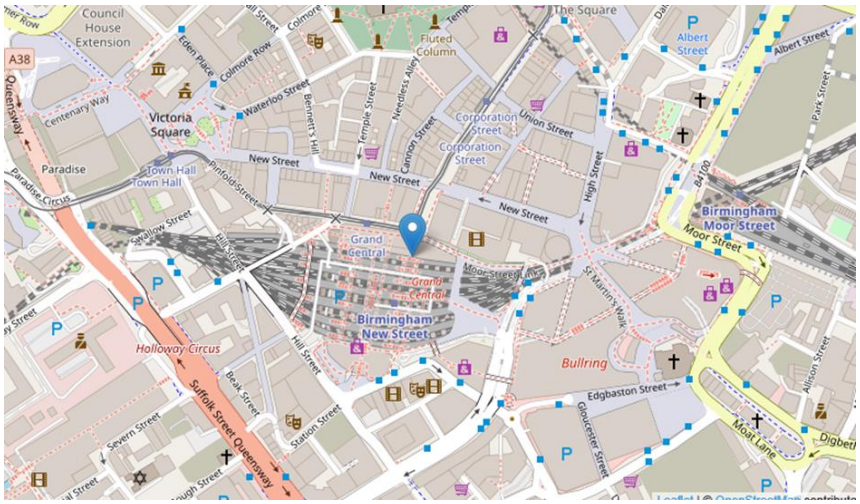


Figure 6-2: Map of New Street station in its street context (Streetcheck)

Although very well located in the centre of Birmingham (Fig 6-2) the station restricted movement across the city centre. Its appearance was perceived to detract from Birmingham's economic success as a regional economic centre. A combination of constricted and dark circulation routes and limited access points within the station had contributed to this negative impression which needed to be addressed, including through the remodelling of the façade illustrated above (Fig-1).

The Transport Policy Context for the redevelopment included the following:

Transport 2010 – The 10 Year Plan (2000)
Transport White Paper "Future of Transport: a network for 2030" (2004)
The Railways Act (2005)
Eddington Study (2006)
Regional Transport Strategy (2005)
West Midlands Route Utilisation Strategy (RUS) (2005)
A Transport Strategy for Birmingham: 20 Year Vision
Provisional West Midlands Local Transport Plan 2006-2011 (2005-2015)

The Development Regeneration Policy Context for the redevelopment included the following:
A New commitment to Neighbourhood Renewal: National Strategy Action Plan (2001)
Communities Plan Sustainable Communities: Building for the future (2003)

National Planning Policy Guidance
Regional Spatial Strategy (2004)
Delivering Advantage: West Midlands Economic Strategy and Action Plan 2004

The business case for the project was based on the needs of the principle stakeholders and its principle drivers were to address certain key shortfalls in both station functionality as well as regional economic performance.

The partners for the project were Advantage West Midlands, Birmingham City Council, Centro and Network Rail and together they developed 'project objectives' which aligned with the corporate objectives of the participating partners as well as the West Midlands local transport plan and was intended to support the 2008 West Coast Mainline timetable. In addition it would support Birmingham's sustainable socio-economic development programme through its location within two regeneration zones as retail destination and by facilitating the introduction of smartcards.

The key negative aspects of the original station that had to be addressed were:
- Poor access to and permeability through the Station
- Over-crowding /congestion on platforms, circulation routes and waiting areas
- Train delays caused by platform congestion
- Inadequate interchange capability.
- Poor lighting and aesthetic of interior and exterior of station
- The key negatives in terms of Birmingham's performance identified by the Birmingham Economic

Review and Prospects 2005 were a below average performance in both a regional and national context in the following areas: (Steer Davis Gleave, 2010c)
-Output and Employment growth
-Output per employee
-Capital Investment constraining productivity
-Skill Base
-Death Rate for businesses

[3]In order to address these issues the project (partners: 'Advantage West Midland', Birmingham City Council, Centro and Network Rail) had defined certain objectives, which were to:
- Provide sufficient passenger capacity to meet both short term and forecast longer term needs.
- Improve passenger facilities and environment within the station
- Permit the installation of ticket barriers
- Facilitate the manageability of the station
- Improve access to and from the station for all users
- Improve the interchange between the transport modes in the area (pedestrian movements, taxi, cycle, bus stops, future tram system)

- Improve pedestrian access routes to/from/across the city
- Improve access to commercial facilities for all users
- Transform the appearance of the station and the facilities it offers.
- Improve the urban environment and public realm around the station
- Develop an appropriately designed ‘gateway to the region
- Resolve the capacity limitations to the station and prevent future station closures
- Maximise the commercial value of the scheme
- Redevelop the Pallisades shopping centre and car park

6.1.2 NET 2 Context, Business Case, Scope and Procurement

Envisaged as providing the most significant aspect of the ‘integrated transport package’ (Nottingham CC, 2005 p 135) NET Phase 2 was intended to provide a sustainable solution to increasing travel demand and consequent congestion. It was intended to provide additional capacity on principal transport corridors that would take the pressure off the bus services and support their expansion in other areas. It was also intended to increase modal shift from the car and move high passenger volumes from Feeder Bus services and Park and ride facilities as well as bringing people to the centre from the more populous south and west of the city.

The NET (Nottingham Express Transit) is a 32km tramway system which forms a part of Nottingham’s overall transport strategy under the aegis of Nottingham City Council (NCC) and Nottingham County Council (NCoC), the two transport authorities: It has been delivered in two phases (Nottingham City Council, 2011):

Line 1 was initiated in 2000 with the award of the concession contract to Arrow Light Rail Ltd under a PFI (Private finance Initiative). This first phase consisted of a 14.5 km section from the centre of the city to a park and ride site at Hucknall and Phoenix Park. The line became operational in March 2004 and has proved to be popular and well used and is generally regarded as a successful example of the use of this form of procurement for a public transport system.

The second phase (NET phase 2) was initiated in parallel with the concession award for Line 1 with a feasibility study which decided on two further routes; to Chillwell via the Queens Medical School and Beeston and to Clifton via Wilford. This phase consists of 17.5 km of track and interconnects with line 1 adjacent to City Hall, via an overbridge that oversails the station (Fig 6-2)

Figure 6-3: NET2 linking to NET1 adjacent to the Nottinghamshire City Hall having been ‘slid’ over the station.

The construction and installation of the overbridge was a considerable logistical exercise. The majority of the work had to be undertaken in the context of a live railway and station. The bridge was assembled (Fig 6-3 and 6-4) adjacent to the station and ‘slid’ over onto supports located through the platform buildings during out of hours working.

Figure 6-4: Off site construction and assembly of the tram overbridge adjacent to Nottingham Station

A new tram stop (See Fig 6-5) was introduced adjacent to Nottingham Railway station to facilitate modal transfer between light and heavy rail.

Figure 6-5: Trams at the new Nottingham Station tram stop on the Overbridge during testing at handover

The NET2 project was consistent with the policy objectives of the Greater Nottingham Partnership, itself a part of the East Midlands development Agency in that it sought to 'ensure the sustained economic vitality of the greater Nottingham conurbation'

It also had 6 scheme objectives described as sustainable and set out to:

- Provide an alternative to car journeys to mitigate road congestion (particularly on the A453 &A52)
- Support growth by increasing public transport capacity.
- Continue with the social inclusion and accessibility benefits of Line 1.
- Facilitate interchange and integrated public transport.
- Contribute to regeneration, land use and neighbourhood transformation
- Expand take up of an environmentally friendly transport modes.

The Jobs Hub, referred to in the previous chapter in connection with the Nottingham Station Hub project, offered significant opportunities by: Creating an employer access to a wide labour pool which matched local and regional labour to local opportunities as well as providing pre-employment training at no cost. The programme was able to create sufficient jobs to employ 1100 people, including 400 from Nottingham City, and 350 from Greater Nottingham. This was perceived to be a significant benefit to emerge from

the project and as exemplified by the poster in Figure 6-6, its positive message was widely communicated,

Figure 6-6: Poster indicating the Project Benefits of the NET2 light rail project.

A number of procurement options were considered (Nottingham City Council, 2011) :
Design, Build, Finance, Operate & Maintain (DBFO)
Design, Build, Operate & Maintain (DBOM)
Design, Build, Finance & Maintain plus Operate (DBFM+O)
Design & Build plus Operate & Maintain (DB+OM)
The first option (DBFO) was selected because it was considered that it would provide greater overall benefits, which included optimum risk allocation and whole life value.

6.1.3 East Midlands Re-Signalling Project: Context, Business Case, Scope and Procurement

The Nottingham Re-Signalling project was developed and designed as a separate project but was part of a much larger Re-signalling programme relating to the Derby Railway Operating Centre (ROC) aspects of which have been completed relitivelt recently. The project happened to coincide with the HUB

and NET2 project between 2011 and 2013 during which Nottingham Station was a significant focus of activity for the three projects. Re-signalling programmes require particularly extensive and intensive planning and lead-in times. The Nottingham Re-signalling Project had originally been planned to take place a year earlier. So although there had been no long term planned integration of the 3 projects the project teams were able, with relatively short notice to repond to the opportunities offered by their coincidence.

The East Midlands Re-signalling Project was probably the least visible of the three projects associated with Nottingham station but required the highest level of funding. The work undertaken was the most substantial upgrade to the East Midland Mainline for over a century. So the 3 projects in combination represented a significant enhancement of integrated rail capacity for the Nottingham area.

Figure 6-7: Approach to Nottingham Station during the refurbishment passing under Carrington Road

The £100m project involved the replacement of life expired signalling infrastructure and the relocation of signalling control from the Trent Powered Signal Box (PSB) to the East Midlands Control Centre at Derby [the Derby Railway Operating centre – or ROC]. This relocation or migration of signalling control was the final phase of a six year transition period which had begun in 2007.

In order to achieve its objectives the final stages of the programme required a virtual shut down - or blockade of Nottingham Station, shown shrouded in scaffolding with the track and some asscociated signalling infrastructure in the foreground (Fig 6-7) for 37 days which enabled the necessary works to be undertaken. This included the construction of a new platform, to be completed through round the clock shift patterns. In addition to this the principle project components were:
Renewal of Beeston and Derby ‘Interlockings’ with Control transferred to Derby

Enhancement of Signalling Equipment
The remodelling of the Junction Layouts
The design and construction of 10 miles of New track
The installation of 143 New Signals

6.2 SURVEYS AND INTERVIEWS: MODIFICATIONS TO DESIGN, DISTRIBUTION AND DATA COLLECTION

As described in Chapter 5, section 7, it was apparent that the basic approach, structure and direction of the pilot study appeared sound. It was providing support for the extent as well as indications of the nature of expertise enhancement, with the he latter beginning to emerge as themes. Nevertheless, it had become apparent that there were certain modifications which needed to be made to both survey and interview process and content in order to maintain and enhance effective communications and illicit the relevant information more effectively. At the same time it was also necessary to try to maintain as far as possible the content and structure of both surveys and interviews of pilot and case studies in order to maintain a reasonable level of equivalence across them all.

6.2.1 Surveys

The hard copy survey distribution and collection which had been carried out by the Nottingham Hub Project Team had been unsatisfactory because it had relied on the project team to undertake it. This had taken a disproportionately long time due to the inevitable prioritisation of their project delivery commitments. The Birmingham New street site was a significantly larger but equally active project environment which had similarly demanding challenges. It was therefore decided to use an online survey method which only required the circulation of a link to the project participants. The choice of survey provider took some time because again integrity and security of data was of course a high priority and cost was also a consideration.

After different options were considered, Bristol On-line Surveys (BOS), which had been originally developed by University of Bristol were selected (it has subsequently changed its name to Online Surveys. The hard copy survey format was replicated, as far possible, into the online format. The link was then passed to the project team and the distribution was very effectively expedited via the URL: https://nottingham.onlinesurveys.ac.uk/sustainable-interventions-in-rail-assets-copy-4

Although the format of the survey changed from hard to soft copy (Jisc, 2016) it was important to keep the content broadly aligned in order to make a comparison between the pilot and case studies.

As with the pilot study, the results of the survey were used to set up pivot charts and tables (section 6.5 below) with the following categories.

Age
Years in construction
Years in rail related projects
Formal qualifications
Formal qualifications relating to rail or construction or other
Skill / knowledge / expertise at project start
Skill / knowledge / expertise on day of survey
Increase in skill / knowledge / expertise in specialist area
Increase in skill / knowledge / expertise in environmental / green issues

6.2.2 Interviews

As indicated in chapter 5, it had become apparent during the Pilot Study interviews that some questions were prompting conversations and eliciting responses more effectively than others. The content and number of questions remain unchanged but they were re-ordered during the Case Study interviews in order to facilitate the fluency of the interview and aid conversation. Where the questions had interrupted the conversation in a way which did not appear constructive or had required extensive explanation, they were repositioned. These groupings and the questions associated with them are laid out below.

Category A: Area of work.
Category B: Expected Range and depth of Skill, Knowledge and Expertise.
Category C: Extent of enhancement of Skill, Knowledge and Expertise.
Category D: Extent to which work-streams are considered sustainable.
Category E: Extent to which on the job training enhances skill, knowledge and expertise.
Category F: Extent to which non-quantifiable benefits have influenced the project.

A	Q1: Revised interview-order -> Unchanged -> Please describe briefly the area/field in which you work.
B	Q2: [Revised interview-order -> Unchanged ->

Broadly outline the range and depth of: a: qualifications b: competencies (skill / knowledge /expertise) expected of those in your management line, particularly those that report directly to you.

C

Q5: [Revised interview-order -> To No 3]
Do you consider that the level of competency skill / knowledge / expertise of your team is actively enhanced as a result of working on the project.

Q6: [Revised interview-order -> To No 4]
Do you consider that the level of competency skill / knowledge / expertise of your team can be demonstrated / measured? If so how?

D

Q3: [Revised interview-order -> To No 5a]
Do you consider that those work-streams on your project/programme/portfolio can be described as 'sustainable' – ie: demonstrating 'an enduring and balanced approach to economic activity, environmental responsibility and social progress'.

Q4: [Revised interview-order -> To 5b]
Briefly describe the focus/emphasis of the sustainability effort, as you see it, on the project.

Q7: [interview-order -> To 5c]
Are you able to distinguish between the change in / enhancement of basic / core skillsets and their 'sustainable' component.

Q8: [interview-order -> To 5d]
Do you think there is a meaningful distinction between core skillsets and sustainable skillsets.

E

Q9: [interview-order -> To 6a]
Do you consider that the basic/core skills would be increased if day to day workstreams were combined with on the job training.

Q10: [interview-order -> To 6b]
Do you consider that the sustainable component of core skillsets, would be increased if day to day workstreams were combined with on the job training.

Supplementary 6c: do you see a distinction between the development of core technical skills/associated
technical skills & management leadership skills.

Q11: [interview-order -> To 7a]
When evaluating the business case for the project, to what extent did the non-quantifiable benefits influence the decision to undertake it.

Q12: [interview-order -> To 7b]
F What do you percieve those non-quantifiable benefits to be?
[Supplementary 7c]: was the project/programme whole life costed. Do you know how this was done.

Q13: [interview-order -> To 8] To what extent do you consider that you would achieve a more effective evaluation of a potential project if you did take these externalised benefits into account at the outset.

6.3 ANALYSIS AND RESULTS

6.3.1 Survey Results

The survey sought to provide an initial description of the relationship between participation in the project or programme and the perceived uplift in skill, knowledge and expertise achieved as a result of doing so. It also sought to establish the extent to which that relationship was influenced by: Age, time on the project, rail and construction experience and qua lification.

The results are illustrated in Figs 6-8 to 6-27. They are laid out by project and then aggregated at the end. There was a relatively low participation in the surveys: Birmingham 28, Nottingham NET2, 15 and the East Midlands Re-Signalling Project 5. They were consistent across the case studies and were also consistent when aggregated across pilot and case studies. The central questions (the extent to which there was a perceived enhancement of skill, knowledge and expertise achieved through participating in the project) again received an emphatically affirmative response and reflected the results of the pilot study. The reference to ‘specialist area’ was not defined yet all the survey participants were able to provide an answer to the question suggesting that they felt able to associate themselves with an

identifiable level of expertise in an identifiable area of activity which they could describe as their specialism.

This carried the implicit recognition that the focus or centre of gravity of their skill, knowledge and expertise was evolving and dynamic and also suggested that it had shifted in accordance with the enhanced perspective gained through amalgamated experience and associated seniority.

Whle the results indicated that there is a clear relationship between participantion in projects / programmes and the participants' perception that their level of expertise is enhanced. There was no discernible relationship between this level of agreement and the other factors that were introduced as variables: age, length of time on the project, qualification, experience, in construction and experience in rail related projects.

Birmingham Survey Results (No of Participants: 28)

Figure 6-8: Birmingham: Level of agreement that expertise had been enhanced overlaid by Qualifications

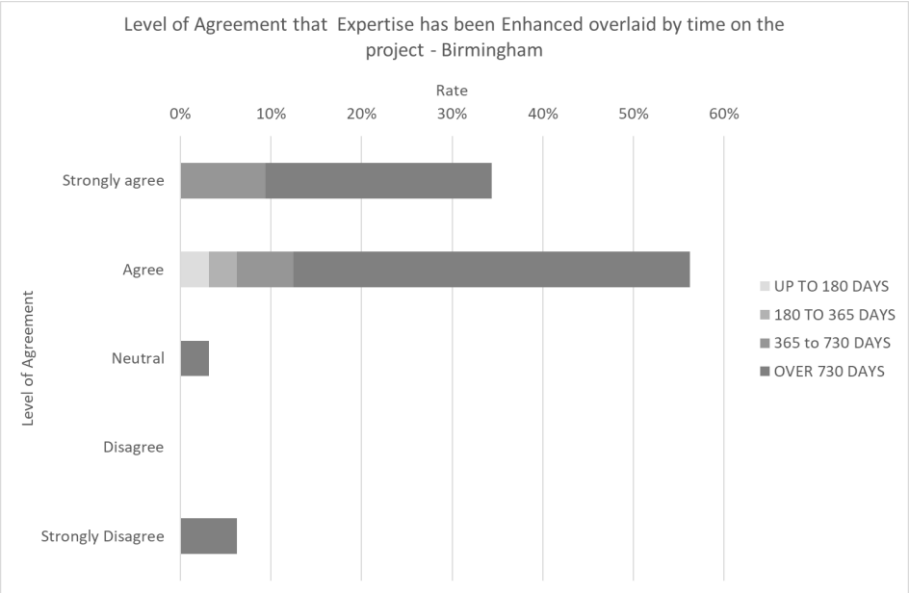


Figure 6-9: Birmingham: Level of agreement that expertise had been enhanced overlaid by time on the project

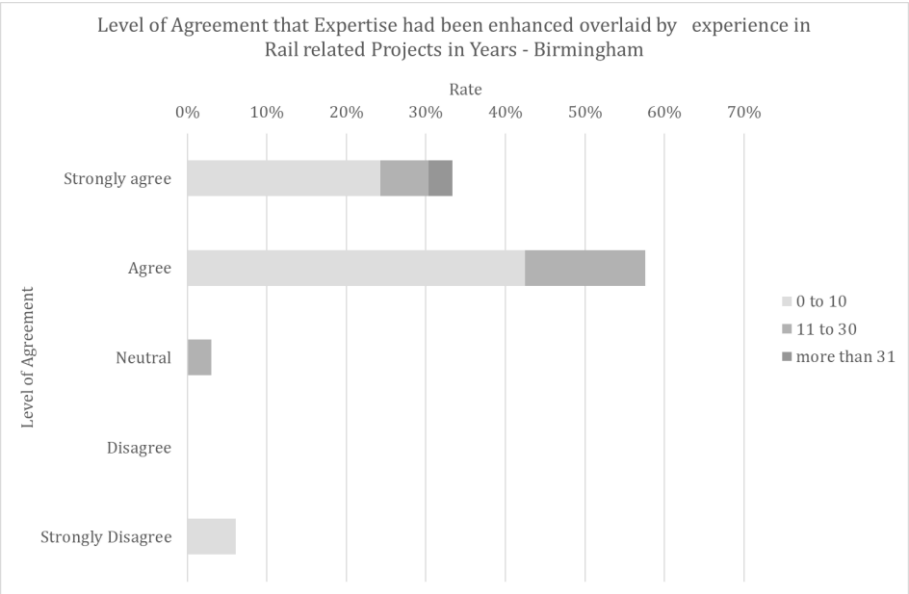


Figure 6-10: Birmingham: Level of agreement that expertise had been enhanced overlaid by experience on Rail related projects

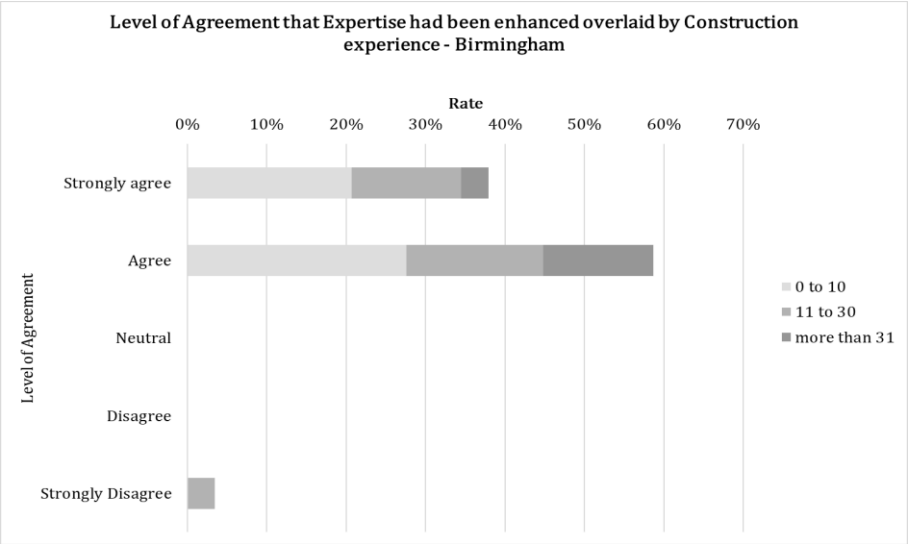


Figure 6-11: Birmingham: Level of agreement that expertise had been enhanced overlaid by Construction Experience.

