

Investigating the business process implications of managing road works and street works

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INVESTIGATING THE BUSINESS PROCESS IMPLICATIONS OF MANAGING ROAD WORKS AND STREET WORKS

By
Rizwana Shaheen Hussain

A thesis submitted in partial fulfilment of the requirements for the award of the degree
Doctor of Engineering (EngD), at Loughborough University

June 2017

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DEDICATION

To my late Father, Mohammed Akram – may your soul rest in peace, and may you be granted the highest rank in Jannah-ul-Firdous.

And, also dedicated to my Mother, Talat Shaheen – where my Jannah lies.

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“And say: My Lord, increase me in knowledge!” Quran 20: 114

“The seeking of knowledge is obligatory for every Muslim” Prophet Mohammed (SAW)

(Tirmidhi)

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Lastly... my final thanks is to my most precious and beautiful unborn child – Mummy and Daddy can’t wait to meet you soon baby! ☺

ABSTRACT

Around 2.5 million utility works (street works) occurred in England in 2016 with a construction cost of approximately £2 billion. Comparative figures for highway works (road works) are not readily available, but are expected to be similarly significant. Unsurprisingly, the volume of road works and street works (RWSW) activity in urban areas is considered to have a negative impact on the road network causing disruption and premature deterioration, blighting the street scene, damaging local business trade, and significantly increasing social, economic and environmental costs. Indeed the social costs of street works alone are estimated to be around £5.1 billion annually. Despite the economic significance of highway infrastructure, the subject of road works and street works management is under-researched, with greater research emphasis on technology-based, as opposed to policy-based management approaches. Consequently, the aim of this study was to investigate the efficiency and effectiveness of managing the business process of RWSW.

Due to limited academic literature in the subject domain, earlier research focused on identifying the industry actors, their motivations, as well as drivers and barriers to RWSW management. Semi-structured interviews with industry stakeholders highlighted the industry's complexity and revealed that several issues contributed to ineffective RWSW management. Principal problems included Street Authorities (SA) failing to take enough ownership of the RWSW coordination process, highway legislation not encouraging joint working due to inherent challenges arising from reinstatement guarantees, and entrenched attitudes and adversarial practices in the construction industry encouraging silo working.

The Derby Permit Scheme (legislative tool) was intended to improve RWSW management through giving SAs greater control of highway works. Accordingly, RWSW activity was

tested through a statistical time series intervention analysis to separately examine the impacts of the Highway Authority (HA) led works and utility industry led works over 6.5 years. The Permit Scheme was found to reduce utility works durations by around 5.4%; equivalent to 727 days, saving between £2.1 - £7.4 million in construction and societal costs annually. Conversely, the Permit Scheme did not noticeably reduce the HA led works. Instead, the introduction of a works order management system (WOMS) to automate some of the back office road works process was found to reduce works durations by 34%; equivalent to 6519 days and saving between £8.3 - £48.3m per annum. This case study highlighted that more considered practices were required by the HA to reduce RWSW.

The stakeholder study and the automated WOMS technology found that well-managed business processes tended to lead to better executed highway works on-site. Informed by these experiences, the sponsor was keen to re-engineer its internal business processes. Business process mapping was adopted to identify inefficient practices and improved coordinated working opportunities on three key internal teams involved in the road works process. Findings revealed that silo working was inherent and that processes were built around fragmented and outdated Information Technology (IT) systems, creating inefficiencies. A subsequent validation exercise found that certain practices, such as restricted data access and hierarchical management styles were culturally embedded and also common across other local authorities. Peer reviewed recommendations to improve working practices were made, such as adopting an integrated Highways Management IT system, vertical integration between the customer relationship management IT system and the Highways IT systems, and the provision of regulatory training. In conclusion, based on the finding of this study, a generic logic map was created with potential to transfer the learning to other local authorities and for their use when evaluating road works administrative processes.

KEY WORDS

Road works and street works, policy, public sector, utilities, stakeholders, time series analysis, business process reengineering

PREFACE

The research presented in this doctoral thesis was conducted to fulfil the requirements of an award for Doctor of Engineering (EngD), at the Centre of Innovative and Collaborative Construction Engineering (CICE) at Loughborough University. The EngD programme is described as a radical alternative to the traditional Doctorate of Philosophy (PhD), as it is more geared to meeting industry needs.

The EngD is examined on the basis of a thesis containing between three and five research publications and/or technical reports. Presented within this thesis for examination are

- two published journal papers (Appendix A and B);
- one presented and published conference paper (Appendix C); and
- and one journal paper under review (Appendix D).

Furthermore, the RE also presented and published a further two peer reviewed conference papers (which preceded the journal papers included in this thesis for examination in Appendix A and B); whilst these have not been submitted for examination, details about these papers can be found in the ‘List of Papers’. All papers are primarily authored by the candidate, this means that the literature analysis, research design, data acquisition, analysis, interpretation, and drafting were primarily and substantially undertaken by the RE.

USED ACRONYMS / ABBREVIATIONS

ADMINISTER	ADMINIstrating StreeT work Events and Road works
AEC	Architecture, Engineering and Construction
ARIMA	Auto Regressive Integrated Moving Average
BPM	Business Process Modelling
BPR	Business Process Reengineering
CRM	Customer Relationship Management
CSR	Corporate Social Responsibility
DCC	Derby City Council
Defra	Department for Environment Food and Rural Affairs
DfT	Department for Transport
DLO	Direct Labour Organisation
DTI	Department of Trade and Industry
DWI	Drinking Water Inspectorate
EA	Environment Agency
EngD	Engineering Doctorate
E-procurement	Electronic Procurement
ESPRC	Engineering Sciences and Physical Research Council
EToN	Electronic Transfer of Notices
GDP	Gross Domestic Product
HA	Highway Authority
HAMP	Highway Asset Management Plan
HAUC	Highways and Utilities Committee
HE	Highways Engineering Team

HIPO	Hierarchy plus Input-Process-Output
HM	Highways Maintenance Team
HPA	Health Protection Agency
HR	Human Resources
HSE	Health and Safety Executive
IDEF0	Integration DEFinition Language
IHMS	Integrated Highways Management System
IS	Information System
IT	Information Technology
JAG UK	Joint Authorities Group United Kingdom
LA	Local Authority
LTA	Land Transport Authority
MRR	Maintenance, Rehabilitation and Reconstruction
NHAUC	National Highways Utility Committee
NJUG	National Joint Utilities Group
NM	Network Management Team
NOx	Nitrogen Oxides
NParks	National Parks Board
NRSWA	New Roads and Street Works Act 1991
OFCOM	Office of Communications
OFGEM	Office of Gas and Electricity Markets
PAA	Provisional Advance Authorisation
PM	Particulate Matter
PUB	Public Utility Board
QA	Quality Assurance

RE	Research Engineer
RWSW	Road Works and Street Works
SA	Street Authority
SU	Statutory Undertaker
SUE	Subsurface Utility Engineering
TMA	Traffic Management Act 2004
UK	United Kingdom
US	United States of America
WOMS	Works Order Management System

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LIST OF PAPERS

The following papers, included in the appendices, have been produced in partial fulfilment of the award requirements of the Engineering Doctorate during the course of the research.

JOURNAL PAPERS

PAPER 1 (SEE APPENDIX A)

Hussain, R. S., Ruikar, K., Enoch, M., Brien, N., and Gartside, D. (2017) Process mapping for road works planning and coordination, Built environment project and asset management, 7:2, pp. 157-172

PAPER 2 (SEE APPENDIX B)

Hussain, R. S., Brien, N., Gartside, D., Enoch, M. and Ruikar, K. (2016) Street works policy in England, UK: insights from stakeholders, Infrastructure asset management, 3:2, pp. 61-70.

REFEREED CONFERENCE PAPERS

PAPER 4 (SEE APPENDIX C)*

Hussain, R. S., Brien, N., Gartside, D., Enoch, M. and Ruikar, K. (2016) Evaluating the road works and street works management Permit Scheme in Derby UK, Transportation Research Board Annual Meeting 2016, 10-14 January, Washington DC, USA

JOURNAL PAPER UNDER REVIEW

PAPER 3 (SEE APPENDIX D)*

Hussain, R.S., Enoch, M., Quddus, M., Ruikar, K., Brien, N., Gartside, D. (2017) Determining the impacts of local authority interventions on the duration of highway excavations, Transportation, under review.

*Please note that Appendix C and D are linked papers. Appendix C was successfully presented as a conference paper. Feedback given at the conference and further developments in examining wider policy interventions meant that a more detailed and robust paper was produced and is currently submitted for review as detailed in Appendix D.

OTHER CONFERENCE PAPERS

Hussain, R. S., Brien, N., Gartside, D., Enoch, M. and Ruikar, K. (2017) Improving the road works planning process – a case study of an English Urban Authority, Transportation Research Board Annual Meeting 2017, 8-12 January, Washington DC, USA

Hussain, R. S., Brien, N., Gartside, D., Enoch, M. and Ruikar, K. (2015) Stakeholder perspectives of street works management in England, UK: In: WIT Transactions on the Built Environment, 168:2, 867-878, 2-4 June, Valencia, Spain

OTHER PUBLICATIONS

Hussain, R. S. (2015) Improving street works management in England, Innovation and Research Focus, 100: p.2, accessed 1 September 2016, available at www.innovationresearchfocus.org.uk/issues/PDFs/IRF100%20Final.pdf

LECTURES

Shaheen, R. (2014) Road works and street works management, Loughborough University, Loughborough, 15 May (lecture to undergraduate students).

Hussain, R.S. (2015) The problem with road works, Loughborough University, Loughborough, 3 February (lecture to undergraduate students).

PRESENTATIONS

Hussain, R. S (2016) Evaluating the road works management process at Derby City Council, focus group at Derby City Council, Derby, 4 July (focus group presentation to industry experts as part of validation exercise).

Hussain, R. S (2015) Business process re-engineering of road works processes, Derby City Council, Derby, 25 November (presentation of 'as is' process maps to the core group).

Hussain, R. S (2015) Stakeholders perspectives of collaborative street works management in England, East Midlands Universities Association Conference 2015, Lincoln University, Lincoln, 3 September (dissemination of research findings to date to peers).

Hussain, R. S. (2015) Women in Engineering, Women in Engineering week at Derby Moor Community Sports College, Derby, 24 June (STEM presentation to year 10-12 students about working in the engineering industry).

Shaheen, R. (2013) Reengineering the management of highway excavation to provide best value and enhanced collaborative working, Loughborough University Doctoral research seminar, Loughborough, 26 March (dissemination of research findings to date to peers).

Shaheen, R. (2013) The management of road works and street works in England, Utility Street Works Conference, London, 11 March (presentation to national utility industry inviting participants to a stakeholder scoping study).

Shaheen, R. (2013) Collaborative highway engineering to provide optimisation and best value, Derby City Council Permit meeting, Derby, 5 March (presentation to local utility industry inviting participants to a stakeholder scoping study).

1 BACKGROUND TO THE RESEARCH

Quality of life is closely associated with a reliance on often invisible utility infrastructure (energy, water and wastewater and telecommunications) and a visible transportation infrastructure network (to support migration of people and goods) (Hunt and Rogers, 2006). The boom in technology and affluence in the last 200 years has meant utility infrastructure has come a long way since 1807 when the first UK utility company powered street lights in Pall Mall, London (Derry and Williams, 1993). Today, over 150 utilities in the United Kingdom (UK) have rights to install and access utility apparatus in the British highway, with the combined utility network exceeding 4 million kilometres in length (House of Commons, 2011; Rogers et al., 2012). Indeed an estimated 2.53 million utility works occurred in England and Wales in 2016 (Asphalt Industry Alliance, 2016).

The rights enjoyed by utility companies to embed and access apparatus in the highway causes two major problems. Firstly, the short-term impacts of utility works include: congestion, disruption and inconvenience (House of Commons, 2011; Transport Research Laboratory, 2008); increased social and economic costs (Eddington, 2006; Goodwin, 2005; House of Commons, 2013; McMahon et al., 2005); increased environmental impact (Lepert and Brillet, 2009; Burtwell et al., 2006); and a compromised street scene (Transport Research Laboratory, 2009). It is estimated that congestion by ‘work zones’ (on-site works activities) in the United States (US) accounts for 10% of overall congestion (Cambridge Systematics Inc, 2004) as well as 10% in the UK (Eddington, 2006). Furthermore, in 2014 traffic congestion caused urban Americans to spend 6.9 million hours travelling longer, using an additional 3.1 billion gallons of fuel, with congestion costs equivalent to \$160 billion dollars (Schrank et al., 2015). The UK social costs of utility works alone is estimated at around £5.6 billion, whilst direct utility construction costs are valued at between £1.5 billion (McMahon et al., 2005), and £2

billion annually (Bennett, 2014). Secondly, in the long term, repeatedly cutting the highway prematurely deteriorates the structure, and reduces its life-span necessitating early repairs often borne by highway guardians (Jordan et al., 2009; Salini et al., 2010; Transport Research Laboratory, 2009; Wilde et al., 2003). English highways are the nation's most expensive asset, with a value of around £344 billion (National Audit Office, 2014), therefore, there is a need to maximise their integrity.

In addition to utility works, the Highway Authority (HA) also performs construction works on highways. HA led construction works are typically necessitated by maintenance, renovation and reconstruction (MRR) needs of highway infrastructure (Schraven et al., 2011). Whilst MRR preserves and pro-longs highway life, the short-term societal impacts are as disruptive as utility works. Therefore, collectively, the combination of HA works (road works) and utility works (street works) conflict with over-ground societal needs for an undisturbed, fully functioning and available transportation infrastructure system. In the UK, this conflict is likely to be exacerbated further by future needs to:

- Supply infrastructure to match proposed national housing growth (HM Government, 2011);
- Supply infrastructure for potential carbon friendly alternatives to energy (such as CHP/DH - Combined Heat and Power with District Heating) (Bolton and Foxon, 2015);
- Repair and maintain ageing, and in some cases, Victorian utility apparatus (Hussain et al., 2016a);
- Cope with forecasted traffic growth (Department for Transport, 2015).

Accordingly, this EngD project aims to investigate the efficiency and effectiveness of managing the business process of road works and street works (RWSW) activity, to minimise its disruptive societal impacts. RWSW may interchangeably be referred to as ‘highway works’ or ‘excavation activity’ in this thesis.

1.1 RESEARCH PROBLEM

The need to manage highway works activity effectively has been an issue for over 100 years (Marvin and Slater, 1997). Major historical government reports and statutory instruments into the subject include the Carnock Committee report in 1939, resulting in the Public Utilities and Street Works Act in 1950, and subsequently the Horne report in 1985: resulting in the New Roads and Street Works Act 1991 (NRSWA) (Deacon, 1995), and most recently the Traffic Management Act 2004 (Butcher, 2014). Whilst the management challenges have evolved, contemporary literature continues to identify RWSW activity as problematic, causing congestion, road user delays, increasing vehicle emissions, increasing social and economic costs, and undermining highway structures and street-scenes (Abdelmohsen and El-Rayes, 2016). Traffic congestion is a result of inefficient road operations and the increased demand for transportation access (Kurzanskiy and Varaiya 2015), furthermore highway excavation activities reduce the efficiency of a road network by placing pressure on road space (Walker and Calvert, 2015; Weng and Meng, 2013) therefore providing a pressing need for management attention.

As a Street Authority (SA) responsible for highway network management, Derby City Council (DCC) recognises these symptoms in the city and has already adopted a Permit Scheme (under the Traffic Management Act 1984) to better manage RWSW activity. However, the authority acknowledges that the Permit Scheme in isolation is not enough, and

that more work is needed to drive down the negative impacts of highway works. The authority is cognisant that there is much to learn about the utility sector for improved processes and practices, to ultimately influence on-street activity. Accordingly, the SA considers that highway works activity, particularly RWSW could be managed in a more efficient manner, limiting the negative impact on traffic (including people) on the over-ground highway network.

1.2 OVERARCHING AIM AND OBJECTIVES

Further to the research problem identified in 1.1, the overarching aim of this project is:

to investigate the efficiency and effectiveness of managing the business process of road works and street works activity.

To help address the previously described research problem and meet the overarching aim, five objectives are defined as follows:

1. To review related work on managing RWSW

RWSW management is part of the wider subject domain on highways, and to some degree utility management. Accordingly, an exploratory phase of seeking and exploring subject knowledge was undertaken, comprising a generic review of academic literature. The review provided an underpinning of the contextual and salient issues in the field including:

- highway management issues – street works history, pavement management systems, financing of highways and policy management techniques; and
- utility management issues – industry privatisation, underground asset management – condition assessment, storage techniques and alternative technologies.

As highway excavation policy has received limited academic research attention, analysis of grey literature was also required, including government, industry and business reports.

2. To establish the current working practices to identify RWSW industry operations

Objective 2 built on the subject knowledge developed through documentary analysis in objective 1, by investigating contemporary issues in the RWSW industry and thus was exploratory and investigative in nature. This objective was necessary to capture stakeholders insights of contributory factors to the research problem. Accordingly, the following tasks were undertaken:

- Collection of primary data through semi-structured interviews with key industry stakeholders to establish the role of the Electronic Transfer of Notices (EToN) system in managing RWSW;
- Collection of primary data through semi-structured interviews with key industry stakeholders to establish the current work culture and salient issues in the RWSW management industry; and
- Assessment of the current workings and making recommendations for improved RWSW management.

3. To assess the effectiveness of managing RWSW at the local level

Objective 3 explored and evaluated the existing local approach to RWSW management; specifically the newly implemented Permit Scheme and Works Order Management System (WOMS) for programming Highway Authority (HA) works. The study purpose was to assess whether these new policy tools were effective in reducing RWSW activity of the HA and

utility companies, also known as statutory undertakers (SU) industry in Derby respectively.

The following tasks were undertaken:

- Identification and collation of primary (works duration) and secondary (control variables) data over a 6.5 year period for HA and SU works;
- Application of Autoregressive Moving Average (ARIMA) models to identify and quantify the overall Permit Scheme and WOMS (HA only) impact; and
- Analysing the models and making recommendations for improved working techniques to manage RWSW.

4. To develop business process maps and identify opportunities for the improved management of the RWSW sector

This stage involved a detailed case study analysis of DCC to identify and document their road works business processes. The purpose was to use business process mapping to investigate improvements in back office processes through efficiency, and intra-organisational working.

The tasks undertaken were:

- A state of the art analysis of business process re-engineering and the identification of a suitable process mapping technique;
- Collation of primary data through conducting interviews with DCC and documenting business processes;
- Creation of ‘as is’ maps of extant processes, and analysis of the maps to identify process improvement and coordination opportunities; and
- Development of ‘to be’ maps proposing improved working practices at DCC.

5. To evaluate proposed process maps for their effectiveness, and develop a logic map for the management of RWSW activity for transferability to other local authorities

Due to time limitations, the ‘to be’ maps could not be operationalised, therefore a validation exercise of the proposed maps with industry experts was undertaken instead. The tasks completed were:

- Identification and recruitment of a focus group and interview participants to evaluate readiness of the proposed ‘to be’ processes; and
- Development of a logic map incorporating the findings from objective 4 and the expert validation.

Figure 1.1 gives an overview of the research project, and associated published academic outputs. Additional published work not submitted for examination is included in the list of papers at the beginning of this thesis.

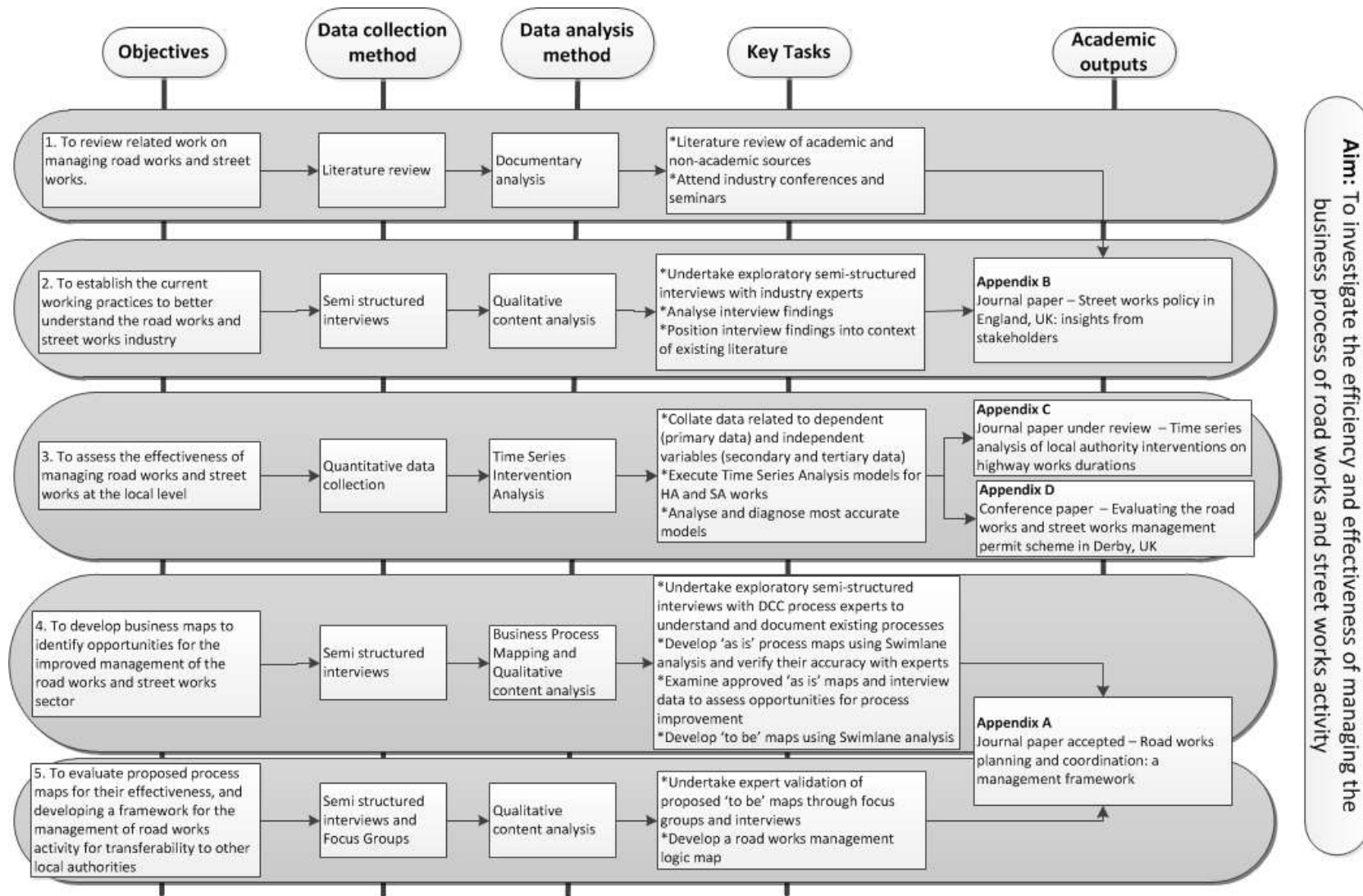


Figure 1.1 Research plan linking aim, objectives and outputs

1.3 NOVELTY AND IMPORTANCE OF RESEARCH

Despite RWSW management and coordination being critical for urban traffic management, there are few examples of literature giving attention to highway works policy, particularly UK policy (Fisher, 2012; Tseng et al., 2011). Within the industry, the Permit Scheme created a significant paradigm shift in how works were planned and managed (Hussain, 2016a; Keyworth, 2008), however, there is little literary evidence of any significant attention to the Permit Scheme and its impacts in academic literature.

Recent research on the contribution of doctoral research to knowledge found that originality alone is not enough, and that theses must have substantial impact on advancing knowledge in the field. It is argued that innovation and creativity incorporate originality, in the form of novelty in research. Furthermore, given the nature of current knowledge based economies, doctoral education is also commonly expected (context dependant) to have immediate relevance for economic purposes as shown in Figure 1.2 (Bapista et al., 2015).

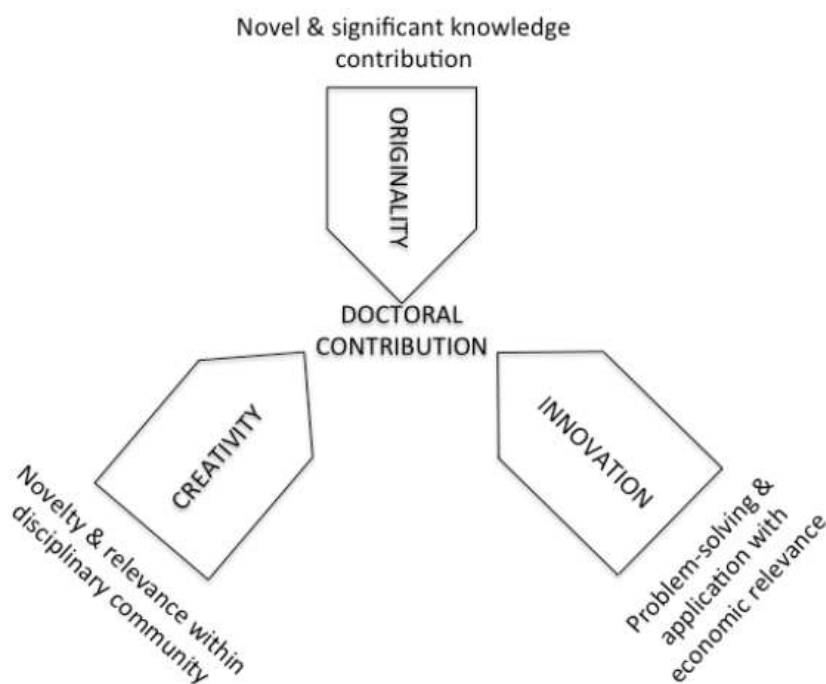


Figure 1.2 The relationship between originality, creativity and innovation. (Source: Bapista et al., 2015)

With these thoughts in mind, this research is original and significant, because it presents new knowledge in an important economic field where there is limited academic research. For example:

1. Stakeholder study – policy views about RWSW in England are presented including original views about the Permit Scheme, industry culture and other difficulties in coordinating highway works. This study is novel, because it presents views previously unexpressed, such as operational complexities, perceived legislative incoherence and entrenched cultural barriers to collaborative working based on stakeholder's views from across the industry. This is important, because it helps appreciate the barriers and opportunities for improved RWSW management based on first-hand stakeholder experiences.
2. Analysis of the Derby Permit Scheme – empirical research presenting a statistical analysis of the scheme impacts. This contribution is novel because this is the first time a recognised statistical method is used to test the Permit Scheme and compares the performance of the HA and SUs. It is important because the UK Permit Scheme is in its relative infancy, and subject to general resistance from the utility industry where it is commonly seen as superfluous and profit making; this study provides statistical validity of the Derby Permit Scheme.
3. Process Analysis – the operations of selected DCC teams are mapped and analysed, with new processes proposed to improve efficiency and internal coordinated working. This is novel because the road works planning and Permit application and approval process has not been mapped before. This contribution is important because it helps improve operational practices in industry, which is critical, particularly due to the continued local government funding cuts. Furthermore, the element is innovative

because it provides a transferable road works management logic map for other local authorities (LAs) to adopt.

1.4 THE INDUSTRIAL SPONSOR

DCC is a unitary Local Authority (LA) located around 200 km north of London. The Authority employs around 6,750 people and is managed by a paid Chief Executive. Politically, the Labour administered authority comprises 51 Councillors across 17 wards serving around 250,000 residents. Since 1 September 2015, the Council has three directorates: People Services, Communities and Place, and Organisation and Governance.

DCC has suffered sustained and significant grant cuts as part of central government austerity cuts (Lowndes and Pratchett, 2012). As a result, savings of £116 million have been delivered since 2010, whilst a funding gap of £45 million remains. Notwithstanding this, the Council wishes to remain a forward, modern, flexible and resilient authority, creating a safe, strong and ambitious city. Amongst many Council priorities, there is a focus on ‘making the most of our assets’ and to ‘deliver our services differently’. Continued focus remains on utilising resources well, ensuring value in every hour spent, and that every hour spent is productive. The Council continues its journey through transformation to adapt to prevalent budget conditions (Derby City Council, 2016a).

This research is placed within the Network Management team, in the Traffic and Transport sub-division, amongst other traffic services including traffic management, parking, air quality, sustainable transport and public transport services. The Traffic and Transport subdivision falls within the division of Strategic Partnerships, Planning and Street Pride, alongside the divisions of Highways and Engineering, Planning and Waste Management in the Communities and Place directorate.

1.5 THE GENERAL SUBJECT DOMAIN

HAs have a statutory duty to manage and maintain the structural life of their highway assets (The Highways Act, 1980). LAs are the ‘HAs’ for the local road network which encompasses around 238,000 miles in Great Britain. Highways England (owned by the Secretary of State), Transport Scotland and the Welsh Government are HAs for Britain’s Strategic Road Network (SRN) of around 7,600 miles of motorways and trunk roads (Butcher, 2015; DfT, 2016; Highways Agency, 2014). In addition to the HA duty, LAs also have a statutory duty to coordinate highway works under NRSWA, therefore DCC is also a ‘Street Authority’ (SA). Despite being the same LA, both HA and SA roles are entirely independent. DCC is also a Drainage Authority, Flood Defence Authority and Planning Authority in respect of highways matters amongst other roles.

Separately, SUs have statutory duties to provide essential supplies and services. SUs therefore have rights to break open the highway to access, maintain, repair and replace underground apparatus as necessary under the following primary legislations (DfT, 2011) & (DfT, 2012):

- Gas Act 1986 as amended by the Gas Act 1995 (schedule 3)
- Electricity Act 1989 (schedule 4)
- Water Resources Act 1991 (section 159)
- Telecommunications Act 1984 as amended by schedule 3 of the Communications Act 2003

In summary, both HAs and SUs need to access the highway for repair and maintenance works, whilst the SA is responsible for coordinating the activity.