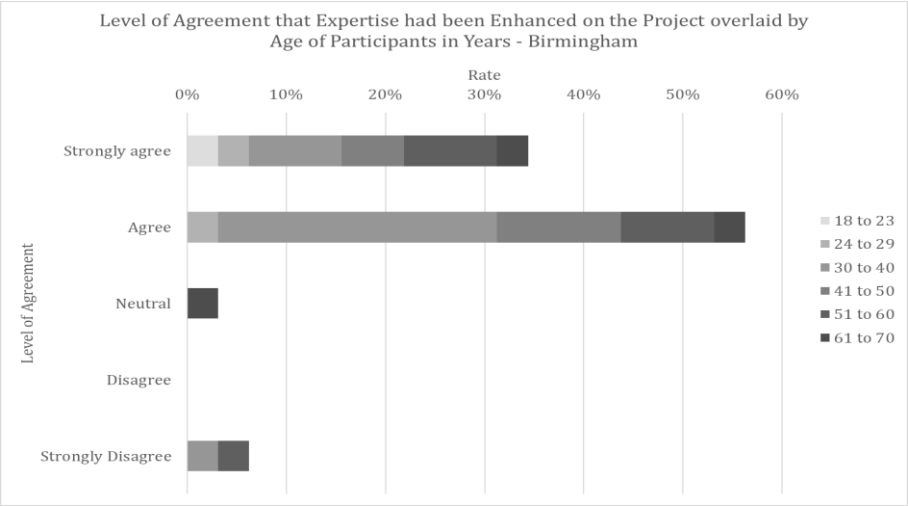


Figure 6-12. Birmingham: Level and Rate of Agreement against Age of participants in Years

Nottingham Tramway Extension NET2 Survey Results (No of Participants: 15)

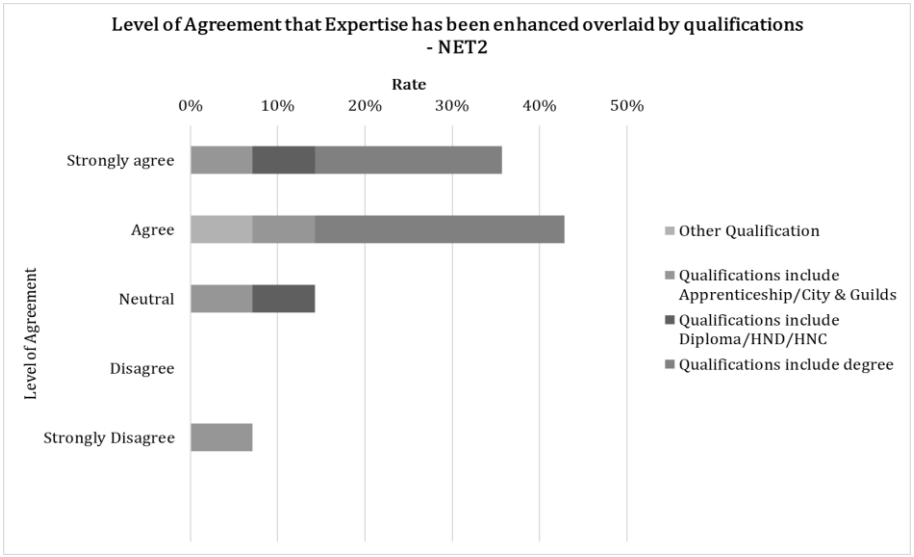


Figure 6-13: NET2: Level of agreement that expertise had been enhanced overlaid by Qualifications

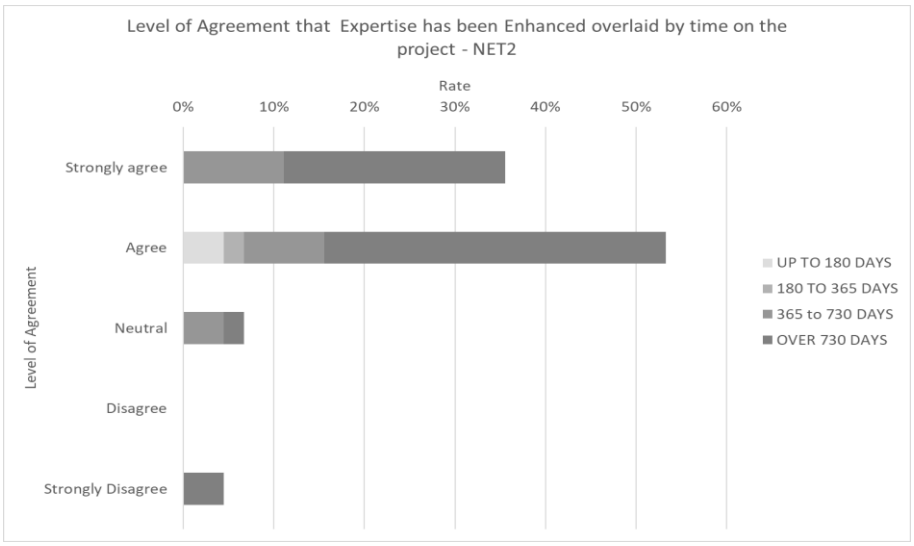


Figure 6-14: Birmingham: Level of agreement that expertise had been enhanced overlaid by time on the project

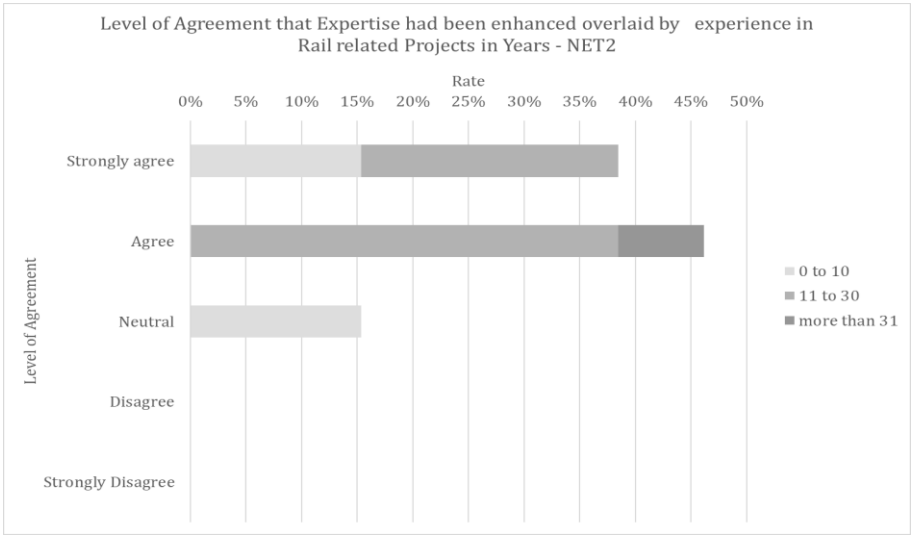


Figure 6-15: NET2: Level of agreement that expertise had been enhanced overlaid experience on Rail related projects.

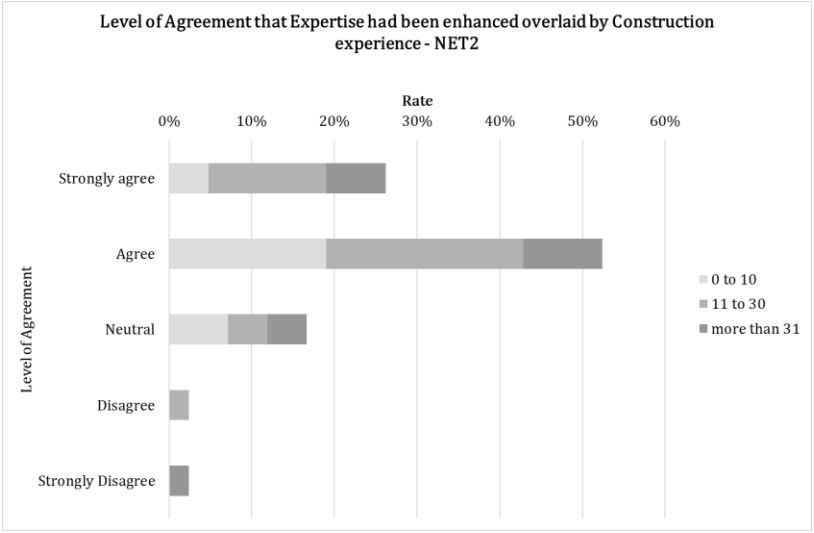


Figure 6-16: NET2: Level of agreement that expertise had been enhanced overlaid by Construction Experience.

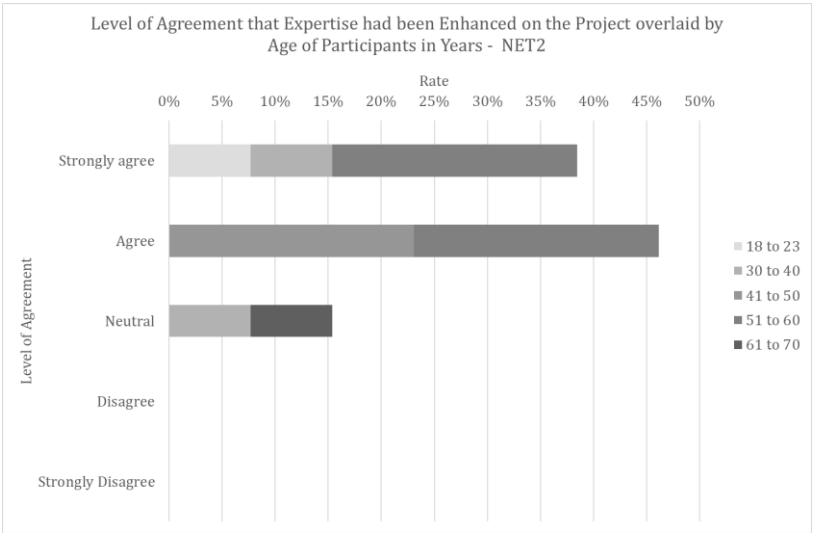


Figure 6-17: NET2: Level and Rate of Agreement against Age of participants in Years

East Midlands Re-signalling project Survey Results (No of Participants: 5)

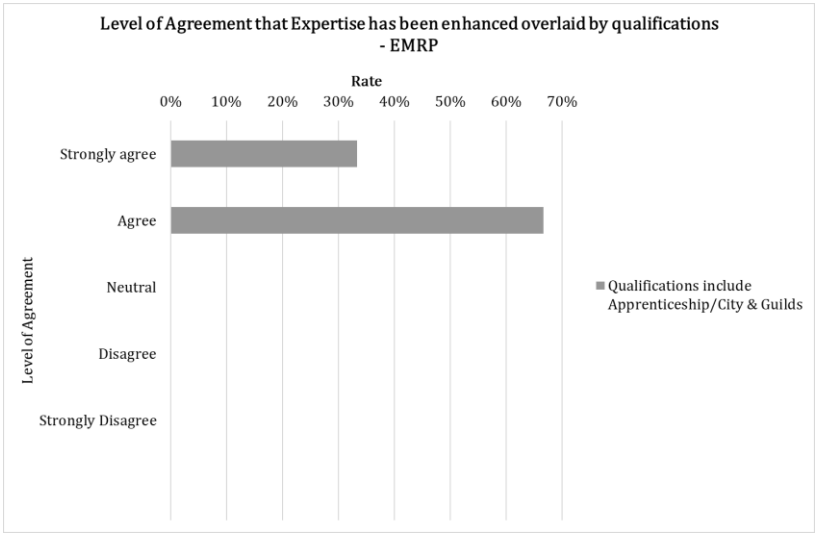


Figure 6-18: EMRP: Level of agreement that expertise had been enhanced overlaid by Qualifications

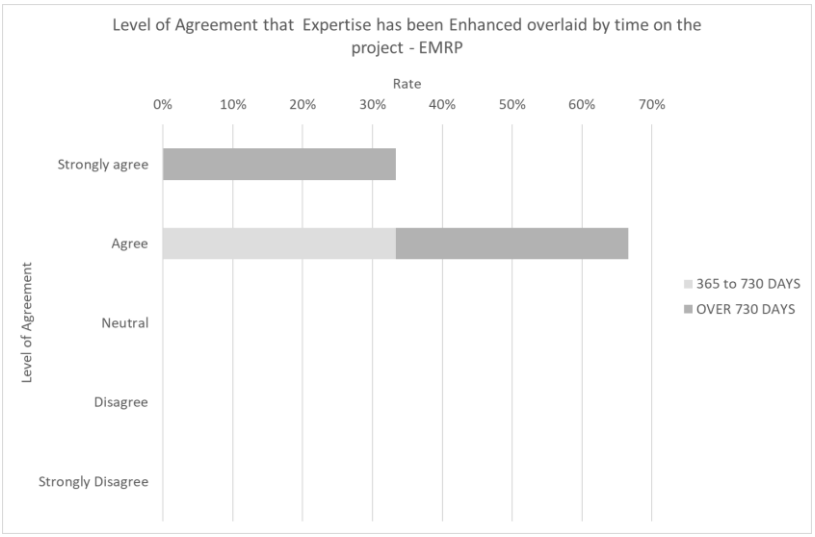


Figure 6-19: EMRP: Level of agreement that expertise had been enhanced overlaid by time on the project

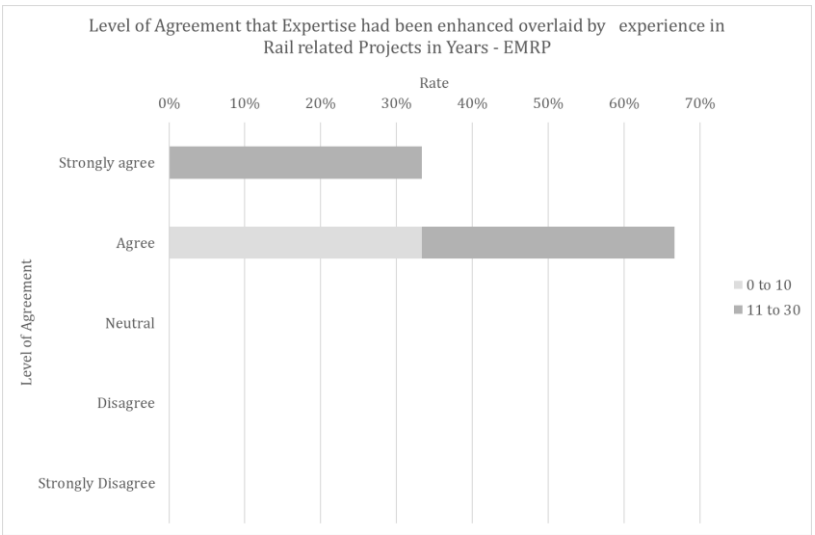


Figure 6-20: EMRP: Level of agreement that expertise had been enhanced overlaid experience on Rail related projects.

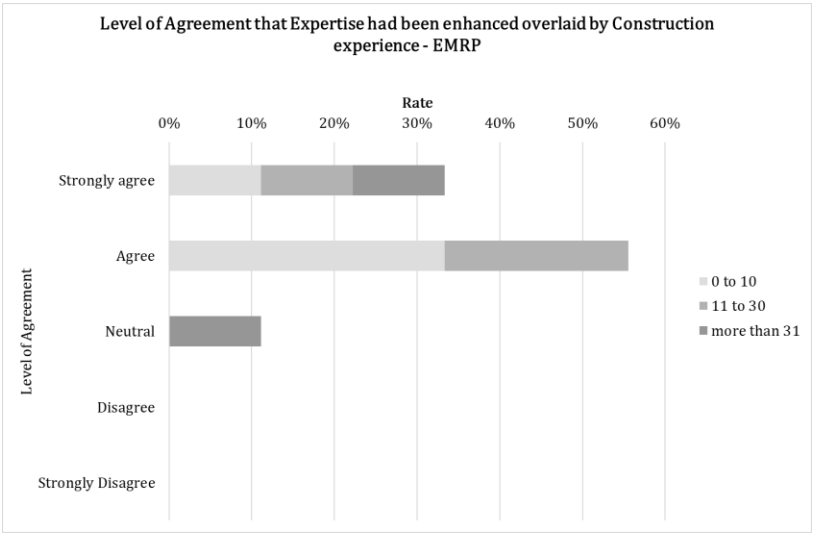


Figure 6-21: EMRP Level of agreement that expertise had been enhanced overlaid by Construction Experience.

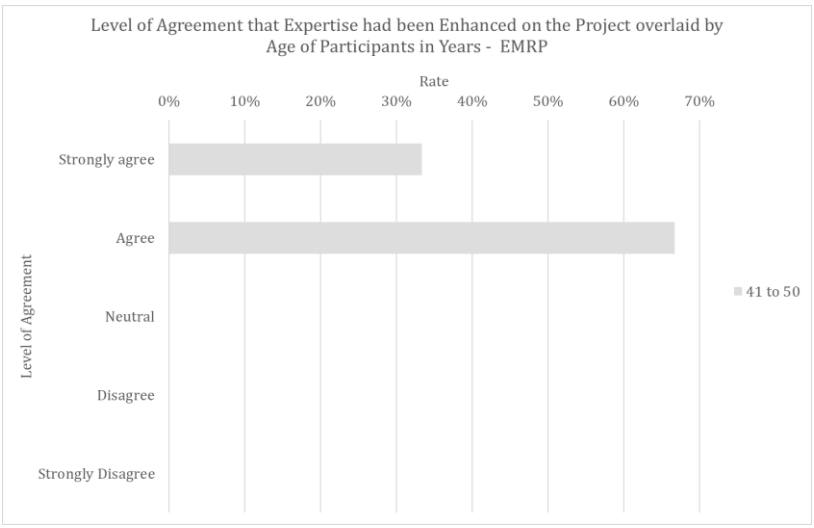


Figure 6-22: EMRP Level and Rate of Agreement against Age of participants in Years

Combined Pilot and Case Studies Survey Results (No of Participants: 85)

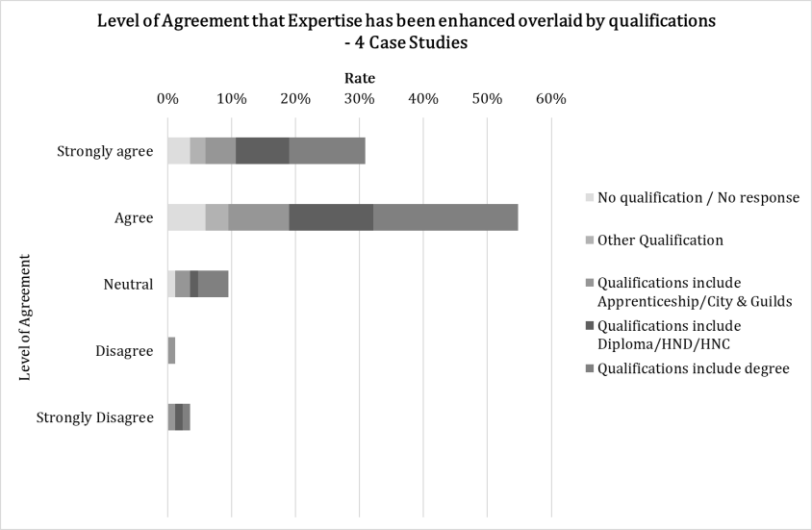


Figure 6-23: Combined Pilot and Case Studies: Level of agreement that expertise had been enhanced overlaid by Qualifications

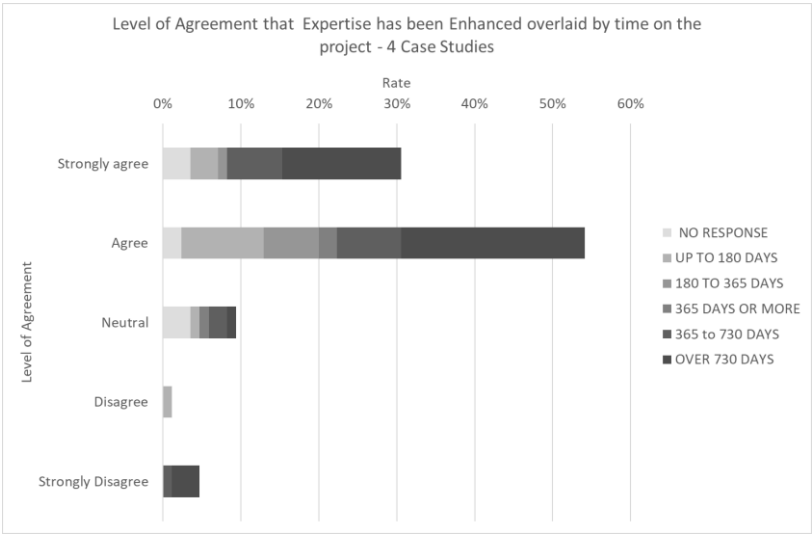


Figure 6-24: Combined Pilot and Case Studies: Level of agreement that expertise had been enhanced overlaid by Time on the Project

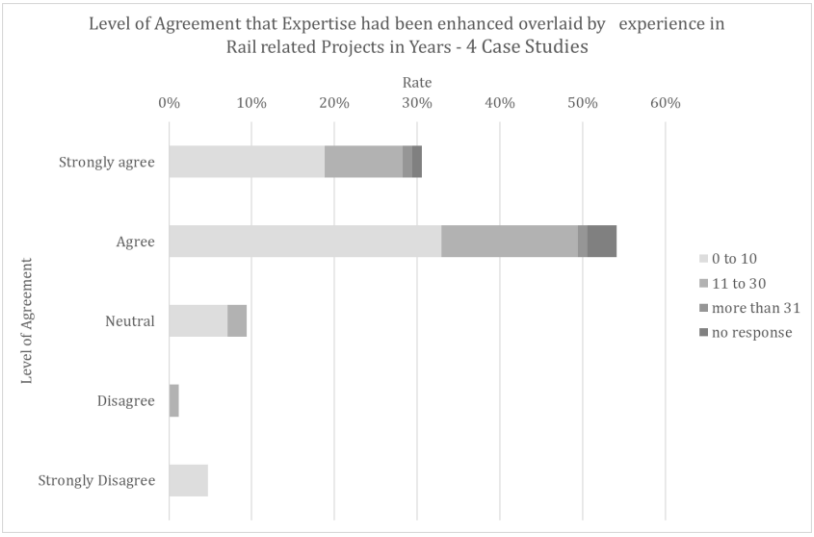


Figure 6-25: Combined Pilot and Case Studies: Level of agreement that expertise had been enhanced overlaid by Rail related projects

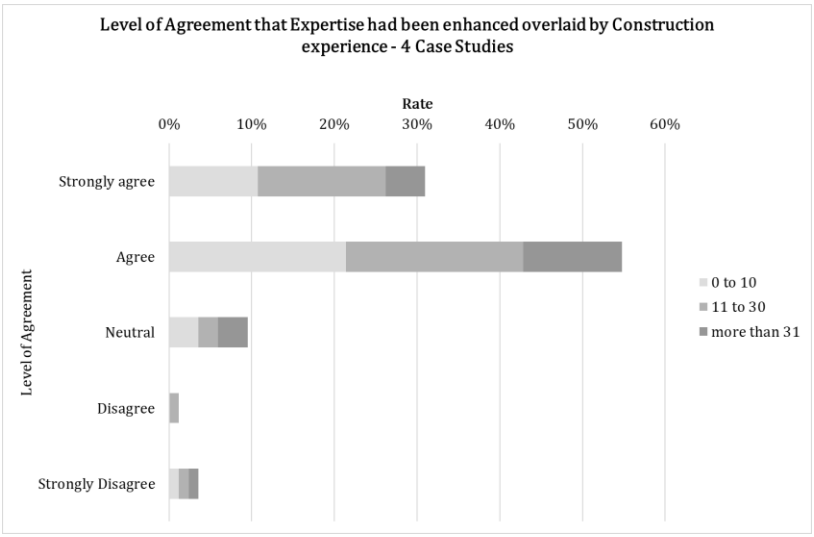


Figure 6-26: Combined Pilot and Case Studies: Level of agreement that expertise had been enhanced overlaid by Construction Experience

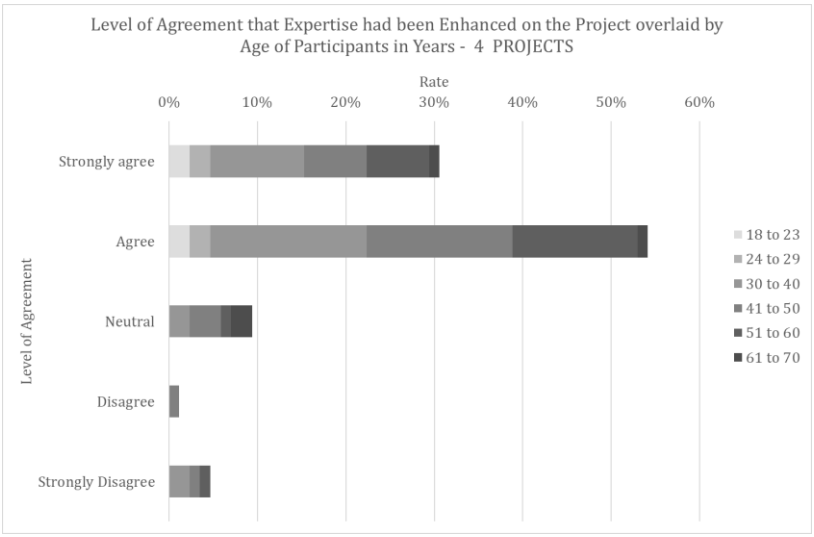


Figure 6-27: Combined Pilot and Case Studies: Level of agreement that expertise had been enhanced overlaid by Age Grouping of Workforce

6.3.2 Interview Results.

As with the pilot study, the case study interviews were set up with the more senior members of the project team. The Birmingham New Street interviews (11 Participants) took place in the project office during the active stages of the programme. The NET2 interviews (9 Participants) took place at Nottingham city hall and associated offices. The East Midlands Re-signalling Project (3 Participants) interviews took place at Beeston depot. As with the pilot study they were recorded and some limited notes were taken during the interviews. However, as described in Chapter 5 it had become apparent that priority needed to be given to maintaining the flow of the conversation rather than writing up the notes at the same time. The recording of the interview, therefore was the principle way in which the interviews were documented. They continued in alignment with the principles of Grounded Theory outlined in Chapters 1 and 5. Themes were identified from the responses to each question. The Themes which emerged fron each question group were then condensed into supra-themes which traversed the different Case studies. Finally 'cross cutting themes, which traversed both case studies and the different questions were identified. The strength of the agreement with the response was also evaluated.