1.5.1 NETWORK MANAGEMENT

Amongst the wide overarching responsibilities of highway management, this project is particularly concerned with network management. The ‘network management duty’ is specifically prescribed under the Traffic Management Act (2004), obliging English LAs to manage their highway network activity to facilitate the expeditious movement of people and traffic. The Act suggests that technology, working arrangements and a network management plan may be considered in discharging this duty (Canning, 2010). However, whilst delivery of the network management duty is incumbent on all services delivered by the Council, the coordination of RWSW activity is the primary enabler in meeting this duty and is typically managed by the SA.

1.5.2 ACTORS INVOLVED IN NETWORK MANAGEMENT

RWSW management is a complex function involving a number of actors, with varying roles and motivations as follows:

- SAs – have a regulatory duty to coordinate highway works activity to facilitate the best network use and to ensure expeditious traffic movement (Canning, 2010; Hussain et al., 2016).
- HAs - have a duty to provide reactive, routine and programmed maintenance of their pavements to encompassing MRR works (Roads Liaison Group, 2013). English and Welsh Local HAs were allocated around £2.88 billion for road maintenance activities in the 2016/17 financial year (Asphalt Industry Alliance, 2017). In England, pavement management works, alongside other works such as street lighting works fall under the definition of ‘road works’ (Gov.uk, 2014).
- Utility companies – also known as ‘statutory undertakers’ (NRSWA, 1991) have a duty to install, inspect, maintain, repair or replace private apparatus in the highway to

supply essential public services (Canto-Perello, 2009; Marvin and Slater, 1997).

Utility related highway construction activity is known as ‘street works’ in England (Gov.uk, 2014; NRSWA, 1991).

Other important stakeholders include:

- Utility industry regulators - The UK utility industry is privatised and subject to independent economic regulators that govern the permitted remits within which organisations can operate (see Chapter 4.1). Regulators are usually motivated by protecting the quality, health, and service provided to customers. Separately, the UK Competitions Commission also have wide ranging powers to prevent anti-competitive practices in SU industries, including blocking mergers and selling parts of a business (Competitions Commission, 2013).
- The National and Joint Utilities Group (NJUG) formed in 1977, is a powerful industry group which represents the joint interests of utilities in regards to RWSW operations (NJUG, 2013).
- The Joint Authorities Group (JAG) comprises membership of primarily LAs, and similar bodies whereby their key activities are governed by highways and traffic management legislation. JAG represents the LAs’ expert perspectives and interests in RWSW discussions on collaboration with SUs by inputting into NHAUC. In addition JAG develops good practice advice notes to assist RWSW coordination and supports practitioners in their personal development.
- National Highways and Utilities Committee (NHAUC) - The HAUC group are a multi-disciplinary and cross-sectoral group of HAs and SUs which advise the Secretary of State on street works legislation, street works matters, and guidance to practitioners. The current HAUC UK structure comprises national and regional HAUC groups, NJUG, Joint Authorities Group (JAG), Network Rail, the Highways

England, Department for Transport as well as the Scottish, Welsh and Northern Ireland governments (HAUC UK, 2017).

- Society – residents and businesses as utility and highway users (Hayes et al., 2012). Communities and businesses are also negatively affected by street works through delays to road users, disruption, environmental damage as well as increased levels of noise and air pollution. Societal costs of street works has been valued at £5.5 billion per year in Britain (Parker, 2008).

1.6 THESIS STRUCTURE

This chapter outlined the research problem, along with the study aim and objectives to address the problem; Figure 1.1 signposts the different projects executed to meet the objectives, along with the outputs of the overall study. The novelty and originality of this EngD is discussed, as well as highlighting the importance of this study to industry and academia. The chapter also provides information about the industrial sponsor and subject domain for overarching context. The remainder of this study is divided into the following chapters:

Chapter 2 provides an analysis of literature examining state-of-the-art of highways management around the world.

Chapter 3 provides a methodology, which details a study research plan, as well as addressing the research approaches, styles and overarching methods of data collection and analysis adopted to meet the study objectives in Chapter 1.

Chapter 4 is the findings section, which presents the works undertaken to meet the research objectives detailed in Chapter 1, in accordance with the methods described in Chapter 3. A number of small studies were undertaken, with the chapter presenting the study context, findings and recommendations. Each project includes a critical discussion and a short ‘Check point’ summary which provides a snapshot of how the project has contributed new insights to

RWSW management knowledge and in some cases how the project has helped to address the research problem described in Chapter 1.1.

Chapter 5 presents the key study findings and details how the study aim and objectives from Chapter 1 have been met through findings detailed in Chapter 4. The chapter also details contributions to theory and practice, implications for the sponsor and wider industry, recommendations for industry, critical evaluation, and ends with recommendations for further research.

Appendix A details a published journal paper;

Appendix B details an ‘accepted’ journal paper;

Appendix C details a conference paper;

Appendix D details a journal paper currently under review;

Appendix E – F detail the questions used for semi-structured interviews as part of objective 2; and

Appendix G – H details ‘as is’ and ‘to be’ process maps as part of objectives 4 and 5.

2 RWSW MANAGEMENT LITERAURE

Examination of current literature enables the development of an account of the published literature/knowledge on a subject matter. Accordingly, this chapter explores extant literature, firstly to provide a positioning of RWSW management in the wider subject domain, and secondly to document the state-of-the-art of highway works management through using technology and policy based techniques. A critical analysis is provided to identify the strengths and weaknesses of described approaches in managing highway works activities. The exploration, examination and analysis of state of the art literature meets objective 1: to review related work on managing RWSW; and objective 2: to establish the current working practices to identify RWSW industry operations; and identifies gaps in knowledge.

2.1 HIGHWAY MANAGEMENT

A well-established transportation infrastructure system supports the nation's economic growth and social welfare (Caerterling, 2011; Schraven et al., 2011). Effective infrastructure management is vital for a well-functioning highway system, and the conveyance of people and goods (Jha et al., 2012). Securing the operation and longevity of this resource is considered a highway management function; a broad remit comprising management of: highway pavements, bridges, road congestion, road safety, public transportation assets, intermodal transport facilities/ functions, and traffic monitoring data (Markow, 1995).

Highway management around the world typically falls on central or local government, although, notable exceptions include commercial management on behalf of government, including privatised highway construction in Japan (Dharish, 2014); franchised operations of Melbourne's train and tram network (World Bank Group, 2016a); and franchised management of French toll roads (Bonnafous, 2015). Highway construction is expensive, thus privatisation initiatives tend to be financially driven where governments cannot afford high

capital investment costs (World Bank Group, 2016b). Accordingly, considerate highway stock management is critical for prolonging infrastructure life, and to reduce associated maintenance costs. Indeed a major contemporary challenge for current government bodies is financing needed highway maintenance in the UK and USA, against a backdrop of depleting highway rehabilitation funds (Asphalt Industry Alliance, 2016; Dumortier et al., 2016; Jha et al., 2012; Hussain et al., 2016). Therefore the current government financial circumstances, reinforce the need for reduced, effective and cost efficient RWSW management.

2.2 ROAD WORKS AND STREET WORKS MANAGEMENT

The social cost of highway excavations is significant (Parker, 2008) as detailed in Chapter 1. Therefore the need to reduce or better manage highway cuts is recognised to: minimise highway structural impacts (Wilde et al., 2003; Chou, 2008; Salini, 2010), and reduce associated risks of vehicular accidents, utility accidents, suspension of utility services and inconvenience to society and businesses (Zhang, 2016). Furthermore, with approximately 2 million utility cuts in the UK annually, there is significant political will to reduce RWSW societal impact (Local Government Association, 2012). The management of highway works falls into two broad categories: technology based approaches and policy based approaches (US Department of Transportation Federal Highway Administration, 2016; Wilde et al., 2003). The remaining chapter will examine these approaches to explore the current state-of-the-art.

2.2.1 TECHNOLOGY BASED MANAGEMENT APPROACHES

Conventionally utility apparatus are housed underground in many modern and densely populated cities in the UK, US, China and Japan (Jaw and Hasim, 2013). This section will examine traditional trenching, locating underground utility assets, and examine alternatives to trenching such as trenchless technologies, and utility tunnels.

Traditional trenching

Traditionally, utility apparatus have, over the past 200 years, been placed underground through the construction and reinstatement of trenches. Whilst this method is relatively the cheapest method to access/install utility apparatus (Hunt et al., 2012) (compared to other methods discussed later), it is also highly socially disruptive, causes congestion and impacts on local businesses, whilst repeated digging and backfilling structurally weakens the transportation infrastructure (Rogers et al., 2012; Metropolitan Transport Commission, 1999; Zaneldin, 2007).

Structural damage to pavements by utility works was confirmed by a study in Austin, Cincinnati, Washington DC and 38 different sites in the UK, where pavement life was found to have reduced by around 36% in the US and 17% in the UK (Jordan, 2009; Wilde et al., 2003), at a cost to English LAs of around £70.1 million annually. To address this, the Transportation Research Laboratory proposed a charging structure to recover costs for parties prematurely damaged highways from trenching. Maximum charges of £45.48/m² proposed were based on carriageway condition and volume of traffic carried (Jordan et al., 2009). Despite this proposal, there is little evidence that any UK authority adopted the charges, possibly because utilities already feel 'overcharged' by street works (Hussain et al., 2016). 'Street deterioration fees' have also been considered in the US, although, the issue remains contentious and the likelihood of legal enforcement remains questionable, due to the inability to attribute direct link between individual utility cut and deterioration (Metropolitan Transport Commission, 1999; Gaglione, 2014).

Asset location technologies

Poor quality, inaccurate and sometimes non-existent locational asset records lead to unnecessary utility excavations - a major problem in the UK and USA (Hayes et al., 2012; Marvin and Slater, 2007; Rogers et al., 2012; Thomas et al., 2009; Transportation Research Board, 2010). Poor locational data creates unnecessary works in locating apparatus, and

increases risks of accidentally striking other apparatus – third party damaged utility apparatus alone costs around £150 million in the UK annually (Burtwell, 2006), which not only exacerbates social costs, but also prolongs works unnecessarily (Zayed and Mahmoud, 2013).

To address locational inaccuracy problems, the US and Canada developed Subsurface Utility Engineering (SUE), a discipline dedicated to mapping subsurface utility data (Arcand and Osman, 2006) by utilising air/vacuum excavation and surface geophysics technologies to accurately locate assets. SUE is used extensively across State Departments of Transport in the US (US Department of Transportation, 2013), and is a statutory requirement where estimated construction costs exceed \$400,000 (Transportation Research Board, 2010). Evidence suggests that the greater the value of the project, the greater the cost/benefit saving is utilised by SUE (Jung, 2012). This suggests disproportionate cost for smaller works, making SUE particularly suited to large/major works. Inspired by SUE, the UK has embarked on a ‘Mapping the Underworld’ project where, a prototype multi-sensory device is being developed to locate differing of utility assets. The device combines the use of ground penetrating radar, acoustics and low frequency passive and active electromagnetic fields (Goddard et al., 2012; Mapping the Underworld, 2012; Muggleton and Papandreou, 2014). Once the British multi-sensory device is fully developed and more widely available to the construction industry, it is likely that based on SUE and project economies of scale, best value may be limited to deployment to larger value highway projects.

On-site construction techniques

A number of innovative techniques have been developed to reduce RWSW impacts on-site, namely plating and bridging, temporary backfill and rapid cure concrete amongst others. Accordingly, Table 2.1 demonstrates the use of different materials and their strengths and limitations, used to return trenches to full public use quickly, to minimise RWSW disruption, as well as.

Table 2.1 Comparison of construction techniques to facilitate quicker usability of trench

<i>Technique</i>	<i>Description</i>	<i>Advantages</i>	<i>Disadvantages</i>	<i>Source</i>
Plating and bridging	For covering open trenches using plates to create a bridge, thus allowing pavements to be reopened to the public and traffic in the UK and Singapore. Used in the USA and Canada to additionally minimise impact on waterways and reduce environmental impact.	Can be installed and removed quickly making them ideal for returning road to use during peak hour congestion; ideal for use over large trenches.	Plates can be noisy, affect the drive experience and health and safety need to be considered when affixing them. Vulnerable to vandalism and theft.	McMahon, 2012; Transport Research Laboratory, Transport for London, 2013; Department for Transport, 2014; National Cooperative Highway program, 2010.
Temporary backfill	Temporary backfill material is used to backfill sites for short periods, using materials of lesser specification than typically prescribed for interim or permanent reinstatements. Used in the UK, Singapore and Canada.	Does not require specialist materials and can be more flexibly used than plating and bridging.	Less suited to large excavations and can be time consuming in installing and excavating.	Department for Transport, 2014; Land Transport Authority, 2010; Hamilton Public Works Department, 2013.
Rapid cure concrete	Materials which gain strength and can cure in around 3 hours compared to traditional concrete which requires 12-18 hours. Used in the UK and Korea	Cures faster compared to traditional concrete and has a smaller carbon footprint than typical concrete.	Requires swift transportation from factory to site, to prevent material setting in advance. Material tends only to be available in small quantities. Bond strength is poorer than traditional concrete and this can affect its service life.	McMahon, 2012; Senatore, 2010; Rith et al., 2016

Figure 2.1 shows a diagram for the plating and bridging technique, whilst **Figure 2.2** shows on-site use of temporary backfilling material.

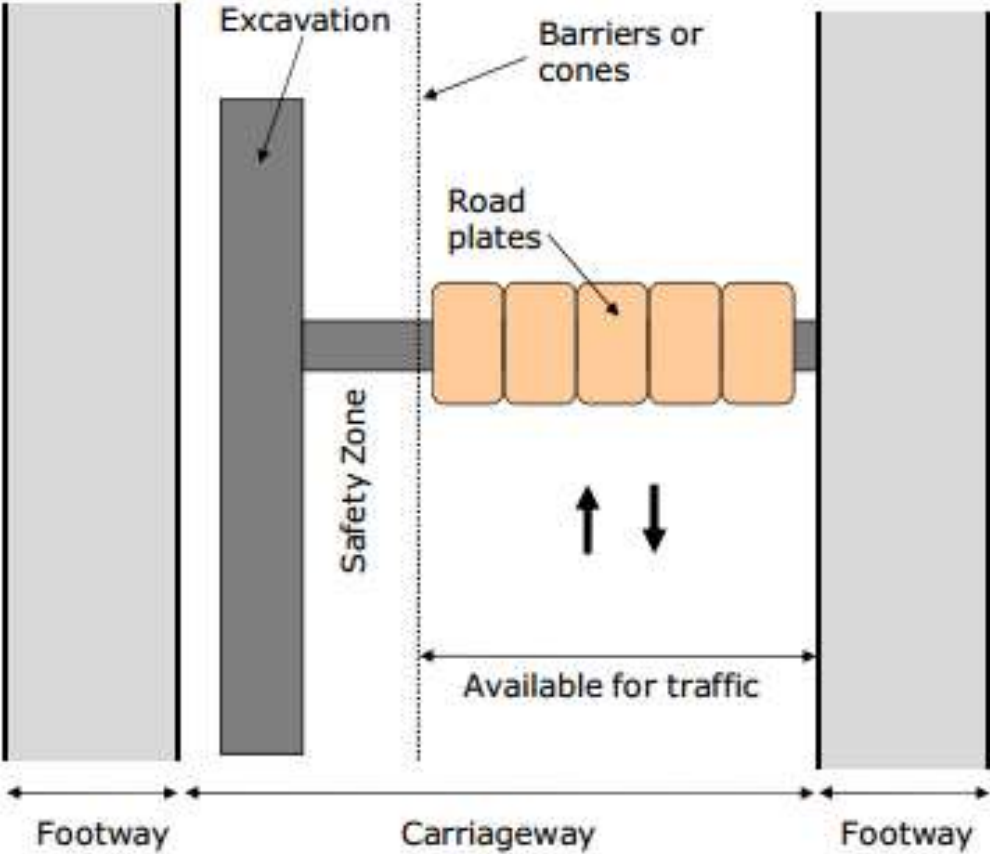


Figure 2.1 Use of the bridging and plating technique. Source: McMahon (2012)



Figure 2.2 Temporary backfilled pavement. Source: Department for Transport (2014)

Trenchless technologies

‘No dig,’ also known as ‘trenchless technologies’ is an alternative to traditional open cut trenching. Trenchless technologies incorporate different technologies to execute underground works with minimal or no use of trenching (American Society of Civil Engineers, 2004; Read and Vickridge, 2004), which significantly reduces the public impacts of RWSW. Ariaratnam et al. (1999) defines the term as a group of methods, materials and equipment for the installation, replacement or rehabilitation of existing underground infrastructure, with minimal intrusion and impact on the over-ground network and associated activities. Innovation in this field is being driven by the international challenge for addressing extensive rehabilitation of aging infrastructure within constrained global financial circumstances (Rogers and Knight, 2014). Whilst trenchless technologies are being utilised extensively in Abu Dhabi, Canada, China and the United States (Abu Dhabi Sewerage Service Company, 2013; American Society of Civil Engineers, 2004; Atalah and Ampadu, 2006; Beard, 2013; Ma and Najafi, 2008), the extent of their use, and their relative cost to the UK industry are less understood. Some of the key trenchless technologies used around the world are reproduced in Figure 2.3 by Zanelidin (2007). Please refer to Iseley and Gokhale (1997) for more detailed information about trenchless techniques and usage conditions.

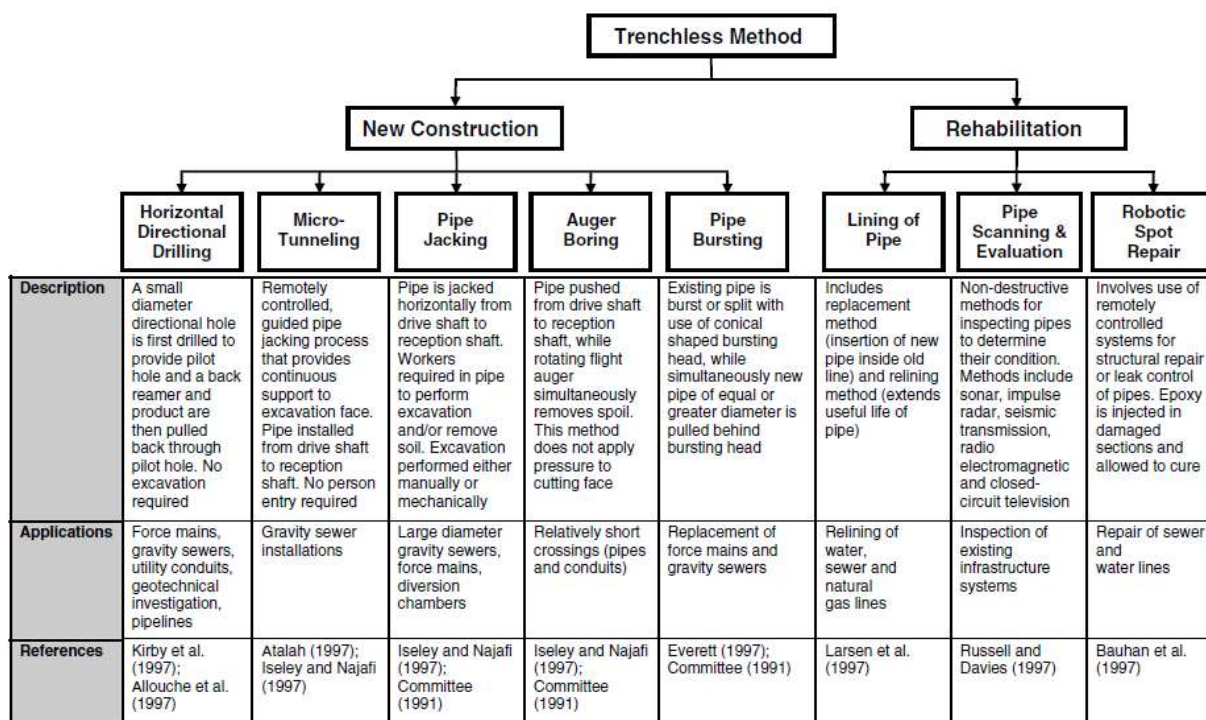


Figure 2.3 A comparison of trenchless construction methods - Source: Zaneldin (2007)

A number of key advantages and disadvantages of trenchless technologies exist over traditional trenching as detailed in Table 2.2.

Table 2.2 A comparison of the advantages and disadvantages of trenchless technologies

<i>Advantages</i>	<i>Disadvantages</i>	<i>Sources</i>
<ul style="list-style-type: none"> Minimal surface disruption. Minimal utility diversion. Significantly reduced excavation and disposal of ground materials. Significantly reduced spoil and quarried material. Significantly reduced carbon footprint. Significantly smaller construction sites. Minimal impact on society. Minimal impact on flora, fauna, water and air. Minimal aesthetic impact during construction. Reduced construction duration. Road can remain open to traffic. 	<ul style="list-style-type: none"> Requires greater capital outlay than open-cut methods. Greater risk in utility strikes due to uncertain locational nature of underground assets. Operators have less quality control over installation process than open cut trenching. Risk of subsidence, surface heave and leaking of drilling fluid. Higher risk is inherent, thus failure can be more expensive to correct. 	Pipe Jacking Association, nd; Gorg and Kruger, 2014; Gupta et al., 2001; Rogers and Knight, 2014; Marlow et al., 2015; O'Reilly and Stovin, 1996; Iseley et al., 1997; Ezeokonkwo and Nwoji, 2014.

The principal traffic management benefit is the reduced social costs, through reduced congestion, site occupancy and transportation of material on site, making works less invasive to society - social costs in open cut trenching account for around 55% of direct costs compared to around 6% in trenchless techniques (Matthews et al., 2015). A major barrier to trenchless technology adoption is the perceived greater costs of specialist equipment and machinery required (Chin and Lee, 2005; Gupta et al., 2001). However, Marlow et al. (2015) report that trenchless techniques can be significantly cheaper for overall project costs, because they require less transportation and disposal of material from site, and are more environmentally sustainable. Accordingly, to increase usage of trenchless technologies, LAs should assess each project for suitability, and where appropriate and proportionate, trenchless technology should be mandated. In the longer term, greater use of trenchless techniques overall could help reduce operational costs, as well as benefiting society through reduced works impacts. Further research is required into developing a tool which enables designers to consider the most appropriate construction method based on total project cost (including social costs).

Utility tunnels

Street works activity, and its undesirable public impacts, could also be substantially reduced through the adoption of bespoke utility tunnel which are used to store utility apparatus. Utility tunnels serve the common purpose of housing single or multiple utility apparatus within a purpose built enclosure and an access chamber, fit for human entry and working – see Figure 2.4 for a photograph of a utility tunnel entrance in Barcelona.



Figure 2.4 Entrance to a utility tunnel in Barcelona. Source: Canto-Perello et al. (2009)

Utility tunnels have also been referred to as, Multi-utility tunnels, Utilidors, Utility Corridors and Pipe Subways, and are operational in Barcelona, Helsinki (see Figure 2.5), Hong Kong, London, Paris, Tokyo, Seattle, and Singapore (Canto-Perello et al., 2009; Hunt and Rogers, 2006; Pike, 2005; University of Massachusetts, 2013; URS, 2009; Vahaaho, 2014).



Figure 2.5 A typical utility tunnel in Helsinki. Source: Vahaaho (2014)

The key advantage of utility tunnels is that over-ground, they negate the need for street cuts or excavations, whilst under-ground, utilities are stored in a planned and sustainable manner, as opposed to the un-coordinated maze of underground conduits and cables associated with traditional trenching, which risk utility strikes associated with traditional trenching (see Asset location technologies section).

Utility tunnels are praised for maximising valuable urban space, reducing street cuts and thus extending pavement life, whilst increasing network reliability and decreasing maintenance costs simultaneously. From a traffic management perspective, utility tunnels mean that traffic is minimally interrupted by utility works, which is particularly important in densely populated urban cities (Canto-Perello et al., 2009). Furthermore, asset burial has been linked to improving a city's resilience and sustainability by protecting essential infrastructure in the face of natural disasters such as floods, hurricanes and volcanoes (Hunt et al., 2016; Daly and Johnstone, 2015). Conversely the assembly of several utilities in a confined and accessible place can make them vulnerable to extremist and criminal threat (Canto-Parelo et al., 2013). Utility tunnels are unsuitable in some environments, such as Istanbul, where streets are narrow, steep and hilly (Akiner and Akiner, 2014). Despite their advantages, greater uptake of utility tunnels has been limited to countries where utilities are government owned (Rogers and Hunt, 2006) and where policies promote wider use of underground spaces, such as in Helsinki, Minneapolis and Singapore (Hunt et al., 2016; Vahaaho, 2014). Significant up-front creation costs are highly prohibitive which include: substantially more excavation, geotechnical considerations, space characterisation to provide ventilation systems, interior illumination, emergency systems and drainage facilities in case of flooding, purchase, ownership and maintenance of tunnel space amongst others. The cost of open cut trenching in comparison is far cheaper (Canto-Perello et al., 2009; Canto-Parelo and Esparza, 2013).

Equally, retrospectively fitting utility tunnels is reported as highly complex and financially prohibitive (Cardno, 2013; McMahon et al., 2012).

English utility tunnels are limited to Victorian examples in central London. Contemporary British decision makers face a number of barriers in the wider adoption of utility tunnels, including lack of awareness, limited financial drivers, resistance from utility companies, security issues and ownership amongst other factors (Hunt and Rogers, 2005). Therefore whilst utility tunnels are the state of the art utility storage and access solution, UK uptake is likely to remain low for the foreseeable future given that their high costs are incompatible with current government financial challenges. Furthermore the high financial costs are also likely to be a deterrent in gaining utility sector support, as utilities are financially motivated organisations who seek to minimise their costs. Figure 2.6, shows a photograph of an over-ground utility corridor in Inuvik.



Figure 2.6 An over-ground Utilidor running along the edge of a car park in Inuvik. (Source: Herrington, 2013)

Table 2.3 details examples of various utility tunnels and the contextual motivations for their use.

Table 2.3 Examples of utility tunnels

<i>Location</i>	<i>Description</i>	<i>Motivations</i>	<i>Source</i>
Walt Disney Utilidor, Florida, US	A series of underground multi-purpose corridors incorporating all aspects of infrastructure control including, deliveries, dressing rooms, cafeterias and utilities.	To disguise any evidence of day to day activity. "Nothing that appears in the Magic Kingdom must seem anything other than playful and magically timeless"	Pike (2005)
Inuvik, Canada	Overground pipes for the conveyance of water and sewerage.	Inuvik is an Arctic town where the freezing climate makes the soil subject to permafrost – burial of water based pipes would thus lead to them freezing.	Herrington (2013)
London	Around 15km of pipe subways commenced from the 1800s when electric and water pipes were added to sewers. Most subways have significant free capacity.	Pipe subways were installed at the time of highway construction to remove the need for digging trenches.	Canto-Perello et al. (2009); McMahon et al. (2012); URS (2009)
Helsinki	Part of a network of over 200km of 'technical tunnels', of which 60 km is dedicated to utility infrastructure. Waste water treatment for six towns and cities also takes place underground at the Viikinmaki treatment plant.	A part of the city's dedicated 'Underground masterplan.' A culture of underground construction is prevalent in policy, whereby any property owner with a building over 1200m ² must provide an underground civil defence shelter. Such shelters tend to be multi-use and include swimming pools, halls etc.	Vahaaho (2014)

2.2.2 DISCUSSION OF CONSTRUCTION BASED APPROACHES

The traditional and default approach to UK utility access is through traditional open cut trenching (Hunt, 2012). Whilst alternative construction options are available, such as trenchless techniques and utility tunnels, their uptake is influenced by the upfront cost to the work promoter. Therefore whilst trenching is the most deleterious construction option both structurally and socially (Hunt et al., 2014), it remains appealing to works promoters because it is comparatively cheap construction costs; but, trenching results in high social costs which tend to be dispersed, and absorbed by society as a whole, as well as the LA in repair costs. Hunt and Rogers (2005) presented a number of barriers for the adoption of multi-utility

tunnels and trenchless techniques which include high up-front construction costs, lack of UK knowledge and compatibility problems. A gap in knowledge exists about the extent to which trenchless techniques are currently adopted in the UK (and its relative cost to industry), as well as how designers can identify the most appropriate construction method, incorporating social costs.

It is clear that there is little incentive to change construction practices, unless backed by financial incentive to work promoters (Hayes et al., 2012). However, whilst a charging structure is available to mitigate future repair costs as a result of utility cuts (Jordan et al., 2009), there seems to be no academic or industrial evidence (to the author's knowledge) of its adoption in practice. The resistance to adopt trenching charges may be rooted in nervousness to levy additional charges on utilities given that utilities already feel that "street works are seen as a cash cow" (Hussain et al., 2016a). Nevertheless, a distinct research gap exists in the rationale behind why HAs choose not to adopt the charges.

There is no evidence that Governments have powers to mandate usage of less deleterious construction methods. Accordingly, government policy should be orientated to encourage usage of technologically based approaches, or, SUs need to be realistically incentivised to adopt alternative methods to minimise their public impact. For example, an organisation may be incentivised/decentivised through timings of works; whereas SUs using trenchless technologies may be empowered to work throughout the day, whilst SUs constructing trenches may be prohibited from working in peak hours. Placing a peak hour embargo on works could be highly disruptive for SUs as it would mean stopping and starting works, arranging materials to facilitate temporary road openings over trenches, (see on-site construction techniques) which could increase work durations and associated costs. Furthermore, literature also examines contemporaneous on-site RWSW management, which include: dynamic lane management systems to manage traffic around RWSW (also known as

work zones), reducing work zone lengths, using the hard shoulder (where available), and night time working (Abdelmohsen and El Rayes, 2016; Weng and Meng, 2013; Yang et al., 2013). These methods were not examined further, due to word limit constraints.

2.3 POLICY BASED APPROACHES

Tseng et al. (2011) and Fisher (2012), identify that RWSW management through policy based approaches receives less literary attention compared to technology based approaches. Similarly, the author experienced significant problems finding literature and can confirm the dearth in highway works management policy. The academic literature was therefore, supplemented by grey literature where appropriate. This section will examine legislative tools, and local practices in managing RWSW.

2.3.1 LEGISLATIVE TOOLS

The UK is the most advanced nation in regulating RWSW activity (McKibbin, 2010), with a range of policy tools, such as regulatory management and levies, which include charges for unreasonably prolonged highway occupation (see House of Commons, 2013 for more information about levies). Similarly, Australia and Singapore also have detailed legislation controlling the protocols and procedures for managing road works, with Table 2.4 detailing the similarities between these laws in empowering LAs to manage RWSW (Zhang, 2016).

Table 2.4 Comparison of UK, Australia and Singapore laws in managing RWSW

<i>United Kingdom</i>	<i>Australia</i>	<i>Singapore</i>
<p>NRSA (1991) The act provides for:</p> <ol style="list-style-type: none"> 1. Introductory provisions covering interpretations of road works, road authority and provisions on road work license and emergency works; 2. Road works register, to be maintained by a local road authority for its own geographic area to contain information with respect to the road works; 3. Notice and coordination of works including notice of work types and starting dates, direction on the working time, restriction on works and duties of coordination on road authorities and statutory undertakers; 4. General requirements on execution of road works, eg., safety measures, avoidance of delay/obstruction, and qualification of supervisors and operatives; 5. Requirements on the reinstatements; e.g., the materials, workmanship and standard of reinstatement and the statutory undertakers and the power of the road authority; 6. Charges, fees and contributions payable by statutory undertakers, including the charge for occupation of highway where works are unreasonably prolonged, inspection fees, liabilities for cost of traffic regulation and for cost of use of alternative routes, and contributions to costs of making good long term damage; and 7. Duties and liabilities of statutory undertakers with respect of apparatus affected by road works <p>TMA (2004) gives road authorities further powers to minimise unnecessary disruption caused by poorly planned works and to fulfil their duties through the Permit Scheme instead of the existing Notice system stated in NRSA.</p>	<p>Road Management Act (2004) This Act enables road works management by:</p> <ol style="list-style-type: none"> 1. Establishing a statutory framework for the management of the road network regarding uses of road reserves for roadways, pathways, infrastructure and similar purposes; 2. Setting out certain rights and duties of road users; 3. Establishing the general principles on road management; 4. Providing for the role, functions and powers of a road authority; 5. Providing for the making of Codes of Practice to provide practical guidance in relation to road management; 6. Setting out the road management functions of road authorities 7. Setting out the road management functions of infrastructure managers and works managers in providing infrastructure or conducting works; 8. Providing for issues related to civil liability arising out of road management, and 9. Providing for mechanisms to enforce and administer the provisions of the Act. <p>This Act requires utilities to obtain consent from the LA for works impacting on roads, and provide notification of the installation of the infrastructure; to notify LAs following completion works; to notify other works and infrastructure managers where they will be affected by the street works; to consult with affected members of the community; to have an appropriate traffic management plan and to use appropriately trained and qualified staff; and to take reasonable measures to maintain utility infrastructure or works to a satisfactory standard.</p>	<p>Street Works Act (1995) This Act provides powers of road authority stating:</p> <ol style="list-style-type: none"> 1. Any road work should apply for the prior approval of the Road Authority and the application shall be accompanied by a plan showing the affected work location; 2. The Road authority may give written directions on an application regarding to the compliance with this Act, the location and extent of work and related apparatus to be laid/erected, the provision of footways/diversions roads and the size and specifications of such footways/diversion roads, the design and construction method, the works period, provision of temporary traffic signs and other road related facilities, and the reinstatement of any affected public street/bridge; 3. Works contravening provisions of this Act, the Authority can order the cessation of the works, the removal of any installations, the reinstatement of any affected public street or bridge, work or alteration to be carried out to cause the works to comply with the provisions of this Act; 4. If an order is not complied with, the Authority may, or may cause to demolish, remove or alter the works and recover all costs and expenses incurred by the Authority from the person in default; 5. Any person failing to comply with the order shall be guilty of an offence and liable on conviction to a fine, the amount which depends on the situation of offence; 6. The Authority may levy a charge on a person carrying out road works, execute/cause any works to be properly carried out, and recover associated costs to this person.

Source: Zhang (2016)

Currently, it appears that there are three main regulatory RWSW management techniques for the purpose of traffic management: Noticing, Permitting and Lane Rental schemes. Table 2.5 summarises the advantages and disadvantages of the schemes, followed by subsequently detailing the purpose and use of the schemes.

Table 2.5 Advantages and disadvantages of Noticing, Permit and Lane Rental schemes

<i>Scheme type and description</i>	<i>Advantages</i>	<i>Disadvantages</i>
<p>Noticing – where the work promoters sends notification of their intention to work under prescribed timescales of NRSWA</p> <p>Permit Scheme – where work promoters must seek permission to work in the highway through a chargeable permit application process. Cost is restricted to permit application and amendment costs.</p> <p>Lane Rental – where work promoters pay varying charges for the occupancy of the highway lane for the duration of works. Costs are greater on the busiest roads at the busiest times of the day.</p>	<ul style="list-style-type: none"> • Free of charge • Suited to areas with low levels of congestion • LAs have powers to re-direct works • Provides greater ability for LAs to coordinate works. • Fixed Penalty Notices can be issued for working without a permit, or breaching permit conditions. • Easier to monitor over-running works due to specific days authorised for working. • Makes highway occupancy during the day an unattractive proposition. • Focuses on reducing duration (days) of highway occupancy. • Offers incentives to work outside of peak hours through lower or no charging. • Surplus cash can be reinvested in the highway works sector. 	<ul style="list-style-type: none"> • Hard for LAs to monitor over-running works. • Hard for LAs to coordinate works. • Significantly increases administrative costs for LAs and utility companies through increased administration. • Can be a significant cost burden where Permits are cost-free chargeable. • May not be cost neutral for the LA where charges apply. • Bear little relationship between work duration and congestion. • Can be difficult to negotiate peak hour working in traffic sensitive streets. • Charges do not apply to LAs. • Financial costs for updating of EToN compliant software for all users. • Significantly higher costs to utilities through up-front costs, which are ultimately absorbed by bill payers and tax payers. • Increases workforce and health and safety costs through encouraging night working. • Potential for noise pollution from night working costs. • Does not focus on coordinating works with others. • Can delay non-urgent planned maintenance works on aging assets creating a higher number of emergencies. • Financial costs for updating of EToN compliant software for work promoters and LAs.

Sources: Arter, 2010; Bennett, 2011; Ecorys, 2015; House of Commons, 2011; Quiroga, 2014; UK Parliament, 2011

Noticing

English HAs and utility companies are primarily required to submit Notices (cost-free) to individual LAs within prescribed timescales to execute RWSW. In exceptional circumstances, LAs can redirect works in the interests of traffic, as well as challenge proposed works durations where timescales are considered excessive (NRSWA, 1991), however, this is not considered an effective tool in encouraging behavioural change (Transport Research Institute, 2016). LAs must have an interoperable Electronic Transfer of Notices (EToN) Information System (IS) to enable electronic exchange of notices with work promoters (Department of Environment, Transport and the Regions, 1999).

Works executors in Scotland must also serve Notices, however these are submitted to a single point - the Scottish Road Works Register (SRWR). The register is an online system (available at www.roadworksscotland.org) and is maintained by the Scottish Road Works Commissioner. In contrast to England, utilities are not required to use additional specialist EToN software, and furthermore they do not need to contact individual LAs (Scottish Government, 2013), which is administratively simpler for Scottish SUs. Similarly, utilities operating in South Australia must submit 'notification of works' to the Government of South Australia when working on arterial routes. Additionally, work promoters must notify all local residents and businesses of any potential disruptions at least two weeks before starting works (Government of South Australia Department of Planning Transport and Infrastructure, 2013).

The 'notification' nature of the Noticing system by default means that authorities have less control over works occurring on highways, which can reduce management and control of RWSW. To address public concern and to exercise greater control over RWSW, the Permit Scheme was introduced as an alternative management technique (House of Commons, 2013).

Permit Schemes

Permit Schemes are used to control and authorise highway works activities and operate on a chargeable and non-chargeable basis in London, Singapore, Australia, Taiwan, Aachen and Russelsheim (Germany), Texas, Hong Kong and New York (Chou et al., 2008; Land Transport Authority, 2014; McKibbin, 2010; National Cooperative Highway Research Program, 2010; Quiroga et al., 2014; Russelsheim Stadtverwaltung, 2015; Transport Research Laboratory, 2012; Zhang, 2016). English LAs can manage RWSW through Permit Schemes, enabling more proactive management and control of activities on their road networks to reduce congestion and traffic delays. Additionally, Permits enable the application of site specific working conditions to best meet local traffic conditions and demands (House of Commons, 2011). Derby Permits cost between £105 - £231 (Derby City Council, 2013) whilst HAs are exempt from charges nationally. The absence of HA Permit charges were heavily criticised by NJUG, who argue that they fail to incentivise HA behavioural change, despite HAs being equally accountable for highway works (UK Parliament, 2011).

The English Permit Scheme has caused a major paradigm shift in practice (Hussain et al., 2016), blamed on inconsistent rules, increasing costs, decreasing productivity, and increasing penalties for failing to comply with Permit conditions (Guest, 2013). However, there is limited literature analysing the scheme's performance nationally and internationally; except a proposed methodology for the Cost Benefit Analysis of the Kent Permit Scheme using fuzzy logic (Shrivastava, 2010). Regulations require LAs to initially evaluate Permit Schemes after 12 months, then subsequently 36 months for effectiveness (DfT, 2014). However SUs criticise these evaluations on the basis that they are uncomprehensive for failing to reflect the true impact and costs borne by utilities (NJUG, 2012). Arter (2010) found that Permit costs bore little correlation between congestion and work durations, whilst performance analysis reports reveal the following reductions:

- London Permit Scheme - 2% reduction in average duration in the first year (London Permit Scheme Operational Committee, undated);
- Kent County Council - 18% reduction in ‘impact of road works’ over four years (Kent County Council, 2014);
- Yorkshire Common scheme – 21% reduction in duration over two years (Yorkshire Common Permit Scheme, undated).

Although the reports are somewhat detailed, they identify data limitations, and report on pre-agreed performance indicators agreed with the Department for Transport (DfT), they arguably lack rigour and certainty in results due to presenting limited method processes, particularly collection methods, analysis techniques, and statistical sensitivity testing of results. Moreover, the results are not subject to peer review or feedback from the DfT which reinforces uncertainty; therefore an absence of robust Permit Scheme analysis data remains, as also considered by the Transport Research Institute (2016). Similarly, international analysis of Permit Scheme performance and impact is also absent reinforcing an important gap in knowledge. A notable although dated comment by Chou et al. (2008) stated that the Taiwanese Permit Scheme did not motivate roads authorities to coordinate works or communicate with utility owners, and so consequently it failed to transpose into controlled or reduced highway cuts, demonstrating that Permit schemes are not necessarily a traffic management tool. Furthermore, whilst coordination of works is part of the Texas Permit Scheme (Quiroga et al., 2014) it is unclear from this or other international examples whether Permit Schemes are a works management tool (similar to the UK), or whether Permits simply enable an inventory and history of highway works activity.

Lane Rental schemes

Lane Rental schemes operate on a pioneer basis in London and Kent, and permanently in Sydney, Australia. UK utilities are charged up to £2,500 daily for occupying the busiest roads

at the busiest times of the day (DfT, 2012a), whilst in Sydney charges range from a non-refundable application fee of £813, to lane rental fees of £879 per day (City of Sydney, 2014). Lane Rental seeks to incentivise efficient working in the least disruptive manner outside peak hours (DfT, 2012a); so 92% of London works are now conducted outside peak hours, as opposed to only 30% previously (Transport for London, 2013). Preliminary independent analysis of the English Lane Rental schemes found that they were successful and had facilitated major behavioural change (Transport Research Institute 2016), with case studies of the Hammersmith Flyover and Marylebone Road schemes showing savings of £8 million from averted congestion (Ecorys, 2015).

In contrast to Permit Schemes, Lane Rental schemes focus on the expeditious completion of works rather than coordinating works with others (Hayes et al., 2012), which though is positive for traffic management, is less effective for asset management, as it is unlikely to reduce overall utility cuts which cause long term pavement damage. Lane Rental schemes encourage night time working, which is disadvantageous because it can introduce noise pollution in residential areas at night (Ecorys, 2015); notwithstanding this, the Transport Research Institute (2016) did not find evidence of increased noise complaints despite more planned overnight works. Furthermore, night working exposes road construction workers to disproportionate risk of incidence and severity of accident, as fatalities are five times more likely compared to day-time construction (Arditi et al., 2007; Harb et al., 2008; Mukhopadhyay et al., 2007). Therefore whilst night working is beneficial for traffic management because of lower road network demand, it can inadvertently and severely compound worker safety.

2.3.2 LOCAL MANAGEMENT PRACTICES

This section will examine the role of restricted working conditions, coordination meetings, and the one-call system in managing RWSW disruption.

Restricted Working Conditions

Localised traffic management techniques can be adopted to manage transportation around RWSW. For example, work promoters in Singapore require a ‘One for One lane replacement’ where deactivated lanes must be substituted by temporary lanes to maintain network capacity (Local Transport Authority, 2014). Whilst lane loss is highly disruptive and provokes capacity loss of around 25-40% in the remaining open lanes (Walker and Calvert, 2015), substitute lanes are not always possible, particularly in densely populated urban cities, although suspended parking bays can be used to accommodate running lanes.

In terms of managing road closures, any works requiring road closures are generally restricted to a Sunday in Sydney, whilst Singapore prohibits peak hour working and Hong Kong bans working between the hours of 7am–7pm daily (City of Sydney, 2014; Land Transport Authority, 2014; Transport Research Laboratory, 2012). Prohibiting daytime working is highly effective in preserving network capacity, but increases workforce costs, as well as seriously exposing them to risks of injury and fatality in night working (see Lane Rental Schemes subsection).

Coordination Meetings

UK legislation requires SAs to lead regular coordination meetings with utility companies to plan and coordinate works to minimise highway impacts (Department for Transport, 2012). Similar practices occur in Singapore where Road Opening Coordination Committees, incorporate wide membership of utility companies, service providers, the Housing and

Development Board as well as the National Parks Board (LTA, 2015). Figure 2.7 depicts a typical Singapore Road Opening Coordination Committee meeting, where stakeholders discuss coordination of works.

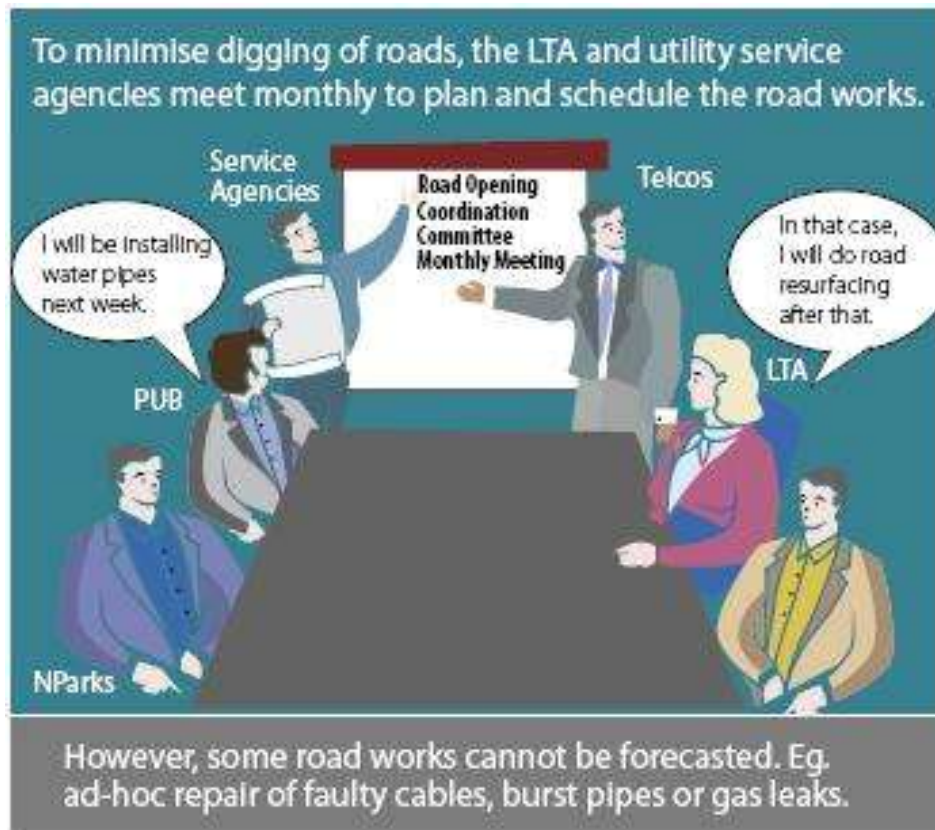


Figure 2.7 Singapore Road Opening Coordination Committee meeting. Source: LTA, 2015

In the New York/New Jersey/Connecticut region, regional works coordination is facilitated annually by the Transportation Operations Coordination Committee (Transcom), while within smaller state jurisdictions, New York City Department of Transport (DOT), New Jersey DOT and Pennsylvania DOT coordinate monthly meetings with utility companies (National Cooperative Highway Research Program, 2010). Communication and face to face meetings are crucial for collaborative working as they help build and maintain working relationships, and facilitate the discussion and agreement of mutually beneficial programs of work (Patel, et al., 2012; Johnson et al., 2010). However, coordination meetings should be purposeful and constructive; despite Pennsylvania's coordination processes and practices, Intercounty Paving

Associates Ltd successfully sued them for \$760,000 (£567,000), for failing to adequately perform its coordination duties which caused works delays by 223 days (Charneski, 2010).

One Call System

Utility works are also managed through the US One Call system, which is an online ticket entry system for locating and marking of underground facilities. This is an important process as the correct location of underground utility assets help to reduce utility strikes, and thus prevents prolonging works. Iowa is one of 12 US states offering the One Call system. All excavators (including residents) must telephone the free Iowa One Call (IOC) notification system reporting any planned excavation at least 48 hours in advance (Transportation Research Board, 2010). The IOC members (owners and operators of underground facilities) have a statutory requirement to fund and join IOC (Iowa One Call, 2014). A similar free service is also provided in Australia, where users can download an app, make enquiries online, or by free phone (Dial before you dig, 2015). A National One Call system also operates throughout the UK, operated by a private company, however, in contrast, the company is not subject to any mandatory membership, instead, the company contacts utilities for data on behalf of applicants for a minimum charge of £99 (National One Call, 2015). Despite the advantages of tracking utilities, the One call system is not exhaustive as it can only report on the asset data available (Jung, 2012): large numbers of utility locational data is poor, inaccurate or missing (see asset location technologies).

2.3.3 DISCUSSION OF POLICY BASED APPROACHES

Policy based RWSW management literature shows that governments use various policy approaches to control highway works for effective traffic management. Controls are exercised primarily through regulatory practices for registering works such as Noticing, Permitting or Lane Rental Schemes, or local practices including restricted working, coordination meetings and the One-Call system. Evaluation of the limited performance data

available for regulatory schemes, namely the Permit Scheme, shows that scheme successfully reduced highway works durations. However, the data is flawed because calculation methods could not be validated; indeed, literature overall failed to provide robust performance data for the Noticing, Permit or Lane Rental Schemes, therefore additional research is required in this area. Furthermore, there is no qualitative data providing performance feedback on RWSW management – the filling of this gap would help to better establish the effectiveness, barriers and opportunities of RWSW management, which could help reduce their impacts on the general public.

As highlighted by Tseng et al. (2011) and Fisher (2012), policy based approaches to RWSW management generally receive limited literature attention, demonstrating a thoroughly under-researched area in general, as re-enforced by this latest review of literature. For example, whilst high level schemes of local management practices were identified, the macro-level data meant that there was little subject richness; therefore, more in-depth research is required at the meso and micro-levels. For example, by looking in detail at processes, practices, problems and opportunities for RWSW, it could help to provide more appropriate solutions to address the research problem better. Similarly, qualitative data representing the insights and perspectives of those within the industry could also not be found. Critically, whilst the cost of street works has been subject to some studies as detailed in Appendix D, there is no evidence of any such study for road works. Given the significance and value of the highway, and the substantial societal impact of RWSW, the lack of research was unexpected. There is a need for greater research in general in all areas of RWSW management as the subject is thoroughly under-researched.

2.4 CHAPTER CONCLUSION

The problems caused by ineffective management of RWSW are defined in Chapter 1. The purpose of this chapter was to investigate existing subject knowledge to explore the state-of-

the-art of RWSW management practices. Whilst the review helped to appreciate different technological and policy techniques around the world and their strengths and limitations, policy research into RWSW management was very limited. A number of key gaps in knowledge emerged from available literature and are detailed in Table 2.6.

Table 2.6 Gaps in knowledge

<i>Area</i>	<i>Research gap number</i>	<i>Description</i>
Technology	1	The extent to which trenchless techniques are currently adopted in the UK and its relative cost to industry.
	2	The mechanisms for designers to identify the most appropriate construction method based on total project cost (including social costs)
	3	The reasons for the lack of adoption of the charging structure for trenching the highway
Policy	4	The performance of regulatory RWSW management schemes – Eg. Noticing, Permit and Lane Rental schemes
	5	The business processes in the RWSW industry, and their performance
	6	Industry practitioner perspectives of RWSW performance, policies and practices.
	7	The economic value of road works.
	8	Further research into the economic value of street works
	9	Further research into the societal costs of RWSW

Research into these areas is critical for the economic advancement of the nation, not only because the highway is our most expensive asset (National Audit Office, 2014), but also because a well-functioning transportation network is crucial for a nation’s economic growth and social welfare (Caerterling, 2011; Schraven et al., 2011). Currently, the research problem as detailed in Chapter 1 requires the reduction of societal impact of highway works management, through finding solutions and mechanisms for reducing highway works. However there are gaps in knowledge about highway works management policy (see Figure 2.8). These gaps in knowledge distinctly demonstrate that further works are required to analyse the UK RWSW management landscape better. The aim and objectives of this study as highlighted in Chapter 1, incorporate parts of research gap numbers 4, 5 and 6 (Table 2.6) which could contribute to addressing the overall knowledge gap, in conjunction with the research map detailed in Chapter 3.

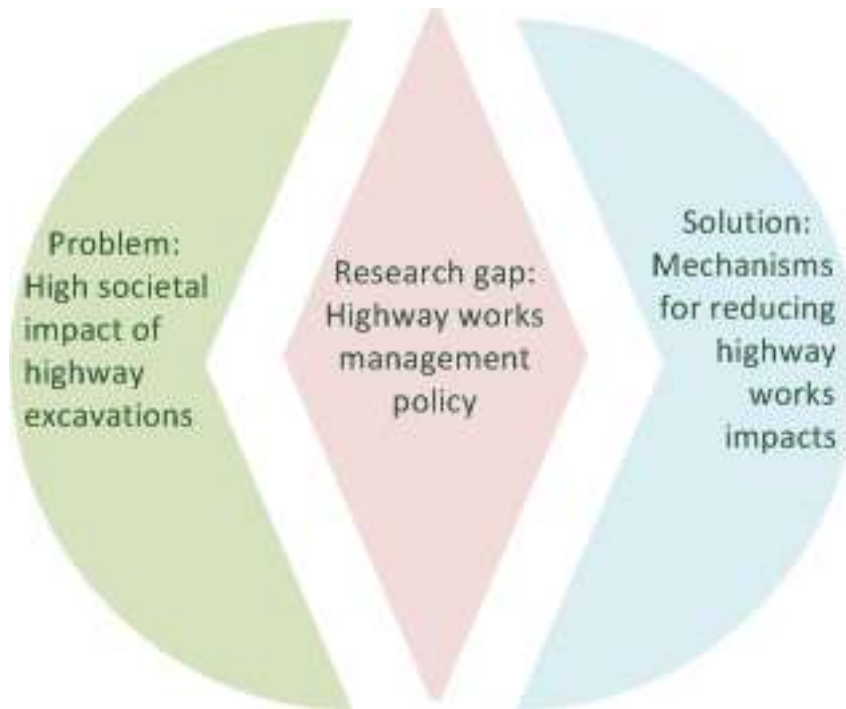


Figure 2.8 The research gap in highway works management policy

2.5 CHAPTER SUMMARY

This chapter has provided a record and critical review of the state-of-the-art of RWSW management literature. The chapter has also identified some gaps in knowledge which have emerged from the literature review. In addition, key research gaps which are to be investigated further as part of this project have been highlighted. The next chapter will discuss the research methodology and methods adopted for this project.

3 METHODOLOGY AND METHODS

Research can be defined as a scientific and systematic investigation to establish facts to further existing knowledge and develop new knowledge (Kothari, 2004). The identification and application of appropriate research methods is critical to address the core research problem, project aim and subsequent objectives. Accordingly, this Chapter examines the methods used to investigate the business process implications of managing RWSW, in accordance with the objectives detailed in Chapter 2. This chapter is structured in four parts and will be discussed in turn:

3.1 Research Methodology: provides a review of the over-arching research types and approaches available;

3.2 Research Design: provides a design for the study;

3.3 Overview of Research Methods: describes the research data collection and analysis methods used in this study; and

3.4 Application of research methods: describes the research objectives of the study and how the data collection and analysis methods were applied.

3.1 RESEARCH METHODOLOGY

A research methodology is a strategy of how a research problem should be approached, providing a basis for adopting appropriate research methods (Denscombe, 2010). This section describes the different research paradigms or perspectives considered for this EngD, namely; research type and research approach.

3.1.1 TYPES OF RESEARCH STUDY

It is important to adopt approaches which are best aligned with responding to the research problem. The research purpose can help to determine which of the following types of study to explore (Blaikie, 2010; Grix, 2010; Yin, 2014):

- Descriptive – typically a descriptive account of a particular matter, process or person, where an accurate account is sought through words or numbers;
- Exploratory – mainly scoping and seeking answers to test a hypothesis before committing to further in-depth research, where the subject or context is little known, or to establish avenues of explanation; and
- Explanatory – usually involves finding explanations through making generalisation by extrapolation of case studies, and it can be used to account or explain a phenomena.

Given the limited research in the policy sphere of RWSW management (Fisher, 2012; Tseng et al., 2011), initially an exploratory approach was required to gain a basic and broad appreciation of the RWSW industry and their working methods for objectives 1 and 2. To enable deeper analysis, a descriptive approach afforded detailed and specific investigations into the effectiveness of RWSW policy interventions, and to investigate greater coordinated working opportunities within Derby as part of objectives 3 and 4. Finally an explanatory approach was required for objective 5 to enable reflection and dissemination of objective 4, and to make generalisations for wider applicability. Figure 3.1 shows how the three research approaches were adopted.

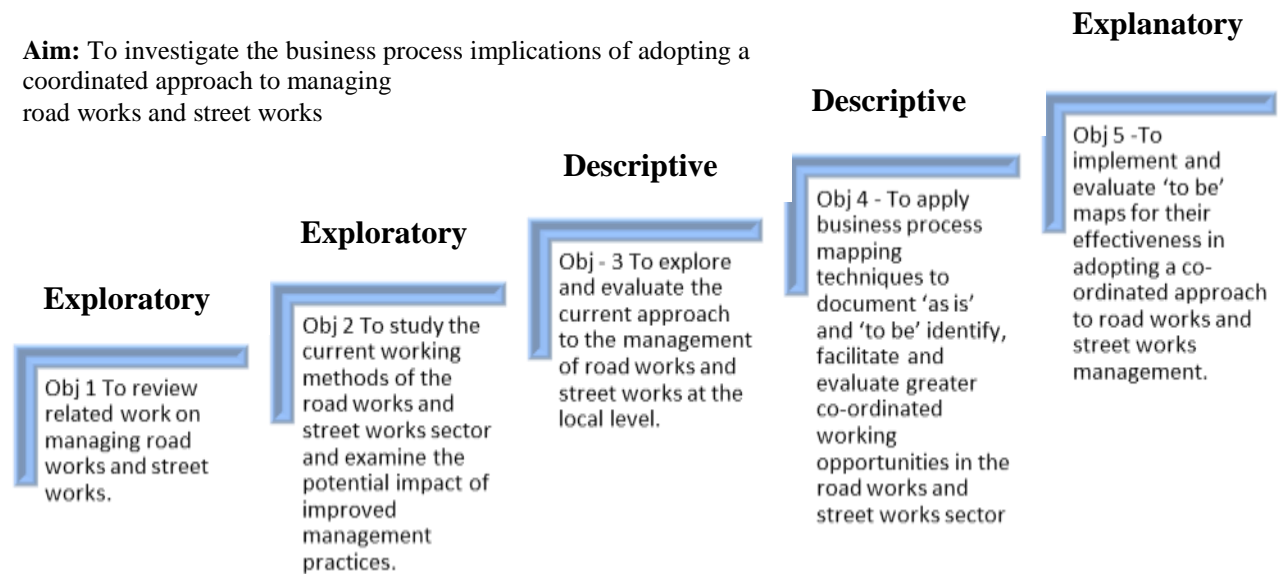


Figure 3.1 Research approaches applied to study

3.1.1 RESEARCH APPROACHES

Further to research types, research approaches are overarching investigatory approaches which broadly fall into two main categories: qualitative or quantitative. ‘Triangulation’ is the adoption of both qualitative and quantitative approaches (Brewer, 2007).