The Summary of the evaluation of interviews from all the Case Studies are laid out below. In relation to the central question; the extent to which the participants believed their expertise had been enhanced. The extent of the level of agreement was clearly in alignment with that of the Surveys.

Category A – Area of work.

The participants ranged across the types of disciplines associated with large infrastructure projects. These included: programme and project managers, construction managers, design managers, engineering managers, commercial managers.

Question Category B – Range and depth of skill / knowledge / expertise

The range of competencies skill/knowledge/expertise of the interviewees were quite broad. In responding to this question they often described their own technical discipline origins, as well as the technical and managerial capabilities expected of their management line. Continuiing this line of enquiry further and follow through the participants' development in relation to their original discipline was considered. Indeed, it would have offered the opportunity to further evaluate the shift in the centre of gravity of the expertise and to compare current working roles and domains in relation to original discipline and domain training. However it was reluctantly discounted because of the risk to anonymity requiremnts and because it would have overextended the scope of the study.

The responses were both direct and informative and the question offered the interviewees the opportunity to succinctly describe their perception of the project and team requirements. They described the range of technical and managerial competencies/capabilities/skill/knowledge/expertise that were expected, as well as the consequences of a shortfall in them.

The interviewees consistently referred to the need for qualifications, capabilities and competencies associated with a large multidisciplinary project. This included the ability to engage with a broad range of stakeholders in a complex multi-disciplinary environment.

Question Category C – The extent to which Skill, Knowledge and Expertise is enhanced by working on Projects

The level of agreement with this question aligned with the survey responses reflecting agreement or strong agreement with the question.

The responses and subsequent discussion in this category (Questions 5&6) were most directly addressing the research question outlined above and provided a powerful support for the data collected from the surveys. The overwhelming majority of the respondents subscribed to the view that their expertise and that of their team had been significantly enhanced. The associated question relating to the measurement of expertise was more equivocal, as dicussed in 5.4, 5.5 and 5.6. This reflected the challenges of arriving at an appropriate method of measurement for such an essential attribute and how that might be calibrated. This notion of achieving an effective means of quantification and its association with meaningful attributions of value (Multi-dimensional evaluation, 7.2.3) was a consistent topic in the intial chapters and presented as emergent themes in the concluding chapters.

The responses to the questions gave a clear indication that the participants implicitly accepted that the focus or centre of gravity of their skill knowledge and expertise had shifted and evolved from what were often technical origins to one with a greater management focus (as noted for Category B above). They described the complexity of the technical and managerial interfaces as well as the governance challenges and how this revised perspective had enabled them to intervene constructively on the project and had improved their understanding of the significance of the tasks they were undertaking. This included the following attributes which were reflected in the themes that emerged from the interviews.

- A recognition of the value of complexity was clearly associated with the project. Numerous interviewees cited the complexity of the project as their initial reason why projects were effective as vehicles for expertise enhancement. There was a consistent implicit and explicit understanding that the large number of managerial, technical and organisational aspects to the projects were important contributors to this overall level of enhancement. There was also a recognition that they needed to be effectively integrated, to achieve both interdisciplinary and stakeholder alignment. There was also:

- A recognition of the importance of teamwork and collaboration as a critical ingredient of the managerial expertise necessary to run a successful project.

- A recognition of the importance of knowledge transfer and mentoring.

- A recognition of the notion of expertise identity attributed to the project. This was reflected in all the projects and was particularly apparent with NET2 because of the specifics of Light Rail that were clearly identifiable.

- An appreciation of the importance of integrating the range of inter-related skills (particularly the technical, engineering and constructional with those of project management) to ensure a cohesive delivery of project requirements.

The response to the question around the possible measurement of expertise was more nuanced. While the majority view was that expertise enhancement might be ultimately measurable, the nature of what that measurement might be was far less clear because of its complex and multi-dimensional nature. The inference being that the current tools available to undertake the measurement would be too imprecise because of the nature of the quality it would be seeking to evaluate. As noted above this echoed the discussions outlined in the initial chapters and was reflected in the condensed themes under the heading multi-dimensional evaluation

The recognition of the significance of complexity as a pre-requisite for expertise enhancement prompted much discussion about the distinction between ‘technical’, ‘non-technical’, ‘core’ and ‘associated’ disciplines. It was generally claimed that the more technical the expertise, the easier it was to measure. This led on to further discussions about the nature and implications of ‘technical’, as opposed to ‘non-technical’ project management: The extent to which effective project management requires an adequate technical domain competence on behalf of the manager. A constant topic of debate in the theory and practice of project management.

Some considered that the extent of the enhancement could be measured through the successful delivery of the project. Although describing success in that context was not straightforward. Some suggested using other forms of key performance indicators (KPIs), such as safety performance, to provide the measurement. However, the general view was that these would be too blunt an instrument suggesting that they would be unable to pick up the more intricate systemic interconnections that would adequately describe the accretion of expertise. For example they would not be able to measure the ability of the participants to take into account the reputational concerns of particular statkeholders. Or to appreciate the subtle, often undocumented, considerations that can affect funding approvals. Decision making also needs to accommodate considerations such as the Iconic impact of Architectural solutons or macro-political requirements, if the true value of the projects are going to be represented and acknowledged.

The significance of knowledge transfer and mentoring also emerged as underlying themes in relation to the measurement of expertise and not surprisingly mentoring and continuous improvement emerged as

cross cutting themes. There were also suggestions that the extent of recruitment and also innovation would be effective measures of the extent to which expertise had been enhanced.

Question Category D - The extent to which work-streams are considered sustainable.

These questions were directed towards understanding more about the interviewees' perception of sustainability and the extent to which they regarded the activities on the project as being sustainable. Given that the projects were directed towards engineering / constructional solutions it was not surprising that the responses addressed the environmental more than the socio-economic aspects of sustainable development. It was considered that these environmental requirements and aspirations were driven by client requirements which were reflected in the environmental design and performance of the project. The participants recognised and applied sustainability tools and mechanisms such as BREEAM and CEEQUAL which reflected these aspirations. However greater the recognition of the need to develop and introduce these types of approaches and solutions the less useful or meaningful any distinction between what could be described as sustainable expertise (and their associated technical solutions) and expertise per se, will be. Another interesting thread was the association of the notion of iteration, not only with design process but also with the management process. That it was not only design solutions but also management solutions that needed to undergo a process of iteration. A process that was perceived to render them both resilient and sustainable.

Notwithstanding the understandable emphasis on environmental sustainability in all the case studies, the interview participants did demonstatrate an awareness of sustainability's broader dimensions. Several of the interviewees appeared to have a significant appreciation of the broader social and community benefits of the project. These included making the connection between the process of continuous learning / improvement and how such continuity in corporate knowledge and memory contributed towards the sustainability of their programmes. A contributory factor here could have been the cost and scope of the project as well as the high profile of the local authorities. Interestingly this broader understanding of sustainability indicated an alignment with the emerging notion that the sustainability of the asset base resided in the effective engagement of its people.

The responses to this question further reinforced the indications that had emerged from the pilot study (5.6.1 and 5.7). Rather than looking for the value of the enhancement of skill, knowledge and expertise in the different disciplines or sub-disciplines of sustainability. It seemed that it would be more appropriate to consider sustainability as being an attribute that should be assigned to the sustained accumulation and amalgamation of skill, knowledge and expertise generally. That an increased recognition of the value of expertise and the implementation of the appropriate measures to maintain its prioritisation would also, by implication be the means to ensure its self-perpetuating continuity. And, also by implication, the sustainability of the general asset base.

Question category E – The extent to which skill, knowledge and expertise would be enhanced if day to day workstreams were combined with on the job training.

These questions and responses were directed towards the benefits of learning and training, both formal and informal. There was a recognition that significant benefits could be achieved through the effective combination of formalised (on site or off-site) 'on the job training'. Again mentoring re-emerged as an important method of supporting and implementing the latter. There was also a recognition of how mentoring could contextualise more formal academic training activity and how an informed alignment between technical design and informed management could result in effective and often innovative solutions to a broad range of challenges.

There were two interpretations forthcoming in relation to 'on the job training'. Firstly that it was an extension of the mentoring process which took place in the live project environment. Secondly that there were formal courses being run in conjunction with project activities, whether on site or off -site. The former, achieved by mentoring or 'sitting by Nellie' was universally seen to be positive and a process which was, de facto, being undertaken by default. The second was less straightforward. While there may have been a recognition of the value of a formal training programme, run in parallel with project work that supported individual development. There was a reluctance to provide sponsorship for it unless it was directly related to the project work-streams of those undertaking them. This view, reflected by project managers, construction managers and others across all the case studies, appeared to suggest a quite narrow view of the value of training and seemed to run counter to an understanding of it as an educational tool to enhance overall perspective and therefore the consequent enhancement of expertise (see 4.5). With the enhancement of perspective being a significant factor in the evolution of expertise as it contextualises the immediate discipline with a broader view which extends beyond the immediate domain. There was, therefore, either a recognition of these benefits but an unwillingness or inability to support them or a lack of recognition of the benefits. The consistent recognition, by the interviewees, of the general benefits of the sustained accumulation of knowledge and experience suggest the former was the case, rather than the latter.

Group F – To what extent might externalised benefits have influenced the decision to undertake the project.

The final section tried to gain some insight into the interviewees' understanding of the importance given to the more indirect objectives of the projects during the process of project approval. And to what extent these should be recognised as project benefits. This group of questions was the least defined and the ones which the interviewees generally felt least qualified to answer because they had not been involved in decision-making at the inception of the project. However they did recognise the influence that these complex, multi-dimensional stakeholder requirements had exerted on client requirements, which in turn had a significant influence on contractor requirements. Indeed many were able to offer informed opinions

from their different perspectives of the non-quantifiable broader strategic socio-economic justifications for their projects.

There was also a recognition of the distinction between public and private projects and that public projects tended to be more difficult to quantify. There was also an appreciation of the value of 'intangibles' such as civic pride which would add to the value generated by the practical benefits of the refurbishment. There was also an understanding that the stations can work as catalysts for regeneration, in a similar way to St Pancras or Kings Cross in London. As well as a recognition that the perspective of the local authority needed to be broader than that of the developers and that they also had the responsibility to realise many of the more complex social deliverables. Some of these were less immediately obvious, such as encouraging a more sustainable employment policy which sought to engage more effectively with potential project participants.The industry had not reached the aspiration to regularise and systematise the construction process or the recruitment for it and there needed to be a more effective alignment of the different capabilities that were being assembled for the project.

Table 6-1 illustrates the supra themes that emerged from each question group. As described above in the opening paragraphs of 6.6.2 the emergent themes from each group of questions across all the case studies were condensed and noted. These supra themes were then further condensed down across the different groups of questions to arrive at the cross-cutting themes which emerged across both case studies and across the groups. Indicative levels of agreement are also noted against each question group which served to support findings from the surveys.

Table 6-1: Summary table describing the interview results incorporating Cross Cutting themes

Question Groups A-F.and Indicative level of Affirmation/Negation Supra –Themes: Themes That Emerged in each Question Group across all the Case Studies Cross-Cutting Themes: Themes that emerged across the different Question Groups across all the Case Studies. 23 Participants		
Question Group	Supra theme	Cross- Cutting Themes
Group A: Area of work [Indicative Level of Affirmation/Negation: N/A]	Management of complex systems within the context of engineering disciplines and domains - Engineering - Construction - Project/Programme - Civils - Design - Commercial"	
Group B: Range and Depth of capabilities / skill / knowledge / expertise	Integration of project management into design delivery Engagement with a broad range of multidisciplinary stakeholders	- The Benefits and Challenges of complexity

[Indicative Level of Affirmation/Negation: N/A]	Broad range of engineering design and management competencies Ability to operate in complex major projects Negative consequencies of a shortfall in skill, knowledge and expertise Broad range of development/training modes	- The value of collaboration with multiple stakeholders, - Mentoring– a vehicle to contextualise learning and enhance perspective. - The value and challenges of a comprehensive multi-dimensional evaluation - The systemic interconnection of skill, knowledge and expertise for individuals, teams, projects and programmes - The project as a focus for sustainable continuous improvement - The iterative links between interelated disciplines - The project as a driver for multi-dimensional sustainability - The need to move from fragmentation to integration. - Project contextualising formal instruction - The identity of project and programme expertise.
Group C: Questions: - 5 , 6 Expertise Enhancement Extent of Skill/ Knowledge/ Expertise active enhancement by working on the project [Indicative Level of Affirmation/Negation: Strongly Affirmative or Affirmative 29/29] Measurability of enhancement [Indicative Level of Affirmation/Negation: Affirm 21/29, Neutral: 7/29, Negate: 1/29]	Importance of integrating project management with other disciplines Benefits of a complex and challenging project to enhance expertise Integrating interelated disciplines and skills Knowledge transfer - mentoring-personal development Enhancement of collaboration Connection to innovation Project as exemplar of enhanced integrated working The complex multidimensional nature of measurement Relationship between technical and managerial enhancement of expertise Delivery a measuremnt of succcess Benefits of mentoring not measured Recruitment a vehicle for the measurement of expertise Positive and negative consequences of KPIS Need for basic knowledge base Connection to innovation	
Group D: Questions:3,4,7,8 Extent of Sustainable Work-streams [Indicative Level of Affirmation/Negation: Affirm 21/29, Neutral: 7/29, Negate: 1/29] Meaningfulness of distinction [Indicative Level of Affirmation/Negation: Affirm 7/29, Neutral: 17/29, Strongly Negate/Negate: 7/29]	Limitations on attribution of term Demonstrating environmental sustainability through recognised mechanisms Demonstrating socio-economic credentials through a range of activities Project / client driving sustainability requirements Project as a focus for (sustainable) continuous improvement Uncertainty re recognition of term and distinction Separate dedicated teams imply distinction Safety a constant Need to integrate into workstreams Contractor driven by client requirements Crossing discipline boundaries	
Group E: Questions: 9,10 The extent to which skills would be increased if work-streams / Sustainable Workstreams were combined with on the job training	Alignment of individual and project need Benefits of contextualising formal training Mentoring Integration of interdependent disciplines Iterative process of design /construction/management	

[Indicative Level of Affirmation/Negation: Strongly Affirm 28/29, Neutral: 1/29.]	Potential for innovation.	
Group F: Questions: 11,12,13 Extent of influence of externalised benefits in decision to undertake the project [Indicative Level of Affirmation/Negation: Strongly Affirm/Affirm 19/29, Neutral: 10/29.]	Project as catalyst for cooperation Contractor requirements driven by programme / client requirements. Difficulty of quantifying intangibles-such as reputational and associated benefits. Local Authority's wider perspective and appreciation of intangibles	

6.4 OVERALL CONCLUSIONS FROM PILOT STUDY AND CASE STUDIES

The answer to the central question; the extent to which there is a positive enhancement of expertise, skill and knowledge following participation in projects was answered convincingly through questionnaire and interviews. In the surveys the level of agreement and strong agreement to this question was 80% (Figs 6-8 to 6-27) above. The surveys also demonstrated that age, qualifications, length of time on the project and length of time in industry have no significant influence on the level of agreement. This level of agreement to the central question was also supported in the interviews with the more senior project participants. The responses from the interviews built on the responses to the survey by indicating emergent themes perceived to be intrinsic to expertise enhancement (Fig 6-1). The Cross cutting themes provided the basis for the further condensed cross cutting themes which are described in Chapter 7, (7.2). These condensed themes were aligned both with the conceptual models or arguments put forward in the initial Chapters (2 to 4) and with the signposts as to how these principles were gaining traction in the concluding chapters 7 and 8.

This level of agreement was explicit in response to the direct question whether participation in projects had enhanced expertise (Group C) and implicitly reflected in the response to the other questions. The interviewees had generally come from a broad range of disciplines and had either continued with or evolved into a managerial role.

The supra and cross-cutting themes which emerged from the interviews describe the qualities of the projects which the participants believe contributed towards the enhancement of their skill knowledge and expertise. These qualities include the provision of a broader perspective that enabled the different elements of the project to be viewed in an appropriate context. How these elements combine together to form a series of interconnections that enable the effective overall operation of the whole. This was

exemplified by an appreciation of the need to integrate the varied and sometimes apparently divergent requirements of the very broad range of stakeholders engaged in the project.

As the study progressed a number of factors from the surveys and particularly from the interviews became apparent:

While the focus of the interview discussion tended to remain on the evolution or incubation of individual expertise, there was also extensive reference to teamwork or the workings of the team and what could be described as the collective expertise that emerges from the sum of the conjunction of individuals in a project. It assumed a collective identity which was recognisable and was considered to have value and was perceived to be greater than the sum of the parts. There was a general appreciation of the hard won collective expertise, and a recognition of the potential opportunity and benefit of bringing it to bear on a project of a similar nature. There was also an appreciation of the opportunity cost of not doing so: The latter was particularly apparent on NET2 where the the team, with their light rail experience were, at the time, unable to transfer onto a similar scaled project.

The notion of a ‘specialist’ or ‘core’ area was a relatively dynamic concept. Although it was not defined, the interviewees were able to respond to references to it without requiring further clarification as to its meaning. This suggested an assumption that it referred to the amalgamation of their accumulated capabilities at that point in time. A progression up the stages of an evolving area of expertise, resulting in a significant broadening of perspective from which to understand the domain within which they operated. Thereby implying breadth as well as depth. This broadening perspective, gained through participating in projects appeared to result in a shift in the centre of gravity and nature of their expertise. This, in turn, increased the chances of taking on new roles and responsibilities.

Many of the interviewees, had originated from a technical, often engineering, background but were working in project/programme management and would regard their area of expertise or specialism to have moved closer to management rather than engineering. There were examples of this in all the case studies. For example on the Birmingham case study a senior project participant commented on the extent to which their expertise had been enhanced in both their awareness of related engineering disciplines as well as in the managerial skills associated wirh the effective management of the team. There was also the example of a participant who had originally trained in engineering whose focus and interest had shifted to ‘people’ and how they functioned within a project environment. Similarly on the NET2 project a senior project a participant had evolved from a civil engineering training but had been increasingly involved in the organisation of light rail projects and their associated management and governance.

These observations, therefore, highlighted a distinction emerging from the study between breadth and depth of expertise. The notion of the expert is generally associated with depth of understanding in a specific field or domain or area of expertise. However the majority of respondents felt that while they had not necessarily increased the depth of the original area of expertise. They did believe they had

significantly expanded other management capabilities, such as stakeholder management as a result of the range and number of stakeholders they were required to deal with. Thereby suggesting a broadening rather than a deepening of expertise. Although there is, of course a sense in which an expansion of the breadth of qualities associated with management must also imply a deepening of the skill/knowledge/expertise attributable to that discipline.

Chapters 5 and 6 have therefore sought to achieve the following:

- To demonstrate that a relationship exists between participation in projects and programmes and the consequent enhancement of knowledge, skill and expertise.
- To gain a greater understanding of the extent of this beneficial relationship and the factors associated with it.
- To consider the factors which emerge as consistent themes when evaluating the relevant beneficial characteristics of projects.
- Provide indications as to how this information can be used to sign post the way forward and be applied. Some initial indications of which, are described in chapter 7.

- Illustrate how the themes emerging from the case studies both reflected concepts emerging from the initial chapters relating to the notions of sustainability, assets and evaluation and pointed forward to Chapter 7 and 8 to signpost the ways in which they are being and could be applied in a project environment.

Note regarding Causation:

There were no controls in the case studies which, on the face of it, is a challenge to the attribution of any form of causation between project participation and expertise enhancement. However it could be argued that the case being made for necessary and contributory (but not sufficient) causation is not an inductive argument dependent on controls but is an argument based on an understanding that the enhancement of skill, knowledge and expertise of those participating in the interventions can only be achieved through participation in the interventions. That is to say, the former is intrinsically bound up in the latter.

This work is arguing that the successful demonstration of the linkage between project participation and expertise enhancement as project benefit would offer significant opportunities:

- It would support the argument that expertise enhancement should be a targeted project output as well as an incidental project outcome.

-It would facilitate a shift of emphasis between the physical infrastructure and the expertise required to deliver it thereby benefitting both.

It would support the argument that interventions in the form of projects and programmes could be used as active tools for the enhancement of skill, knowledge and expertise.

The implications of this are:

-That genuine multi-dimensional sustainable asset interventions offer an opportunity to incorporate a recognition of the value of the enhancement of Skill, Knowledge and Expertise that comes about as a consequence of carrying out the intervention.

- That the recognition of this consequential benefit is essential to any meaningful understanding of the real value of projects. And that acting on this recognition would “shift the emphasis towards the evolution and incubation of the expertise stream that is a necessary condition for those components to be delivered”. (Langdon et al., 2016)

The outputs of both surveys and interviews offer substantial support for this. Suggesting that the range of activities and work-streams implicit in projects and programmes contribute significantly to continuous improvement and expertise enhancement. And that they do this by providing the essential preconditions for them to take place.

Many of the respondents referred to the complexity of the project as a precondition for its role as a focus and receptacle for expertise enhancement for all the participants. This complex, collaborative multi-stakeholder environment provided an ideal set of conditions for the necessary systemic challenges and opportunities for the participants to move along the requisite stages of their development. This would often be done in conjunction with some form of mentoring process. This finding aligned with the argument presented in Chapter 4, section 5 which described how such a dynamic multifaceted setting provides the appropriate real world conditions for the necessary development of expertise. Enabling the participant to move from an analytical and compartmentalised grasp towards an intuitive and holistic understanding of the whole context in which their skill, knowledge and expertise is situated.

It can be argued that the process of the less experienced gaining experience in the presence and under the guidance of the more experienced is an inevitable characteristic of projects. All the case studies were dependent on the initial assembly of participants who had a relatively high level of experience in the areas of activity that the project was engaged in. They also were dependent on the addition of others with less experience and an implicit mentoring process which was managed through the line management reporting process. This was particularly emphasised on the East Midlands Re-Signalling Project where the technical requirements in a niche area of signalling were critical. This aligned with the arguments put forward in 2.7 and 3.5 which drew attention to the significance of mentoring in relation to both sustainability and the asset base.

It was also apparent that participation in the project environment offered the participants the opportunity to reposition the centre of gravity of their expertise, including, along a hypothetical spectrum from technical to managerial. And further that expertise, skill and knowledge could be enhanced at a number of levels: Individually, within teams, within projects, within programmes and within portfolios. And that these different manifestations of, what can be described as, expertise identity needed to be recognised.

It may be worthwhile considering at what point an evolution from a ‘deep’ technical discipline to a broad management discipline then further transforms into a deep management discipline. And how that process would be evauated along the scale with the calibrations we currently have available.

6.5 CONCLUDING DISCUSSION

This work has focussed on the enhancement of expertise that is achieved as a consequence of participating in projects. This consequential enhancement of skill, knowledge and expertise can be juxtaposed with the pre-requisite skills that need to be in place for people to join a project. A shortfall in the latter is often referred to as the ‘skills gap’. The implication of such a skills gap is that there is a defined addition to a finite body of skills/ capabilities/expertise that needs to be ‘filled in’ in order to achieve a fully understood and rounded set of requirements and capabilities. It also implies that the identity of all the constituent parts of this ‘rounded whole’ are known. A fully defined set of skills for a fully defined project that produce defined outputs. At one level the idea of ‘skillsets’ to fill the ‘skills gap’ to provide the competencies and capabilities to undertake a project appears self-evident. However it is important that such an image of a closed, compact and finite system doesn’t serve to undermine opportunities for possible expansion of both skills and project outputs. And of course, the consequential enhancement of skills achieved in one project can constitute the pre-requisite skills for the next. This consequential enhancement can occur in the range of projects from the more tightly scoped to those more innovative projects where neither the ‘rounded whole’ nor the extent of the component parts are either fully understood or scoped.

A shift of emphasis towards a formal recognition of the value of capturing this enhancement could occur across the range of project types described above. From repetitive ‘roll-outs’ to the one off transformative programmes. Such an approach would offer opportunities to absorb a whole range of capabilities, from the basics to those that that go significantly beyond. The latter, possibly contributing to the continually evolving dynamic expansion of the system boundaries and domain integrity that is essential to their development.

In addition to the evolution of individual expertise, the project itself has the potential to accumulate its own expertise identity, through the aggregated contributions of its participants. Unfortunately, this ‘project identity’ is rarely given due recognition and more often than not this aggregated expertise is fragmented and dissipated at the end of the project (see chapter 7). The lessons learnt process, generally, does not adequately address this missed opportunity.

Shifting the focus towards expertise evolution as project output would imply a shift of emphasis towards subject, discipline and domain development through a careful evaluation of their strategic directions of travel. Developments that would need to be aligned with the evolving programme requirements as well

as the disaggregated needs and aspirations of the individual project participants. This therefore, represents an opportunity to support the ongoing evolution of that amalgamated project or programme identity while at the same time accommodating the development of individual project participants and their individual development plans. The Covid pandemic and Williams Schapps review has offered an opportunity to carefully reconsider priorities in the light of a strategic re-examination of the Railways' activities. This will be an ideal time to undertake just such a strategic re-evaluatoion of purpose.

To ensure that projects can accommodate this shift of emphasis, different ways of undertaking them could be evaluated. This could involve a process of option (and risk) evaluation that would explicitly target and support the evolution and incubation of the expertise required to deliver them. By adopting this approach, the programme would have the potential to become a significant vehicle, catalyst and reference point for the ongoing evolution and development of the project participants and their individual development plans. This corresponds with a more expansive and meaningful approach to establishing project value and calibrating that evaluation, including shifts of emphasis in the different ways in which they are resourced (4.5). This is further considered in 7.4 and 7.4.1 in terms of early traction and potential opportunities.

A recognition of the intrinsic value of this shift of focus towards expertise evolution and incubation add value at a number of different levels. If projects can be understood as contributory and necessary conditions for and causes of expertise enhancement (see previous section).Then the greater will be the opportunity for them to act as focal points for the development of a broad range of associated capabilities. If managed carefully and in alignment with the relevant institutions and organisations, they could serve as an effective catalyst and reference point for the provision of a broader range of training and educational benefits. Benefits that will be recognised as being intrinsic to any meaningful evaluation of the transactions taking place in rail investment.

Although this work has argued for the recognition of skill, nowledge and expertise as an externality in a whole life evaluation of asset interventions. It has also sought to demonstrate that skill, knowledge and expertise are not extrinsic or external to a whole life cost 'calculation' of the value of an asset intervention. But rather that they are intrinsic to it and constitute essential constituents of such an evaluation. Further work could be undertaken to consider how this intrinsic benefit could be applied at a number of levels to ensure that the opportunities arising from this shift of emphasis are understood and taken into account at a personal, team, project, programme, portfolio and industry level.

While the focus of this work is on rail, this could also be extended to other associated infrastructures. Rail as a key mode within transport infrastructure forms an important part of the UK's key economic infrastructures. Transport, together with Energy, Waste, Water and Telecoms the other key Economic Infrastructures underpin the social infrastructural systems, such as health, education and finance on which the UK economy depends. The effectiveness of the interconnections within and between these infrastructural systems, will be determined by the skill knowledge and expertise that is contained, developed and incubated within the associated projects, programmes and portfolios. This has the

potential to enable a scale effect where the benefits derived from the whole are greater than the sum of the parts. This scale effect which is generated within projects can also be transferred within and across the different infrastructural systems. So the enhancement of skill, knowledge and expertise resulting from interventions in railway asset base not only provide the preconditions for the development and delivery of significantly enhanced railway infrastructure but also have the potential to provide important constituent contributions to the skill, knowledge and expertise required for the development and delivery of the other key economic and social infrastructures. And in addition such an approach has the potential to provide support for the preconditions for economic growth through the consequential enhancement of labour productivity.

The next chapter describes how the argument put forward in this work supported by the findings from the case studies have begun to gain traction. It also suggests some shifts of emphasis in the organisation and management of projects to facilitate its effective incorporation into project governance.

7 EMERGENT ACTIVITY AND EARLY TRACTION

7.1 INTRODUCTION

Chapter 6 provided support for the argument that: Expertise is enhanced when participating in projects and programmes and that this requires effective recognition when assessing their real value. Several of the themes elicited from the case studies, together with the arguments laid out in the initial chapters serve as signposts towards the mechanisms that have the potential to realise and enable these benefits.

This chapter sets out to consider:
- The distillation of some of the themes that have emerged from the research and also to provide some early indications of the way in which they are gaining traction.
- How the progress to date provide indications of possible ways to facilitate their application.
- Further ways in which this approach could be applied and developed in the future.

7.2 SIGNPOSTS FROM THE CASE STUDIES

The case studies established the existence of a relationship between participation in projects and the participants' perception that their expertise had been enhanced as a consequence of doing so. A significant majority of the respondents (Chapter 6 Figs: 6-8 to 6-27) had recognised the positive change in expertise brought about through their participation in the projects. The interviews also drew out a range of themes, supra-themes and cross-cutting themes from the responses to the questions (table 5.1 And 6.1. These responses had provided an indication of the ways in which project participation had enhanced expertise, in particular by indicating aspects of the project environment which they considered had provided the pre-conditions for doing so. These cross-cutting themes are further condensed in Table 7-1 and their significance explained in Sections 7.2.1 – 7.2.5. The process of moving from the Interviews to the final condensed cross cutting themes illustrated in the table were in alignment with the principles of Grounded Theory and involved the following stages:

- Interviews undertaken and recorded and some very limited contemporaneous notes taken in order to maintain pace and facilitate communication.

- Recordings reviewed a number of times and repeating themes from each question for each interviewee were noted.

- Themes that repeated in the response to each question across the different interviewees were noted against each question.

- These themes were then further condensed down to what are described as ‘supra-themes’ which were also noted against each question across the four case studies

- The themes or concepts or topics which oversailed the individual questions were captured in what are described as ‘cross-cutting themes’

- Finally the Cross-Cutting themes have been further condensed down in the table 7-1 below in order to encapsulate the overriding subject matter that emerged.

The process of using semi-structured interviews allowed a rich source of opinion, presented from a broad range of perspectives, to emerge. The emergent themes were sometimes quite explicitly stated or were apparent from the direction of the conversation. For example the notion of complexity emerged as a very obvious and apparent theme because it was consistently referred to by several interviewees in response to the central question as to whether participation in the project had enhanced expertise. It was clear in the initial recordings and remained throughout the process of reduction described above.

On the other hand the notions of continuous improvement and its relationship to mentoring were less explicit, although they were clearly implicit in the the interviewees understanding of a learning process that was taking place on the project. With the less experienced able to benefit from working with those with more experience throughout the project duration.

The case study findings also indicated a shift of emphasis in the way in which the topic of sustainability was addressed. Rather than treating it as a specific area of expertise that might or might not be enhanced. It became apparent that it was the enhancement of expertise as a whole that would render the rail asset base sustainable.

As the research had progressed it had become increasingly apparent that the notion of a sustainable intervention in rail assets was intrinsically bound up in an adequate understanding of value and the process of evaluation. The adoption of engineered solutions or potential solutions and their management towards effective implementation was dependent on the embedded values inherent within the way value was calibrated. Therefore, the ‘centre of gravity’ of the research appeared to be moving towards the area of ‘economics’ and economic evaluation and the way in which business case appraisals and cost-benefit evaluations are undertaken in order to arrive at optimum solutions that were capable of implementation. Solutions that demonstrated a robust linkage between the engineered system infrastructure and what can be described as the skill, knowledge and expertise system infrastructure on which it depends.

From the cross-cutting themes which emerged from the case studies some consistent threads emerged (ref Table 7-1). These serve as signposts to indicate the alignments and potential between project participation and expertise enhancement and how the shift of emphasis that would be required to implement this might be achieved.

Table 7-1: Condensed Cross Cutting Themes

Condensed Cross Cutting Themes	Value of Complexity	Contextualised Continuous Improvement	Multi-dimensional evaluation	Derivation of Expertise Identity	Linkage and Integration
Cross Cutting Themes	The benefits & challenges of complexity	Mentoring as vehicle to contextualise learning and enhance perspective	Value of a comprehensive multi-dimensional evaluation	The systemic interconnection of skill, knowledge and expertise for individuals, teams, projects and programmes	- the iterative links between Interelated disciplines
	The value of collaboration with multiple stakeholders	Project as focus for sustainable continuous improvement	Project driving multidimensional sustainability	The identity of project and programme expertise.	The need to move from fragmentation to integration.
		Project contextualising formal instruction			

These threads or themes which refer back to the arguments presented in the initial chapters have forward alignment with the management and governance of project, programmes and portfolios. At their core is the engagement of the energies of project participants and the removal of obstacles to their productive engagement and effective implementation. They also appear to reflect many of the aspirations of a positive approach to sound project governance and are described in more detail in Section 7.3 and 7.4.

7.2.1 The Value of Complexity

During the interviews, the fact that they were working on complex projects (Tables 6-1 and 7-1) was regularly cited by the participants as a reason why the project provided the preconditions for the perceived enhancement of skill, knowledge and expertise. This complexity was understood to manifest itself at many levels and within different domains. There were a large number of stakeholders who were operating within and between different technical, organisational and political dimensions. The projects were clearly technically complex as major infrastructural enterprises. They involved different types and levels of engineering and construction disciplines and crafts. They were also perceived to be complex in terms of the number and variety of stakeholders that (from the perspective of programme management) had to be managed and aligned. Collaboration with multiple stakeholders was regarded as an important aspect of project participation and was an attribute which the participants believed would improve their capabilities. It had also become apparent that the focus of the participants' expertise had

evolved from, typically an engineering discipline towards stakeholder and programme management. There were examples of this in all the case studies. A senior participant on the Hub followed a ‘definite’ affirmation that the project had enhanced expertise with a reference to the complexity of the project. A senior participant on Birmingham New Street also followed an ‘absolute’ affirmation with a reference to ‘one of the most complex projects ever worked on’ and one that would ‘stand them in good stead for future projects’. There were similar explicit references to complexity in response to the key question 5 from almost all the management interviewees on the Birmingham Project. There were also implicit and explicit references to complexity in both the NET2 and EMRP projects.

Almost by definition, complexity manifests itself on multiple levels and dimensions. There have been numerous attempts to provide order and a framework for its different manifestations (Zhu and Mostafavi, 2017) and its natural association with large scale rail infrastructure (Chapman, 2016). The presence of Complexity is also one of the key criteria used to evaluate the level of competence of project managers (Association for Project Management, 2009). Here, the criteria for the evaluation include: cultural and social context, degree of innovation, project organisation and leadership, teamwork and decisions. The ability to facilitate communication and collaboration in a complex project or programme environment are critical to success. This work does not seek to set out to introduce further frameworks or to re-order existing ones. Rather it points to the consistent attribution of the notion of complexity by those seeking to describe the qualities of the project which, in their view, contributed to the enhancement of expertise.

The importance of collaboration was an associated and consistent theme throughout the interviews. There was an ‘internal’ collaboration within the immediate project team as well as the more ‘external’ collaboration with the broader range of stakeholders. A Participant involved in the design, for the Birmingham Gateway project made reference to ‘needing all the partners on board’ while also emphasising the ‘importance of working as a team’. Another participant referred to everyone being ‘brought together in site conditions’ and then ‘somehow everyone makes it work’.

The significance and importance of a collaborative environment to move forward an innovative change project is also described in the Institute of Railway Signalling Engineers White Paper (Institute of Railway Signalling Engineers, 2018) and the preceding IRSE workshop (WSP / IRSE, 2017).

The way in which these complex collaborative environments are sub-divided for management and governance is obviously of great importance. In particular to ensure that the complex interconnections are not disrupted by over simplistic conceptual or organisational segmentations. Organisational divisions that are intended to simplify and facilitate delivery but which can have the effect of weakening the connection between the practical delivery of technical solutions and their management and programming. A factor that was highlighted, to varying degrees, across all the case studies.

7.2.2 Contextualised Continuous Improvement

The notion of an evolving, developing and improving set of capabilities emerging from the project environment was a consistent theme during the interviews. This was reflected in three of the cross cutting themes: Mentoring, as a vehicle to contextualise learning and enhance perspective, the project being a focus for continuous improvement and the project contextualising formal instruction. A senior participant on Birmingham referring to mentoring explained that most people 'have had to enhance skills by being alongside and by working with those with less experience. On the EMRP a participant referred to the benefit of the classroom making site work more meaningful, another referred to the need for less experienced project participants to see things built.

The general view was that training needed to be tailored closely to project requirements. They considered that it was difficult to justify a general broadening of perspective in a real-time project with clear deliverable project requirements. However, there was a general, albeit implicit appreciation that project participants were also autonomous entities who needed to develop their own career paths. One response from a Birmingham participant referred explicitly to the need to reference not only the project requirements but also the individual personal development plans. This suggested a recognition that a broad based learning process would support the integration of a much broader range of capabilities.

Such a process of integration would align with the argument that the broader the context within which the domain knowledge is set; the greater the mastery of the domain (Farrington-Darby and Wilson, 2006). This would be especially relevant if it involved a domain whose centre of gravity and boundaries were shifting as a result of its evolving relationship with others within a flexing system. Indeed it could also be argued that this broadening of perspective would further support the evolution, transference and development of that domain knowledge beyond the parameters of the project or programme environment. This work has not engaged in detail with the mechanisms of knowledge acquisition or knowledge elicitation in relation to specicific rail specialisms. However the use of projects as contained entities that are recognised as facilitating the enhancement of expertise would provide the appropriate environment for the 'field work' advocated in the Darby-Wilson paper.

7.2.3 Multi-dimensional Derivation of Value

This consistent theme, related to the derivation of value, brought to the fore the recognition that the notion of value is multifaceted. Not all its attempted calibrations are easily or readily measurable or effective and that cost based evaluations alone will not adequately represent its many dimensions.

Examples of this were described across all projects. There were references to:

The Hub (Nottingham Station) linking the south and north of the city. The Nottingham and Birminham developments and refurbishments serving as a catalyst to opening up parts of the City which were previously less active.
The intangible value of an improved aesthetic as a result of the Designs.
The importance of recognising the value of Civic Pride. The distinction between 'public' and 'private' projects, with the latter being distinctly easier to quantify through their level of profitability, whereas the former was required to take into account and promote a multi-layered representation of civic value.

This broader multi-dimensional recognition of value has been recognised across the industry, in areas addressing costs directly, including the Contracts and Procurement transformation programme at Network Rail. This programme has recognised that there are a range of 'Value levers' within Network Rail's toolbox that could be used more effectively when trying to engage multi-dimensional value (Network Rail, 2019). That there should be a shift of emphasis from driving down price towards driving income and innovation.

7.2.4 Derivation of Expertise Identity.

The notion of the project generating its own collective expertise that could also assume its own identity that was more than an aggregation of the expertise of individual participants, began to emerge from the interviews. This addressed the distinction between individual and collective knowledge as well as the extent to which capabilities and evolving domain competences could be said to develop for both the individual and the broader team. How they distil themselves into varying levels of skill, knowledge and expertise. And how this derived expertise identity can manifest at an individual, project, or programme level. For example a participant on NET2 referred to everything 'focussing around the project and of expertise evolving evenly through the team.' with expertise developing around the whole delivery process.

There was therefore a recognition of the collective amalgamation of project or programme expertise that emerged concurrent with a successful project delivery. Also that there would be significant scale benefits to be able to go on to retain that amalgamated expertise and apply it to similar projects requiring similar outputs. The opportunity offered by the electrification programme, or the NET2 tram projects (Mott Macdonald, 2006) were good examples of how this collective expertise could have been harnessed. Unfortunately, principally because of funding constraints, these continuity projects, together with their scale benefits did not materialise. Neverthless, this work provides support for the value of the engagement with and exploitation of, that amalgamated project identity while at the same time accommodating the development of individual project participants and their specific expertise trajectories.

7.2.5 The Importance of an Appropriate and Integrated Linkage

The identity and interconnectivity of different manifestations and levels of expertise relies on the appropriate, integrated linkages between their component parts. It also relies on the essential interconnection between design, construction and project management disciplines. Where the process of arriving at an optimum integrated solution involves recognising potential interconnections and appropriate areas of porosity between the different domains. For example on the Birmingham and Nottingham Hub projects there was an emphasis on the need for a more integrated linkage between the technical requirements of the project and the project management teams' appreciation of their significance. There was also an awareness on all the projects of the local authorities need to maintain a constant oversite of the strategic social impact of the project within the urban design context within which the projects were set.

Shifting the focus towards expertise evolution as project output would imply a shift of emphasis towards subject, discipline and domain interconnection through a careful evaluation of their strategic directions of travel. Developments that would need to be aligned with the evolving programme requirements as well as the disaggregated needs and aspirations of the individual project participants. However, to be effective it is important that the managerial and administrative compartmentation required to order and control the governance and development of an evolving domain trajectory does not fragment or disconnect these intricate interconnections.

There had also been some discussion across all the projects relating to the distinction between domain specific / technical and general / non-specific / non-technical capabilities in relation to management. The extent to which a technical understanding of the area and disciplines within which the project is operating is necessary in order to be able to enable effective management. Not surprisingly, there were different views on this, however they reduced down the capacity to of the manager to recognise the path to achieve the appropriate solutions. The ability to make the appropriate linkages between the component parts in such a way that it contributed to the accumulation and refinement of an adequate and informed perspective on the area in which they were operating.

7.3 : WAYS IN WHICH ARGUMENT IS GAINING TRACTION & CHALLENGES TO BUSINESS AS USUAL

The material that constitute this work (the hypothesis, the case studies, the paper, the arguments and the supporting material) have been communicated within the organisation and to the wider industry in different ways. In addition to the specific instances referred to below the author has used the opportunities presented in meetings, forums and workshops to describe, explain, test and promote the ideas put forward in this work. Given the extended and extensive scale of the organisation and industry as a whole, the effect of the dissemination of the argument has inevitably been diffuse and varied. Nevertheless the author believes that this process has but has made a meaningful contribution to a shift of emphasis in the direction that this work has proposed. And while there are some demonstrable linkages, others are connected less directly. Examples of direct, indirect linkage and alignment include:

- Contributions to the Digital Rail Programme, including the direct citation of the 2016 paper (Langdon et al., 2016) in the Digital Rail Strategic Business Case (The Digital Rail Programme, 2016).

- Contributions to and outputs of associated workshops and think tanks relating to the Digital Rail programme organised on behalf of the Institute of Railway Signalling Engineers, including a series of references to the importance of expertise in the IRSE white paper (see above).

- Contributions to State of the Nation report with the direct citations of the paper in the State of the Nation Report (Institute of Civil Engineers, 2017b).

- The appearance on and the contributions to the agenda of an expert panel at the Shaping the Digital world conference in 2017.

- Contributing to an increase in the profile of the Quadrant or Tier 3&4 Benefits when evaluating Business Cases.

It is worth noting that while this chapter includes a number of references to the digital railway in general and the Digital Rail programme in particular, the arguments put forward in this work originated long before the programmes inception. So while they are relevant to the programme, they were not developed specifically for it and are equally applicable in areas not covered by digital technology or the other areas that fell within the scope of the programme.

7.3.1 The Digital Rail Programme Business Case

The Digital Rail Programme (The Digital Rail Programme, 2016) was set up within Network Rail to act as a catalyst for the introduction of a range of technologies, processes, systems and business change onto the rail network. Given the constraints on building more physical infrastructure, the principal purpose of the project was to increase the capacity and also the connectivity of the network. In order to secure its future funding there was a requirement to submit a series of Business Cases to the Department for Transport based on the 5 Case Model (Department for Transport, 2013). This process involved a series of increasingly detailed submissions which put forward the argument for the continuation and development of the programme. During the process of developing these increasingly detailed submissions a series of drafts were circulated for comment and amendment.

The author was invited onto the programme in order that the ideas contained in this work would contribute to the formulation of the associated policy and strategy. Through the evolving iterations of the drafts the arguments presented in this work were put forward and were, able to influence the strategic direction of the programme by emphasising the potential enhancement of expertise that would accrue from it.

This represented an opportunity to advance the case that, there would be significant benefits to be gained as a result of the expertise enhancement that would follow in the wake of the implementation of the programme. An enhancement that would be achieved in a range of areas that were evolving and developing as the systems associated with the programme developed and matured. Ammendments and suggestions were put forward at various stages in the iteration of the 5 Cases of the Five Case Model business case and particularly the Strategic Case in order to make that case more effectively and emphasise the benefits for shifting the emphasis towards the enhancement of skill, knowledge and expertise.

This was an extended and extensive process which took place over three years and was consolidated when the 2016 version of the Strategic Business Case (The Digital Rail Programme, 2016) acknowledged this works contribution with the citation of the recently published paper.

7.3.2 The State of the Nation Report

The State of the Nation Reports are produced annually by the Institute of Civil Engineers and focus on different topics. The subject of the 2016 report addressed Devolution (Institute of Civil Engineers, 2016) The development of the ICE State of the Nation Report for 2017 addressed the Topic of ‘Digital Infrastructure’ (Institute of Civil Engineers, 2017b). The author was invited to contribute to the report both as a particant in the Digital Rail Rail programme (7.3.1) and because of this research which was being undertaken in alignment with it.

The research undertaken and arguments put forward in this thesis informed the report's development, notwithstanding that this work is not specific to the digital domain, digital implementation or the Digital Rail programme. It nevertheless became increasingly clear that the arguments put forward were very relevant to the challenges and opportunities offered up by moves towards the implementation of digital infrastructure.

The 2017 report's purpose was to consider …'how digital technology and data are transforming how we design, deliver and operate infrastructure'. It proposed a shift of emphasis towards recognising that data relating to a physical asset was itself an asset. With clear references to Building Information Modelling (NBS, 2019). It argued that a 'digital twin' would need to be managed collaboratively as an asset in itself to deliver an infrastructural service. It also argued that 'We must adopt new integrated digital approaches' to achieve a shift of emphasis with its focus on outcomes leading to a 'Whole Life approach' (Institute of Civil Engineers, 2017b p3).

Despite its apparent overtly technological title, the report addressed the topic of digital infrastructure under the headings of Productivity, Behaviours and Resilience rather than with a more overtly technological headings and focus. This suggested an implicit recognition that a conceptual separation of the 'technical' from the people and processes that brought them about would be inadequate and misleading. And that it would fail to adequately represent the extent of the system which it was seeking to describe. Throughout the text there were several references to the need for collaboration and integration in order to achieve the required communication and connectivity. Messages that, again, were consistent with the themes presented in this work.

The Behaviours stream, within the report emphasised how organisational culture and skills' would be critical in determining success and it was under this Behaviours stream that the report made the most direct reference to the subject matter of this work, 'Major infrastructure projects have been shown to be effective incubators for both innovation and upskilling the workforce' (Institute of Civil Engineers, 2017b p17) . The paper (Langdon et al., 2016) was cited directly in this section together with a call on government to follow trough on this opportunity.

The behaviours section of the report also refers to innovation and upskilling and goes a significant way towards recognising the comprehensive expertise enhancement which is achieved as a consequence of participating in projects and programmes. It also draws attention to the role that projects can play in providing such an appropriate environment for the evolution of expertise.

The report also called for a 'shift of emphasis' in relation to Infrastructural data and highlighted the preconditions that would be required to alter the perception of data in relation to the infrastructure it was supporting. Emphasising that it should be seen as an infrastructural asset in itself. This work would argue that it is not a great step from this to the further recognition that both physical infrastructure and the supporting data is itself dependent on the underlying infrastructural asset of the skill, knowledge and

expertise that enabled their realisation. The recognition of which would require a similar shift of emphasis.