Qualitative research - comprises data collection in non-numerical form to interpret people’s views and perspectives. Data can be based on interviews, diaries, journals, and even photography. Qualitative research is less bound by artificial research features, enabling free expression as opposed to being limited to a researcher’s pre-established options. Qualitative research offers rich insight enabling the development of new concepts and interpretations (Yin, 2016). However, qualitative research can be criticised for perceived bias towards anecdotes which can undermine research representativeness and generality. Furthermore, social context immersion can also undermine the researcher’s objectivity, inclining personal opinion over substantive evidence to support arguments (Grix, 2010).

Quantitative research – comprises gathering, analysing, interpreting and presenting numerical data to investigate relationships (Fellows and Lui, 1997). Data examined tends to

originate from real data, observations or questionnaires to test a hypothesis or theory (Kaplan, 2004). Quantitative studies are typically characterised by collating data, executing statistical testing and interpreting outputs (Grix, 2010). The robust process, substantiated by confidence levels, gives statistical research the scientific respectability, not given to qualitative approaches (Denscombe, 2010). However, qualitative research relies heavily on measureable phenomena, which is difficult in social contexts such as emotions. Also, researchers can find it difficult to detach from finding measureable correlation between findings and casual statements, particularly as it is rare that a particular variable is the sole cause of something (Grix, 2010). Furthermore, whilst the process is ‘scientific’, the researcher can subtly influence findings (Denscombe, 2010).

Triangulation - also known as ‘mixed methods,’ whereby both qualitative and quantitative approaches are adopted. The different approaches tend to be used in separate studies which are ultimately combined. Triangulation facilitates greater rigour, enabling richer and stronger findings because the researcher answers more complex research questions, without being limited to one approach (O’Leary, 2004; Yin, 2014). A key disadvantage of triangulation is the time required to conduct each method to a professional standard (Robson, 2011).

To meet the project aim of investigating the business process implications of managing RWSW, a triangulation approach was adopted. The comprehensive approach meant that complementary research approaches could be investigated to robustly address the research objectives. Adopted approaches were influenced by how they could help to better appreciate the research problem as detailed in Chapter 1. The approaches were adopted as follows:

- Objective 1 required the exploration of existing literature to establish current RWSW management techniques and state of art, therefore a qualitative approach was adopted;
- Objective 2 required establishing the current working practices of the RWSW industry. Rich and in-depth data about current working practices through interviews

was needed; accordingly, a qualitative approach was warranted to capture industry experience.

- Objective 3 required the assessment of the effectiveness of managing RWSW at the local level. Given the focused local study nature, it was considered that a quantitative approach could be used to measure the effectiveness of managing RWSW scientifically. A quantitative approach would also complement the qualitative approach used in objectives 1 and 2, giving the study greater robustness.
- Objective 4 required the development of business process maps, and the identification of the challenges and opportunities for improved RWSW sector management. This study required a qualitative study through talking to process experts to accurately document their processes.
- Objective 5 required the evaluation of the proposed process maps for their effectiveness, and the development of a logic map for managing RWSW. It was considered that the evaluation of this exercise was best suited to talking to industry experts as it provided direct and rich feedback, which subsequently led to the development of the logic map.

3.2 Research Design

The EngD research design was informed by the project aim and the objectives (see Chapter 1), enabling the selection of the most appropriate research methods. Figure 3.2 details, the study objectives, along with the data collection and analysis methods used (as described further in Chapter 3.3), key tasks conducted to meet objectives (See Chapter 3.4 for method application); along with associated academic outputs, upon which this thesis is based.

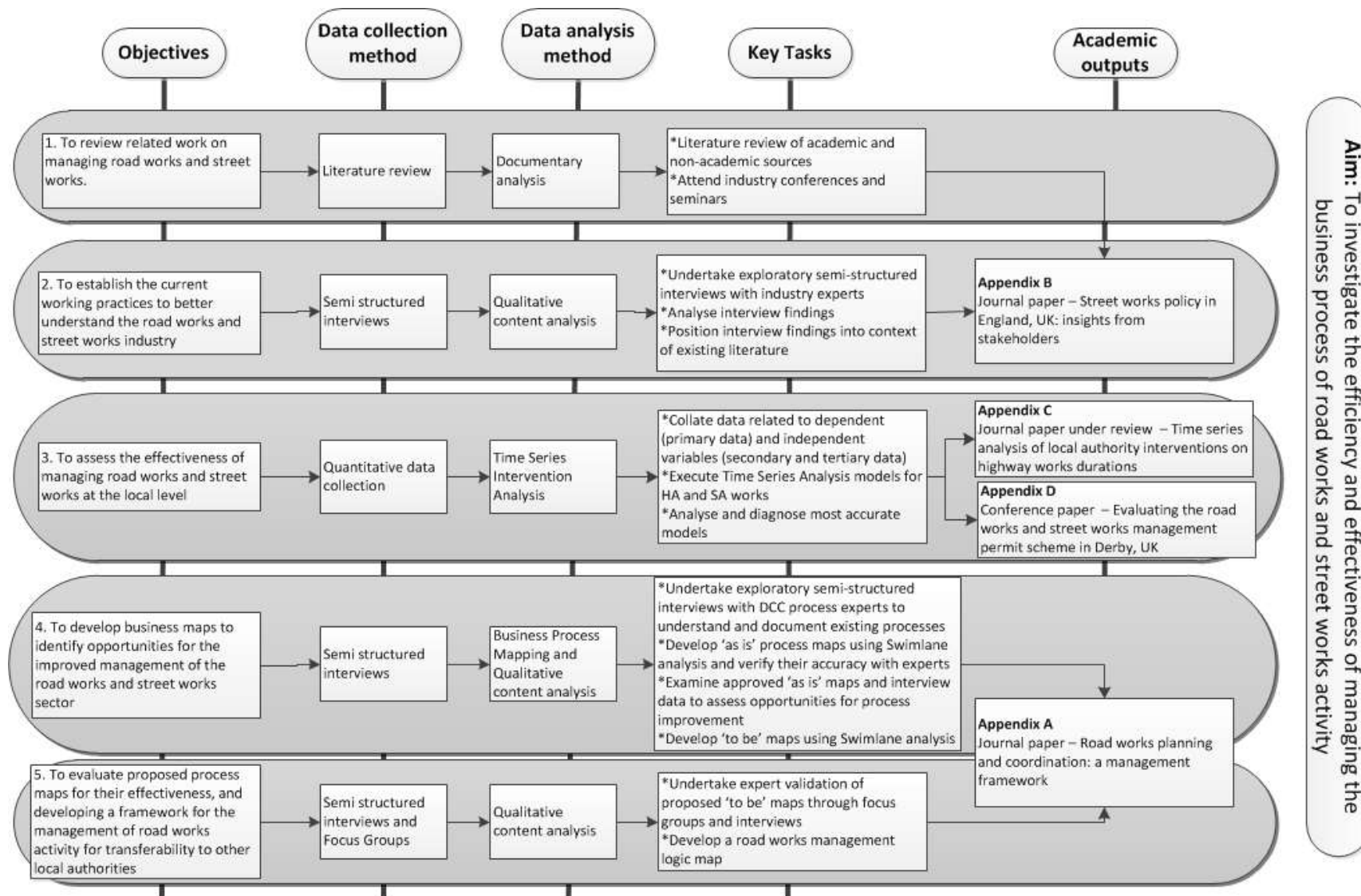


Figure 3.2 Research map

3.3 OVERVIEW OF RESEARCH METHODS

This section provides a brief description of the research methods used, following which Chapter 3.4 details their application in the research. Firstly, this section will examine data collection methods, followed by data analysis methods.

Both data collection and analysis are important and complementary methods used to make sense of research data. Whilst data collection comprises gathering data for analysis, data analysis is to summarise, describe data, and make inferences of the population from which the data is drawn (Uyo, 2002). Table 3.1 details the data collection methods used in this research, along with the corresponding analysis techniques.

Table 3.1 Data collection and associated data analysis methods

<i>Data Collection Method</i>	<i>Associated Data Analysis Method</i>
Literature review	Documentary analysis
Interviews	Qualitative content analysis Business process mapping
Focus groups	Qualitative content analysis
Quantitative data collection	Time Series Intervention analysis

3.3.1 DATA COLLECTION METHODS

Firstly, this section will examine the data collection techniques used in this study, namely the literature review, interviews, focus groups and qualitative data collection. Chapter 3.2.2 will detail the techniques used to analyse the data collected from the methods described.

3.3.1.1 Literature review

Examination of current literature enables the development of an account of the published literature/knowledge on a subject matter. Literature reviews provide researchers with

background information on the subject matter, state-of-the-art, and highlight key terms, debates and concepts dominating the area (Grix, 2010; Silyn-Roberts, 2013). Literature provides initial insights helping to identify gaps in knowledge, which subsequently inform further research (Blaxter et al., 2003).

3.3.1.2 Interviews

Interviews involve verbal questioning from the interviewer of the interviewee, on a defined theme or subject to gain a real life situation. Interviews are a compelling research source, providing a richness in data that quantitative methods or questionnaires can miss. Differing interview types provide different levels of flexibility in response (Gilham, 2005):

- Structured interviews - associated with predefined, close ended questions;
- Unstructured interviews – associated with open ended questions allowing flexibility in discussion around the subject theme;
- Semi structured – these combine the benefits of structured and unstructured interviews.

However, interviews are time-consuming and costly to conduct, particularly where interviewees are geographically dispersed. Additionally, successful interviews are conditional on the reliance of honesty and unbiasedness, which can be undermined by the formal interview nature and interviewee inhibitions (Denscombe, 2010).

3.3.1.3 Focus Groups

Focus groups typically involve 6 - 8 participants convening to ‘focus’ on and discuss particular themes or topics. Focus groups seek to gather information on what participants feel about a subject matter; accordingly, participant recruitment is based on their relevance to the subject matter. A moderator leads the group to stimulate and probe discussion, and ensures its relevance, but should not offer personal opinion. Focus groups can be highly insightful

providing time savings compared to individual interviews (Krueger and Casey, 2000). However, focus groups can be dominated by stronger characters, leading to bias and power struggles, therefore skilful management is required to ensure full group member participation (Robson, 2011).

3.3.1.4 Quantitative Data Collection

Quantitative data collection comprises the numerical collection of data for statistical analysis.

Data used for statistical analysis can be primary, secondary or tertiary.

- Primary data is raw data generated by the researcher and categorised into ‘captured’ or ‘exhaust’ data. For example, captured data could be collated through direct observation, traffic survey or field experiment, whereas ‘exhaust’ data tends to be a by-product of a main system, such as data obtained through a booking system or tickets sales system (Kitchin, 2014).
- Secondary data is where the researcher makes use of data made available to re-use by others, thus effectively using someone else’s primary data (Kitchin, 2014).
- With tertiary data, the researcher is two-steps removed from the original source. Government census reports can be referred to as tertiary data as the data has invariably been summarised, categorised and manipulated from the original data-set (Blaikie, 2010).

Whilst data access is valuable to produce meaningful statistical information; however, data quality is critical. With primary data risks are attached with the correct collation and input of data. However risks are compounded with secondary and tertiary data as the researcher is removed from the original source and cannot examine its authenticity; thus appropriate caution should be exercised to ensure data reliability.

3.3.2 DATA ANALYSIS TECHNIQUES

This section will analyse data analysis techniques used to analyse data collection methods described in Chapter 3.2.1.

3.3.2.1 Documentary analysis

Documentary analysis is used to analyse written sources about the phenomenon of interest, requiring rigorous adherence to research standards and ethics. Documentary analysis should crucially withstand the following tests:

- authenticity - to ensure that evidence is genuine and from impeccable sources;
- credibility - to ensure that the evidence is typical of its kind;
- representativeness - whether the documents consulted are representative of the totality of the relevant documents; and
- meaning - whether the evidence is clear and comprehensible.

The internet increasingly provides easy access to data; therefore it is crucial to apply quality testing to literature. Whilst documentary analysis is relatively easy and cheap to undertake, the burden lies on the researcher to establish its authenticity and credibility (Mogalakwe, et al., 2006). For example, government publications and official statistics may initially seem credible and an attractive data source, however the extent to which documents can be accepted as factual, objective and authoritative is questionable (Denscombe, 2012).

3.3.2.2 Qualitative content analysis

Qualitative content analysis analyses and draws meaning from interviews. The technique involves manual textual analysis to find detail and depth in interviews (Forman and Damschroder, 2008). Research focuses on conversational language, with particular attention to content, meaning and context (Hsieh and Shannon, 2005). Alan Bryman's four principals

of detailed thematic analysis are: text analysis, coding and categorising salient terms, theming codes together, and writing a report (Gibbs, 2011). Whilst specific training is unnecessary, incorrect coding is highly problematic, leading to misinterpreted findings if not addressed. Overall, the meticulous and iterative analysis process can be time consuming, particularly if there are open, semi-structured or large volumes of interviews (Royse, 2008).

3.3.2.3 Business Process Modelling

Business Process Mapping (BPM) also known as Business Process Analysis is a modelling technique using graphical presentation to define a business process. Hungerford et al. (2004) reason that diagrammatic representations of complex processes are better suited than text-based representations. BPM enables the comprehension, investigation and evaluation of complex business processes for process efficiency and effectiveness; subsequently allowing redesigned processes for improved outcomes (Biazzo, 2000). Whilst process modelling is a highly useful exercise, disadvantages can lie in too much time spent in unnecessary over-analysis, referred to as ‘paralysis by analysis’ (Sharp and McDermott, 2001); furthermore, experienced Process Analysts can bring pre-conceived bias, leading to semi-predetermined outcomes, as opposed to fresh creativity (Kesari et al., 2003).

3.3.2.4 Time-Series Intervention Analysis

Time-Series Intervention Analysis is a statistical technique for testing intervention impacts over a time period. The method is characterised by data comprising equally spaced observations (dependent variable) before and after an intervention. The pre-intervention period data is classified as baseline data, post intervention data constitutes the intervention stage, whilst a group of control variables (independent variables) can isolate parts of the series from impact stemming from the intervention (Huitema et al., 2014). Time Series Analysis helps to determine intervention effects over a time period; but problems can arise if data is improperly collected, maintained and documented which can undermine the integrity of base

data. Also, results can be exaggerated if there is limited data before or after the intervention (Yaffee, 2000).

3.4 APPLICATION OF RESEARCH METHODS

This section details how the data collection and analysis methods described in Chapter 3.3 were used to address each objective in turn.

3.4.1 REVIEW OF RELATED WORKS ON MANAGING RWSW

Objective 1 focused on reviewing and analysing related literature on the general management of RWSW. A qualitative approach was adopted which involved comprehensively examining literature (see Chapter 3.3.1.1) from different sources including, academic literature, government reports and studies, internet searches and industry reports. Academic literature was primarily sought through the Science Direct, Ingenta, Scopus, and Google Scholar databases.

Whilst Chapter 2 presents a broad state-of-the-art literature review of RWSW management around the world, a more in-depth literature review and documentary analysis was required to explore RWSW policy management. Accordingly, literature analysis involved examining highway management and utility management, as well as RWSW management which linked the industries and was the focal research point. The findings from this review can be found in Chapter 4.1. Figure 3.3 depicts a Venn diagram showing the research areas and their overlaps.



Figure 3.3 Venn diagram for research Objective 1

3.4.2 ESTABLISH CURRENT WORKING PRACTICES IN RWSW INDUSTRY

Objective 2 sought to build on findings of the state of the art literature analysis conducted in Chapter 2, by investigating how the industry currently operated. This required qualitatively investigating existing RWSW industry working practices, which involved examining the inter-relationships between the HA and SU as highway works executors/work promoters, and the SA as the works regulator. Figure 3.4 depicts the areas of interest for this objective and how they overlap. To help establish current working practices, a two-stage approach was adopted. Firstly, the EToN IT system was examined, as it is a core data transfer system used by almost all the industry; secondly, a stakeholder study provided direct information about current working practices.



Figure 3.4 Venn diagram for research Objective 2

EToN is a critical and central tool for the SA to interchange planned/ongoing highway works Notices/Permits, to improve coordination and cooperation of highway works (DETR, 1999) (See Appendix A). Notwithstanding the technical EToN software specification, there was little other literature about the system and its coordination role. Therefore, an exploratory qualitative approach investigated EToN, through semi-structured interviews with stakeholders (see 3.3.1.2). Interview questions are attached in Appendix E.

As DCC enjoyed regular meetings with regional SUs, accordingly convenience sampling was adopted to invite participants for the EToN study at one of these meetings in 2013. Firstly a presentation was made to eight members, representing seven SUs about the purpose of the study and the involvement sought, this was followed by sending email invites to the eight attendees along with a participant information sheet documenting the purpose and intent of the study. Of those invited, six SUs agreed to participate in the study, which led to a total of 15 utility interviewees participating in the study through snowball sampling - two of the interviewees also had dual roles of representing both utility companies and having senior management roles in HAUC. Additionally, as an EToN user, one participant from the host

authority was also interviewed (convenience sampling), as well two representatives from central government (purposive sampling). The EToN study was found to be a very compelling source of data because it not only informed of EToN processes and functionalities, but also uncovered industry attitudes and cultures. Therefore to investigate current RWSW working management practices further, a second stage of interviews was proposed (see interview questions in Appendix F). Accordingly ten further interviews were undertaken with LAs, utility industry financial regulators and business representatives; these interviewees were targeted because they were considered to be significant actors in RWSW management as detailed in Chapter 1.5.2 Different approaches were adopted to target potential interviewees as follows:

Government - LAs were targeted through snowball sampling, based on recommendations from other interviewees and purposive sampling was used to target specific LAs regarded highly for RWSW. Convenience sampling was used to contact neighbouring LAs as these were geographically close. Accordingly an additional five LAs were contacted, of which two agreed to participate with a total of four participants.

Utility regulators - all three English regulators representing the energy, water and telecommunications utility industries were contacted, however only one agreed to participate, comprising two interviewees.

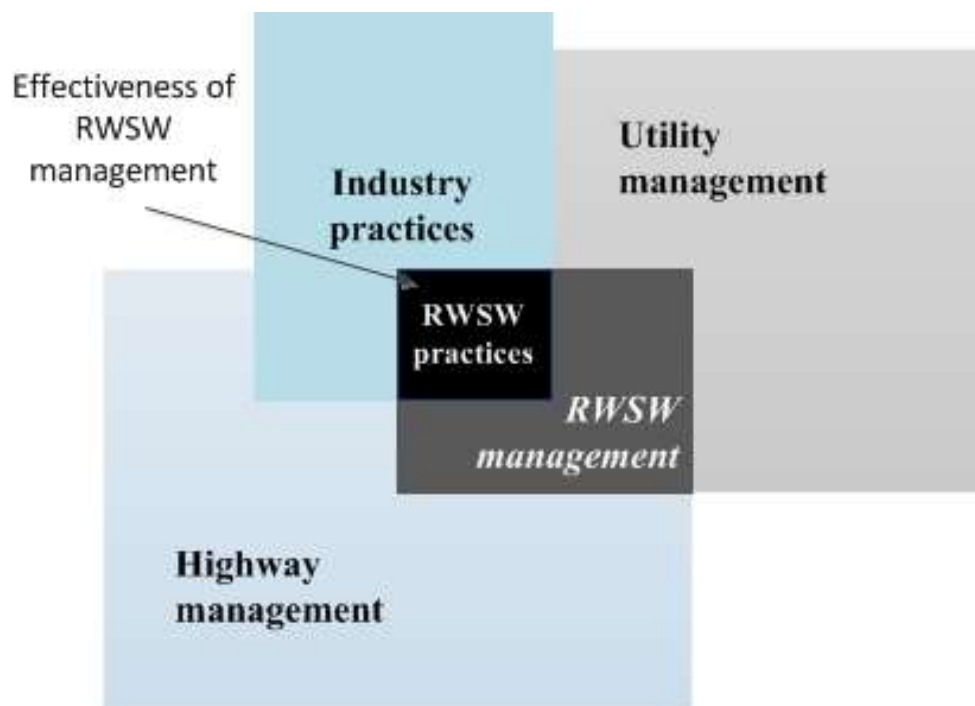
Business and public representatives – these were targeted through convenience sampling based on geography in order to minimise costs. Of the total of five organisations contacted, only two agreed to participate, comprising four interviewees. Table 3.2 provides a breakdown of the interviewees. Detailed analysis of the interviews was undertaken using qualitative content analysis (see section 3.4.1.2), and described further in Appendix B.

Table 3.2 Breakdown of interviewees for stakeholder scoping study

<i>Group</i>	<i>Subgroup</i>	<i>Number of organisations</i>	<i>Interviewee Codes</i>	<i>Number of interviewees</i>	<i>Interview stage</i>	
					<i>1</i>	<i>2</i>
Government	Central	1	NG1-2	2	✓	
	Local	3	LA2	1	✓	
				LA1, LA3-5	4	
Regulator		1	R1-2	2		✓
Utility	Electric	1	UE1-3	3	✓	
	Water	2	UW1-4	4	✓	
	Gas	3	UG1-3	3	✓	
	Telecoms	2	UT1-2	2	✓	
	Miscellaneous	1	UM1-2	2	✓	
	Industry representative	1	UR 1	1	✓	
Business and Public	Business	2	B1-2	2		✓
	Public	1	P1-2	2		✓
Total interviewees				28	18	10

3.4.3 ASSESSING THE EFFECTIVENESS OF LOCAL RWSW MANAGEMENT

Objective 3 specifically focused on assessing the effectiveness of RWSW management locally as shown in Figure 3.5.

**Figure 3.5** Venn diagram for research Objective 3

A quantitative approach was adopted as it provided a quantifiable and robust way of measuring effectiveness. To meet this objective, the impact of key policy interventions recently introduced by DCC were measured. The investigation primarily focused on the Permit Scheme (introduced in October 2013 and considered superfluous by SUs – see Appendix B). The scheme sought to encourage work executors to better plan future highway works to mitigate their negative impacts through improved coordinated working.

Simultaneously the scheme sought to enable SAs to improve management and coordination of highway network activity (DCC, 2013). The following policy interventions were also tested:

- Works Order Management system (WOMS) – introduced in October 2011, to automate the works management paper-based process;
- JCB Pothole Master - purchased and introduced in August 2013, to accelerate pothole repairs; and
- Direct Labour Organisation – introduced in September 2013, by bringing in-house construction operations for financial savings.

The assessment of these interventions was considered important to determine if their introduction had reduced RWSW works durations, as a proxy for improved RWSW management (see Appendices C and D) (see Chapter 1 for research problem). To conduct this study primary, secondary and tertiary data was collated (see 3.3.1.4), as detailed in Table 3.3.

Table 3.3 Data collection for Time Series Analysis Study

<i>Variable Type</i>	<i>Variable</i>	<i>Variable Description</i>	<i>Variable format/unit</i>	<i>Source</i>	<i>Data type</i>
Dependent variable	Average works per month	Total volume of works/total duration of works/	Count/days	DCC reports	Primary
Intervention variable	Regime	Type of management regime - Notice or Permit Scheme	Binary/(0/1)	DCC	Primary
Intervention variable (HA model only)	Works Order Management System (WOMS)	Works Order Management System – Manual or real time electronic system	Binary/(0/1)	DCC	Primary
Independent variable	Gross Domestic Product (GDP)	An indicator of economic activity. Based on household final consumption expenditure - ‘current price’ (CP) per month (£ million)	Ratio	(Office for National Statistics (2015a))	Tertiary
Independent variable	Construction industry output (overall)	An indicator of economic activity. Money spent on constructing new housing, infrastructure and ‘other’ works – commercial and private per month in UK (£ million)	Ratio/£-GBP	Office for National Statistics (2015b)	Tertiary
Independent variable	Construction housing output	An indicator of economic activity. Money spent on new public and private housing per month across UK (£ million)	Ratio/£-GBP		Tertiary
Independent variable	Construction infrastructure output	An indicator of economic activity. Money spent on public and private (industrial and commercial) infrastructure per month across UK (£ million)	Ratio/£-GBP		Tertiary
Independent variable	Daylight hours	An indicator of working conditions. Number of hours of daylight per day (hours: mins)	Count/hours	Weather Channel (2005)	Secondary
Independent variable	Air temperature	An indicator of working conditions. Mean air temperature over month - °C	Ratio/Degrees Celsius	Met Office (2015a)	Secondary
Independent variable	Precipitation	An indicator of working conditions. Based on amount of rain fallen – mm	Count/millimetres	Met Office (2015b)	Secondary
Independent variable	Vehicle miles travelled	Distance travelled on all roads in UK by all classes of vehicles per year (billion miles)	Count/miles	DfT (2015)	Tertiary
Independent variable	School holidays	An indicator of road activity. Based on the proportion of school holidays over week days per month	Count/%	DCC (2015a)	Primary
Independent variable	Christmas restrictive period	An indicator of a period of typically low excavation activity and high traffic volumes between mid-November and early January over Christmas period	Binary/(0/1)	DCC (2015b)	Primary

To analyse this data, ARIMA time series models were developed to examine the HA and SU works impacts on described interventions (see Chapter 3.4.1.4 – Time Series Analysis). Specifically the models tested the impact of interventions on highway works duration (dependent variable). The time series model can be defined as:

$$y_t = f(X_t, I_t) + N_t$$

In which t is the discrete time (i.e month), y_t is the appropriate Box-Cox transformation of Y_t , say in Y_t , Y_t^2 or Y_t itself (Box and Cox, 1964), Y_t is the dependant variable (i.e the mean duration of each works activity) for a particular time, $f(l,X)$ is the deterministic part of the model which contains the intervention component (I) and the deterministic effects of independent control variables (X) and N_t is the stochastic or noise component.

The random component (N_t) follows an autoregressive integrated moving average (ARIMA) model that is normally denoted as ARIMA ($p.d.q$) model in which p is the order of the non-seasonal autoregressive (AR) process, d is the order of the non-seasonal difference, q is the order of the non-seasonal moving average (MA) process. The ARIMA model can be expressed as (Box et al., 1994):

$$\phi(B)(1 - B)^d N_t = \theta(B)u_t$$

In ϕ is the regular AR operator, θ is the regular MA operator, B is the backward shift operator, and u_t is an uncorrelated random error term with zero mean and constant variance (σ^2). The seasonal version of the models and their details can be found in Box and Cox (1964).

The intervention function is defined as:

$$f(I_t) = \mathcal{G}_0 I_t$$

where \mathcal{G}_0 is a constant, and I_t is the intervention variable which takes a value of 0 for every month before the implementation date (i.e. t') of the policy intervention and a value of 1 for every month thereafter, i.e.,

$$I_t = \begin{cases} 1 & \text{for } t \geq t' \\ 0 & \text{elsewhere} \end{cases}$$

Therefore, the full ARIMA model can be presented as follows:

$$y_t = \mathcal{G}_0 I_t + \beta X + \frac{\theta(B)u_t}{\phi(B)(1-B)^d}$$

Individual SU and HA ARIMA models were developed and tested with the Permit Scheme intervention. However, as discussed, the HA model was additionally affected by three other interventions, namely the introduction of WOMS (October 2011), the purchase of a JCB Pothole Master (August, 2013) and new DLO for internal highway construction works (September, 2013). However, as the former two interventions occurred within two months of the Permit Scheme, the timings were considered too close to the Scheme, which meant their inclusion could cause model distortion, causing difficulty in confidently attributing impact appropriately. In the circumstances, only the Permit Scheme and WOMS interventions were tested in the HA model.

The dataset comprised 6.5 years of data commencing October 2009 on Permit applicable streets (traffic sensitive streets), constituting approximately 20% of Derby's roads (DfT, 2012). The ARIMA model analysis process entails the identification, estimation and diagnosis of data (Tabachnick and Fidell, 2006) – (see Appendix D for more detailed information). A number of independent variables were used as control variables in the model to represent externalities which could individually affect the dependent variable's performance (see Table 3.2). A time series regression model should have at least 50 observations for more reliable results (Chatfield, 2004); this study tested up to 78 monthly observations.

3.4.4 BUSINESS PROCESS RE-ENGINEERING OF ROAD WORKS PROCESSES AT DERBY CITY COUNCIL

Objective 4 required the development of business process maps and the identification of challenges and opportunities for improved RWSW management in the sector, as shown in Figure 3.6.