7.3.3 Shaping the Digital World Conference

The following year the 'Shaping the Digital World' conference (Institute of Civil Engineers, 2017a) developed several of the themes from the 2017 Report. There were three work-streams that were run concurrently: 'Fostering changes in Behaviour', 'Enhancing Resilience' and 'Delivering Productivity'. The author was invited onto an 'expert panel' in the Behaviours Work-stream addressing 'Major Projects as Skills Incubators' with Chris Bagley, Head of Infrastructure Knowledge Transfer Network and chaired by Phil Wilbraham, Expansion Programme Director at Heathrow.

It covered a range of topics under the heading of 'Skills Incubators'. Two out of four of the panel topics related directly to this work: 'Should the enhancement of Expertise, Skill and Knowledge be a defined output of projects and Programmes' and 'Major projects can act as a model for incubation'. How can we maintain and control the uplift once a project ends'. These topics were amalgamated from a list of five suggestions which the author had been asked to submit for consideration. It was intended that these would be evaluated as subject matter for the panel discussion. The other topics put forward were:

-Should the enhancement of expertise, skill and knowledge be a defined output of projects and programmes?

-Should major projects include future innovation/transformation/disruption as part of project outputs?

-Should the Incubation of expertise within major projects and programmes provide Civil Engineers the opportunity to ask 'Why' as well as 'How' and 'What'?

-Should all major projects incubate transformation, innovation and disruption alongside skill knowledge and expertise?

-Should major projects accommodate the incubation of innovation/transformation/disruption as programmed output as well as desired outcome?

The reference to innovation, transformation and disruption referred to projects and programmes such as the Digital Rail Programme which contained such potential. This work has referred to these possibilities in relation to transformative programmes in 3.2 where outputs, outcomes and the capabilities required to define and deliver them are uncertain but none the less, of significant value.

The reference to 'How', 'What' and 'Why' questions were referred to in section 2.5.4 in relation to the enhanced perspective that a 'rewired' system would offer. In particular the opportunity for that system perspective to offer engineers and others the opportunity to consider the undelying reasons for strategic decisions. The 'Why' as well as the 'How' and 'What'.

As noted above, the central arguments put forward in this work had not been developed specifically in relation to digital infrastructure or work-streams associated with digital technology or digitisation. Nevertheless they were entirely relevant to many of the issues which the 'State of the Nation' report and the 'Shaping the Digital World Conference were addressing because any consideration of the evolution of any infrastructure must ultimately defer to the expertise on which it depends.

7.3.4 The Institute of Railway Signalling Engineers – White paper - Making a Success of the Digital Railway

In parallel with the development of the Business Case the Institute of Railway Signalling Engineers initiated a series of workshops/Think Tanks (WSP / IRSE, 2017) These were intended to consider the strategic intentions and approach to the implementation of the Digital Railway programme. The author was invited to this forum because of the unusual situation of being both a student researcher and an experienced full time project participant. The output and outcome of these were addressed in the publication of a White paper (Institute of Railway Signalling Engineers, 2018). The author was invited to participate in the think tank workshops. There were again opportunities to introduce and re-emphaise several of the ideas that have been developed in this work.

As with the State of the Nation Report referred to above, the discussion and subsequent analysis elicited two apparently non-technological topics: Topic One addressed: People, Culture and Collaboration. Topic 2 addressed Supply chain engagement and Involvement. The themes that emerged from these discussions demonstrated significant alignment with the cross-cutting themes described in section 7.2 as well as the argument developed throughout this work.

Topic 1 included: The shortage and lack of development of skills. The 'Stop – Start' nature of projects inhibiting adequate mobilisation of resources and skills development. The lack of confidence about projected future workload. The lack of vision and expertise. The abrupt disgarding of steadily accumulated project or programme expertise. Thereby inhibiting the opportunity for the future delivery and completion of projects and programmes. The need to select projects that will 'bring benefits to the operational railway and also systematic learning' (WSP / IRSE, 2017 P4). The proliferation of negative and counter-productive industry practices and their unintended consequences.

Topic 2 addressed 'Supply Chain Engagement and Involvement'. The themes addressed here again referred to the skills and processes needed for delivering the programme. It was emphasised how collaboration involving the integration of technology, people and processes were critical to success. And conversely how the ineffective application of these processes would be counterproductive and wasteful. While there was a clear reference to and appreciation of the skills associated with digital technology.

There was also a clear reference to the skills associated with building long term relationships, innovative approaches to funding and avoiding wasteful processes. Also the need to recognise that they were operating in a complex but potentially creative and productive working environment.

The White Paper, which followed on and drew its material from the workshops, highlighted seven key themes (Institute of Railway Signalling Engineers, 2018 p 4) which had emerged from the discussions. The White Paper argued that they needed to be addressed in order to achieve the required outcomes. These were perceived to be: Aligning Industry objectives, Targeted implementation, Confidence, Collaboration and Culture, Expertise to Deliver, Contracting, Delivering Efficiently and Technology Options and Optimisation.

Interestingly among many salient points, the White Paper highlights two key factors which have a significant influence on the delivery of such an innovative project: That it was a transformative project and the notion of a skills shortage and skills gap. Throughout the paper there are opportunities to make important connections. The programme is presented as a 'Transformation' project or programme whose business case is handicapped by having to be delivered in isolation, thereby missing out on an economy of scale and making it too inefficient if undertaken on its own. There is an assumption here that a defined 'transformative' solution is potentially available. Its scope and parameters are understood and that it just needs to be activated and delivered in order to be realised. While some specific 'technological' solutions may have been developed, the overall scope, composition and philosophical direction of the programme remained the subject of considerable debate. These were not addressing a series of theoretical refinements but rather the critical constituent parts of the operational railway. Such is the open-ended nature of transformative projects where the extent and nature of the deliverable is far from defined or understood. Indeed, it is in this area of interdisciplinary interaction and testing of domain boundaries that there resides the potential for significant expertise enhancement and the related evolution of a robust expertise trajectory. These are complex, nuanced considerations; the evaluation of which must be carefully calibrated. They are not the types of projects that should be judged on their compliance with an economy of scale.

Similarly, under the section on expertise The White Paper refers to a lack of skilled people as a 'skills shortage' and to the lack of expertise as a 'skills gap' (3.3 and 3.5). While these terms can help to draw attention to an area of concern, a shortfall in capabilities, they also appear to suggest the absence of a defined, scoped and understood 'skills whole' out of which a piece is missing. These types of descriptions or analogies can easily lead to misunderstandings which can, in turn, lead to significant missed opportunities. For while there may be specific and defined capabilities required within the project – that is 'gaps' which can be 'filled' in a relatively straightforward way. The evolution of expertise is a complex, dynamic and open ended process. And potentially transformative projects can provide just such a dynamic and initially open ended environment within which skill, knowledge and expertise is allowed the space to develop to its (and the programmes) greater potential. An evolution which can shape the boundaries of the relevant domains and the capabilities that sustain it, while facing continuing examination and scrutiny. Even the domain boundaries of the signalling system itself, the ultimate fall

back for railway safety, are not rigidly pre-determined or constrained, and must be able to face robust challenges to its its methods of operation, that this and any other programmes may present. Arguably, the distinguishing feature of the present DR programme is not that it employs digital technology but that it aims to make more intelligent and informed use of data to design and manage the railway.Signalling systems (in the widest sense of the term) are 'becoming data driven control systems, using data from diverse origins to inform better decision making that provides all sorts of customer benefits, including a highly reliable service as well as releasing latent capacity currently constrained by existing control systems'. (WSP / IRSE, 2017 P6)

This clearly makes the point that there is no defined gap, even in such a critical system, that is simply waiting to be 'filled in'. The nature and extent of the whole as well as the gap is flexing and evolving. Nevertheless transformative programmes have the potential to act as catalysts for potential solutions that can serve to adjust or re-locate some fixed points of reference that, in turn, can serve to facilitate and enable a consolidation of a realigned system identity that will be reflected in the emergent reinvigorated expertise on which it depends.

7.3.5 Tier or Quadrant Benefits

Chapter 3 referred to the low population of qualitative benefits (quadrant 3 and 4) when compared with quantitative benefits (tiers 1 and 2) in authority papers which authorise spending. Internal and external qualitative benefits had received less attention when compared with quantitative benefits. Indeed the re-placement of the title 'Tier' with 'Quadrant' Benefits avoided the inference that qualitative benefits are intrinsically less important than quantitative ones, including any suggestion that items which might be safety related would be given a lower priority because they were not readily monetizable.

This has aligned with a recent re-evaluation of benefits delivery as part of a transformation exercise within the 'Contracts and Procurement' department, where there has been a recognition of a broader range of opportunities to obtain value. This re-evaluation refers to 'Value Levers' (mechanisms to achieve or leverage greater value, which fall into the categories of 'Driving Down Price', 'Taking Cost Out', 'Driving Income and Innovation' and 'Reducing Risk'. While there is no direct relationship between the value levers and the Tier /Quadrant benefits there are alignments. 'Driving Down Price' and 'Taking Out Cost' can be said to relate to Quadrants 1 and 2 respectively and are essentially quantitative in nature. Whereas the themes of 'Drive Income and Innovation' and 'Reducing Risk' tend to be more qualitative in nature and align more with Quadrants 3&4.

The re-evaluation or transformation programme has drawn attention to the fact that, 'traditionally there has been a focus on driving down Price' as a method of enhancing value. The programme presents the case that the application of other 'value levers' would release greater benefit but that this would require higher levels of capabilities and greater collaboration within the organisation and broader industry in

order to do so. Higher levels of collaboration would imply the application of higher levels of expertise on the part of the contracts and procurement team to achieve it. Interestingly the calibration of the axes 'Business value and Impact' has the high end requiring higher levels of 'Capabilities' and Collaboration'. A recognition that higher value is derived from higher levels of capabilities. These observations are consistent with the themes that emerged from the case study interviews relating to Multi-dimensionality and Collaboration when describing the characteristics of projects which they considered were significant contributors to the overall enhancement of expertise. The calibration of an axis in this way suggests a recognition of the importance of the expertise being exercised by those deciding on the most appropriate procurement methods to enhance value.

7.4 POTENTIAL MECHANISMS TO FACILITATE THE SHIFT OF EMPHASIS

The shift of emphasis towards the recognition and valuation of the enhancement of expertise achieved through participating in projects could be facilitated by considering different ways of undertaking the projects and delivering the deliverables. Understandably the latter is central to the purpose and meaning of such undertakings and almost everthing else is subordinated to it. This includes the provision, or more importantly the sustainable provision, of the skill, knowledge and expertise necessary to deliver them. The proposed shift of emphasis would move from a situation where expertise is treated less as being subordinate to project deliverables or outputs to one in which they are regarded as symbiotic with them. Indeed, to work towards the inclusion of the systemic enhancement of expertise as a required project output. This could involve a process of option (and risk) evaluation that would explicitly target and support the evolution and incubation of the expertise required to deliver the different project components. Instead of simply 'resourcing the projects' to deliver the outputs. Projects would also be 'supporting the marshalling of the resources to both deliver the outputs and optimise the outcomes.

A recognition of the intrinsic value of this shift of focus towards expertise evolution and incubation could add value at a number of different levels. The more projects and programmes are understood as contributory and necessary conditions for expertise enhancement. The greater the opportunity for them to act as focal points for the development of a broad range of evolving capabilities. If managed carefully, in alignment with the relevant academic institutions they could serve as an effective catalyst and reference point for the provision of a broader range of training and educational benefits. For example having a closer and more dynamic relationship with research development optioneering at feasibility stage or an ongoing active lessons learnt process during project delivery. Factors such as these could be recognised as being intrinsic to any meaningful evaluation of the benefits that could be realised as a result of all the transactions taking place in rail investment.

7.4.1 Whole Life Evaluation

Given such a recognition and the predisposition to shift the emphasis in the way described, there are a range of mechanisms, or enablers, which could help to support this. These include: the absorption of expertise enhancement and its associated benefits into a whole life evaluation of the viability of a project, programme or portfolio of activity. As discussed above in 7.4 and in 4.1, such a comprehensive evaluation, which recognised the value of the qualitative externality of expertise enhancement could turn an incidental outcome into a targeted output.

Notwithstanding the increased use of Whole Life Cost mechanisms, (including Network Rails' approach outlined in 4.2) in recent years, none currently explicitly include expertise enhancement as an externality (British Standards Institute, 2017 p 7). A form of whole life evaluation which included this externality could be embedded in a range of Business Case templates, including, within the Green Book 5 Case Model business case ref 7.3 above.

Closely linked to the above would be a further mechanism which would facilitate this shift of emphasis. This could be undertaken through 'Optioneering' or Option Analysis for different approaches to projects. This would involve comparing different ways to undertake them which allowed greater accommodation for expertise enhancement. This might involve options which included extended time, extended funding or extended resources. Such a potential benefit could be included as an important factor in applications for the release of project funding, including in in the 'quadrant benefit' section of the authority paper. This could be agreed in principle at Inception stage. The different options then would need to be described and compared at the stage when the authority to release funds was being sought as the different approaches would be likely to have have significantly different cost and programme implications. For example there may be aspects of a project not on the critical path, such as heritage refurbishment of station buildings, which could be extended in order to accommodate the training, re-training or further development of project participants who would benefit from working in this field. This principle could be considered for other disciplines, including those within more immediately operational domains which were less time critical, where an extended period to undertake the work could be offset by other potential benefits. These benefits would include using the additional time to enable the enhancement of the capabilities of other project participants. Or to increase the number of participants to a particular level of capability, inevitably using the project as a vehicle for mentoring. Such an opportunity may be even more realisable in the post covid world and in the light of the William-Shapps report and its emphasis on innovation and skill enhancement in a reconfigured infrastructural system.

While such an approach might increase the cost and programme of an individual project; the enhancement of the overall expertise benchmark in different domains it would, over time, reduce both their cost and programme implications by increasing the availability of the necessary resources to realise them. Such an approach would require, more than incidental adjustments to the business case (Association for Project Management, 2012) but some substantially different assumptions about the scope of the project, as well as the nature of their outputs and outcomes.

7.4.2 Project Management Body of Knowledge and Competence Framework

The approach being outlined in this work would affect to some degree all the categories of the Body of Knowledge (Association for Project Management, 2012). However those sections noted below would be particularly relevant in relation to the shift of emphasis described above For reference we will refer to the APM Body of Knowledge (Association for Project Management, 2012) and Competence framework (Association for Project Management, 2009).

1.0 PM In Context
- 1.5 Sponsorship – Ensures Benefits Realised
- 1.6 Project Office – Enables and Drives Lessons Learnt

2.00 Planning the Strategy
- 2.1 Project Success & Benefits Management
- 2.3 Value Management
- 2.4 Project Management Plan
- 2.5 Risk Management.

3.0 Executing the Project Strategy
- 3.1 Scope Management
- 3.3 Resource Management
  - Replenishable
  - Reusable

4. Techniques
- 4.5 Value Engineering

5. Business and Commercial
- 5.1 The Business Case

6.0 Organisation and Governance
- 6.2 Concept
- 6.3 Definition

7.0 People
7.6 Human Resource Management
7.8 Learning and Development.

There is a comparison to be made between the Skill, Knowledge and Expertise demonstrated by those undertaking project management and the specific competencies described by the categories listed above. Of course these distinct, recognisable categories of competence or capability serve an important function in relation to governance and competence evaluation. However, the multidimensional derivation of expertise considered in 4.5 suggest these and other distinct capabilities which contribute to the assimilation of project management expertise need to be seen in the broader context. Indeed the distinctions between 'Project Management Expertise', 'Generic Skills' and 'Managerial Skills' (Chipulu et al., 2013) throws up some interesting challenges. Not least because the derivation of the upper levels of expertise are critically dependent on a broad context which can facilitate the move from rule based stages to seing the situation as a whole. In that sense such notions as 'Generic skills' or 'Managerial

skills' are so intrinsically bound up in and inextricably linked to 'project management expertise' that the distinction is of limited value.

7.4.3 Value Management

Value management is described as. "A framework that allows needs, problems or opportunities to be defined and then enables review of whether the initial project objectives can be improved to determine the optimal approach and solution"

The notion of Value is determined on the basis of the 'satisfaction of needs' being divided by the Use of resources. (Association for Project Management, 2002 44-6) (Association for Project Management, 2006 2.3)

$$\text{VALUE} = \frac{\text{SATISFACTION OF NEEDS}}{\text{USE OF RESOURCES}}$$

The principle assumption being that the less the resources used in relation to needs satisfied; the greater the Value.

This calculation of value, understandably, treats the application of resources, including (reusable) human resources as a form of cost, effectively a negative to be minimised. An implication of the argument put forward in this work suggests an alternative perspective. That an increase in human resource allocation, if it were to be seen as a positive benefit, could actually increase overall the 'Value Calculation'. Thereby inverting the assumed 'Satisfaction of Needs': 'Use of Resources ratio'. Thereby changing the perception of resource allocation as no longer simply a cost to be minimised but also a potential benefit to be optimised.

An increased allocation of resources would add value to the project because expertise enhancement would become a specific and required output of the project or programme and a need to be satisfied. It could also add value to a broader programme which was looking to benefit from the consequent continuity of capabilities from one project to another. Capabilities which would be allocated to those subsequent projects which had the potential to benefit from them. It would then as a consequence add value to the portfolio of programmes because they would benefit, not only from the above but also from the evolving expertise trajectory further into the future. The allocation and management of these benefits could, then, be addressed within project success and benefits management (Association for Project Management, 2012 Section 2.1)

7.4.4 Resource Management

Resource Management (Association for Project Management, 2012 p 241) (Association for Project Management, 2019 pp 48, 215) is another area which would contribute to this shift of emphasis, with the increasing reference to 'Talent management' in association with 'Resource Management' possibly indicating a move towards a more comprehensive recognition of value.

This section of the Body of Knowledge (BOK) refers to two types of resources which are used on a project. Replenish-able and Reusable. An example of the former being finance or money, an example of the latter being people. Resource management involves the efficient mapping of resources against activities, requiring that resources are used as efficiently as possible. Again a general assumption about the efficient use of resources implies that people's interaction with the project should be for as limited a duration as possible in order that the re-usable resource can be re-allocated. This carries the implication that there are a defined set of capabilities for a defined task and that their engagement with that task should be minimised for the sake of apparent efficiency. A principle reason for this, of course, is to minimise the use of a replenish-able resource: the funding. The management of the process involves such mechanisms as resource smoothing and resource levelling, the purpose of which is, within these parameters, to allocate resources in such a way as to minimise any associated negative influence on the project.

The general tendency to minimise the engagement of human resources with the project leans towards two assumptions. Firstly that the tasks tend to be finite and defined and that the capabilities needed to address them tend to be finite and defined. It also has the implication that that human resource allocation is simply a cost to be minimised.

The proposed shift of emphasis towards this more effective recognition of expertise enhancement could and likely would include: An extended duration to accommodate the significantly more extensive 'training and mentoring' opportunity that this would provide. This would again require a re-appraisal of the assumption that the 'reusable' human resource allocation should have the minimum contact possible with the tasks it is allocated to, in order to minimise costs. So, if viewed from the alternative perspective outlined above there is the potential for the enhanced allocation of resource to be perceived as a positive aspiration, outcome and also a specified output for projects.

This approach would require an acknowledgement that the application of this 'reusable resource' should not necessarily be minimised ~~in order to~~ but rather should have its contact with the project extended in order increase the opportunity for the enhancement of skill, knowledge and expertise which would contribute towards this more comprehensive notion of value. Indeed within the context of a strategic expertise trajectory there may be distinct benefits in prolonging programmes to accommodate the development of individual or collective skill, knowledge and expertise in specific directions. This would

take into account whichever trajectories of the different dimensions of domain knowledge had the potential to realise the more significant short, medium and long term benefits. Benefits that would also include cost savings for future projects, programmes and portfolios and which would have the potential to contribute in part to a quantitative, monetizable whole life cost calculation.

7.5 Conclusions

This chapter has considered the way in which the distilled themes (Condensed Cross Cutting) which emerged from the research aligned with the perspectives being presented in the initial chapters in relation to sustainale interventions in rail assets. How they are relevant to project realisation, and also provided some early indications of the way in which the arguments put forward in this work are gaining traction within Network Rail and the broader industry. It described how the progress to date has indicated possible ways to facilitate their application and indicated possible adjustments and shifts of emphasis which could support a modified approach and facilitate their development into the future.

The Condensed Cross Cutting themes described the characteristics of projects perceived, by the participants, to contribute to the enhancement of expertise: Complexity was repeatedly cited as a pre-requisite for the enhancement of expertise. Effective engagement with this and other project attributes would lead to an ongoing process of continuous improvement for the project participants and the project as a whole. Thereby generating a multi-dimensional value which went beyond a monetary calculation. A demonstration of value which superceded the simple aggregation of the enhanced expertise of the individual participants. A collective whole expertise identity, manifesting at different scales, which could be described as superceding the sum of the individual parts. All of these characteristics dependent on effective linkages and interconnections between the different technical and governance disciplines that constituted the scope of the project, programme or portfolio.

This chapter also described how the arguments and ideas presented in this work have gained varying degrees of traction through a range of programmes, fora and products. Several of which coalesced around the notion of Rail's Digital Infrestructure. Not only the programme itself but also associated outputs such as the State of the Nation report and associated conference.

It also went on to consider how certain changes of emphasis in project governance could help to facilitate the engagement of human resources in a more productive way. This could include treating the project explicitly as a vehicle for delivering expertise enhancement as one of its outputs and could be facilitated through a range of project management mechanisms, which might include an extended delivery periods. This facilitation of expertise enhancement would have the potential, in conjunction with other mentoring, training and educational vehicles, to contribute towards a direction of travel and associated expertise trajectory that would more effectively allocate rail asset value where it belongs

The next chapter considers the overall implications of the work and draws some further conclusions as well as indicating some possible directions for future research.

8 CONCLUSION.

This work has argued that a more explicit engagement with skill, knowledge and expertise would help to sustain the integrity and ongoing evolution of the rail infrastructure asset base.

The first four chapters have provided the background and built the case for shifting the emphasis of policy and strategy towards a greater recognition of the value of the enhancement of expertise that is inherent within asset value. They have outlined how the notions of sustainability, the asset base and a comprehensive evaluation provided the different facets for the arguments and hypothesis which were tested in the subsequent case studies. They have presented the case for treating expertise enhancement as an explicit output, as well as intrinsic outcome, for any project or programme. That a shift of emphasis towards the development/incubation of expertise would be a significant benefit and that this should be factored in to any evaluation of the viability of projects and programmes. These initial chapters also set out the argument for a greater and more formalised recognition that projects which are designed to enhance physical asset value also enhance the expertise that is a necessary condition for its ongoing evolution. Implicit in this is the need for a step change in the attribution of value towards the evolving expertise that ultimately underpins it. A complex and systemic process that makes its impact on a number of levels, affecting the individual, the team, the project, the disciplines and the industry.

Chapters 5 and 6 provided support, through case studies for the argument and hypothesis described above. The results from the case studies described a strong relationship of 80% agreement (or strong agreement) that participation in projects had resulted in the enhancement of their skill, knowledge and expertise. The case studies were undertaken using a multi-strategy approach using surveys and interviews. These provided some quantitative but principally qualitative support for this hypothesis. In addition to describing and demonstrating this relationship, the output from the interviews, based on Grounded theory, drew out themes that had emerged from each question. These were further broken down to cross-cutting themes that traversed the individual questions. These, in turn, have provided indications or signposts for the mechanisms that can be used to bring about the proposed shift of emphasis that has been developed in this work.

Chapter 7 sought to continue on from the support derived from the case studies to consider some of the themes that emerged from the surveys and interviews and provided some early indications of the way in which they are beginning to gain traction. It also described how the progress to date provide further indications of possible ways to facilitate their application and considered possible ways in which these ideas could be applied and developed in the future.

This final chapter draws overall conclusions as to how value can best be assigned in relation to interventions in railway infrastructure and how it can be most effectively sustained in the short, medium and long term. It has argued for a shift of emphasis that would alter the relationship between the realisation of project outputs and the realisation of both the prerequisite capabilities that are required to

deliver them and the consequent capabilities that emerge from them. Between the physical infrastructure and the intellectual infrastructure on which it depends.

It has argued that the explicit acknowledgement and incorporation of the enhancement of skill, knowledge and expertise as an externality in a whole life evaluation of business cases would be a significant step towards the recognition of the nature of the investment needed in the potential of its key resource, its people and how this would be intrinsic to asset value.

This work is, therefore, arguing for a formal recognition of the value of capturing this enhancement, which could occur across the range of project types, from the repetitive roll-outs to the one off innovation. Such an approach would offer opportunities across the broad spectrum of capabilities. From the basic competencies to cutting edge innovation. The latter contributing to the continually evolving dynamic expansion of the system boundaries and domain integrities. Thereby increasing the likelihood of real time re-assesessment and linkage between operational requirements, research and innovation.

This could manifest itself in a range of different ways; for example if the project, or more likely aspects of the project, were not deemed to be time critical and could accommodate the dissemination, accumulation and amalgamation of relevant capabilities in a live project environment. Under such conditions it may be possible to incorporate the less experienced (those significantly lower on the Master – Novice spectrum) into aspects of the project that they would not normally encounter. Their overall development could be continued in alignment with the relevant evolving domain trajectories as well as the short to medium term project and programme objectives. One way to approach such an enhancement of an anticipated expertise trajectory could be to consider the adoption of different approaches for scheme development. This would imply different ways in which available resources could be applied during the planning of a project or programme. Approaches such as these would offer varying degrees of opportunity to enhance the expertise of individual participants as well as accommodating the evolution of the general domain within which they were operating.

This would involve a move away from the comparison of different project options, where the allocation of human resources are generally deployed to enable the delivery of defined components with the lowest expenditure of resources. With the implicit assumption that greatest value or ‘satisfaction of need’ is achieved by minimising the time of those deployed on the project.

The proposed development put forward here would involve the explicit targeting of the resourcing of the project in order to facilitate the enhanced development of a significantly greater number of participants. Such an approach, which sought to optimise the investment in human capital, would seek to accomodate:

-The delivery of immediate operational requirements,

-The preparation for and resourcing of future operational requirements,

-The evolving integrities, boundaries and trajectories of the associated domains and systems as they mediated between operational need, the evolution of evolving and innovative trajectories and longer term research and development opportunities.

This shift of emphasis would provide benefits on a number of levels:

- It would accelerate the delivery of project benefits in the form of the ongoing enhancement of expertise which would be realised prior to other project outputs.
- It would recognise the value of using the project as a catalyst to facilitate a refocussing on the expertise trajectory of people, programme and domain disciplines.
- It would recognise the value of expertise enhancement when evaluating the viability of the project or programme. It would bring forward some projects in a form that would provide benefit to: Both the skills, knowledge and expertise of the participants as well as the evolution of the expertise inherent within their domain.
- It would make explicit the re-positioning of projects, as contingent upon the necessary enhancement of expertise which would become a required project output. The way in which projects were resourced would become critical to their viability.
- It would encourage a more symbiotic relationship between projects, programmes and portfolios and the evolution of expertise of their associated domains
- It would have the implication that projects and their management would benefit from assuming a degree of 'responsibility' over their longer term resourcing strategies. To take a longer term view of the implications of the resourcing strategies that extended significantly beyond the short term needs of the project. They would also need to take a far greater role in the direction of expertise evolution in order to optimise its strategic direction.

Of course, at one level projects don't have responsibilities. They are simply vehicles for delivery. However if it can be argued that if the notion of a project assuming an expertise identity is meaningful. It can be also argued that the notion of the project taking a level of responsibility for the development of the skill, knowledge and expertise upon which that identity ~~it~~ depends could also be said to be meaningful. This could be facilitated and supported by acadamies in order to train some of the key disciplines associated with their programme domains thereby enabling the project itself to become a significantly more active vehicle for the incubation and evolution of the expertise that is intrinsic to the realisation of its outputs.

The set of diagrams below (8-1) seeks to describe this evolution and shift of emphasis from a focus on isolated and compartmentalised projects and their associated expertise. Towards the inverse of that relationship which prioritises the necessary expertise trajectories in relation to the contingent (albeit, often critical), project outputs. A shift of emphasis which would result in the sustained enhancement of both neccessary expertise and contingent outputs. Figure 8-2 develops this notion of an expanding expertise trajectory with its permeable boundaries depicting projects drawing on that evolution in order to 'filter out' contingent outputs that can be consistently consolidated into operational deliverables. Emphasising again that the physical manifestation of the railway network is essentially the latest consolidation of the latest state of skill, knowledge and expertise at any point in time.

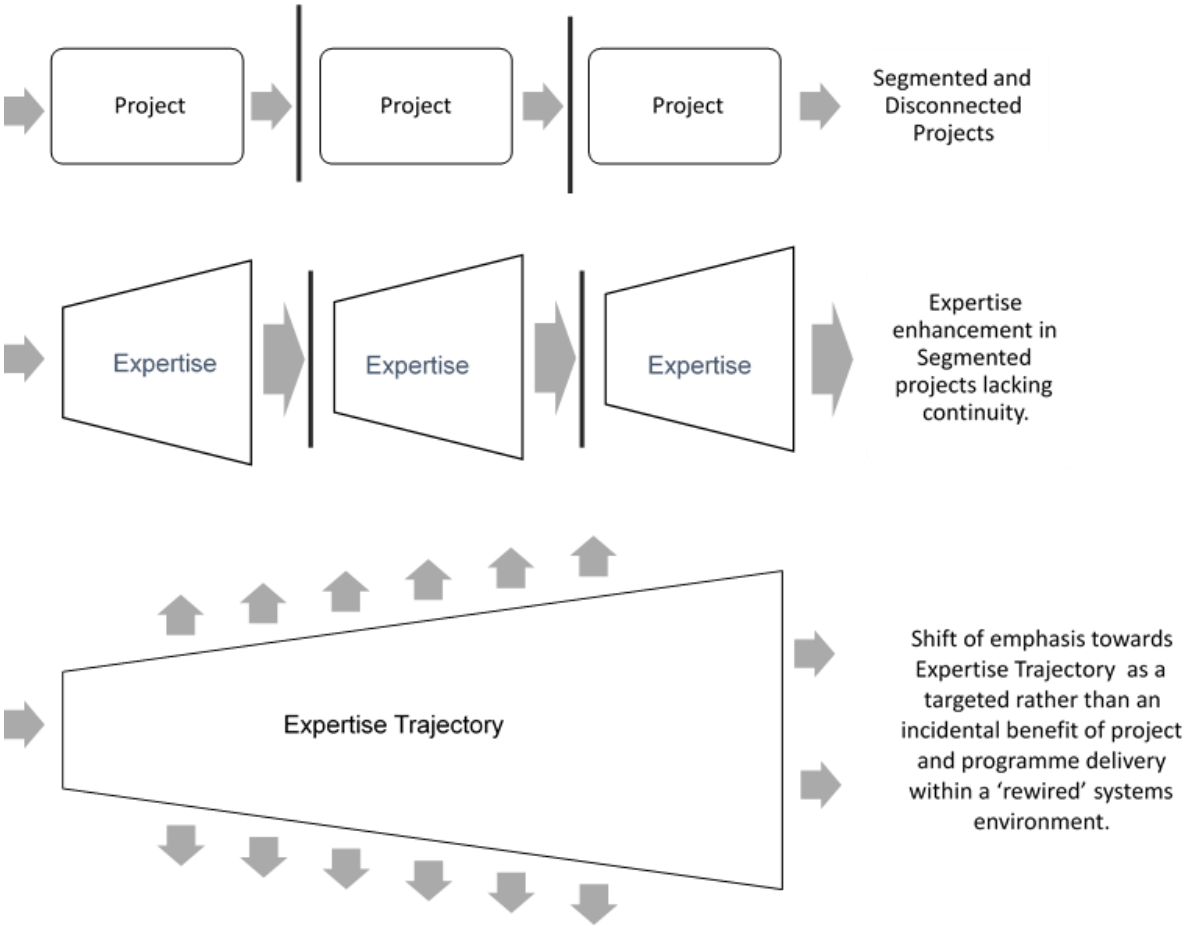


Figure 8-1: A graphic representation of the potential for a shift of emphasis from segmented projects and their associated expertise towards a more integrated, evolving expertise trajectory which accommodates and enhances the outputs of projects (Langdon et al 2016)

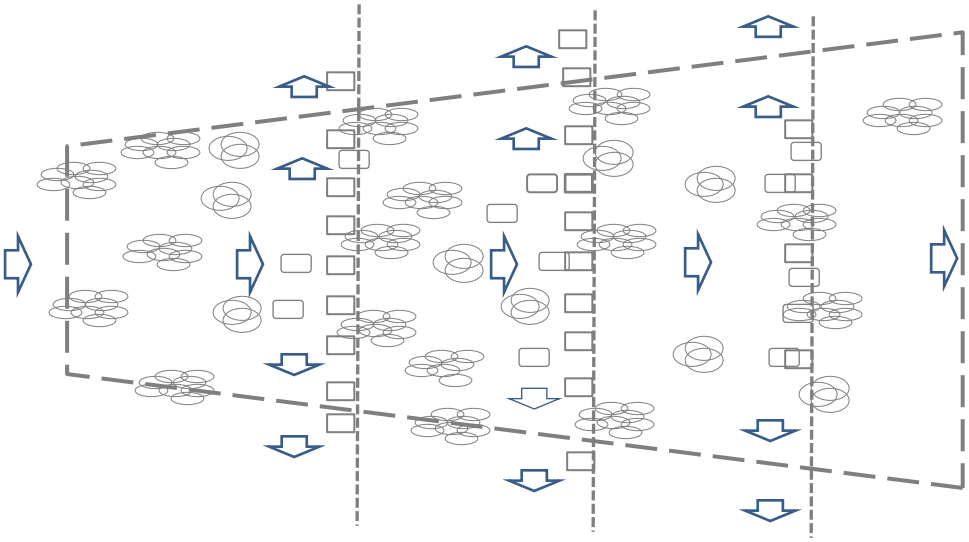


Figure 8-2: A more developed graphic representation of the notion of a necessary, dynamic and permeable expertise trajectory which is able to accommodate the delivery of critical but contingent project outputs. The shift of emphasis towards the necessary enhancement of the expertise trajectory also results in the enhancement of contingent project outputs.

The associated actions to implement this approach would have significant implications, and would entail:
- A re-prioritisation of the relationship between the delivery of infrastructural solutions and the Skill, Knowledge and Expertise required to realise them.
- A significant reconfiguration of projects and programmes to accommodate this re-prioritisation.
- A greater prioritisation of qualitative benefits when evaluating project or programme viability
- A greater engagement with a broader range of infrastructural systems and the associated domain trajectories of their dependent and enabling capabilities.
- The expansion of expertise associated with one domain demonstrating its relevance to other domains and the associated benefits of scale that this will bring.
- Significant modifications to the procurement approaches and models to accommodate this adjustment.
- Projects and their outputs becoming more clearly seen as a spatio-temporal filter and reference point for the current state of expertise evolution
- The provision of a unifying concept within which the many advocates of collaboration, integration, coordination and systems thinking could coalesce.
- A greater and more effective alignment between short, medium and long term discipline trajectories.

This work has attempted to call into question certain assumptions about our understanding of infrastructural assets. Both physical and intellectual. It has not sort to redefine terms but rather to suggest a possible realignment of our understanding of the relationships that exist between them. Such a realignment would serve to provide an alternative perspective from which to view their short, medium and long term development, via the vantage point of the principle mechanisms for asset delivery. The argument for a shift of emphasis towards skill, knowledge and expertise, the intellectual infrastructure has not implied a shift away from the physical assets that constitute the physical infrastructure. Instead, it is arguing for a re-alignment that would ensure the enhancement of both.

This has led to a range of juxtapositions which have been a constant theme of this work and have manifested in different ways and in different contexts throughout. These include: the distinctions between technical and non-technical capabilities; outputs and outcomes; quantitative and qualitative evaluations; a defined and scoped project and an apparently open ended one. Not to mention the notion of an ‘externality’ which is intrinsic to an effective and meaningful evaluation. By drawing attention to these juxtapositions, this work has not sought to set up mutually exclusive choices. Rather: it has sought to recognise the reality of the conditions within which rail infrastructure assets are delivered. There is of course a practical requirement for consistent, predictable and predefined outputs and these need to be designed, developed and delivered within a project environment. While at the same time recognising that these project outputs are necessarily dependent on an evolving skill, knowledge and expertise base that is incubated within that same environment. An environment, which, in turn can accommodate an expanding evolution of those capabilities and their associated, contingent solutions.

While the focus of this work is on rail, the approach could also be extended to other associated infrastructures. Rail as a key mode within transport infrastructure forms an important part of the UK’s key economic infrastructures. Transport, together with energy, waste, water and telecoms constitute the

other key economic infrastructures. These in turn underpin the social infrastructural systems, such as health, education and finance on which the UK economy depends. The effectiveness of the interconnections within and between these infrastructural systems, will be determined by the skill knowledge and expertise that is contained, developed and incubated within them. This will enable a scale effect where the benefits derived from the whole are greater than the sum of the parts (H M Treasury, 2015c)

This scale effect which is generated within projects and programmes could also be transferred within and across the different infrastructural systems. The resulting enhancement of skill, knowledge and expertise not only provides the preconditions for the development and delivery of significantly enhanced railway infrastructure but would also support and supplement those of the other key economic infrastructures as well. And in addition provide the preconditions for economic growth through the consequential enhancement of sustained labour productivity.

So in essence, this work has been about harnessing the potential of the Skill, Knowledge and Expertise of the people who constitute the railway infrastructure's principle asset. To bring that potential to bear on the development and deployment of a range of integrated, interrelated and evolving, disciplines and domains. And to ensure that they have the capacity to meet the practical infrastructural challenges and opportunities that are presenting themselves and will continue to present themselves now and in the future.

8.1 CONTRIBUTION TO KNOWLEDGE AND UNDERSTANDING

The argument being put forward in the thesis is a carefully assembled interdependent construct that systematically and deliberately addresses the opportunity that a revision of our current understanding of sustainable interventions in Rail assets would provide. It contributes to knowledge and understanding through a considered examination, re-arrangement and amalgamation of its constituent parts in order to locate asset value closer to where this work has argued that it should reside. Seeking to provide an informed insight and enhanced perspective on the evaluation of rail assets that is changing and will continue to change the perception of asset value.

It explains how a current state of understanding or knowledge in relation to the evaluation of rail assets could be modified through a shift of emphasis that moved the onus of evaluation of projects towards the greater recognition of the enhancement of expertise that would come about as a consequence of undertaking the project. And that this would firmly locate value closer to where it belongs, which it argues, would constitute the most significant contribution possible to the sustainability of the industry.

Recognising the enormous technical and organisational scale of the rail industry as well as its practical and iconic significance, the thesis works from the premise that an apparently modest/ incremental modification in the angle of perception of the value of rail asset interventions would have a significantly

disproportionate effect on the sustainable enhancement of asset value. Particularly for its principle asset, its people.

A shift of emphasis that would move along the spectrum from a lowest common denominator of monetary evaluation of deliverable output towards the highest common multiple of the skill, knowledge and expertise which underpins that output. Recognising that a significant proportion of asset interventions take place through projects and programmes this work argues that these are both contributory and necessary causes of expertise enhancement and need to be treated as such.

It addresses the systemic challenge of sustainable interventions in Railway Assets from three perspectives: The notions of Sustainability, the notion of the Asset and the notion of Evaluation. It considers how these provide an enhanced understanding of their significance, interrelationship and interdependence in the context of Rail Asset Value. It goes on to explain how this enhanced understanding leads to a significant shift of emphasis that modifies our assessment of value when addressing interventions in Railway assets. In particular, the value that would be realised by shifting the emphasis towards the enhancement of skill knowledge and expertise and the consequent benefits to its principal asset, its people.

Firstly it addresses the different dimensions of Sustainability and which of its manifestations provide the greatest insight into the continuing enhancement of value in relation to railway assets. Recognising that the notion of Sustainability has many perspectives, including its traditional tripartite subdivisions (Environment, Economic and Social) it describes a natural association of Environmental Sustainability with Engineering infrastructure.It considers how these traditional tripartite subdivisions compare with other models and considers the limitations of these conceptualisations.

It provides an insight into the range of opportunities explicitly and implicitly embedded in policy and strategies to recognise, accommodate and deploy the potential of the skill, knowledge and expertise of, its people. How the effective accommodation and deployment of this potential provides the most pronounced and significant manifestation of sustainability in the context of rail infrastructure.

Secondly from the perspective of the ‘Asset’: The thesis advocates a revised perspective on the elemental and systemic dimensions of both the physical engineered infrastructure, social infrastructures and their dependent intellectual infrastructure. The sustainability of the latter depending on its effective incubation within conditions that can most effectively accommodate and promote its ongoing evolution. This includes the challenging of discipline and domain boundaries in order to develop and re-evaluate new interrelationships between the constituent parts. Acknowledging that projects, provide an appropriate environment for this ongoing iteration, integration and consequential enhancement of expertise; this work argues that its enhancement should be more than just an incidental outcome of infrastructure delivery but a designated output of projects: A developed understanding of the nature of the asset base that would underpin all the different manifestations of its ongoing and sustainable evolution.

Thirdly, from the perspective of Evaluation. How methods of project evaluation can fail to adequately recognise the significance of the enhancement of expertise in the determination of their viability. How the approach to evaluation inevitably reflects the value that society invests in the different and varied manifestations of its infrastructure as well as the value to be derived from them. How an excessive reliance on quantitative monetary evaluation misses significant opportunities to adequately represent this investment and how a shift of emphasis towards a more comprehensive approach to evaluation would result in a more comprehensive understanding of the potential to be realised from the different manifestations of railway assets. A shift of emphasis that would move along the spectrum from a lowest common denominator of monetary evaluation of deliverable output towards the highest common multiple of the expertise of its principal asset, its people. A common thread that requires appropriate representation in the calibration of the worth and affordability of asset interventions. And while this recalibration may be initiated via the notion of an externality in a whole life evaluation. This needs to be juxtaposed with the awareness that rather than being an external attribute of asset value, the enhancement of skill, knowledge and expertise is, in fact, intrinsic to it. .

Informed by these three perspectives on the notion of sustainable interventions in rail assets the Case studies were intended to test this argument together with the hypothesis that: A sustainable intervention in the rail infrastructure asset base which effectively demonstrates a meaningful form of whole life value will include externalities. Among these externalities will be a positive change in the knowledge, skill and expertise of those participating in the interventions, a significant proportion of which are carried out through projects. The enhancement of skill, knowledge and expertise underpins and is integral to the sustainable evolution of the infrastructure asset base. Therefore, this externality also needs to be recognised as intrinsic to any meaningful understanding of the value of any intervention in the railway infrastructure asset base. (1.6)

The Case studies and the associated surveys and interviews produced results which supported the assertion that there is a necessary and contributory causal relationship between project participation and the enhancement of the expertise of the participants.

The findings describe both a strong relationship (80% agreement / strong agreement) between project participation and expertise enhancement.

They also provide further insights into the nature of that enhancement through the identification of themes, supra themes, cross-cutting themes and condensed cross cutting themes: which described the characteristics of projects which were integral to the various dimensions of this enhancement. These themes were distilled down to: The Value of Complexity Contextualised Continuous Improvement, Multi-dimensional evaluation, The Derivation of Expertise Identity and Linkage and Integration. Finally distilling them further in order to discern an overarching theme (reflected in the Title) of how an effective shift in the process of evaluation both reflects and also promotes a shift in the inherent values of the industry.

These insights were consistent with the three perspectives on the nature of sustainable interventions in rail assets laid out above, as well as contributing towards an enhanced understanding of the nature and potential of project evaluation and asset enhancement. How this could contributes significantly towards a revised understanding of the nature of sustainable interventions in rail assets and serve to revise the calibration of value towards the expertise of project participants.

This insight also supplements our understanding and knowledge of asset value and the ways in which interventions in the asset base through projects provide the pre-conditions for the incubation and enhancement of expertise. This enhanced understanding has been cited and applied in a number of active strategic and policy contexts. These include: National Infrastructure Policy formulation, The Programme Strategy and Business Case formulation for a major infrastructure programme. It also influenced the strategic direction of the Safety, Technical and Engineering function in Network Rail in terms of the motivation and mastery of engineering as well the reduction of ongoing costs.

Citing the 2016 paper, which described the argument set out in this thesis, the 'State of the Nation' report called on the government to recognise the potential of Major Projects to incubate expertise:. 'Major infrastructure projects have been shown to be effective incubators for both innovation and upskilling the workforce'

These constituted demonstrable contributions to the understanding of how greater emphasis needs to be given to trajectory and evolution of expertise in the context of project implementation.

In undertaking the study the use of terminology and its use has drawn attention to their implications in relation to the application of resources. An example of this is the notion of the externality. An economic term which has been considered at length during the thesis This engagement with the term has been of value in increasing knowledge and awareness of how certain economic and management assumptions relating to resource allocation might be challenged.

The 'internalisation of externalities' would involve the full costs and benefits (social, economic and environmental) involved in determining the allocation of resources, and thereby the price. This work has sought to encourage the move away from an underlying assumption that the lower the resource allocation the greater the value. And that the allocation and use of resources are not necessarily inversely proportional to the value of the output. That the deployment of human resources is not a finite one to be conserved but an infinite one to be stimulated, increased and 'leveraged'.

The notion of affordability is also implicit in this Juxtaposition between the notion of finite and infinite resources. With the former approach leading to a more restricted and negative understanding of affordability in this context. While the latter approach suggests that the opportunity cost of failing to adequately accommodate human resource potential is both comprehensively unaffordable and unsustainable.

The thesis was submitted as the University was shutting down for the Covid 19 Pandemic.which has obviously had a very significant impact on the industry. Not least the massive drop in passenger numbers has meant adapting from a situation of unprecedented and rising demand to one of unprecedented reduction. In parallel with this a White Paper for a reform of the whole industry (Williams Shapps, 2021) will involve the assimilation of Network Rail into 'Great British Railways'. The report has highlighted the need and opportunity to improve what are perceived to be the negative aspect of a complex and disparate industry and build on its many positives. The report includes a number of areas which reflect some of the themes in this work, these include:

The report describes the need to move from a fragmented industry to a more cohesive whole with a 'single controlling mind' in order to integrate and unify its disparate constituent parts. It also seeks to exploit innovative potential of the private sector to import customer focussed expertise which is not specific to railways such as 'data and banking' - a somewhat constrained view of the source and direction of the opportunity. While this work is aligned with the deployment of expertise and the informed and considered extension of domain boundaries where appropriate. It is important that as an engineered infrastructure, it retain the integrity of its essential disciplines and core domains.

This work has directed much of its attention towards large scale rail infrastructure construction projects. A characteristic of such projects is that they seek, for good reasons, to derive benefit from off site prefabrication where factory produced packaged components can be brought to site and fitted together. However this neat assembly of neatly compartmentalised components very often encounters challenges at their interfaces when they encounter the reality on the ground. It is often in that hinterland in which the value of the whole enterprise comes to be realised. This work has sought to encroach on other hinterlands in order to test and stretch the permeable boundaries between innovation and research, the promotion of continuous learning and operational need and efficiency. And how these could be realigned or shifted in order to recover an informed and theoretically robust recognition of where the integrity of asset value truly resides.

POSTSCRIPT

The submission of the Thesis coincided with the onset of the Covid Pandemic, which has had a significant effect on the Rail Industry and the people working in it. Passenger numbers fell dramatically when lockdown was introduced and while the numbers are anticipated to return to some degree, they are not anticipated to be restored to pre-pandemic levels in the short to medium term. It is anticipated that the effects of adapted working patterns are likely to result in adapted travel patterns. The increased flexibility around the workplace is likely to continue and increase the use of the train as a working environment. However such an extension of the workplace requires the physical and virtual connectivity to be effectively aligned with other transport modes and other forms of economic and social infrastructure.