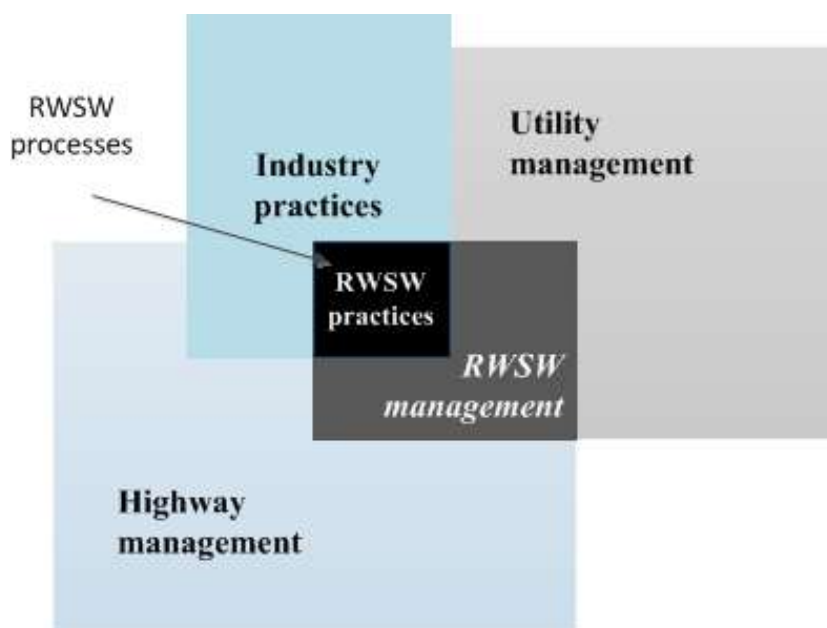


Figure 3.6 Venn diagram for research Objective 4

Accordingly, to meet this objective the study focused on how DCC's existing road works management practices could be enhanced. This study was motivated by:

- the stakeholder study – stakeholders reported that efficient internal processes often led to efficient on-site works (see Appendix B); and
- time series analysis study – the study identified that process automation through WOMS (detailed in Chapter 4.3) was highly successful in reducing RWSW durations (see Appendix D).

Both examples link efficient business processes in reducing RWSW impact. Therefore it was considered that assessing the business processes of DCC through business process mapping (see Chapter 3.4.1.3) would help to improve the effectiveness of managing RWSW. This objective was executed in two stages: literature analysis and process mapping.

A two part literature analysis was conducted (see method in Chapter 3.3.1.1); firstly the role of business process re-engineering (BPR) was investigated to investigate the opportunities and barriers to change, and the role of change management. The review also analysed BPR

techniques, which found that BPM was highly effective in interpreting complex business processes; this enabled both efficiency and effectiveness evaluations to be undertaken, underpinning re-designed processes with improved outcomes (Biazzo, 2000; Hungerford et al., 2004) (See Appendix A).

The subsequent literature exploration investigated state of the art process mapping techniques.

Table 3.4 details the advantages and disadvantages of process mapping techniques examined.

Table 3.4 A comparison of BPM techniques

<i>Technique</i>	<i>Advantages</i>	<i>Disadvantages</i>
Flow charts – a graphic representation of a logical sequence of work	<ul style="list-style-type: none"> • Flexible • Process can be described in wide variety of ways • Easy to recognise the processes described • Easy to process • Good for low level plans • Allow sub-processes 	<ul style="list-style-type: none"> • Too flexible • Boundaries of the process may not be clear • Can get too big and unruly • No difference between main and sub-activities which can make charts hard to read • Not easy to identify actors or departments
Data Flow diagrams – diagrams showing data flow through a process linked by data stores	<ul style="list-style-type: none"> • Suitable for sequential representation of information flow • Processes can be broken into sub-processes • Shows how information enters and leaves process • Shows where information is stored 	<ul style="list-style-type: none"> • Shows flow of data and not materials involved • Shows data flow as opposed to work flow • Can be cumbersome in representing large systems
IDEFO – a structural graphical representation with input, output, control and mechanism related to each activity	<ul style="list-style-type: none"> • Very popular technique and widely used • Hierarchical structure facilitates quick mapping at high levels • Strict rules 	<ul style="list-style-type: none"> • Can be overly complicated for simple processes • Can be misinterpreted as representing a sequence of activities • Shows ‘what’ is done rather than ‘how’ it is done • Can be difficult to interpret
Entity relationship diagrams – graphical presentation of entities and relationships within a process	<ul style="list-style-type: none"> • Shows relationships between entities, and the attributes thereof • Multi-level views enable greater detail • Visualises business data 	<ul style="list-style-type: none"> • Does not provide information about dataflow or workflows • Does not define a process
HIPO (hierarchy plus input-process-output)	<ul style="list-style-type: none"> • Shows high level information • Useful for early and overview system design • Identifies procedural flow from input to output 	<ul style="list-style-type: none"> • Difficult to interpret if several steps • Not suitable for complex systems • Does not show how a system works
Swimlane analysis – graphical presentation of rows of actors and the movement of workflows	<ul style="list-style-type: none"> • Easy to read • Enables sub-processes • Little training required to read or design • Easier to identify bottlenecks • Simple symbols 	<ul style="list-style-type: none"> • Shows sequence of activities as opposed to data flow

Sources: Aguilar-Saven, 2004; Chen, 1976; Davis and Yen, 1999; Damij, 2007; Durugbo et al., 2011; Jacka and Keller, 2009; Linfeng et al., 2011; Sharp and McDermott, 2001; Thalheim, B., 1998.

Amongst those reviewed, Swimlane diagrams were most appropriate because they permitted detailed, complex and multi-actor processes, reflecting DCC's processes. Additionally, the maps were easy to read and interpret, recorded decision points and enabled documentation of sub-processes, which was crucial. Swimlane diagrams highlighted process interconnections, with specific regard to actors, and the roles they performed. Consequently, each swimlane represents a 'role' and the resulting process map helped identify gaps and inefficiencies in existing processes (see Appendix A).

The second stage involved process mapping which was facilitated through talking to process experts. 'Experts' constituted those with interpretative and technical process orientated knowledge (Miles and Huberman, 1994), accordingly process expertise was sought from those individuals who undertook process, and were thus intimately familiar with the tasks, as opposed to managers, who may have restricted process awareness. The teams selected for the study were Highways Maintenance (HM), Highways Engineering (HE) and Network Management (NM) teams, as these teams were directly involved in undertaking or facilitating road works. Snowball sampling enabled group managers for each team to select two process experts each in order to document the process. Accordingly, the following experts were selected:

HM team - a clerical member of staff, and a Highways Inspector were selected, from a pool of two clerical staff and four Highway Inspectors.

HE team – two Highway Design Engineers were selected from a pool of five design engineers and three technicians.

NM team – one clerical member of staff and one team manager were selected of an entire team of three people.

Semi-structured interviews (see Chapter 3.3.1.2) were conducted in a workshop format where participants helped to record existing processes. With the exception of the HE team, there

were different levels of seniority amongst the teams; however, this did not create any bias as the experts reported factually on the process parts relevant to the individual.

Processes were recorded from design stage to Permit issuing stage. Processes were recorded on large sheets using sticky labels, whilst any additional comments were manually recorded, and subsequently analysed using qualitative thematic analysis (see Chapter 3.4.1.2). Participants were encouraged to elaborate on related issues or problems which undermined the overall process. Swimlane mapping was subsequently used to document the 'as is' processes, which underwent an iterative checking/amendment cycle with interviewees to ensure accurate representation (See Appendix E). The graphical depiction of the complex processes enabled the clear visibility of actors, their interconnections, bottlenecks, duplications and inefficiencies. Based on guidance by Sharp and McDermott (2001) a detailed procedure then began to review the existing processes which involved reviewing each decision point to examine what value it added to the process and to identify leverage points, whereby small shifts could lead to big changes. Sharp and McDermott (2001) also recommend assessing processes by overarching enablers which comprise workflow design, IT, motivation and measurement, Human Resources (HR), policies and rules and facilities. Table 3.5 identifies examples of attributes to consider in each enabling category; for example when considering workflow design, are there too many actors or handoffs? Does this mean the process yoyos unnecessarily between staff? These considerations identified tend to be associated with a poorly managed process.

Table 3.5 Reviewing 'as is' processes by considering enablers

<i>Enabler category</i>	<i>Considerations when examining process</i>
Workflow Design	Are there too many actors/handoffs? Does the data yoyo between staff? Are there duplications/non-value adding step? Are there bottlenecks?
IT	Is information unavailable/ is there a lack of shared data? Are there duplications? Is there inconsistent formats/structures or semantics Are staff reconciling different information sources
Human resources	Are the right people, with the right skills, in the right jobs performing the right tasks? Are skills matched to job? Do staff have the right training?
Policies and rules	Why do we request 3 bids for values more than £1000? (It could cost more to solicit, review and select from bids) What are the constraints or requirements that impact on the conduct of the business or work flow?

Further to this, 'to be' processes were developed with improved processes and practices taking into account participant feedback (see Appendix F). The findings are detailed in Chapter 4.4 and Appendix A.

3.4.5 PROCESS VALIDATION AND LOGIC MAP DEVELOPMENT

Objective 5 required the validation of the 'to be' process maps for their effectiveness, and the development of a logic map for the administrative management of RWSW to benefit other LAs (see Figure 3.7). It was felt that to enable effective evaluation, a qualitative approach would enable rich and comprehensive feedback, subsequently supporting the development of a logic map.

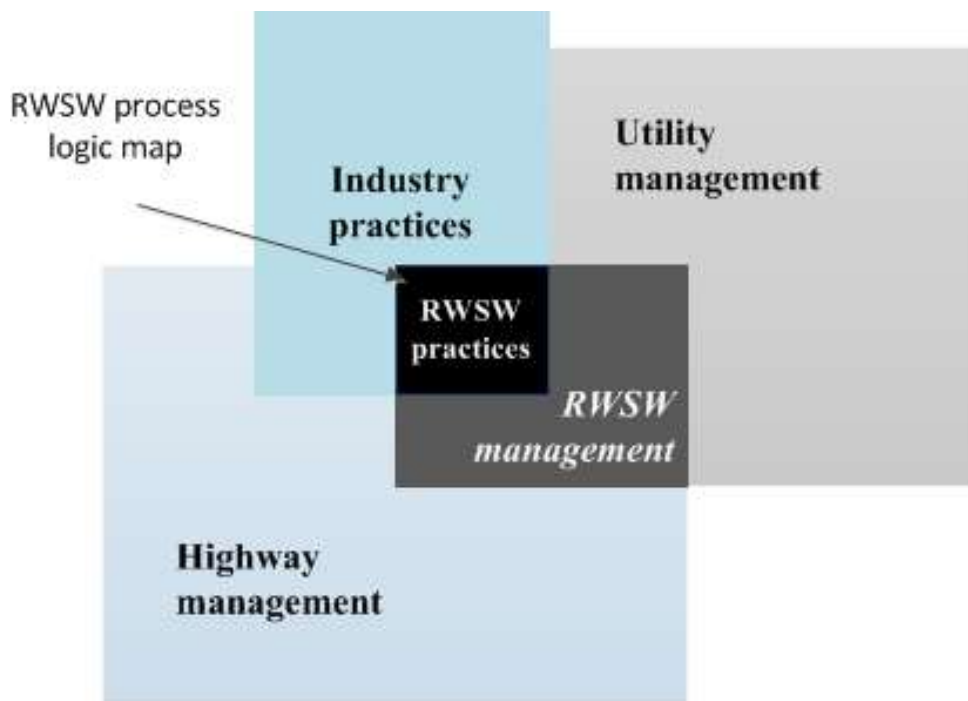


Figure 3.7 Venn diagram for research Objective 5

Validation took place through focus groups (see Chapter 3.3.1.3) and semi-structured interviews (see Chapter 3.3.1.2) where interviewees could not attend the focus group. Convenience and purposive sampling was used to invite middle and senior Highways Managers from eight LAs (constituting neighbouring LAs, or LAs regarded highly for road works management), and representation from the Highways Authority and Utilities Committee (HAUC). Three LAs and a senior HAUC member agree to participate in the study. Accordingly, the validation group was made of six DCC managers, one Highways Manager from a neighbouring LA, one Highways Manager from a rural County Council, who also was a senior member at HAUC England, and also another Senior HAUC member who also held a position at NJUG, therefore also representing a utility.

Process validation was undertaken by highway management experts to benefit from their experiences and broader overview of managing RWSW. ‘Experts’ constituted those with interpretative and technical process orientated knowledge (Miles and Huberman, 1994). The meetings aimed to discuss the ‘to be’ proposals and exchange ideas about their value and their workability. The focus group was held at DCC’s office and moderated by the RE, whilst

interviews took place on interviewee premises. Session findings were recorded using qualitative content analysis (see Chapter 3.4.1.2). Stakeholder feedback was accommodated, and where appropriate, ‘to be’ maps were amended accordingly.

Finally, a logic map was developed for potential transferability to other LAs. Logic maps are a graphical representation of how an organisation’s, processes or strategies should work, typically incorporating the underlying context, principals, and activities/practices necessary for short, medium and long-term outcomes (Knowlton and Phillips, 2013; WK Kellogg Foundation, 2004). A logic map is a road map for focusing on key and overarching system attributes and can be used for internal management functions and performance-based management processes (McLaughlin and Jordan, 2004). The logic map was based on findings from this study, validation exercises and academic literature. Specifically, it considered the key processes in road works management, and identified the key inputs required, leading to key activities, and the support required, as can be seen in Chapter 4.5 and Appendix A. The process map was validated by 3 industry experts and amended based on their feedback.

3.5 SUMMARY

This chapter discussed the methodology and methods adopted for this EngD research project. First, it reviewed different research methodologies, discussed the research design, described specific methods adopted, and detailed their application. Chapter 4 will describe and discuss research findings.

4 THE RESEARCH UNDERTAKEN

This chapter presents research undertaken to meet the EngD aim and objectives, detailed in Chapter 1, in accordance with the methods provided in Chapter 3. The chapter is structured to address objectives sequentially; each objective provides study context, reports key findings, discussion, conclusion with recommendations, and concluding with a ‘check point’ box which provides a snapshot of how the project has contributed new insights to RWSW management knowledge, or contributed to addressing the research problem as described (see Chapter 1).

4.1 OBJECTIVE 1 – REVIEWING RELATED WORKS ON RWSW

To meet objective 1 of reviewing related work on managing RWSW, the RE was immersed in the host company and attended various conferences and training courses. Additionally, literature research on RWSW management was conducted in order to document the current knowledge and state of the art on the subject matter as detailed in Chapter 2. Furthermore, the RE kept up to date on industrial developments through a review of industry articles including Surveyor, Local Transport Today, Highways Magazine and Utility Week.

4.1.1 THE UTILITIES INDUSTRY AND HIGHWAY MANAGEMENT

As a starting point for the research, the RE investigated the key industry players in RWSW management. In accordance with the method described in Chapter 3.4.1, a literature analysis helped to identify the role, purpose and motivations of SUs. This was important because almost half of RWSW are conducted by SUs (see Appendix C), although little was known about their industry; therefore knowledge was sought on how their industry and backgrounds impacted on managing RWSW, as this could help to reduce RWSW impacts.

4.1.1.1 Context

HAs and SUs are directly involved in highway construction works, and thus key contributors to the research problem (see Chapter 1). Accordingly the RE sought to build a brief and

succinct background picture of the utility industry through undertaking a documentary analysis to explore their policy landscape. The focus of this investigation was to learn about the basic construct of the utility sector, their history, motivations, and their role in RWSW management. This exercise was considered important as it formed a basis for providing an insight of the actors, which would help the RE contextualise their approaches to RWSW management for the remainder of the study. Figure 4.1 shows some key organisations directly involved in the RWSW management industry, to demonstrate industry scale.

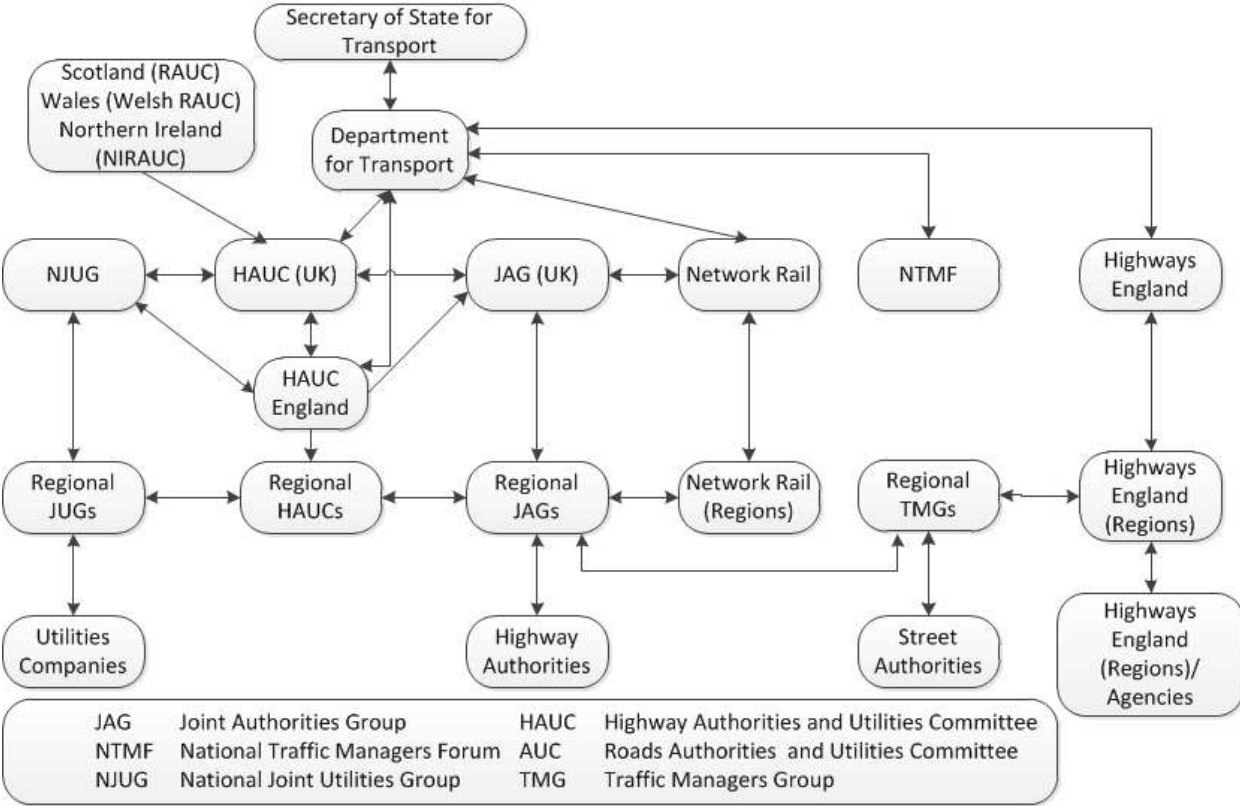


Figure 4.1 Diagram of the organisations directly involved in RWSW management. Source: Kent (2016)

4.1.1.2 Findings

Literature research about the RWSW industry operations (see method in Chapter 3.3.1.1) provided key insights into the industry actors’ rationale, their commercial positioning and their motivations. In turn, this subsequently helped to draw connections and deduce meanings between actors, operations and how RWSW are managed, which are detailed in the discussion

in Chapter 4.1.1.3. In the first instance, it is important to draw attention to the ‘big issues’ that became apparent as follows:

- **Privatised industry** – British utility industries were privatised from the late 70’s, and thus are profit driven industries (Feigenbaum et al., 1998). The changeover from public to privatised mean that LA’s public serving interests are adversarial to SU’s profiteering interests. Therefore, the occurrence and frequency of utility works are inadvertently motivated by the SU’s financial interests.
- **Monopoly utilities** – The specific transmission and distribution of energy (gas and electricity), and the entire water industry operations are competition-free; whereby infrastructure ownership is monopolised either nationally or regionally by private corporations (Bailey, 2003; Simmonds, 2002b; Simmonds and Bartle, 2004). On-street this means that specific monopolised water, gas or electric companies are responsible for supplying and maintaining infrastructure, thus only these individual companies execute works in each geographic region. Monopoly SUs are helpful in managing RWSW because they reduce the number of organisations who would need to excavate the highway.
- **Free market utilities** - The telecommunications (telecoms) industry operates in a ‘free market,’ whereby there are no monopolies, thus the competitive market conditions control prices, allowing countless telecoms companies to install apparatus in a geographic area (Newberry, 2001; Pye et al., 1991; Stern, 2016). Whilst free market conditions provide consumers with choice to choose suppliers, on-street it means that several telecoms companies can have independent infrastructure in any given street, which inadvertently increases volumes of utility cuts. It further congests the underground with utility apparatus, which already span several millions of miles (see Chapter 2.2.1 Asset locational technologies), creating greater risk for utility

strikes. Indeed telecoms infrastructure is most vulnerable to accidental utility strikes (Metje et al., 2015); repairs can inadvertently compound RWSW.

- **Highly regulated industry** - The monopoly utility industry is highly regulated to ensure SUs provide consumers best financial value and high quality service. SUs are heavily financial scrutinised, whereby financial regulators control release of subsidy payments, conduct regular pay reviews, prescribe maximum limits on customer charges, regulate infrastructure spends and control customer response timescales (Lawrence, 2002). The regulators also have powers to direct SUs to undertake asset maintenance works, eg. replacement of metallic gas pipes with polyethylene plastic pipes as required by the energy regulator (Dodds and McDowell, 2013), leading to increased street works. Consequently, this demonstrates that regulators are powerful and significant, and indirectly influence street works, yet in practice, little evidence supports this. Given the impact that regulators have on on-street RWSW, this highlights whether regulators should be directly involved in RWSW strategic discussions such as through HAUC or NJUG. Table 4.1 details the various regulators and their function or interest across the utility industry.

Table 4.1 Utility regulators

<i>Industry</i>	<i>Regulatory Body</i>	<i>Function or Interest</i>
Water	Water Services Regulation Authority (OFWAT)	Economic regulator of the water and sewerage industry in England and Wales
	Drinking Water Inspectorate (DWI)	Drinking water quality regulator
	Environment Agency (EA)	‘Raw’ water quality regulator – concerned with underground water, marine and estuarial waters
	Health Protection Agency (HPA)	Safeguarding public health
	Natural England	Biodiversity, wildlife and natural sites
	English Heritage	Works near scheduled monuments and registered historic parks
	Local authority – Environmental Health Teams	Environmental protection within local authority areas
	Consumer Council for Water	Consumer interest
Electric	Office of Gas and Electricity Markets (OFGEM)	Economic regulator
	Competition Commission	Prevent abuse and market dominance
	Department of Environment, Food and Rural Affairs (DEFRA)	Energy efficiency and air quality
	Environment Agency	Pollution prevention regulator
	Department for Trade and Industry (DTI)	Planning policy and construction consent for power stations and overhead electricity lines
	Health and Safety Executive (HSE) and Department of Trade and Industry (DTI)	Health and safety
	Energywatch	Consumer interest
Gas	Office of Gas and Electricity Markets (OFGEM)	Economic regulator
	Competition Commission	Prevent abuse and market dominance
	Department of Energy and Climate Change	Environment reporting and regulation, offshore installations and pipelines, exploration and production
	Environment Agency	Pollution prevention regulator
	Health and Safety Executive	Health and safety
Telecom’s	Office of Communications (OFCOM)	Financial and competitions regulator

Sources: Department of Energy and Climate Change (2014), Simmonds (2002a), Simmonds (2002b), Thames Water (2014a)

In terms of overall RWSW management, several attempts have been made over the last 80 years to standardise and control both HA and SU practices, to improve overall highway works management. Consequently, numerous studies, working groups, practices and legislative tools have been enacted, as detailed in the timeline in Figure 4.2 (See Fisher, 2012, for more information).

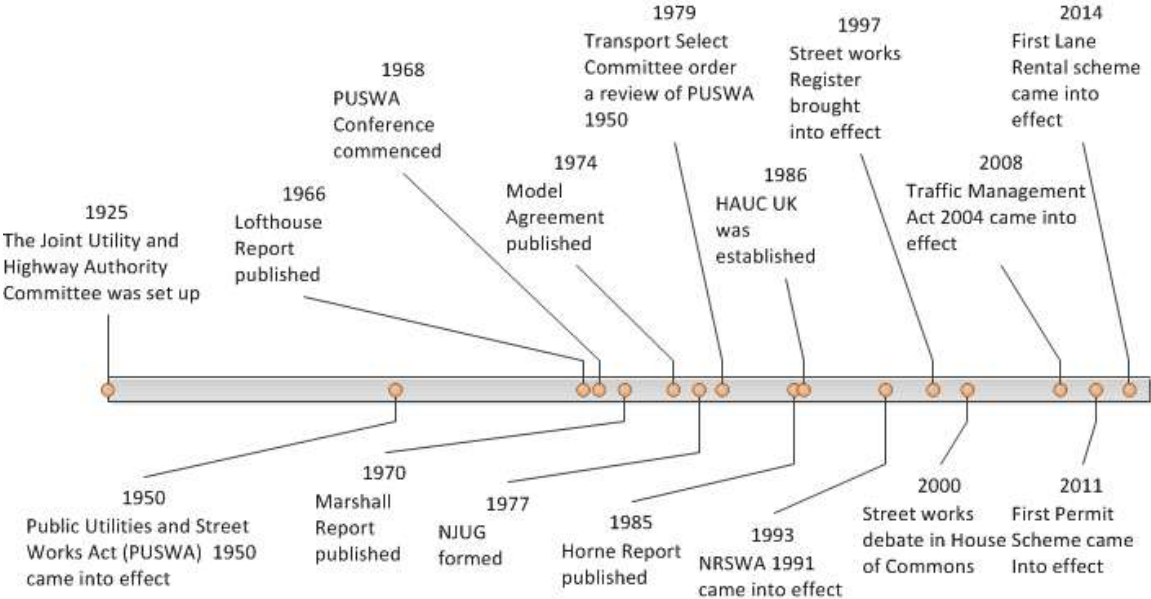


Figure 4.2 Timeline of RSW management policy. Source: Adapted by Fisher (2012)

In summary, the key lessons learnt were that the privatised monopoly utilities and free market telecoms companies now enable over 150 utilities to break open the highway, creating unprecedented levels of highway disruption (House of Commons, 2013), (see Chapter 1.1 - which needs to be managed by the SA to address the research problem (see Chapter 1.1). Additionally, highway maintenance works undertaken by the HA create additional pressures as detailed in Chapter 1.5.

4.1.1.3 Discussion

Utilities are motivated in different ways depending on the market they operate in, but, ultimately their goal remains financial gain. Regulated companies are driven by regulator timescales; failure to comply with strict timescales could mean financial losses which are undesirable for shareholders. Furthermore, whilst telecoms companies are not financially regulated (Stern, 2016), efficient works execution remains important to overtake competition. Consequently, there are clear business advantages of executing works expeditiously in monopoly and free markets. Therefore faster execution of SU works is likely to be more

important than the overall coordinated management of RWSW; contributing to the seemingly high volumes of RWSW, and thus the research problem (see Chapter 1.1).

This study was important because it provided critical insight into the utility industries which frames the historical and current context which may influence their operations today. This study also highlighted that the SUs' profit motivated nature was adversarial to the LA's public service nature; which indicates that SUs are highly likely to execute works to provide greatest financial advantage, over traffic considerations.

CHECKPOINT!

This literature based desk-top study has established that UK utilities are primarily profit driven enterprises and are pressured by high levels of regulation. As a result of their profit driven nature, utilities are not primarily motivated to work together for the betterment of traffic management. Instead, utilities are driven to execute works quickly to either meet regulator timescales (monopoly industry) or for competitive advantage (free market); this means that their operations can lead to high volume of highway works, undertaken in an uncontrolled or uncoordinated manner.

4.2 OBJECTIVE 2 – ESTABLISH CURRENT WORKING PRACTICES TO IDENTIFY RWSW INDUSTRY OPERATIONS

To provide insight into RWSW current working practices, objective 2 sought to establish current industry working practices by undertaking two studies (see methods in Chapter 3.4.2). Firstly, a scoping study was conducted to explore the EToN system, as discussed in Chapter 4.4.1. Secondly, a wider scoping study investigated current RWSW working practices, detailed in Chapter 4.2.2. Both studies sought to learn how existing working practices impacted RWSW management and are discussed further below.

4.2.1 INVESTIGATING THE ROLE OF ETON

EToN is a central and critical tool for SAs to interchange planned/ongoing highway works Notices and Permit applications with work promoters (HA and SUs). Consequently, a qualitative study (see Chapter 3.4.2) was undertaken to establish its effectiveness. The study involved semi-structured interviews with tactical and operational users to obtain dual perspectives about EToN operations.

4.2.1.1 Context

EToN was legislated under sections 59/60 of NRWSA 1991 – which oblige SAs to coordinate RWSW activity, and SUs to cooperate accordingly and respectively. EToN is mandatory for LAs, whilst SUs were motivated to adopt EToN to avoid charges for alternative submission methods (DETR, 1999). There are various timescales for submitting Notices/Permit applications, depending on the works category and stage (see Figure 4.3).

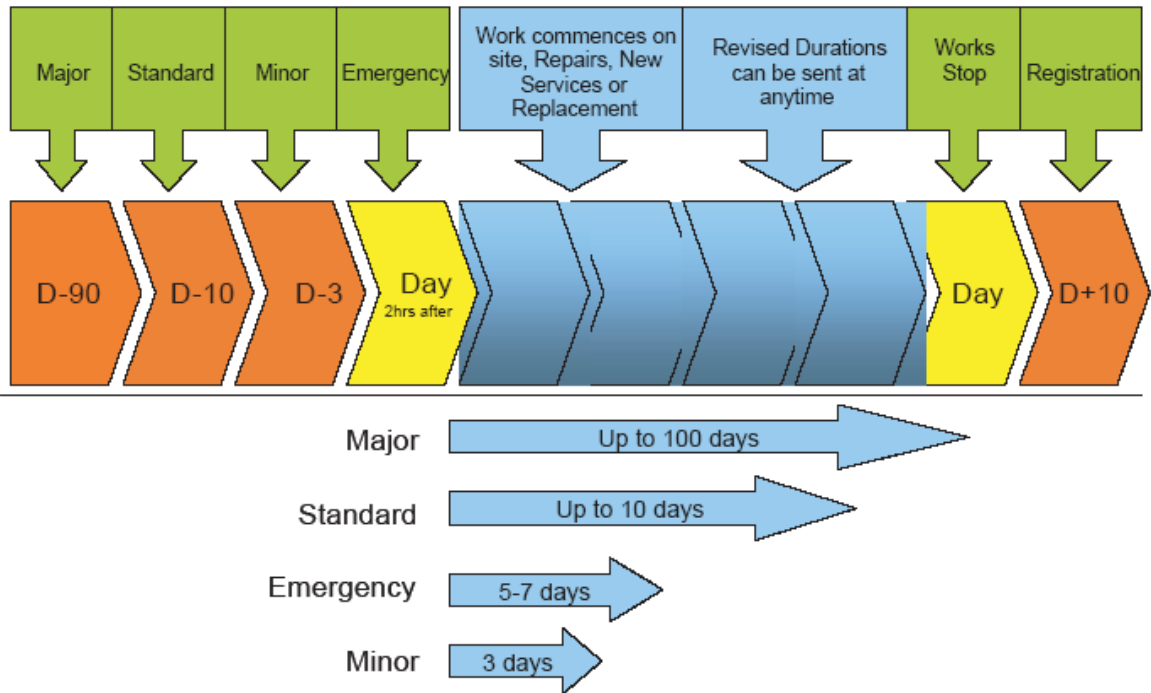


Figure 4.3 Timeline for submitting permit/notices for different categories of work. **Source:** Transport Select Committee HC (2012)

Besides the technical EToN system architecture specification, which alluded to its coordination role by citing enacting legislation, there was little other information about its role, scope or performance. Consequently, it was hard to determine how and how well EToN assisted coordination in practice. Therefore to explore the industry's working practices, a stakeholder study was executed to obtain user views on the EToN systems purpose, features and more. Further to the semi-structured interview method (including thematic analysis) described in Section 3.4.2, the purpose of the study was to explore organisational usage of EToN. Questions included volumes of Notices/Permits processed, aspirations from system, key users of systems, key functions, training, ease of use, strengths, weaknesses and limitations of system, and overall performance amongst others (questions detailed in Appendix E).

4.2.2.2 Findings

Whilst the full findings are appended in Appendix B, the following highlights provide useful insights:

- SUs submitted high volumes of Notices/Permit applications to various SAs. As specific Permit Scheme conditions were unique to individual LAs, geographical inconsistencies often led to mistakes being made by the SU, resulting in rejected permit applications; which incurred resubmission costs;
- The industry was heavily regulated with strict response timescales which took priority over minimising street works disruption;
- Some interviewees were unable to use their EToN system to see whether the organisation had already submitted other Notices/Permit applications for the same geographic area. Limited data access meant poor intra-organisational works knowledge, creating potential for duplicate excavations, instead of joint working;

- Where EToN identified ‘clashes’, works were typically re-scheduled prior to contacting the SA, instead of seeking coordinated working;
- Equally, it was common for SAs to ask SUs to re-schedule works due to ‘clashes’. In some cases, utilities were given names of organisations to arrange coordination with, however with individual officer information this became time consuming and thus highly undesirable; and
- SUs distinctly saw RWSW coordination as the SA’s responsibility; the SU’s role was simply to cooperate with such requests.

4.2.2.3 Discussion

The EToN study demonstrated that whilst the system was introduced to enhance coordinated working, in practice it was predominantly used simply as a mechanism to transfer Notices/Permits. The RE observed operational users typically being process driven, whereby they were keen to start and finish a each job quickly, before moving on to the next ‘job.’ Coordinating highway works was not considered a normal part of the utility interviewees’ job, training or psyche, and thus absent from their organisational culture. Although some SUs could see other organisation’s forthcoming works through EToN, this was seen as a ‘clash’ that needed to be avoided, rather than a coordination opportunity. In general there was little evidence of any regard for, or any consideration of, the RWSW impact on road structure or society when planning and programming works.

Tactical users of EToN reinforced that coordination was the LA’s responsibility, whereby SU’s were simply expected to cooperate with such requests, not drive them (see Appendix B). Overall, SUs were found to operate in complex, pressurised and time constrained industries, where their primary purpose was meeting their own core business aims; coordinating highway works was distinctly not their core business function, and thus a low priority.

The EToN study revealed system processes and functionalities, as well as uncovering cultural and attitudinal issues such as institutional reluctance to coordinate RWSW. The study reinforced the SU's profiteering nature, in preferring silo on-street working to meet regulator timescales instead of multi-agency working. As RWSW policy management is significantly under-researched (Tseng et al., 2011; Fisher, 2012), contemporary RWSW management challenges could not be placed, therefore, a more in-depth scoping study was required as detailed in Chapter 4.2.4.

CHECKPOINT!

HOW HAS THE STUDY HELPED TO UNDERSTAND THE RESEARCH PROBLEM?

This study has helped to reinforce the findings from objective 1. Overall the study has helped to understand that on the functional/administrative level, utility industry operators tended to be process driven with very little consideration of RWSW management. The utility interviewees assumed and expected SAs to manage their duty of coordinating RWSW, and thus focused on the delivery of their utility services. Opportunities to work together were seen as 'clashes' and were predominantly avoided instead of being seen as coordination opportunities.

Overall this study has shown that SUs and SAs were working in a fragmented manner and were not coordinating highway works as a matter of course.

4.2.2 STAKEHOLDER PERSPECTIVES OF RWSW MANAGEMENT IN ENGLAND

Given the insights the EToN study provided, a wider study was undertaken, seeking richer depth into the RWSW industry policy operations, and to obtain wider stakeholder perspectives, as this information was absent from extant literature. This was the second study for objective 2 (see Chapter 3.4.2).

4.2.2.1 Context

There are gaps in knowledge about RWSW management policy in general (Tseng et al., 2011; Fisher, 2012), and particularly stakeholder perspectives of RWSW management as identified in Chapter 2.2. Accordingly, this scoping study sought to consult industry experts on prevalent issues and practices in RWSW management, to obtain a holistic perspective of its impacts (refer to Chapter 3.4.2 for method followed).

4.2.2.2 Key Findings

Stakeholders were asked various questions to explore extant RWSW industry working, and general issues which affected organisational operations. Questions included topics such as the role of coordination, collaborative working, regulations, and performance amongst others. An associated journal paper is appended in Appendix B. The findings are detailed and categorised below into key drivers, barriers and opportunities for RWSW management.

Key drivers

Based on their role, interviewees were asked differing questions about their role in RWSW management, general RWSW management performance, industry context and about future aspirations (see Appendix F). Thematic analysis enabled key drivers to emerge which motivated stakeholders to acknowledge and seek to address RWSW management. Establishing these drivers is important as they can help to reduce RWSW impacts. Key stakeholder drivers for improved RWSW management included:

- Sustained and increasing political and public pressure to reduce RWSW volumes and impacts (see Chapter 1.1);

- Government's increasing use of chargeable mechanisms/penalties to control/reduce RWSW and their impacts (see House of Commons, 2013);
- The mutually positive impact of good working relationships between LAs and SUs, such as flexibility and early starts;
- The public image of organisations involved in RWSW. Well visually managed RWSW were considered representative of a conscientious organisation and corporate social responsibility (CSR), whilst badly managed works reflected negatively. This was particularly important for SUs, because regulators monitored customer satisfaction levels and adverse feedback affected SUs financial remuneration.

Key barriers

Interviews led to numerous key barriers becoming apparent, which stakeholders considered undermined RWSW management. Recognising these barriers is important as they lead to the research problem of disruptive RWSW activities (see Chapter 1.1). Key barriers included:

- Prescribed quarterly coordination meetings (DfT, 2012b) were considered as superficial, poorly managed by SAs, and unfit for purpose;
- SAs failing to take adequate ownership of managing RWSW;
- SUs felt multi-organisational working was a time and resource consuming exercise. SUs felt ill-equipped to coordinate works, as EToN precluded other SUs works;
- SUs strongly resented SA's levying charges such as 'S74 charges' (for unreasonably prolonged highway occupation), Penalty Charge Notices, Permit Scheme and Lane Rental charges as this was considered to undermine working relations;

- SUs did not consider simultaneous working (such as trench sharing) as always appropriate. This was usually impossible on health and safety grounds and precise locational mismatches;
- SUs avoided joint construction working with other SUs because it was ‘risky’, given that NRSWA (S70:1) only recognised one executor per opening, and thus all reinstatement obligations and risks fell solely on the single executor (see findings in Chapter 4.2.1);
- Monopoly SUs felt there were conflicts between utility regulator and NRSWA timescales. SUs acknowledged that meeting financially driven industrial regulatory timescales often took priority over coordinated RWSW;
- Telecoms companies were typically secretive about forthcoming works to prevent commercial theft, which was reported as a significant threat. Similarly, secrecy also existed to a smaller degree in the energy industry due to the free market nature of connections;
- It was felt that the construction supply chain exacerbated silo working due to their entrenched adversarial and profit driven nature and practices;
- The existing suite of rules comprising legislation, codes of practices, working papers and local practices were collectively considered complex and ambiguous;
- Local businesses recognised that highway works were for their long-term economic benefit. However, businesses felt rarely communicated with, reporting SUs perceived limited regard for often devastating financial RWSW impacts on small businesses; and

- Unlike SUs who had long term business plans (often up to 15 years), HA's short term (annual) budget cycles meant that they couldn't adequately plan long term works.

OPPORTUNITIES

Stakeholders welcomed improved highway management as it presented a number of positive opportunities through:

- Improved communication and working relationships, which increased joint working between LAs and utilities;
- Improved quality of highway reinstatements;
- Improving operative training for their workforce; and
- Enhanced public image.

For more information about recommendations for improved working practices to address these issues please see Appendix B.

4.2.2.3 Discussion and Results

The study demonstrated that there were significant issues in managing RWSW activity in general. Ultimately, SU operations were principally influenced by the regulator and their customers, which meant that prioritising their requirements was paramount for financial gain. Financial incentives are recognised motivators for achieving performance standards in the construction industry (Bresnan and Marshall, 1999), which the regulator set through speedy service delivery; inadvertently making silo working an attractive proposition for speedy delivery. In addition, utilities had a network of stakeholders to manage (Figure 4.5), which reinforced the low priority of highway works coordination. Therefore, reduced RWSW

management priority because of regulatory and stakeholders pressures can be considered a direct contributor to the poor management and coordination of on-street RWSW.

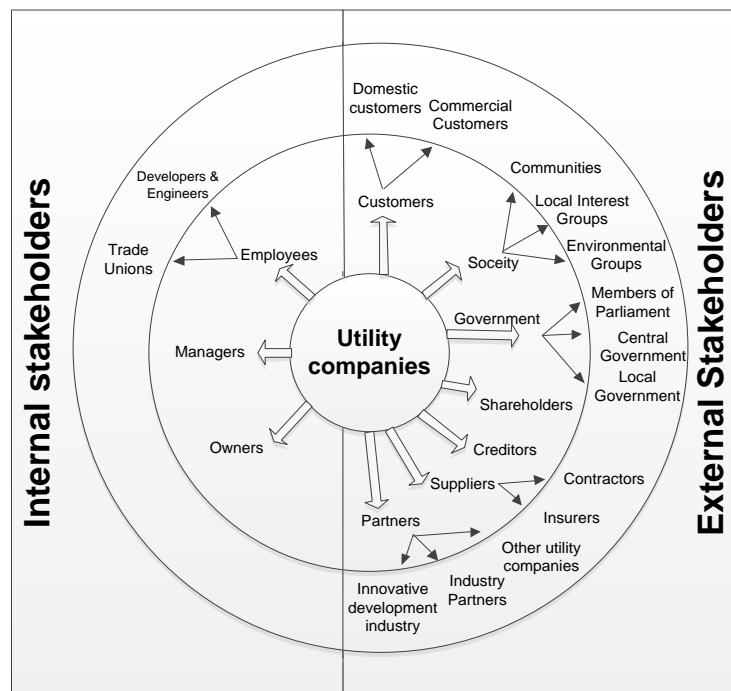


Figure 4.5 Utility stakeholders. Sources: Thames Water (2014); UK Power Networks (2013); United Utilities (2014); World Business Council for Sustainable Development (2012) and stakeholder interviews

There was evidence and acknowledgement of silo working in SU organisations, due to fragmented departmental working affecting communication; eg. an interviewee based in a domestic connections department of an energy company stated “we have no idea what goes on in other parts of the organisation, there is no way of knowing.”. Indeed, construction industry communications are particularly poor due to numerous inter-organisational stakeholders and fragmented internal structures, which, when combined with financial incentives to work faster make joint highway working unattractive (Calamel et al., 2012; Dainty et al., 2006; Johnson et al., 2012). However, highly regulated timescales were generally attached to smaller jobs such as connections and emergencies. The LA also undertook minor works, such as pothole repairs; therefore collectively, the general consensus amongst interviewees was that speedy repair expectations made it inefficient and inappropriate for minor and emergency works collaboration.

Utilities were supportive of collaborative working for major works which lasted over 10 days, however this was subject to the following prerequisites:

- not being exposed to financial liability of third party works (particularly highway reinstatement guarantees);
- not being exposed to greater health and safety risks; and
- coordinated working to be facilitated by the SA.

Stakeholders had distinct expectations of SAs to coordinate works in accordance with their statutory duties, and were critical that LAs did not take enough ownership of this process. A central government interviewee asserted the incumbency on SAs to coordinate highway works. Furthermore, statutorily prescribed coordination meetings (DfT, 2012b) were considered varying in quality around the country, but were generally considered poor and dysfunctional, because attendees did not feel any meaningful coordination resulted. These views indicate a clear expectation for SAs to manage and coordinate RSW, and currently this expectation is not being met well. SAs should therefore seek to facilitate collaborative/coordinated working through taking ownership of street works management, providing genuine leadership, vision, strategy and engaging organisational buy in (Hackman, 1998; Lu et al., 2007; Shea et al., 1987).

Whilst McKibbin (2010) reports that UK's street works legislation was the 'most advanced' in the world, utilities criticised the overload of legislative literature, associated codes of practices and working papers for being ambiguous and open to interpretation – this created uncertainties and risks in joint working and thus discouraged on-street collaboration, which undermines RSW management. An interviewee stated *“there is no incentive and even a reluctance to collaborate because of issues around the last notice.”* The 'last notice' issue

relates to S70 of NRSWA which duty-bounds the ‘executor’ to reinstate the excavation; this removes the option for an SU to excavate the ground whilst a third party SU reinstates. This also meant that a third party SU could work within an excavation without notifying the SA, thus leaving no audit trail of their presence and potentially defective works. SUs found that these ambiguities created high financial risk, particularly as the ‘last noticer’ was bound to guarantee reinstatement performance for at least two years. SUs repeatedly referred to the guarantee period as a liability, which meant they avoided joint-construction. Therefore, if SUs did not feel that multi-utility working exposed them to significant financial risks joint working could be more common, which could reduce RWSW impacts. Accordingly, the terminology in NRSWA, particularly S70 should be amended to recognise and support multi-agency working and thus reduce RWSW volumes, and their associated impacts.

Notwithstanding SUs’ resistance for multi-utility working, utilities were especially enthusiastic about joint working with HAs, and maximised these opportunities. The key advantage of HA and SU collaborative construction was that the HA, as works executor, would typically take reinstatement ownership, and thus the performance guarantee ownership, which removed the guarantee burden from SUs (Department for Transport, 2010). Critically, this demonstrates significant appetite for joint HA and SUs works, and therefore such collaborations should be nurtured. However, prescribed coordination meetings have been criticised for being unproductive, therefore potentially losing key mutually beneficial HAs and SUs joint working opportunities. Accordingly, coordination meetings should be investigated for how they can increase coordinated working between parties, possibly through measuring and benchmarking multi-agency working activities.

The construction industry supply chain also reportedly bore significant influence on the RWSW industry. Both HAs and SUs heavily relied on the construction industry to execute their works creating competition for resources. The supply chain itself is made up of a high

number of small specialist contracting constructions firms, driven by an entrenched culture of adversarial working for personal profiteering. The workforce was reported as having low educational requirements at entry level which attracted manual workers who tended to stay in the profession, thus embedding the adversarial culture. This had a deep impact not only coordinating RWSW but also the overall industry. A regulator commented:

“A lot of control is with the site operatives and is difficult to change. The age profile of the workforce is high; some have been there since British Gas days when costs weren’t an issue. A change of mind-set is needed for the old timers – trying to bring technology in is quite some culture shock (sic)”

Indeed as an observer of a National Grid team meeting with construction workers, the RE observed strong adversarial attitudes to new technology and ways of working across the group. Construction literature reports significant problems with silo working and entrenched adversarial working practices in the industry based on mistrust, and motivated by individual benefit and profiteering (Bishop et al., 2009; Cheung et al., 2003; Dainty, 2001; Naoum and Egbu, 2016; Robson, et al., 2014; Thurairajah et al., 2006). Indeed the construction supply chain has evolved into a ‘survivalist’ shape, structure and set of behaviours to respond to the environment in which it operates (Farmer, 2016). These findings indicate that construction firms can be negatively financially impacted by joint RWSW, given that new technologies and joint working reduce working hours which can undermine personal profits. Whilst there is a need to manage the role of the construction supply chain, Green (2011) and Green and May (2003) argue that in seeking radical improvements, the construction industry are unduly marginalised whereby people are treated as passive objects. Furthermore, contractors are forced to lower costs whilst improving delivery, which can exacerbate entrenched cultures of adversarial working. Separately, it is not known how the effect of Brexit will play out RWSW; on one hand, the loss of migrant workers in the supply chain could lead to less

insecurity and less competition which could have a positive impact on RWSW, whilst on the other hand, the loss of skilled members of the workforce could damage the quality of repairs which could exacerbate the public impact of RWSW.

4.2.3 CONCLUSION AND RECOMMENDATIONS

Objective 2 set out to establish the current working practices (see Chapter 1.2) of the RWSW industry as this was currently not documented. Principal research findings are summarised in Table 4.2, along with recommendations to address the issues to help improve RWSW practices and manage the research problem identified in Chapter 1.

Table 4.2 Key RWSW industry management issues and recommendations

<i>Issue</i>	<i>Recommendation</i>
<p>Limited ownership of coordination process - Street works are part of a complex industry with direct actors comprising SAs and undertakers, with industry regulators and the construction industry having a significant role and influence, albeit indirectly. Non-local authority interviewees expressed firm expectations that SAs should take greater ownership of the management of the coordination of RWSW. Prescribed coordination meetings were considered ineffective and superficial.</p> <p>Construction industry culture - Interviewees felt that the construction supply chain played a major role in hindering the effective management and advancement of the street works industry because of its entrenched attitudes, adversarial practices and profiteering culture.</p> <p>Conflicts between industries - There was a perceived conflict between timescales prescribed by NRSWA legislation and utility regulations. In the circumstances SUs tended to give greater priority to regulator timescales as they were driven by financial rewards.</p> <p>Onerous reinstatement guarantees - NRSWA was not considered to encourage SUs to participate in joint working due to the inherent challenges associated with reinstatement guarantees placed on the primary works executor.</p> <p>The HA as the primary executor – SUs showed significantly greater willingness to participate in multi-agency working where the HA was the executor and guarantor of works.</p> <p>Future – Key future concerns were particularly expressed around prolonging the life of highway and utility infrastructure, with technological innovations and the adoption of trenchless technologies and trench charging structures seen as potential opportunities in mitigation. The contemporary prevalent nature of silo working was also seen as an area which would benefit if NRSWA legislation was amended.</p>	<p>SAs need to take full ownership and lead by providing vision and strategic direction. Coordination meetings should be investigated for how they can increase coordinated working between parties, possibly through measuring and benchmarking multi-agency working.</p> <p>Work promoters should pro-actively manage contractors through a performance measurement and management framework to evaluate, and improve performance.</p> <p>Any perceived conflicts should be brought to the attention of HAUC UK to own, investigate and provide remedial measures.</p> <p>NRSWA legislation should be amended to use terminology that is supportive of and recognises multi-agency working as opposed to placing the single onus on the works executor.</p> <p>HAs should undertake reinstatement works on behalf of undertakers on a commercial basis, but simultaneously discharge undertakers of reinstatement performance guarantee obligations (this should however be subject to scrutiny from anti-competitive policies and regulations). This would also help to encourage consistent reinstatement standards throughout areas.</p> <p>In the long term SAs work with their HAs to adopt policies which champion longer highway structural life such as increasingly adopting trenchless techniques and trench charging (see Chapter 2.2.1).</p> <p>In the shorter term, SAs should encourage more sophisticated use of temporary materials as detailed in Chapter 2.2.1 to enable the highway to be returned to use on the same day.</p>

Overall, street works are expensive for industry and society and need to be managed effectively. The significance of this study is that it has identified some of the current problems facing the industry which are impeding the effective management and efficiency of street works practices. Failure to consider and address these issues will lead to sustained increases in RWSW, which is unsustainable, particularly in the current climate of rising street works, decreasing LA budgets and forecasted population and housing growth (CIHT, 2016).

CHECKPOINT!

Overall this study has highlighted that in contrast with the lower/operational level in the utility industry, at a higher/strategic level there is cognisance of the need and drive for improved and coordinated RWSW management.

However, stakeholders felt a number of key issues compromised well managed and coordinated RWSW activity, which include:

- An overload of legislative literature, associated codes of practices and working papers which were considered ambiguous and open to interpretation, creating uncertainties and risks in joint working.
- The failure of LAs to drive coordination, and the lack of effective processes for managing the coordination of RWSW activity. Utility industry processes also appear fragmented and marred by silo working.
- The absence of incentives for the utilities to increase multi-utility working.
- The diverse range of stakeholder that the utility industry were directly responsible to including customers, shareholders and regulators meant that highway management was not their immediate priority.

4.3 OBJECTIVE 3 – THE EFFECTIVENESS OF MANAGING LOCAL RWSW

Objective 3 required the assessment of the effectiveness of managing RWSW at the local level, in order to determine its impact, accordingly the study focus was narrowed to Derby. As detailed in Appendix B, utility companies were critical of the Permit Scheme (see Chapter 2.1.2 for general Permit Scheme information), as they felt it was unnecessary and unjustified,

and that SAs did not exercise parity in HA conducted works, which is a crucial requirement of the underpinning TMA 2004 legislation. Consequently, this objective focused on statistically examining key policy interventions, particularly the Permit Scheme, to assess their effectiveness in managing RWSW activity in Derby (see method in Chapter 3.4.3). The study purpose was to statistically test whether the introduction of key policy interventions impacted on-street RWSWs durations.

The original study findings were presented at the Transportation Research Board Conference in January 2016, which examined the overall impact of the Permit Scheme in isolation, as detailed in Appendix C. However since then, and based on conference feedback, the study was developed further to investigate HA and SU works separately, and consider other HA policy. Consequently a further developed journal paper has been submitted to the Journal of Transportation and is currently under review. The findings detailed in this section are based on this submitted journal paper (see Appendix D).

4.3.1 CONTEXT

DCC in its independent capacities of both SA and HA introduced the following key policies and sought to measure their RWSW impacts:

- The SA introduced the Permit Scheme on traffic sensitive streets, to minimise delays to road users through improved planning and execution of planned disruption to free-flow traffic. Any work promoter seeking to undertake highway works must apply for a Permit (DCC, 2013).
- The HA, who are responsible for maintaining highway infrastructure introduced three key technological/policy changes:
 - Introduced WOMS - a real-time electronic works management system to automate the existing manual paper based process;

- Terminated their highway term maintenance contract, and brought in-house highway maintenance construction after 16 years, supported by DLO to reduce costs; and
- Purchased and deployed a JCB Pothole Master (3CX) to facilitate the efficient execution of pothole repairs, as a part of bringing highway maintenance in-house.

As discussed in Chapter 3.4.3, the JCB purchase, in-house maintenance and Permit Scheme were introduced in three consecutive months, therefore they could not all be tested as they would distort results. Accordingly, DCC tested the Permit Scheme as it was a significant policy change for both DCC and the SUs, and also to measure whether it had delivered predicted reductions of 5.5% overall to RWSW durations (MVA Consultancy, 2012). More information about the Permit Scheme, Permit costs, geographic scope, and other UK Permit Scheme studies and their limitations are included in Appendix D.

Various independent variables used in this study are detailed in Chapter 3 (Table 3.2). Table 4.3 details the volumes and means of RWSW jobs, as well as intervention data compiled for, and analysed in this study.

Table 4.3 Volumes, means and intervention data for time series analysis study

<i>Year</i>	<i>Intervention</i>	<i>HA works volume</i>	<i>SU works volume</i>	<i>All works volume</i>
Year 1 – 2009-10	-----	4819	3693	8512
Year 2 – 2010-11	-----	3783	4418	8201
Year 3 – 2011-12	Oct – WOMS	4466	4160	8626
Year 4 – 2012-13	Aug - JCB Pothole Master	3708	3970	7678
	Sept - In-house maintenance			
Year 5 – 2013-14	Oct – Permit Scheme	5771	3383	9154
Year 6 – 2014-15	-----	5662	3149	8811
Year 7 – 2015 – 2016 (6 months only)	-----	3658	1595	5253
Total works		31,867	24,368	56,235
Mean volume (year)		4902	3748	8651
Mean works duration prior to Permit Intervention (days)		2.8	3.6	-----
Mean works duration prior to WOMS Intervention (days)		3.9	-----	-----

4.3.2 FINDINGS

Two separate datasets were perused to investigate highway works duration for HA and SU works. The separation was important to differentiate the performance of HAs who do not pay for Permits, compared to SUs who pay between £60-£231 per application.

Figure 4.6 shows time series plots of mean durations of activity on a monthly basis for both datasets. Visual examination of the plots shows that SU works remained relatively smooth over the study period, whilst HA works took a dramatic drop in October 2011 coinciding with the introduction of the WOMS system. The surge in HA works evident in August 2013 ties in with the HA changing from an external maintenance contractor to working with a DLO. Whilst, the graph indicates that the Permit Scheme potentially reduced SU works duration, the impact on HA works is less distinct; both datasets are modelled next.

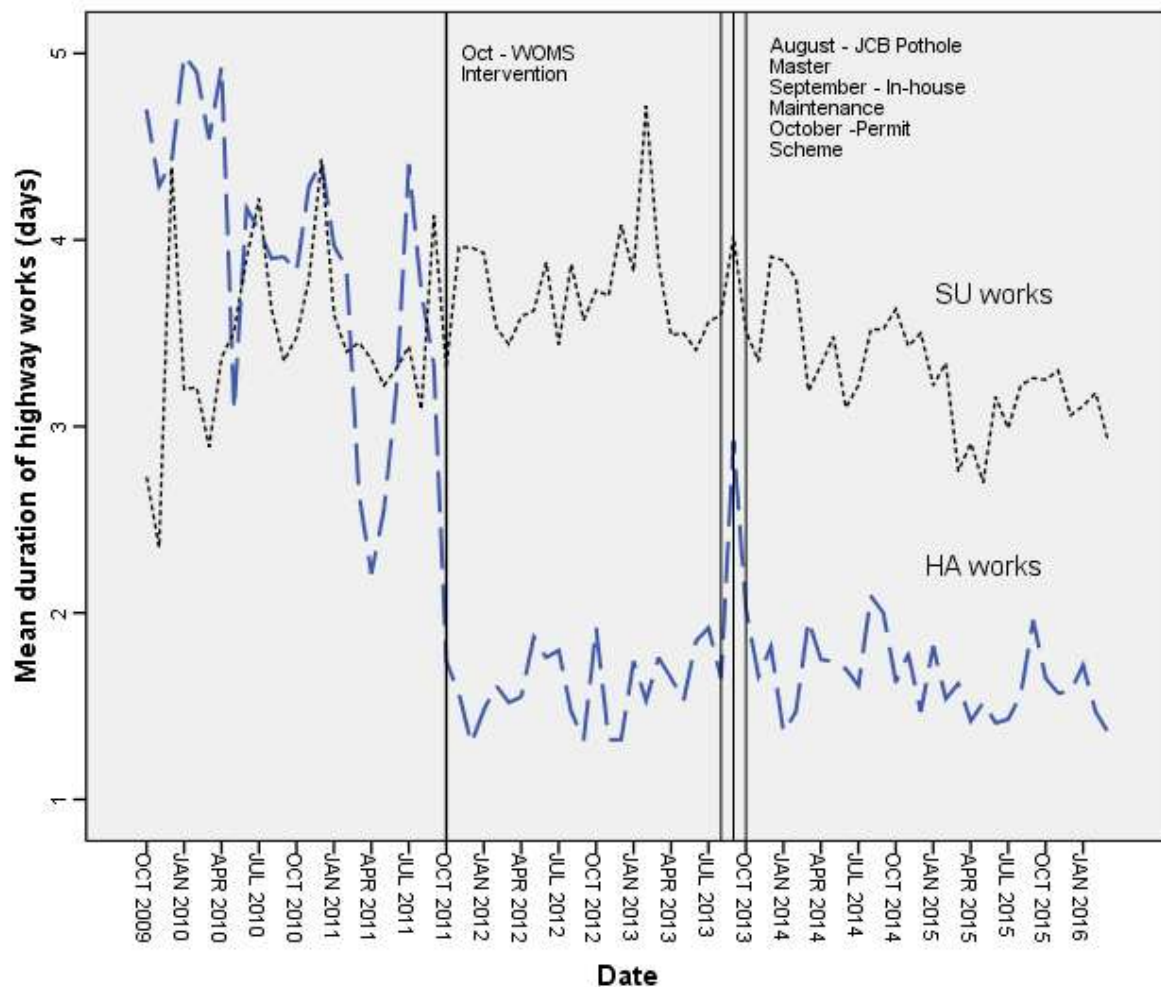


Figure 4.6 A sequence of mean highway works activities (October 2009 – March 2016)

Model 1 – SU works

Optimum results for the SU dataset were found in the ARIMA (1,1,0) model (Table 4.4). The model is a non-seasonal autoregressive model with no indication of any lingering effect of works from previous months; this is statistically significant at the 95% confidence level. The model shows that the Permit Scheme reduced works duration by 0.196 days per activity on average, *ceteris paribus* (if all other factors remain constant) which is equal to 5.4% reduction per annum or 727 days; this was statistically significant at the 99% confidence level. Two independent variables were found to be statistically significant: vehicle miles travelled and daylight hours. This means that should vehicle miles travelled increase by 1 billion miles, the duration of utility works is likely to increase simultaneously by 0.051 days per job on average (significant to 100% confidence). In terms of daylight hours, a one hour increase in daylight

led to works durations decreasing by 0.037 days per activity (significant to 95% confidence level).