These enforced modifications have coincided with the publication of the Government White Paper (Williams Shapps, 2021) 'Great British Railways - The Williams Shapps Plan for Rail', which would notwithstanding the pandemic, have prompted significant changes to the form and structure of the railways. Both represent significant opportunities for the engagement of the significant reserves of skill, knowledge and expertise of those working on the railway. Chapter 6 is entitled 'unleashing the Potential of the Private Sector. While this work has been consistently arguing for an 'unleashing of potential' it is important that the whole industry is involved in this process.

The process of developing this work has inevitably produced a significant number of learning points in relation to the way it was undertaken. It has also provided indications of the way in which this line of research could progress in the future. Several of these have been covered to a greater or lesser extent in the text. However some further observations may be worthwhile.

A number of useful areas of work have emerged from the work that would be worth developing:

- To investigate further the potential for the scope of transport infrastructure projects to extend/integrate their system responsibilities into the hinterland of the Social Infrastructures. Not to transgress rationally allocated domain boundaries but rather to use the expertise and perspective gained in order to inform and challenge the reasoning behind such undertakings.
- To look at the robustness of the mechanisms by which projects could be 'optioneered' to accommodate the enhancement of expertise as output as well as outcome. This will need to take place within the governance structure of the relevant organisations and to ensure their alignment with the appropriate project management methodologies.
- To consider the impact of the control period investment cycle on the more strategic development of capabilities proposed here. Also to do a more detailed analysis of the medium and long term benefits and costs within the context of the different disciplines that adopted this approach.
- To develop and initiate a series of case studies to consider a closer real time linkage between lessons learnt on practical delivery projects and ways in which these can feed into active research programmes.

Much of the work has related to the use and understanding of terminology. Not to try to modify the meaning. But rather to gain a greater understanding of the interrelationship of the different parts of the infrastructural system in general and rail infrastructure in particular. This has been productive and would be worth continuing particularly in relation to some of the juxtapositions that have been considered in the text. Examples of these are: Quantitative/Qualitative evaluations, Intrinsic Qualities/Externalities, Neccessay/Contingent Project Outputs,

The Case Studies were being generally undertaken on live projects which were working to challenging deadlines. Sample sizes for the surveys were limited although this was mitigated by the consistency of response. Understanably, the distribution of academic surveys were not a high priority for the project team.The switch to digital format for the on line survey was a significant improvement. While there are many benefits to using large, live, dynamic and weighty projects as case studies so it is all the more important to have fall back approaches when the inevitable project demands compete with support for the research.

The need for anonymity and data security precluded follow up surveys and inhibited follow up interviews. It would be worthwhile investigating secure ways to follow up some of the the survey and interview participants in order to gauge the development of their expertise enhancement as well as the extent to which their views had evolved.

Some of the proposed adjustments to project management and governance methodologies could be the subject of more granular research in future case studies.

The interview process in the Pilot study interviews revealed lines of questions which were less productive in eliciting informed and spontaneous responses. In order to ensure consistency no questions were removed for the case studies but they were asked in a different order in order to facilitate communication and conversation flow. In hindsight it would have been preferable to have provided more flexibility in the range of Pilot Study questions and then, where appropriate, to remove some from the case studies as their scope consolidated.

As a part-time study there were a number of learning points relating to logistics, co-ordination and governance which had a significant effect on the development and delivery of the research which would be worth addressing.

The development of a paper for publication (albeit in an extended and extensive process) was extremely helpful in testing and condensing the arguments that were evolving from the thesis during the extensive peer review process. It has also been helpful in communicating the ideas more broadly and it has been referred to directly and indirectly in a range of documents and forums.

REFERENCES

Acemoglu, D. 2012. Introduction to economic growth. *Journal of Economic Theory,* 147**,** 545-550.

Allen, R. C. 2009. *The British Industrial Revolution in global perspective / Robert C. Allen,* Cambridge, Cambridge : Cambridge University Press.

Armitt, S. J. 2015. ICE Presidential Inaugural Address.

Association for Project Management 2002. Project Management Pathways.

Association for Project Management 2006. Body of Knowledge.

Association for Project Management 2009. APM Competence Framework.

Association for Project Management 2012. Body of Knowledge 6th Edition.

Association for Project Management 2019. *Body of Knowledge 7th Edition*.

Bank of England 2018. Bank of England - Knowledge Bank.

Becker, G. S. 1962. Investment in Human Capital: A Theoretical Analysis. *The Journal of political economy,* 70**,** 9-49.

Briner, W. 1990. *Project leadership / Wendy Briner, Michael Geddes, Colin Hastings,* Vermont,U.S.A., Vermont,U.S.A. : Gower.

British Standards Institute 2017. *BS ISO 15686-5:2017 - Buildings and constructed assets. Service life planning. Life-cycle costing*.

Broersma, L., Edzes, A. J. E. & Van Dijk, J. 2015. Human Capital Externalities: Effects for Low-Educated Workers and Low-Skilled Jobs. *Regional Studies***,** 1-13.

Brunello, G. 2009. The Effect of Economic Downturns on Apprenticeships and Initial Workplace Training. *OECD*.

Building Better Healthcare 2015. Boom/Bust nature of the Construction Industry leading to skills shortages. *Building Better HealthCare.*

Byrne, J. & Lund, P. D. 2019. Sustaining our common future: Transformative, timely, commons ‐ based change is needed. *Wiley interdisciplinary reviews. Energy and environment,* 8**,** e334-n/a.

Carney, M. 2020. The Grand Unifying Theory (and practice) of Macroprudential Policy

Speech given by Mark Carney Governor of the Bank of England Logan Hall, University College London 5 March 2020.

Carson, R. 1962. Silent spring. 1962.

Chapman, R. J. 2016. A framework for examining the dimensions and characteristics of complexity inherent within rail megaprojects. *International Journal of Project Management,* 34**,** 937-956.

Chipulu, M., Jun Guan, N., Ojiako, U. & Williams, T. 2013. A Multidimensional Analysis of Project Manager Competences. *IEEE transactions on engineering management,* 60**,** 506-517.

City of Nottingham 2009. Sustainable Community Strategy.

Communities and Local Government 2009. Multicriteria Analysis - A manual.

Coyle, D., Mitra-Kahn, B. & Australia, I. 2017. Making the future count. *joint winning entry, Indigo Prize*.

Dadashi, N., Golightly, D. & Sharples, S. 2021. Modelling decision-making within rail maintenance control rooms. *Cognition, technology & work,* 23**,** 255-271.

Department for Transport 2007. *Towards a sustainable transport system : supporting economic growth in a low carbon world / presented to Parliament by the Secretary of State for Transport by Command of Her Majesty, October 2007,* Norwich, Norwich : Stationery Office.

Department for Transport 2013. The Transport Business Cases.

Department for Transport 2017. Transport Investment Strategy.

Dietz, S. & Neumayer, E. 2007. Weak and strong sustainability in the SEEA: Concepts and measurement. *Ecological economics,* 61**,** 617-626.

Dodgson, J. S., Spackman, M., Pearman, A. & Phillips, L. D. 2009. Multi-criteria analysis: a manual.

Dreyfus, S. E. & Dreyfus, H. L. 1980a. A five-stage model of the mental activities involved in directed skill acquisition. California Univ Berkeley Operations Research Center.

Dreyfus, S. E. & Dreyfus, H. L. 1980b. *A five-stage model of the mental activities involved in directed skill acquisition,* Berkeley, University of California (Berkeley). Operations Research Center.

Eddington, R. 2006. *The Eddington transport study / Sir Rod Eddington,* Norwich, Norwich : TSO.

English Heritage - John Minnis 2005. Nottingham Railway Station - An Architectural Assessment.

Erdf 2012-15. Citizens Rail Project https://www.citizensrail.org,.

European Commission 2001. *European transport policy for 2010 : time to decide : white paper / European Commission,* Luxembourg, Luxembourg : Office for Official Publications of the European Communities.

European Commission. Directorate General For, M. & Transport 2011. *White paper on transport : roadmap to a single European transport area : towards a competitive and resource-efficient transport system / European Commission, Directorate General for Mobility and Transport,* Luxembourg, Luxembourg : Publications Office of the European Union.

Farrington-Darby, T. & Wilson, J. R. 2006. The nature of expertise: A review. *Applied Ergonomics,* 37**,** 17-32.

Forum for the Future 2020. The Five Capitals Model – a framework for sustainability.

Giddings, B., Hopwood, B. & O'brien, G. 2002. Environment, economy and society: fitting them together into sustainable development. *Sustainable development (Bradford, West Yorkshire, England),* 10**,** 187-196.

Glaeconomics 2006. The rationale for Public Sector Intervention in the Economy.

Godfrey, P. C. 2014. *More than money : five forms of capital to create wealth and eliminate poverty / Paul C. Godfrey*, Stanford, California : Stanford University Press.

Gourvish, T. R. 1980. *Railways and the British economy, 1830-1914*, Macmillan International Higher Education.

Graymore, M. L., Wallis, A. M. & Richards, A. J. 2009. An Index of Regional Sustainability: A GIS-based multiple criteria analysis decision support system for progressing sustainability. *Ecological complexity,* 6**,** 453-462.

H M Government 2011a. Securing the Future.

H M Government 2017. Building our Industrial Strategy.

H M Government 2011b. LOW CARBON CONSTRUCTION ACTION PLAN

Government response to the Low Carbon Construction Innovation & Growth Team Report

H M Treasury 2015a. Green Book Supplementary Guidance: Using the 5 Case Model. 152.

H M Treasury 2015b. National Infrastructure Plan for Skills.

H M Treasury 2015c. Valuing Infrastructure Spend: Supplementary guidance to the Green Book.

H.M. Treasury 2011. The Green Book. Appraisal and Evaluation in Central Government.

H.M. Treasury 2015. Valuing Infrastructure spend: Supplementary guidance to the Green Book.

Hawkes, J. 2001. *The fourth pillar of sustainability: Culture's essential role in public planning*, Common Ground.

Haythornthwaite, R. 2011. The Place of the Railways in the UK. See http://www.mediacentre.co.uk/resourcesgeorge-bradshaw-address-rickhaythornthwaite-06-09-11.

Hoffman, R. R., Shadbolt, N. R., Burton, A. M. & Klein, G. 1995. Eliciting Knowledge from Experts: A Methodological Analysis. *Organizational Behavior and Human Decision Processes,* 62**,** 129-158.

Holmes, M. R., Neil. 2021. Promoting Workforce Planning as a Means of Embedding a Learning Culture in the Rail Sector.

Huberman, M. M. B. M. A. 1994. *Qualitative data analysis : an expanded sourcebook / Matthew B. Miles, A. Michael Huberman,* Thousand Oaks, Thousand Oaks : Sage.

Iet 2008. *Asset Management: Whole Life Cost or Value?, 2008 IET Seminar on*.

Incose 2021. Systems Engineering Handbook - SE-BoK.

Institute for Government 2016. How to Value Infrastructure.

Institute of Civil Engineers 2016. State of the Nation Report - Devolution.

Institute of Civil Engineers. Shaping the Digital World. 2017a.

Institute of Civil Engineers 2017b. State of the Nation Report - Digital Transformation.

Institute of Railway Signalling Engineers 2018. Making a Success of the Digital Railway.

Iso 2008. *BS ISO 15686-5:2008 - Buildings and constructed assets. Service life planning. Life cycle costing*.

Jisc 2016. On Line Surveys, .

Kirkwood, L., Giuntini, L., Shehab, E. & Baguley, P. 2016. Development of a Whole Life Cycle Cost Model for Electrification options on the UK Rail System. *Procedia CIRP,* 47**,** 1-5.

Kirwan, A. 2020. Discussion Note 1 - Value Frameworks V1.

Laird, J. J. & Venables, A. J. 2017. Transport investment and economic performance: A framework for project appraisal. *Transport Policy,* 56**,** 1-11.

Lam, A. 2000. Tacit knowledge, organizational learning and societal institutions: An integrated framework. *Organization studies,* 21**,** 487-513.

Lane, J. 1996. *Apprenticeship in England, 1600-1914 / Joan Lane,* London, London : UCL Press.

Langdon, M., Gillott, M., Rodrigues, L. & Parry, T. 2016. The case for internalising externalities in a sustainable rail asset base. *Infrastructure Asset Management,* 3**,** 97-105.

Lim, M. M. L., Søgaard Jørgensen, P. & Wyborn, C. A. 2018. Reframing the sustainable development goals to achieve sustainable development in the Anthropocene-a systems approach. *Ecology and society,* 23**,** 22.

Logistics and Transport Focus 2021. UK RAIL INDUSTRY FACES CRITICAL SKILLS SHORTAGE. *Logistics and Transport Focus,* 23**,** 10.

Lovelock, J. 1982. *Gaia: A new look at life on earth*, Oxford Paperbacks.

Mac Donald, K., Rezania, D. & Baker, R. 2020. A grounded theory examination of project managers' accountability. *International journal of project management,* 38**,** 27-35.

Magee, B. 1985. *Popper / Bryan Magee,* London, London : Fontana.

Maheso, N., Mpofu, K. & Ramatsetse, B. 2019. A Learning Factory concept for skills enhancement in rail car manufacturing industries.

Mazzucato, M. 2013. *The entrepreneurial state [electronic resource] : debunking public vs. private sector myths / Mariana Mazzucato,* London, London : Anthem Press.

Mcdonough, W. 2009. *Cradle to cradle : remaking the way we make things / William McDonough & Michael Braungart,* London, London : Vintage Books.

Mengchu, Z., Han-Xiong, L. & Margot, W. 2015. System of Systems Thinking in Policy Development: Challenges and Opportunities. *Contemporary Issues in Systems Science and Engineering.* IEEE.

Mott Macdonald 2006. Net 2 phase 2 - Heritage briefing note.

Mumford, S. A., Rani Lill 2013. *Causation*, Oxford University Press.

National Infrastructure Commission 2016. National Needs Assessment - A Vision for UK Infrastructure.

National Infrastructure Commission 2017. Briefing Paper - National Infrastructure Commission.

Nbs 2019. National BIM Report 2019.

Network Rail 2010. Prioritising Investment to suit our economy.

Network Rail 2011. Asset Policies.

Network Rail 2013a. Alliancing in Infrastructure Projects.

Network Rail 2013b. Benefits Principles.

Network Rail 2013c. Network Rail Technical Strategy.

Network Rail 2016. Network Rail tests market for power infrastructure investors to support Railway Upgrade Plan.

Network Rail 2018. Investing in the Network - GRIP.

Network Rail 2019. Integrated category strategies.

Network Rail / Building Design Partnership 2007. Nottingham Station Heritage Report.

Network Rail / Building Design Partnership 2008. Nottingham Station - Addendum to Design Statement

Network Rail Telecoms 2018. Network Rail Telecom Strategic Plan.

Nottingham Cc 2005. Local Transport Plan for Greater Nottingham | Final Plan 2006/7 - 2010/11.

Nottingham City Council 2005. Nottingham Local Plan.

Nottingham City Council 2011. NOTTINGHAM EXPRESS TRANSIT - PHASE TWO

APPENDIX 1 - PROCUREMENT STRATEGY

NET Phase Two

Full Business Case

Submitted July 2011.

Organisation for Economic Co-Operation and Development 2000. *System of National Accounts, 1993 - Glossary*, Paris: OECD Publishing.

Ottino, J. M. 2004. Engineering complex systems. *Nature,* 427**,** 399.

Patterson, R. E., Pierce, B. J., Bell, H. H. & Klein, G. 2010. Implicit Learning, Tacit Knowledge, Expertise Development, and Naturalistic Decision Making. *Journal of Cognitive Engineering and Decision Making,* 4**,** 289-303.

Popper, K. R. & Hudson, G. E. 1963. Conjectures and Refutations. *Physics Today,* 16**,** 80-82.

Rama, D. & Andrews, J. D. 2015. A holistic approach to railway infrastructure asset management.

Robson, C. 2011. *Real world research : a resource for users of social research methods in applied settings / Colin Robson,* Chichester, Chichester : Wiley.

Rruk 2014. The Academic response to the Rail technical Strategy 2012.

Schumacher, E. F. 1973. *Small is Beautiful*, First Published 1993.

Schumacher, E. F. 1995. *A Guide for the Perplexed*, Random House.

Shaw, N. 2015. The Future Shape and financing of Network Rail - The Scope.

Skinner, M., Kirwan, A. & Williams, J. 2011. Challenges of developing whole life cycle cost models for Network Rail's top 30 assets. Stevenage: Stevenage: IET.

Spencer, D. & Budd, J. 2015. Worker well-being and the importance of work: bridging the gap. 181-196. ISSN 0959-6801.

Steer Davis Gleave 2010c. Birmingham New Street - Business Case Report - Section 4 Scheme Development.

Stern, N. 2006.

Stern, N. 2008. The Economics of Climate Change. *The American Economic Review,* 98**,** 1-37.

Taïbi, S., Antheaume, N. & Gibassier, D. 2020. Accounting for strong sustainability: an intervention-research based approach. *Sustainability accounting, management and policy journal (Print),* ahead-of-print**,** 1213-1243.

Taylor Woodrow 2012. Nottingham Station Hub Contract 2 - INDUCTION RECORDS - ref Figure 4 Pivot table.

Technical Strategy Leadership Group 2012. The Rail Technical Strategy.

The Digital Rail Programme 2016. The Digital Railway Strategic Business Case.

Transport, D. F. 2016a. Transport Infrastructure Skills Strategy - Moving Britain Ahead.

Transport, D. F. 2016b. Understanding and Valuing Impacts of Transport Investment - Updating Wider Economic Impacts Guidance.

Unced 1987. Our Common Future The United Nations Commission on Environment and Development.

United Nations 2007. National Strategy of Sustainable Development Action Plan.

Walden, D. D., Roedler, G. J., Forsberg, K., Hamelin, R. D., Shortell, T. M. & International Council on Systems, E. 2015. *Systems engineering handbook : a guide for system life cycle processes and activities / prepared by International Council on Systems Engineering (INCOSE) ; compiled and edited by, David D. Walden, ESEP, Garry J. Roedler, ESEP, Kevin J. Forsberg, ESEP, R. Douglas Hamelin, Thomas M. Shortell, CSEP*.

Walliman, N. 2011. *Your research project : designing and planning your work / Nicholas Walliman,* London, London : SAGE.

Waterman, A. 2004. *Whole life value : sustainable design in the built environment / Anthony Waterman and Kathryn Bourke,* Watford, Watford : BRE Bookshop.

Whole Life Cost Forum 2012. Externalities.

Williams Shapps 2021. Great British Railways - The Williams Shapps Plan for Rail.

Wilson, J. R. & Sharples, S. 2015a. *Evaluation of human work / edited by John R. Wilson, Sarah Sharples,* Boca Raton

London, Boca Raton

London : CRC Press.

Wilson, J. R. & Sharples, S. 2015b. *Evaluation of human work : a practical ergonomics methodology / edited by John R. Wilson and Sarah Sharples,* London, London : Taylor & Francis.

Wsp / Irse 2017. Digital Rail Round Table 3 - Synopsis of the key topics discussed on June 15 2017.

Yeoman, R. 2014. Conceptualising Meaningful Work as a Fundamental Human Need. *Journal of Business Ethics,* 125**,** 235-251.

Zhu, J. & Mostafavi, A. 2017. Discovering complexity and emergent properties in project systems: A new approach to understanding project performance. *International Journal of Project Management,* 35**,** 1-12.

APPENDIX 1

Hard Copy Survey for Pilot Study:

SUSTAINABLE INTERVENTION IN RAIL ASSETS SURVEY **Date:**

The research behind this questionnaire is trying to understand the relationship between a project [like this one] and the resulting change in the level of skills of those who are involved in it.

The reason for asking the questions listed below is to get a better understanding of the extent of this change. **Please note: participation is entirely voluntary and the data collected will be anonymous [although it is possible that if you have any unique characteristics it <u>may</u> be possible to indirectly identify individuals from that information e.g. a unique qualification that no one else has.]**

1. The section below refers to your level of skill/expertise/knowledge in the area you are currently working in. Please tick the level you believe you were at:

	On the day you started working on the project	**The day you are filling out the survey**
Novice: No experience of working in construction/rail related projects		
Beginner: Beginning to develop a working knowledge of key aspects of specialist area		
Competent: A good working background knowledge and able to apply it without continuous supervision		
Proficient: A significant depth of understanding of the area you work in without supervision		
Expert: Full understanding and control of area of work – regularly asked for advice by others.		
Master: Viewed as being at the top of your area of work.		

2. The statements below refer to your level of skill/expertise/knowledge in the area you are currently working in. Please agree or disagree with them using the 5 points scale provided:

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**N/A**

My Skill/Knowledge/Expertise in my specialist area has increased through my participation in the project.						
My understanding of 'Environmental' [Green] issues has increased through my participation in the project.						

3. Background information:

Gender: Male ☐ Female ☐ Working at which _____

I have been working on this project since: _____

Age: ☐ 24 to 29 ☐ 30 to 40 ☐ 41 to 50 ☐

Years working in the construction: None ☐ 1 to 3 ☐ 3 to 5 ☐ 5 to 10 ☐

Years working in rail: None ☐ 1 to 3 ☐ 3 to 5 ☐ 5 to 10 ☐

10 to 20 ☐ 21 to 30 ☐ 31 to 40 ☐ More than 40 ☐

Formal qualifications: None ☐ Degree ☐ Diploma ☐ Apprenticeship ☐

HND ☐ HNC ☐ City and ☐ Others ☐

If others please specify: _____

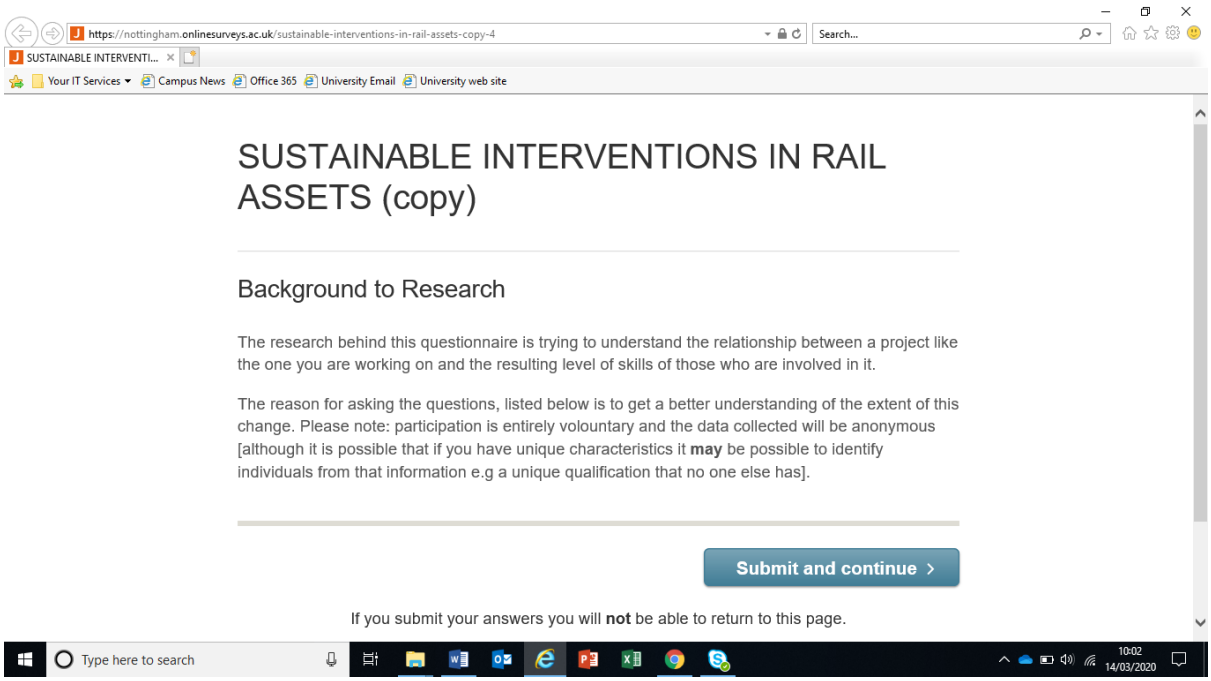
The qualifications you have relate to: (please tick all that apply) Construction Industry ☐ Rail Industry ☐ Others ☐

If others please describe: _____

Please use the section below to make any comments regarding the changes in your skill level, knowledge and/or expertise area. How do you think this project has helped you (or not) to move upwards in the scale presented in section 1? Please include any comments on this survey.

Thank you. If you have any doubts or comments please contact Mark Langdon (University of Nottingham) at laxml2@nottingham.ac.uk.

APPENDIX 2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Background to Research
The research behind this questionnaire is trying to understand the relationship between a project like the one you are working on and the resulting level of skills of those who are involved in it.
The reason for asking the questions, listed below is to get a better understanding of the extent of this change. Please note: participation is entirely volountary and the data collected will be anonymous [although it is possible that if you have unique characteristics it may be possible to identify individuals from that information e.g a unique qualification that no one else has].
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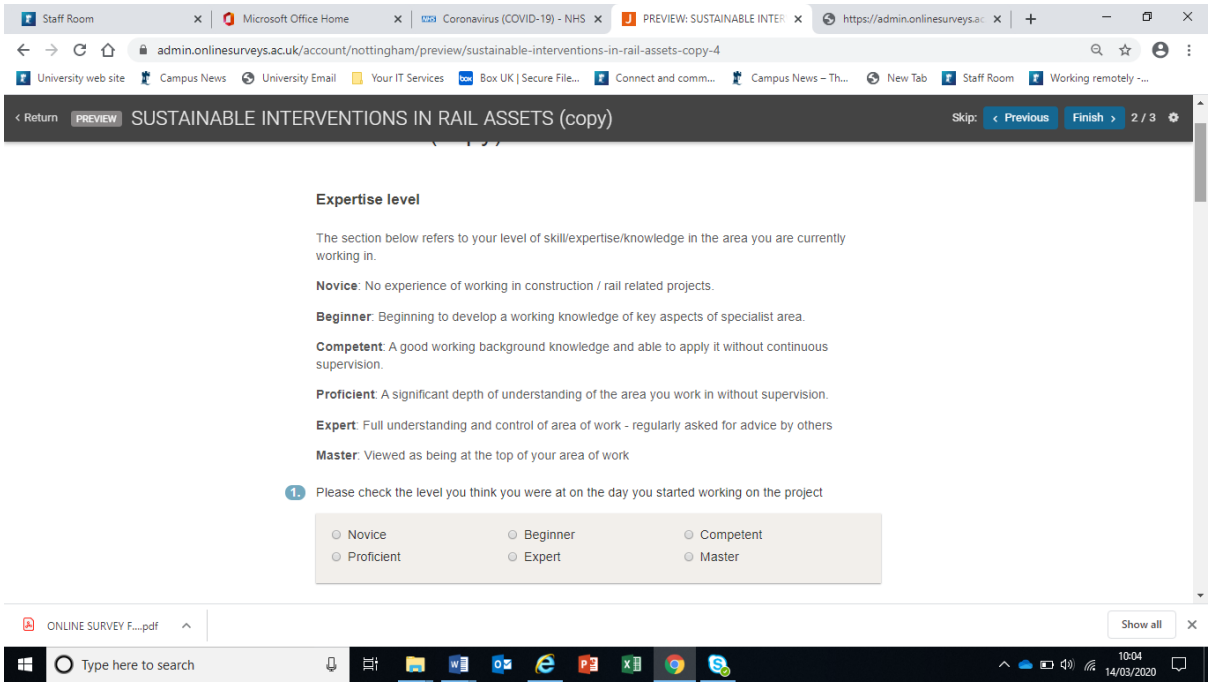
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Expertise level
The section below refers to your level of skill/expertise/knowledge in the area you are currently working in.
Novice: No experience of working in construction / rail related projects.
Beginner: Beginning to develop a working knowledge of key aspects of specialist area.
Competent: A good working background knowledge and able to apply it without continuous supervision.
Proficient: A significant depth of understanding of the area you work in without supervision.
Expert: Full understanding and control of area of work - regularly asked for advice by others
Master: Viewed as being at the top of your area of work
1. Please check the level you think you were at on the day you started working on the project
Novice
Beginner
Competent
Proficient
Expert
Master
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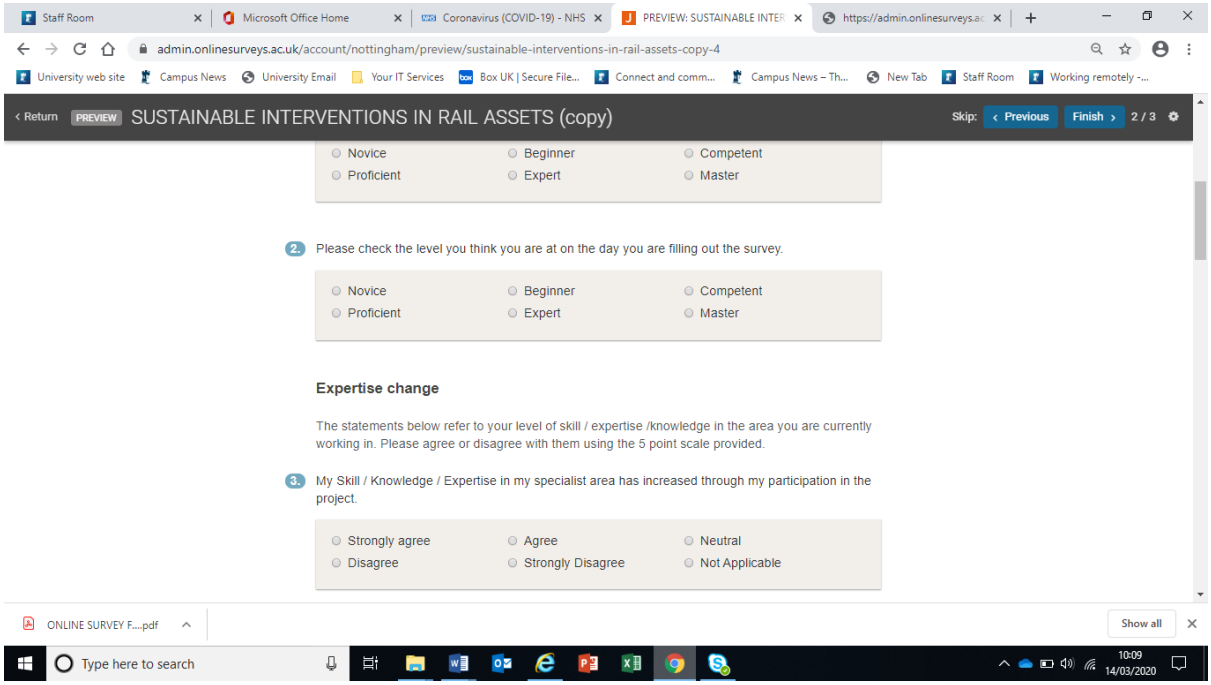
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Novice
Beginner
Competent
Proficient
Expert
Master
2. Please check the level you think you are at on the day you are filling out the survey.
Novice
Beginner
Competent
Proficient
Expert
Master
Expertise change
The statements below refer to your level of skill / expertise /knowledge in the area you are currently working in. Please agree or disagree with them using the 5 point scale provided.
3. My Skill / Knowledge / Expertise in my specialist area has increased through my participation in the project.
Strongly agree
Agree
Neutral
Disagree
Strongly Disagree
Not Applicable
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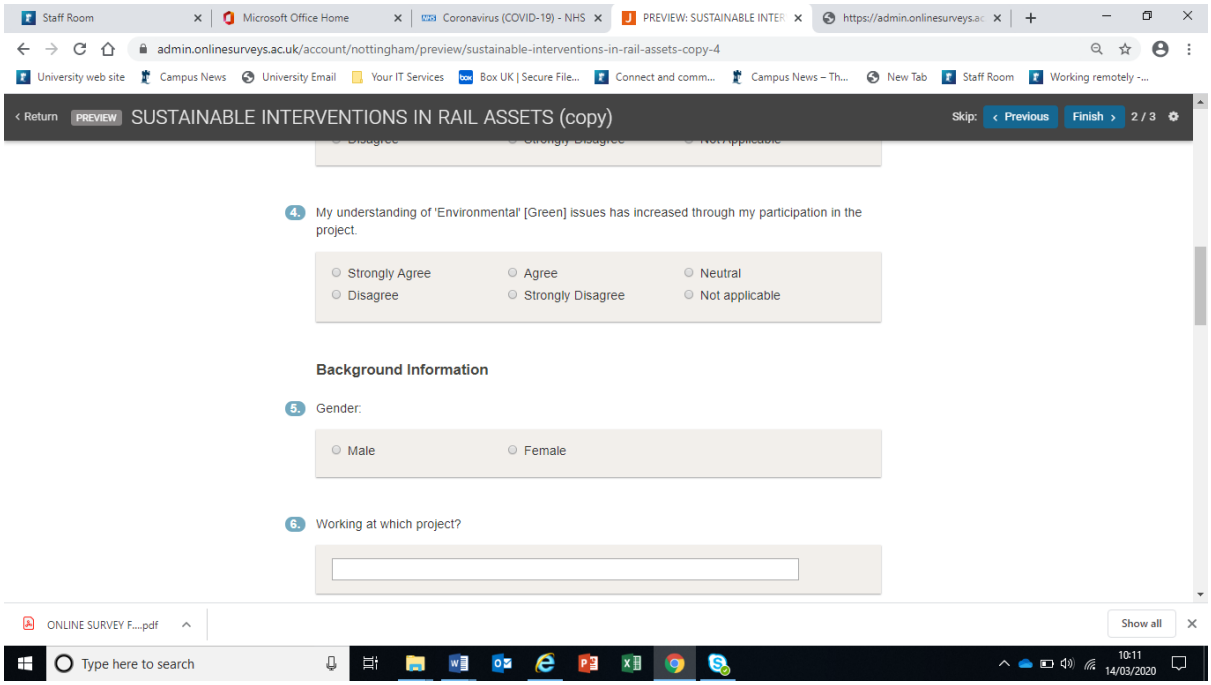
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4. My understanding of 'Environmental' [Green] issues has increased through my participation in the project.
Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree
Not applicable
Background Information
5. Gender:
Male
Female
6. Working at which project?
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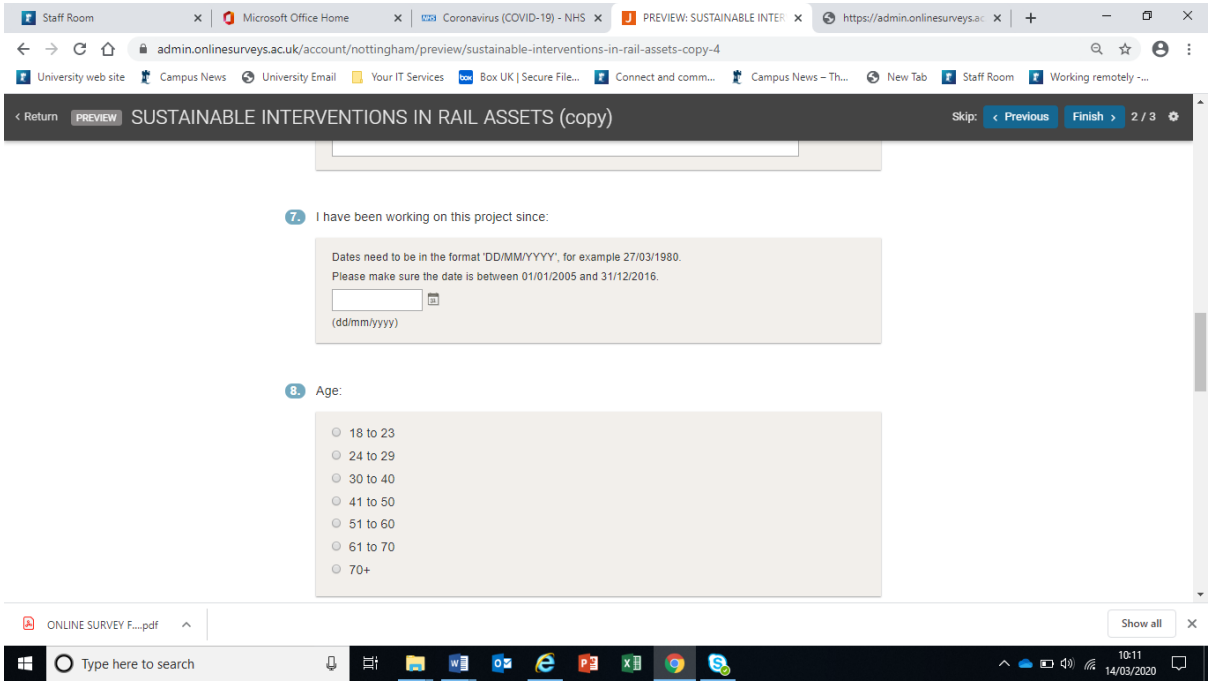
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7. I have been working on this project since:
Dates need to be in the format 'DD/MM/YYYY', for example 27/03/1980.
Please make sure the date is between 01/01/2005 and 31/12/2016.
(dd/mm/yyyy)
8. Age:
18 to 23
24 to 29
30 to 40
41 to 50
51 to 60
61 to 70
70+
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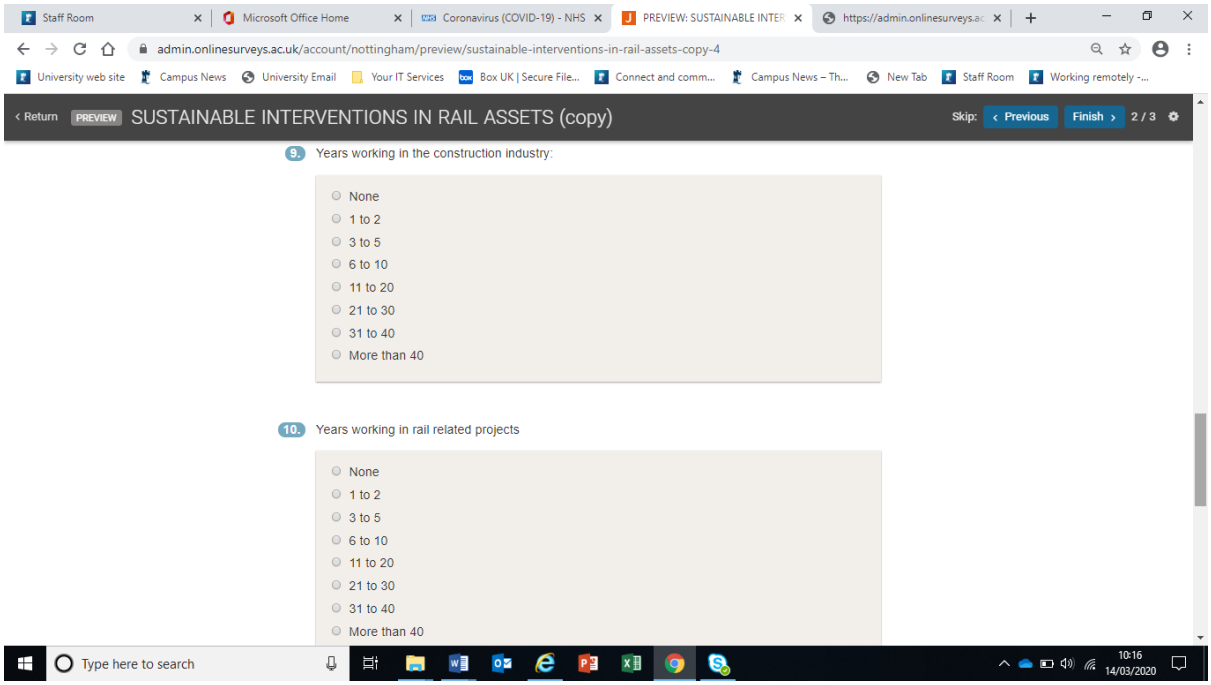
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9. Years working in the construction industry:
None
1 to 2
3 to 5
6 to 10
11 to 20
21 to 30
31 to 40
More than 40
10. Years working in rail related projects
None
1 to 2
3 to 5
6 to 10
11 to 20
21 to 30
31 to 40
More than 40
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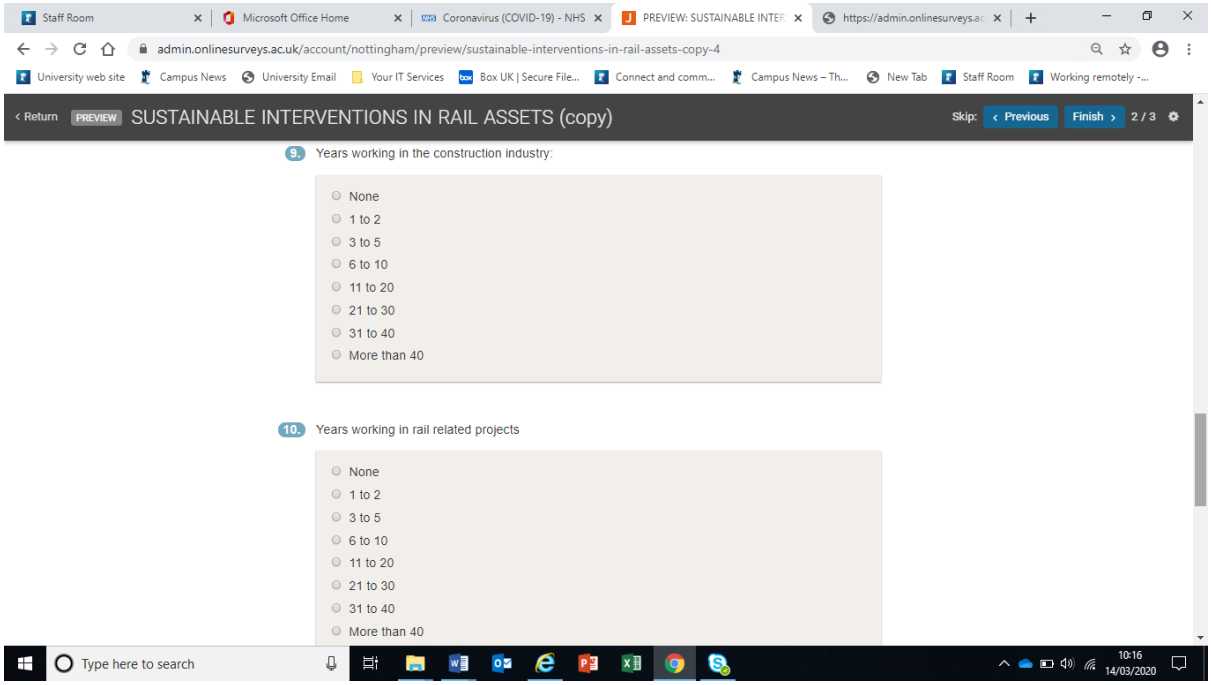
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9. Years working in the construction industry:
None
1 to 2
3 to 5
6 to 10
11 to 20
21 to 30
31 to 40
More than 40
10. Years working in rail related projects
None
1 to 2
3 to 5
6 to 10
11 to 20
21 to 30
31 to 40
More than 40
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APPENDIX 3

Faculty of Engineering

Process for approval of research study involving human participants

Introduction

This document describes the process to be followed when planning and obtaining approval for studies involving human participants within the Faculty of Engineering. This process is based on one previously run within the School/Dept M3. The process is administered by the Faculty Research Ethics Committee, and managed by the Chair of the Ethics Committee and Faculty Research Ethics Officer, Dr. Gary Burnett. All queries regarding the process should be initially sent to the Faculty Ethics Administrator, Dina Martin.

What is Ethics Approval?

When conducting any study or observation or collecting data about individuals, it is essential that full consideration is given to ethical issues and that steps are taken to ensure participant well-being throughout the study.

Participants involved in research studies have a right to:
- Know the goals of the study and who is funding the work

- Make an informed decision about whether or not they wish to participate

- Leave the study at any time if they do not wish to continue

- Know what will happen to them during the study and how long it will take

- Know if they may experience any discomfort
- Know what will happen to the findings

- Privacy of personal information
- Be treated courteously

The University of Nottingham and Faculty of Engineering have an ethics procedure that requires all staff and students to submit an application for ethical approval before conducting any research study involving human participants. Members of the Ethics Committee read through study proposals to check that the researcher has demonstrated that they have given full consideration to ethical issues and that they have provided participants with appropriate and sufficient information.

Who needs Ethics Approval?

ANY member of staff or registered student of the University of Nottingham involved in conducting any study or observation or collecting data about individuals **MUST** adhere to the University Code of Research Conduct and Research Ethics. Those affiliated with the Faculty of Engineering **MUST ALSO** comply with the Faculty ethical approval process before commencing their study.

Ethics application procedure

The attached document outlines the ethics approval process within the Faculty of Engineering. For all applications required to undergo formal review, applications must be submitted to the **Ethics Administrator**, Faculty of Engineering Research Office, Coates Building. The application will then be reviewed by the ethics committee. We aim to return a decision to applicants within two weeks but the procedure may be delayed if the ethics committee require further information. It is the applicant's responsibility to make sure that applications are submitted in good time.

THE STUDY MAY **NOT** START UNTIL ETHICAL APPROVAL HAS BEEN AWARDED

Information you should give to ALL participants

The following list describes the information that should be given to all participants. Normally this should be given in a participant information sheet at the beginning of the study, and participants should be required to confirm that they have understood the nature of the study, and that they are happy to participate.

The following information should be included:

Details of who will be conducting the study.

Details about who is sponsoring the study and what the terms of the sponsorship are (i.e. who will 'own' the data and how the data will be used).

Details about the nature, purpose and duration of the study. (Participants whose first language is NOT English may need further explanation of what is involved as their understanding of some of the terminology may be limited).

What kinds of procedures will be used and what participant will be asked to do.

Details about any hazards, inconveniences and risks associated with the study.

What procedures will be followed if a participant is injured. (only needed if risk of injury has been identified)

What benefits (payments, expenses etc) are attached to the study.

What they need to do in order to receive the payments described above.

What procedures will be employed to maintain confidentiality and anonymity (e.g. removing personal details from data/reports, keeping data in locked files)

What will happen to the data (how it will be used, how it will be stored, in what form it will be disseminated and if it is likely to be used for further analysis).

How you will use photographs or video records (data analysis, illustration purposes, displayed to sponsors/ non-public academic audiences, printed in public domain documents etc).

Details about who to contact if questions or problems arise.

ALL participants must be told that any involvement in the study is voluntary and they are free to withdraw at any time. You should also explain any consequences for the participant of withdrawing from the study and indicate what will be done with the participant's data if they withdraw.

Faculty of Engineering

Application for approval of research study involving human participants

ALL applicants must provide the following information

The applicant must be the person who will conduct the investigations; each application must be made by one applicant:

usually the student in the case of taught or research courses,

usually the researcher (the member of university research or academic staff) who will conduct the study in the case of funded research projects,

usually the principal investigator in the case of applications for ethics approval in advance of submission of a research proposal

If the applicant is an Undergraduate or Postgraduate taught or research student please complete the information below. The application must be approved by a Supervisor.

Name of student:	MARK LANGDON	Student No:	4151807
Course of study:	PhD Engineering	Email address:	laxml2
Supervisor:	Mark Gillott	Lucelia Rodrigues	Tony Parry

If the applicant is a member of university research or academic staff, please complete the information below: For research staff, the application must be approved by the Principal Investigator

Name:		Principal Investigator	
Email address:		PI	Signature: .....

Title of investigation : ……'Sustainable Interventions in Rail Assets'……
……

Planned date for study to begin ……*01 03 2013*…..……..…… Duration of Study ……..……*aprox 2-3 years*……

Please state whether this application is:

N☐ **Revi☒d** A re☐val For a con☐uation study

Selection of review process

Please indicate whether the application is required to go forward to the ethics committee for formal review, or, in the case of projects completed by ***taught undergraduate and postgraduate students only***, whether the application can be approved by the supervisor under the expedited review process.

F☒mal review, application will be ☐ Expedited review, application is approved

submitted to ethics committee by supervisor

Approval by supervisor: expedited review

I approve the application as supervisor of this project, under the expedited review procedure.

Name of supervisor……
Signature…… Date……..