Table 4.4 Results from the ARIMA models

<i>Model</i>	<u><i>2. SU works only</i></u>		<u><i>3. HA works only</i></u>	
<i>Intervention Model</i>	<i>ARIMA(1,1,0)</i>		<i>ARIMA(4,1,0)</i>	
<i>Noise Components</i>	<i>Coefficient</i>	<i>t-stat</i>	<i>Coefficient</i>	<i>t-stat</i>
Autoregressive (AR) 1	-0.486	-4.723	-0.277	-2.65
Autoregressive (AR) 1	-----	-----	-0.339	-3.16
Intervention Variable				
WOMS – (October – 2011)	-----	-----	-1.33	-3.34
Permit Scheme (October 2013)	-0.194	-2.55	-----	-----
Control Parameter				
Vehicle Miles Travelled	.051	3.117	-----	-----
Daylight hours	-0.037	-2.34	-----	-----
Descriptive Statistics				
RMSE		.384		.420
MAPE		7.537		12.96
MaxAPE		36.169		48.47
Ljung-Box Q		.285		.085

Model 2 – HA works

A visual examination (Figure 4.6) suggested that WOMS had a significant and sustained impact on HA works duration, whilst the Permit Scheme impact was unclear. To test this, a large number of ARIMA model variations were tested, however, models were weak and the Permit Scheme impact seemed exaggerated in light of Figure 4.6. It was considered that the inclusion of both intervention variables was disturbing the model; therefore the models were re-run examining the interventions separately. The Permit Scheme was first tested using 52 observations - this involved removing observations prior to the WOMS intervention to ensure model consistency. Despite trying numerous ARIMA models, no statistically significant

model could be found showing positive Permit Scheme impact. Instead using SPSS, a simple mean comparison was run to test work durations before and after the Permit Scheme. The mean comparison showed works duration prior to the Permit Scheme was 1.67 days, and negligibly improved to 1.68 day after the scheme. The slightness in change corroborated the reason a suitable ARIMA model could not be found. However, works durations is not the only proxy to measure success, therefore work volumes were also examined, which showed a distinct increase since the scheme's introduction (see Figure 4.7).

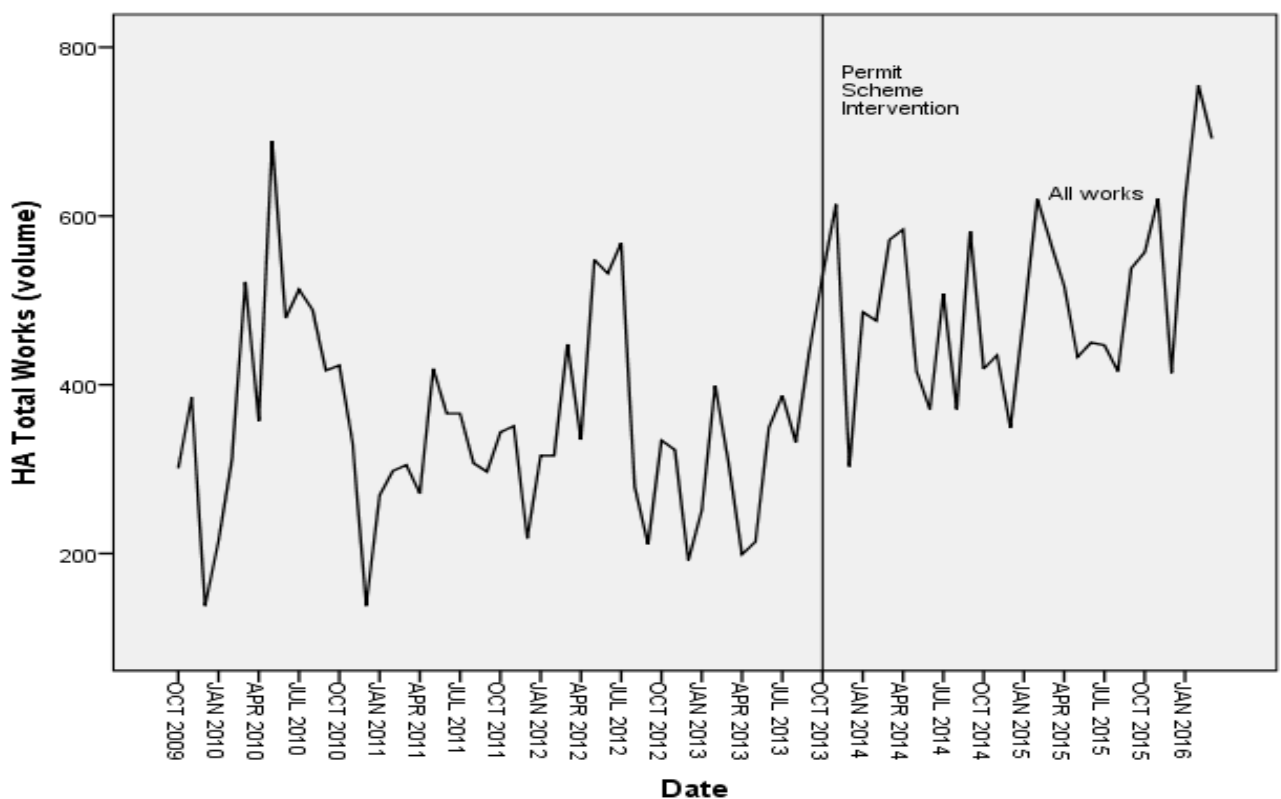


Figure 4.7 Overall volume of HA works

To delve further, the works categorisation was examined which showed that minor works, and urgent/emergency works had shown a marked increase (see Figure 4.8). The overall findings suggest that the Permit Scheme did not noticeably reduce HA works durations, however, an increase in works volume was evident, which could be attributable to the bringing in-house of the construction workforce and the purchase and deployment of the JCB pothole master to increase pothole repairs.

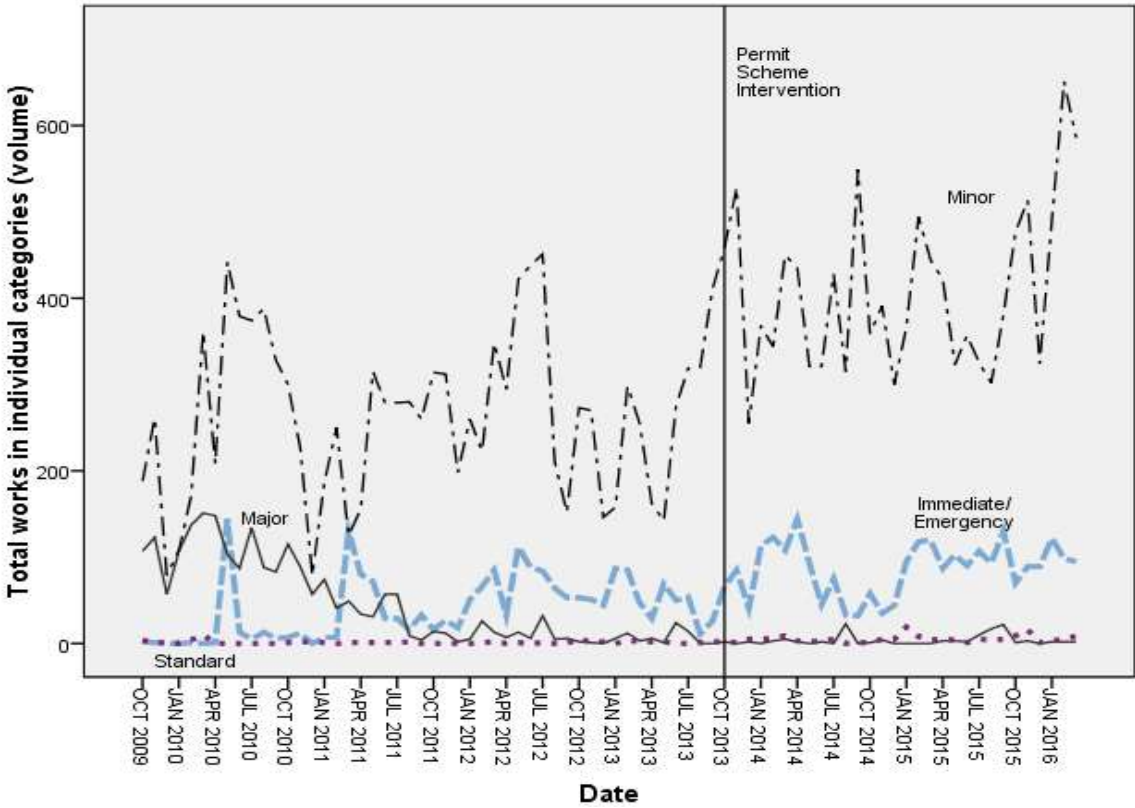


Figure 4.8 Volume of HA works amongst different categories

The second HA model run examined only the WOMS scheme; optimum results were found in the ARIMA (4,1,0) model (see Table 4.4). The model is a non-seasonal moving average model with a lingering effect from the previous month 4 (statistically significant to 95% confidence). The WOMS intervention was found to be significant by reducing works duration by 1.33 days per activity, which is equivalent to a 34% or 6,519 days per annum (significant to 99% confidence) *ceteris paribus*. No explanatory variables were statistically significant in this model.

The overall findings suggest that the Permit Scheme did not noticeably reduce HA works durations, however, an increase in works volume was evident, which could be attributable to the bringing in-house of the construction workforce and the purchase and deployment of the JCB pothole master to increase pothole repairs.

Calculating Impact

As mentioned previously and cited by others (Burtwell, 2001; McMahon, 2005), street works costs have received limited financial study, with no available literature on road works costs. Using Halcrow, (2004); Goodwin, (2005) and McMahon et al.'s (2005) studies, overall costs for RWSW were individually calculated, comprising construction and social costs. Daily street works costs in Derby lay between £2,904 - £10,166. To estimate the cost of HA works, the Authority's previous four year budget records were additionally consulted. Accordingly, Derby road works cost were estimated between £1,266 and £7416 daily (see Appendix D for calculations).

Accordingly, the financial impact of the Permit Scheme on SUs was calculated by multiplying the mean volume of street works (3748), by the mean duration of street works (3.6 days) prior to the Permit Scheme (see Table 4.3). Therefore, the typical volume of utility work in Derby was around 13,492 days annually. The model estimated that the Permit Scheme reduced works duration by -0.194 days (see Table 4.4) per highway works activity, which is therefore equivalent to 727 days or a 5.3% reduction per annum. When multiplied by the daily cost of street works, (based on studies by Halcrow (2004), McMahon et al. (2005) and Goodwin (2005) the total cost of street works savings lies between £2.11m - £7.39m as shown in Table 4.5, based on a daily cost of street works in Derby of £2904 - £10,166 (please see Appendix D for cost derivations).

Table 4.5 **Impact calculations for time series analysis interventions**

<i>Industry and Intervention</i>	<i>Days saved per excavation</i>	<i>Mean volume of excavation activity per annum</i>	<i>Days saved as result of intervention per annum</i>	<i>Cost (£) Incorporating Goodwin's (2005) social cost</i>	<i>Cost (£) Incorporating McMahon's (2005) social cost</i>
SU - Permit impact	-0.194	3748	0.194*3748 = 727	2,904*727 = £2.1m	10,166*727 = £7.4m
HA - WOMS impact	-1.33	4902	1.33*4902 = 6519	1,266*6519 = £8.3m	7,416*6519 = £48.3m

To calculate the intervention impact of HA works, the average volume of road works of 4902 was multiplied by the mean duration of highway works of 3.9 days prior to the WOMS intervention (see Table 4.3), therefore the typical number of HA work days per annum was around 19,117 days in Derby. The model estimated that WOMS reduced works by -1.33 days (see Table 4.4) on average per works activity, which is equivalent to 6,519 days or 34% annual reduction. When multiplied by the daily cost of road works, (see Appendix D) the total cost of road works savings lies between £8.25m - £48.3m as shown in Table 4.5. The Permit Scheme was not found to have any impact.

4.3.3 DISCUSSION

In examining the SU model, the Permit Scheme clearly reduced street works durations by 5.4%, which will have reduced public exposure accordingly. In rationalising the Permit Scheme's effect, a key explanation could lie with the greater pre-planning the scheme demands for application approval. Permit applications, resubmissions, and variations attract fees for the applicant (except to HAs). Rejected applications waste time and create uncertainty; this is likely to be significantly more inconvenient and expensive than the Permit costs itself, especially if it involves re-programming works, plant and equipment, the labour

supply chain, as well as informing stakeholders. Indeed, this confirms the comments by the regulator that Permit Schemes encourage SUs to pay greater attention to planning works, which has ultimately benefitted street works (see Appendix B). Greater pre-planning involves submitting robust site information, plans, methods, techniques, and detailed traffic management information which can lead to greater collaboration with SAs.

Vehicle miles travelled and daylight hours were found to be statistically significant in the SU model - both may be rooted in health and safety as road construction workers are disproportionately killed and injured at work compared to their counterparts (Harb et al., 2008). Firstly, should vehicle miles travelled increase by 1 billion miles, utility works duration is likely to increase simultaneously by 0.051 days per job on average (significant to 100% confidence). Increased vehicle miles travelled could be correlated with greater volumes of cars, which is known to increase safety risks to on-site personnel (Walker and Calvert, 2015), and increase crashes and fatalities at RWSW sites (Debnath et al., 2013). The increased works duration could be reflective of work sites being managed more carefully to prevent accidents, and thus inadvertently increasing works durations. In terms of daylight hours, a one hour increase in daylight led to works durations decreasing by 0.037 days per activity (significant to 95% confidence). A disproportionate number and severity of accidents occur in dark hours (Harb et al., 2008), with fatalities 5 times more likely during night-time construction compared to day-time construction (Arditi et al., 2007). Night-time working increases project costs due to increased personnel and traffic management costs, as well as compromising aesthetic considerations, and workforce productivity (McMahon et al., 2005; Rebholz et al., 2004). Daylight working generally affords improved and productive working, therefore it is unsurprising that longer days reduce works duration. Critically this finding also highlights the significant risk associated with night time working; therefore should RWSW be limited to night time working as a way of minimising public exposure to RWSW, it could impact dramatically on construction operatives' health and safety.

In terms of the HA model, DCC introduced the Permit Scheme to manage highway works better, modelling has not demonstrated that HA works have been managed better, in fact durations have remained relatively the same, whilst volumes have increased. The new in-house resources (DLO and JCB Pothole Master deployment), are likely to have increased works volumes, particularly minor works. This is positive for the HA, because despite financially austere times (Lowndes and Pratchett, 2012), they are now executing more works than before, and for the public, who are experiencing improved road conditions. However for the SA it suggests that more highway works are taking place than ever before, and thus the societal impact of these works is increasing to the effect described in Chapter 1.1. A caveat to this however should be that works are calculated by the day, therefore, despite a straight-forward pothole repair taking around 30 minutes from start to site clearance, it is recorded as 1 day, which can misrepresent works durations. The recording of this information is governed by statutory legislation and thus, is not easily overcome in the short-term. However, the SA could minimise works impacts by conditioning minor works Permits, which prevent works execution during peak travel hours. Also, as the Permit Scheme is not chargeable to the HA, it does not incentivise them to reduce works volumes, which should be addressed. This result will be disappointing for the sponsors, as they had predicted that the Permit Scheme would bring about an overall reduction in all highway works durations of around 5.5% (MVA Consultancy, 2012), including HA works.

WOMS had the greatest impact on HA works durations, which was not expected prior to the study. WOMS enabled Works Managers to allocate and control works information sent to Highways Inspectors which reduced duplications that arose in a manual system. It can be deduced that efficient planning from the outset leads to efficient on-site works execution, culminating in an overall reduction in on-site works duration. The adoption of WOMS also ties in with Government's wider Transformation strategy of using IT to transform government operations and processes (Weerakkody et al., 2011). The result should however, be treated

cautiously, because WOMS is not a construction tool, therefore WOMS has most probably improved work reporting, thus reflecting actual works durations, which can be undermined by delays prevalent in paper-based systems. Notwithstanding this, it is recognised that better planned RWSW help to better works execution on site (Hussain et al., 2016); therefore, the WOM's impact should not be dismissed. Please refer to Appendix D for a more detailed account of this study.

4.3.4 CONCLUSION AND RECOMMENDATIONS

This study sought to evaluate the effects of policy interventions on highway works duration. The Permit scheme effect was analysed in both HA and SU models, whilst the electronic WOMS was additionally tested in only the HA model as detailed in Chapter 4.3. The study found that the Permit scheme played a positive role in reducing SU works duration by 5.4% (equivalent to £2.1 - £7.4m annually); however the scheme had no statistically significant impact on HA works. A number of lessons can be learnt from this study which are provided below.

a. The positive impact on SU works is considered attributed to two possible explanations. Firstly the scheme demands greater pre-planning for application approval. Rejected applications waste time, create uncertainty, are a financial burden and inadvertently risk not meeting regulator timescales (risking financial penalties). Furthermore rejected applications are inconvenient as they can require re-programming works, plant and equipment, the labour supply chain, as well as informing and inconveniencing customers.

Recommendation – Work promoters should invest in pre-planning works through greater communication with the SA, submission of robust site information, plans, methods, techniques, and detailed traffic management information. The Permit Scheme has shown that it can lead to reduced work durations, but it may also lead to greater collaboration with HAs, subject to the SA managing the coordination better.

b. The Permit Scheme did not demonstrate any negligible reduction in HA works durations; it is possible that the absence of financial impact of failed Permit applications, has not driven behavioural change, and thus reduced works durations have not materialised on-site.

Recommendation – The SA should incentivise behavioural and process changes to reduce works durations. Given central government’s continuing austerity cuts (CIHT, 2016), and because the HA and SA are the same Council, introducing Permit charges and penalties would have limited impact and may create an unnecessary administrative burden. Instead the SA should periodically publish performance data detailing works duration data to induce high level public accountability as an appropriate incentive. Outputs should be transferred to meaningful data that are easy for lay people to absorb and judge, for example;

- how many hours of congestion time was saved compared to a previous period;
- what this equates to in monetary values; and
- What this equates to in air quality savings (Derby is due to be designated a Clean Air Zone in 2020 due to illegal exceedances in nitrogen oxides (NOx) and particulate matter (PM) (Defra, 2016).

c. HA works durations, particularly minor works (see Figure 4.8) were found to increase dramatically, coinciding with highway maintenance being brought in-house, and the deployment of a JCB Pothole Master.

Recommendation - Whilst the ad-hoc nature and small temporal durations of minor highway repair works are recognised, more effort should be made to reduce works volume, through better works planning and coordination. Furthermore, the SA could minimise works impacts by conditioning Permits so that minor works execution cannot take place during peak travel hours.

d. The WOMS intervention led to an unanticipated 34% reduction in works durations (equivalent to £8.25-£48.3m saved per annum), as found in the HA model. Again, this is considered linked to the greater pre-planning that WOMS enables, as well as eliminating the duplication of paper based systems. IT investment to replace the paper based management system, yielded positive results, suggesting that making back office processes more efficient can lead to efficient working on site. However, caution should be exercised in the interpretation as it is likely that some credit lies in the improved reporting efficiency WOMS enables over a paper-based system.

Recommendations – That DCC invest in process improvement to make processes more efficient.

CHECKPOINT!

HOW HAS THE STUDY HELPED TO UNDERSTAND THE RESEARCH PROBLEM?

Based on generalising the outcome of the Derby case study, this study has helped to identify that:

- The Permit Scheme can have a positive role in reducing SU works, and therefore could be used as an appropriate management tool to address RWSW in other urban areas.
- The Permit Scheme may not necessarily reduce works duration for HAs, possibly because the absence of charging does not incentivise change.
- Incentives are required for HAs to reduce their societal impacts; whilst charging for Permits is a powerful incentive used for SUs, this would not be logical for the Council, as it would lead to a situation where the authority is paying itself creating unnecessary administrative costs.
- WOMS can play a significant impact in reducing works durations. This demonstrates that improving the business process could lead to improved performance on-street.

4.4 OBJECTIVE 4 – DEVELOPMENT OF PROCESS MAPS FOR IMPROVED RWSW MANAGEMENT

Objective 2 identified that investment in business processes could have positive impacts on reducing RWSW durations, as evidenced by the positive reductions from the Permit Scheme for SU works, and WOMS for HA works (as detailed in Appendix A and Chapter 4.3). Initially DCC proposed examination of business processes of the SUs and the HA to investigate how the different work promoters operated. The study purpose was motivated by the limited knowledge the SA had about SU operations, and also to identify optimal interjection opportunities for the SA to discuss coordinated working opportunities. The RE contacted a number of SUs to participate in the study; unfortunately involvement was limited as follows:

- Electricity (Western Power Distribution) – an interview took place to process map activities, however, for commercial reasons, the level of detail given was superficial, and limited to headline activities. This meant that a detailed account of the organisation’s processes and background practices could not be gained.
- Gas (National Grid) – an initial successful meeting took place to discuss the project, however, despite repeated contact, no further meeting could be arranged.
- Telecoms (Virgin Media) – an initial meeting took place with Virgin Media who were especially enthusiastic about participating and the benefits to their business. However, the day before the meeting, Virgin Media withdrew participation based on instructions from senior managers. It is speculated that this may be because of commercial sensitivity which is a particular issue in the Telecoms industry (Spruytte et al. 2014), and discussed at length during the initial meeting.
- Severn Trent Water – due to budget cuts, internal re-organisation and changing staff, the company advised that they could not accommodate the study. The representative

advised the RE to contact again later in the year, however despite numerous subsequent emails and telephone calls, contact was not returned.

As the required SU participation was not forthcoming, the study was deviated to concentrate singularly on the LA's operations instead. The key motivator for this study was that the SA had a low-level appreciation of HA processes, accordingly DCC wanted to review Permit processes and seek opportunities to simplify them and enhance intra-organisational working. Organisational buy-in was successfully obtained, as senior managers were keen to make financial savings through eliminating inefficient and non-value adding activities. The aim of this study therefore was to investigate how road works administrative processes could be streamlined, and how internal collaborative working opportunities could be increased at DCC. Consequently, it is intended to investigate DCC's road works business processes using BPM by:

- Documenting current processes for designing and planning road works and creating 'as is' maps, showing the processes, inter-connections and actors involved;
- Reviewing the 'as is' road works processes maps to identify redundant and non-value adding steps, and identifying opportunities for intra-organisational working; and
- Proposing improved and re-designed road works processes through developing 'to be' maps with improved practices.

The full paper detailing the study can be found in Appendix A, whilst 'as is' maps can be found in Appendix G, and 'to be' maps can be found in Appendix H. See Chapter 3.3.4 and Appendix A for the study method.

4.4.1 CONTEXT

DCC had a keen interest in applying BPR, as discussed in Chapter 3.4.4 to review and improve its road works management process which was based within the Highways section of

DCC. Accordingly, it was considered appropriate to use Business Process Mapping (BPM) to map the road works processes, in order to subsequently identify improvements in accordance with objective 3 of this study.

The scope of the study was examination from enquiry phase, to Permit issuance phase involving the Highways Maintenance, Highways Engineering and Network Management teams as discussed in Section 3.4.4. In examining the road works processes, it was found that multiple Council teams were involved, who performed different function as follows:

- Derby Direct contact centre – potential receivers of reactive highways enquiries.
- Highways Engineering Team (part of the HA) – responsible for highway asset management and originators of major highway works.
- Highways Maintenance Team (part of the HA) – responsible for dealing with reactive maintenance and small scale highway works.
- In house construction team – may carry out works for the Highways Engineering or Highways Maintenance teams if it falls within their construction expertise.
- Business Support Team – process road works applications on behalf of Highways Engineering and Highways Maintenance.
- Network Management Team (part of the SA) responsible for approving/rejecting Permit applications.

As described in Chapter 3.3.4, Swimlane diagrams comprise multiple roles in a process, therefore, each actor has an individual Swimlane. A box represents each task or step in the process, diamonds highlight decision points, cylinders highlight data storage systems, whilst arrows indicate the sequence of the steps. The highlight of this technique is that the diagrams

show individual actors and emphasize their tasks and interactions with other actors. Each main process has a ‘hand-off’ diagram, to detail the movement of the workflow before it is ‘handed-off’ to another actor (Sharp and McDermott, 2001). The hand-off diagram also details sub-processes, also known as ‘sub-routine’ processes, which are individual decomposed ‘child’ processes that are executed in isolation, but contribute to the overall main ‘parent’ process (Milani, et al., 2012). Sub-routine processes help to avoid long linear processes which can be off-putting to read; Figure 4.9 details the Highways Maintenance hand-off map as an example of a typical hand-off map created in this project; a larger version of the map is contained within Appendix G.

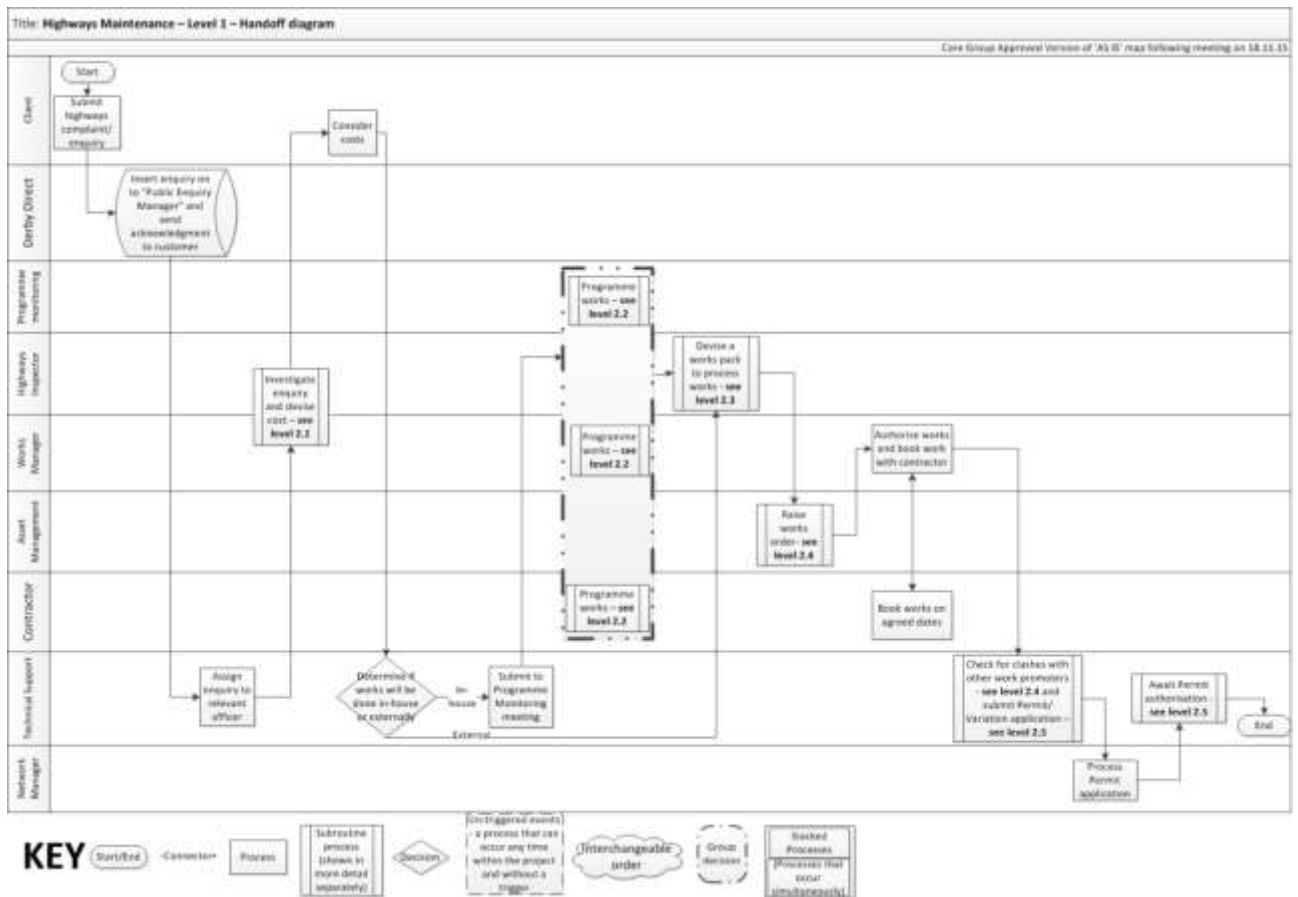


Figure 4.9 Highways Maintenance hand-off diagram

4.4.2 FINDINGS

General findings revealed that Highways Engineering’s projects were larger and tended to be recorded on the annual work programme, whereas Highway Maintenance works were more routine, reactive and smaller natured. The headline stages of highway design and maintenance consisted of receiving enquiries, scheme investigation, detailed design, production of schedule and scheme costs, procurement and booking of contractors, programming works, submitting a permit application and awaiting an outcome. The Network Management team acted as the SA and were responsible for processing Permits and coordinating highway activities. Figure 4.10 details the high level road works planning and Permit application process using a Swimlane Diagram; however instead of detailing the roles of the actors, this time it details the hand-offs between the stages of the overarching process.

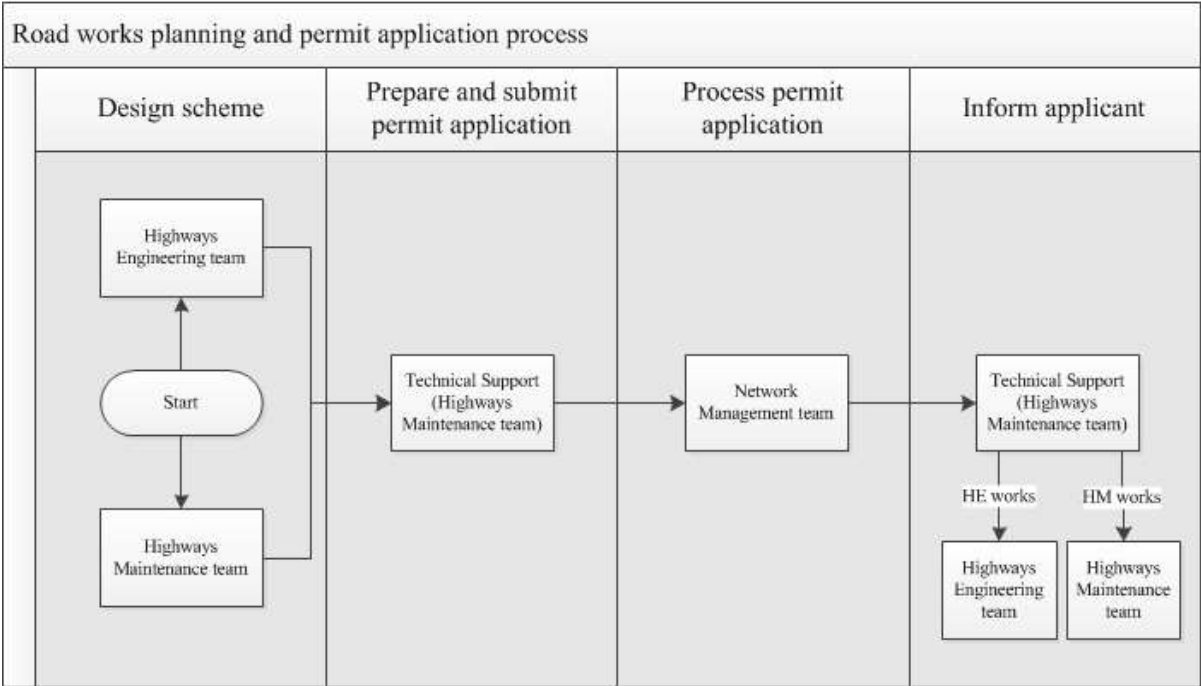


Figure 4.10 High level process map of road works at DCC

The findings of this study were based on mapping three teams processes as detailed in Section 3.4.4, namely Highways Maintenance (HM), Highways Engineering (HE) and Network Management (NM) teams. Whilst the findings from this study fell into three key enabling

themes, namely: Information Technology (IT), workflow design and human resources (HR), and policies and rules (Sharp and McDermott, 2001), in practice these themes overlapped each other. The documentation of the 'as is' process maps, and discussion with process experts identified a number of problems which are detailed in Table 4.6. The table details the project stage where the problem was identified, the teams affected, the respective 'enabler' category as well as a brief description of the problem. Due to space constraints only some of the problems identified will be discussed in the proceeding sections, particularly those which are considered to have the largest impact on process efficiency.

Table 4.6 Overall road works process problems identified as part of documenting ‘as is’ maps

<i>Stages of project</i>	<i>Teams affected</i>	<i>Enabler Category</i>	<i>Problem</i>
1. Receive enquiry	HM HE	IT	Duplicate entry of enquiry across CRM system and Highways IT systems.
2. Investigate enquiry	HM HE	IT	Duplicate system of enquiry across modules of single Highways IT system.
	HE	IT	Manual process requiring paper work and camera.
3. Submit Permit application	HM	Workflow design	Paper works packs for approval and submission.
	HM	HR	Permit applications submitted by Technical Administrative staff.
4. Detailed design	HE	IT	Numerous design software used by different teams and disciplines across department.
	HE	Policies and rules	Poor response rate for information about utility assets and utility future development plans.
	HE	IT	Asset management data (lighting, signals, drainage etc) is not freely available, and must be obtained by contacting individual officers.
5. Submit PAA	HM HE	Workflow design	Not enough advance notice is given about future major works, with less than the minimum 3 months sometimes.
6. Procure contractor	HM HE	Workflow design	Team leader micro-manages procurement process.
7. Programme works	HM HE	Policies and rules	Programme Monitoring meetings are considered a bottleneck which provide no clear value.
	HM HE	IT	The ability to check road space availability is restricted to Technical Administrative staff.
	All	Workflow design	Operational programme of works is not available for common view.
8. Book works with contractor	HM HE		-----
9. Assess Permit application		Workflow Design	Not enough coordinated working with others.
10. Advise applicant	HE NM	IT	Manually check IT system for a response from the SA.
General comments	All	Policies and rules	Silo working at operational level across division.
	HM HE	HR	Officers do not fully understand their duties and responsibilities under Permit Scheme
	NM	Polices and rules	Statutory coordination meetings are considered poor quality and superficial.
	All	IT	Case related data stored in email boxes.

IT

Across the teams and throughout the study, IT in general emerged as a key frustrating factor for officers in multiple ways. Firstly, all three teams were directly, indirectly, and to differing degrees, reliant on a combined Highways IT programme named 'Atlas'. The dual system was used for recording enquiries, raising works orders, and used for EToN (See Chapter 4.2.1). Whilst the combined programme was well intended, synergy was absent between individual modules which meant information was being re-keyed, creating duplications and thus, scope for error. For example Figure 4.11 shows extracts of HM's 'as is' process maps which highlighted examples of duplicate data entry in three modules of the Atlas system. The example in extract A shows the incoming enquiry is inserted into the Public Enquiry Manager; in extract B the data is retyped from afresh into the Maintenance Manager system; finally the data is re-inserted into the TMA Manager module to create a Permit application – this shows an absence of data continuity and characterises an inefficient process where staff time is being wasted, and exposing the system to data entry errors.

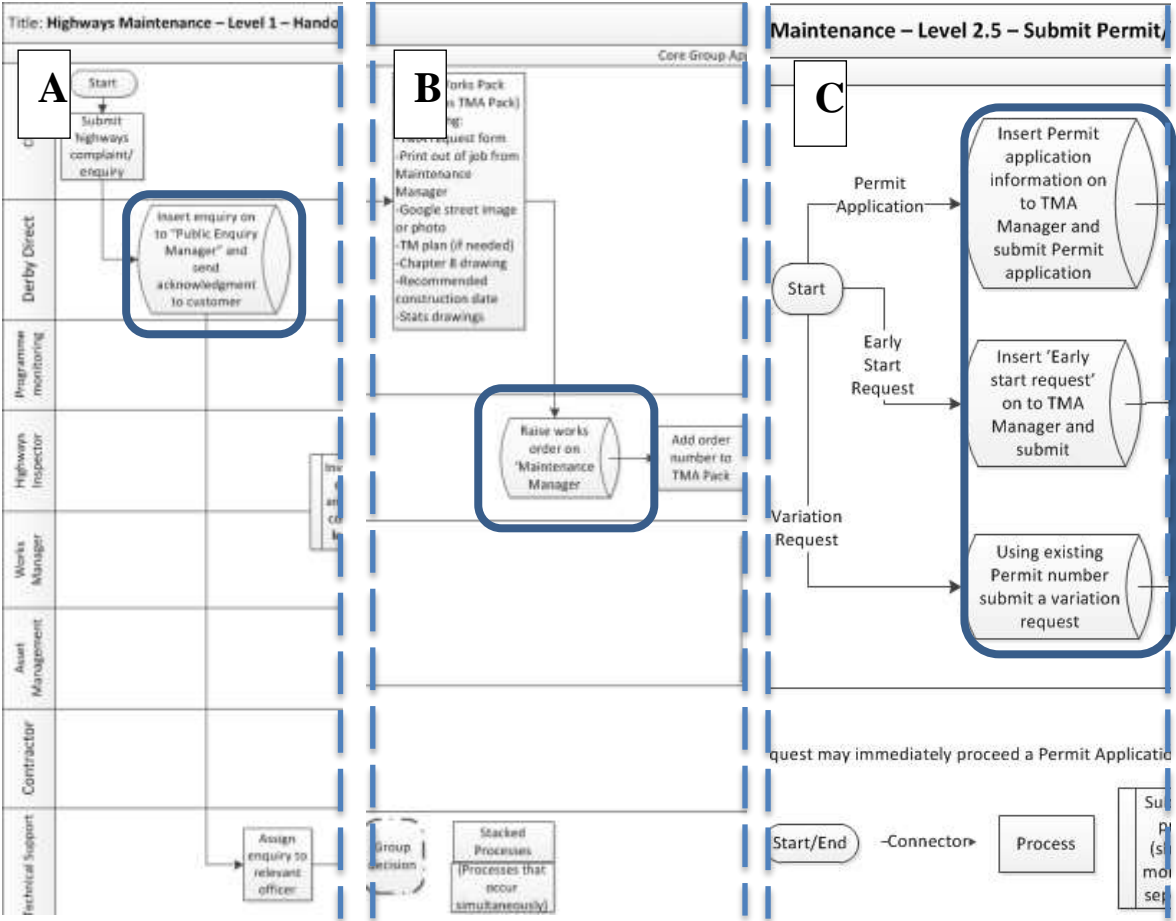


Figure 4.11 Example of duplicate data entry in Atlas across modules: Source: extract A – HM ‘as is’ map Level 1 hand-off diagram; extract B – Devise a works pack to process works ; extract C - HM ‘as is’ map Level 2.5 – Submit permit/Variation request (all available in Appendix E1). Dashed line denotes break in plan.

Process experts reported varying levels of access with little or no training in Atlas’s use, this meant that systems usage was not maximised. Other Highways IT system problems are identified in Table 4.7.

Table 4.7 Highways IT system problems

<i>Item</i>	<i>Problems found in the as-is process with the main Highways IT system</i>
1.	Fragmented IT system, where information has to be re-keyed into each individual module
2.	Inability to upload or store uploads with cases, such as plans or photographs
3.	Failure of system to provide prompts and warnings
4.	Loss of ‘Early start requests’
5.	Not clear whether transactions have been sent
6.	Difficult to produce simple reports
7.	No easy way to ‘sort’ Permit applications based on user need, such as date of receipt

Separately, 5 additional IT packages were used to draw or view scheme designs in the Highways Engineering team (see Figure 4.12), namely, AutoCAD, for drawing overall schemes; Windes, to view drainage design schemes; MX, to view level design drawings; Cadcorp, to view traffic regulation restrictions and LSS, to view topography drawings.

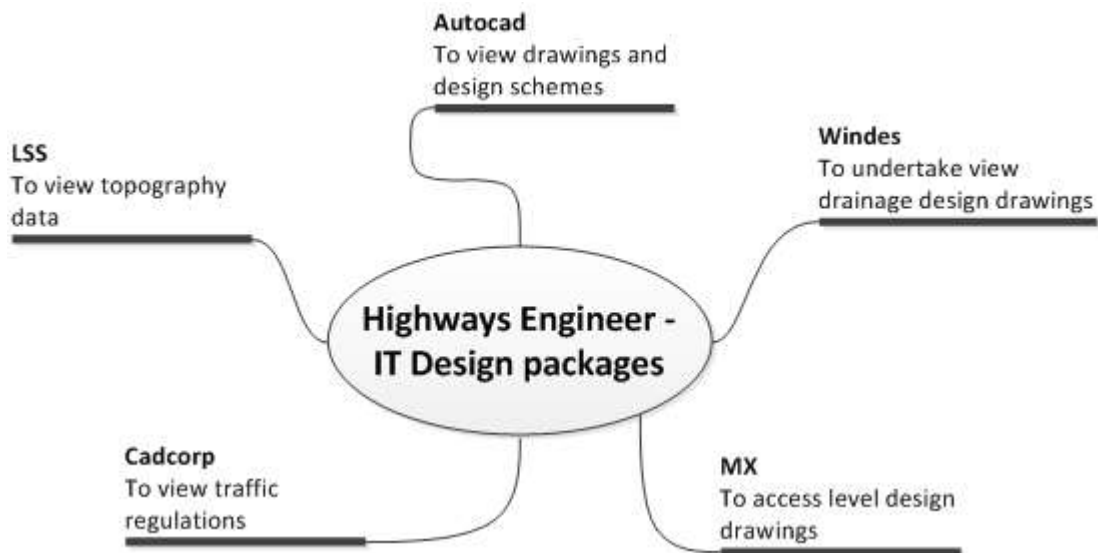


Figure 4.12 IT packages used by Design Engineer

Design engineers felt that the various applications were “problematic” because their lack of synergy interrupted seamless design which made the process time consuming. Furthermore, the lack of access to up-to-date data caused by different systems and operating levels, meant that it was common for staff to be working on old and superseded designs; this led to time being wasted as staff would subsequently repeat work on the correct drawing version.

Workflow design and HR

IT limitations meant workflows were modelled around IT systems creating bottlenecks, particularly, the Highways Maintenance team’s processes. For example, because the ‘Works Manager’ did not have access to ‘TMA Manager’ in Atlas, he could not check the availability of the highway to plan on-site works execution, therefore, this would have to be checked by the technical administration staff, creating an unnecessary bottleneck and causing overall

the undocumented schedule of rates for internal DLO works, whereby cost estimate for internal work requests were emailed to a single Works Manager – see Figure 4.14 (an extract of the ‘HM – Level 2.1 – Investigate enquiry and devise cost’ process map is contained in Appendix G).

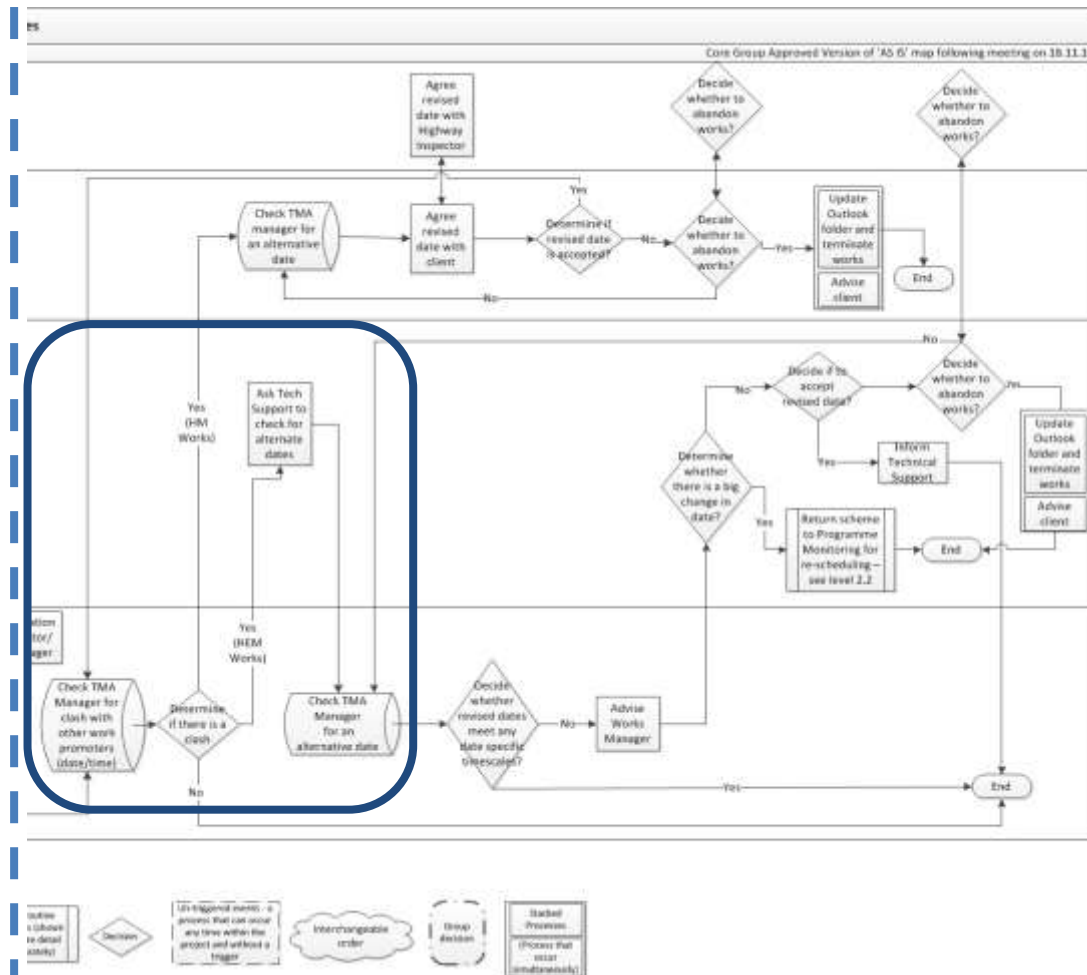


Figure 4.14 Example 2 of a bottle neck caused by lack of data access. Source: HM – Level 2.1 – Investigate enquiry and devise cost

This approach can be considered poor organisational knowledge management, as the process was reliant on one officer to calculate rates based on, on-the-spot estimates of job length and work requirements. Officers reported delays of several weeks before quotes were received, which delayed timely starting of works, and created financial problems (also affecting the Accountancy team) when cost estimates did not match the subsequent actual spend; overspend meant that monies would have to be sought from elsewhere, whilst underspend meant

that money was lost so highway improvements could not be maximised. Therefore, the undocumented schedule of rates had far reaching and negative staff and financial resource implications, which reflects a poorly managed business process, conflicting with the principle that well planned works lead to well executed RWSW as detailed in Appendix B.

Policies and rules

In terms of the external tender and contract procurement process, a team leader was heavily involved in the entire process, presumably to oversee it and provide advice – see Figure 4.15 (an extract of ‘HE – Level 2.2 – Contractor procurement’ process map, see Appendix G1). This practice means that, two officers were simultaneously working on the same task which duplicates resources and potentially reduces employee autonomy.

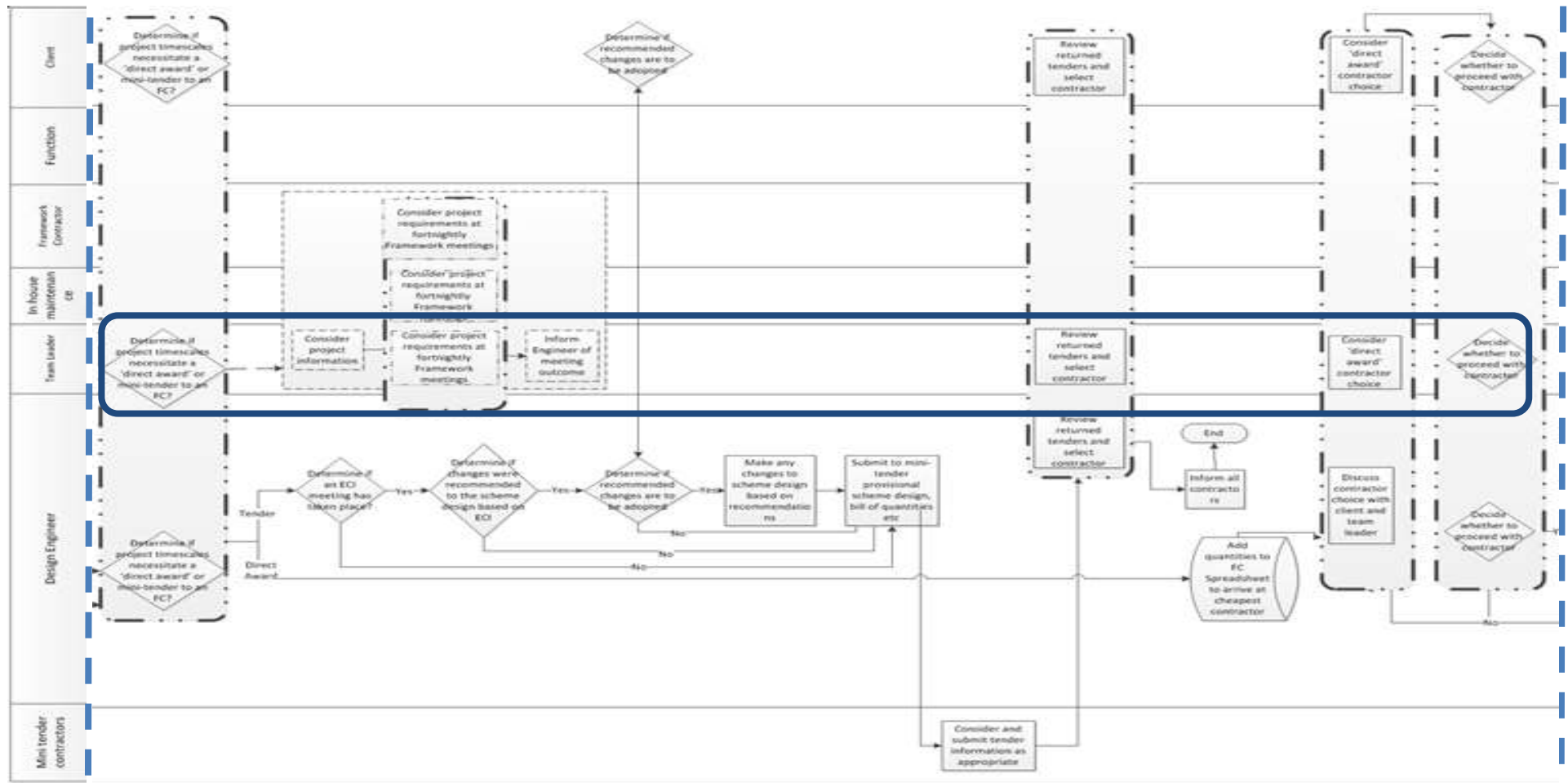


Figure 4.15 Team leader involvement in procurement process. Source: HM – Level 2.2 – Contractor Procurement

4.4.3 DISCUSSION

This section will now provide a discussion to some of the points raised in the findings section. The section is structured in the thematic sequence of IT, Workflow Design and HR, and Policies and rules which were key process enablers identified by Sharp and McDermott (2001).

IT

DCC IT systems were very fragmented and affected work productivity. Indeed, fragmented IT is a significant problem within the architecture, engineering and construction (AEC) sector, due to high data volumes, developed by different professionals, using different IT systems (Beach et al., 2013), which process expert consider is particularly symptomatic of the Highway Engineering Design IT. Poor IT system architecture and integration contributes to process inefficiency (Edwards and Peppard, 1994). During this research, the Atlas IT system was replaced with an Integrated Highways Management System (IHMS) to reduce the problems identified in the findings. However, problems, such as compatibility, access and version control around the suite of highway design IT infrastructure remains, therefore it is recommended that a single cloud-based collaborative working/document management platform (Beach et al., 2013) is considered which would enable DCC stakeholders to design and view drawings collaboratively. A cloud-based collaborative working/document management platform enables access to design files and engineering drawings that are not limited by technological access boundaries, therefore all users have instant access (Bentley, 2016). Such a consistent and uniform system for highway designers could help to bring regularity for officers, and thus promote more faster and efficient design processes. The system should be suitable for minor works to full highway design, and should be accessible for designers, and those with 'view only' interests. Indeed Mir and Pinnington (2014) found a

positive link between a well-managed project and successful project delivery; furthermore the stakeholder study also found that well-planned works led to better on-street execution (see Appendix B). Therefore, IT systems could indirectly help improve on-site RWSW management, as already proven by the automation of the paper based works management system to WOMS, which decreased work durations by 34% (see Appendix B).

Workflow Design and HR

In general, DCC IT limitations meant that workflows were modelled around these systems creating bottlenecks, which stem from compulsory information being unavailable to staff (Sharp and McDermott, 2001). For example staff not being able to access road works data or the schedule of rates resulted in unnecessary delays which could be mitigated by the schedule of rates was published within the IHMS. Accordingly, Figure 4.16 shows an extract of the 'HM investigate enquiry and devise cost - to be' process map (see Appendix H2) which proposes that staff devise a cost for works through using the IHMS.

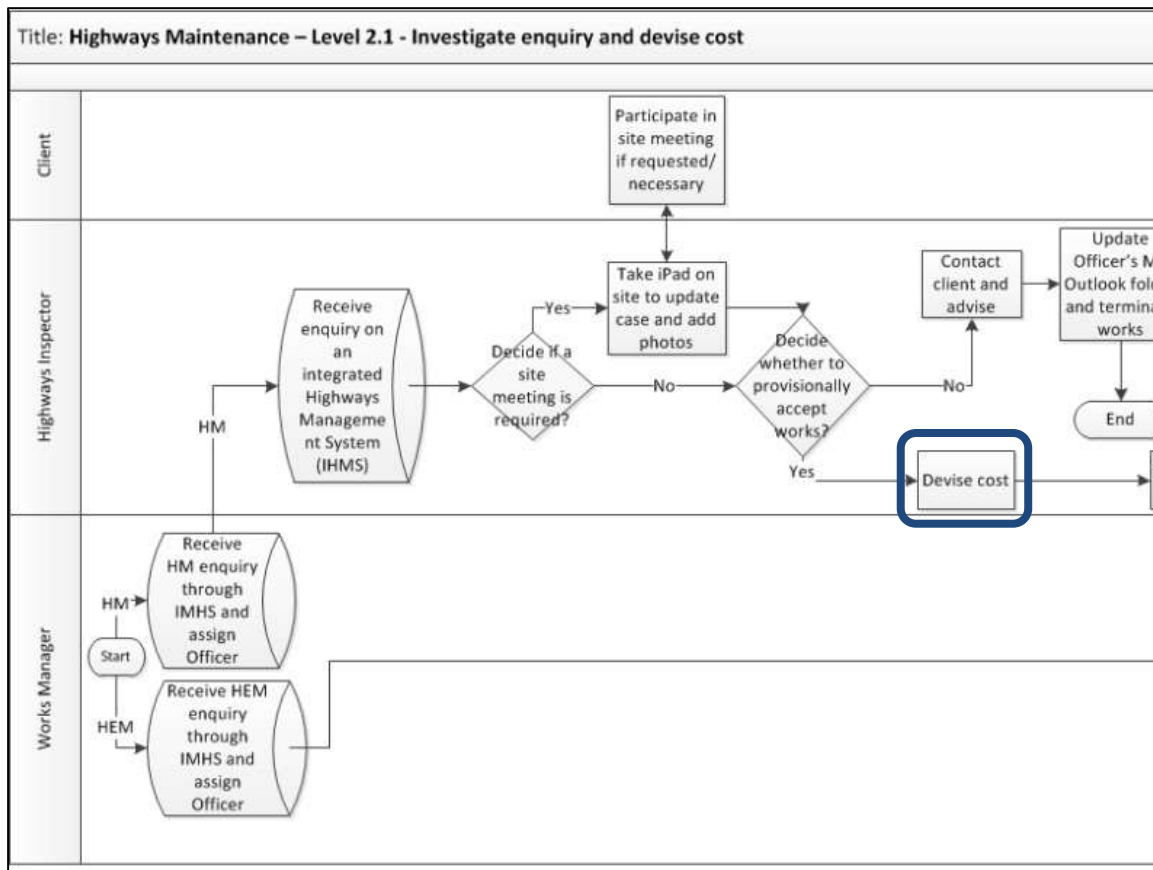


Figure 4.16 Devise cost process. Source: Extract of HM – Level 2.1 – Investigate enquiry and devise cost

Indeed restricted data access is an outdated LA practice, which should be replaced with wider data accessibility for faster works delivery (Weerakkody et al., 2011). However, LA culture is typically characterised by a general resistance to change, which in turn leads to slow-paced developments (Kamal et al., 2015; Janssen and Cresswell, 2005; Thong et al., 2000). Slow paced development was evident at DCC; for example, despite the Atlas being recognised as old, inefficient and unproductive, there was no urgency by the Highways department to upgrade it. The impetus for change was finally forced by the Procurement Team who identified that IT systems over 4 years old had to be re-tendered. This culture of slow change is embedded within the organisation and requires acknowledging and addressing to bring faster paced change for faster results, particularly for bringing efficiency in technology and service.

In terms of the tender and procurement process, the manager's involvement through the entire process is considered micro-management, which can undermine employee autonomy and reduce staff morale. The retention of schedule of rates data identified in section 4.4.2, was also considered a micro-management approach where the Works Manager retaining data was a mechanism to closely control cost estimates. Perott (2002) reported that micromanagement was aligned with the 'managerialistic model' of working, which is an outdated culture still common in the private sector, whereby close managerial involvement and monitoring is assumed to provide greater service, product, or behaviour. Managerialism is considered to deprive employees of power, based on managers' education or exclusive possession of knowledge and 'know how' on how to efficiently run an organisation (Locke, 2009), which is argued as an elitist approach which seeks to protect managers at the expense of undermining staff morale and development (Doran, 2016). Instead Perott (2002) advocates the 'professional model', where the assumption is that trained and qualified staff lead to high quality and professional service, products and behaviour. This is especially important within the current pressurised financial environment where the private sector is expected to 'deliver more with less' (Arnaboldi et al., 2015). Government employee autonomy remains a crucial ingredient for successful public organisations (Thong et al., 2000), consequently, DCC should move away from their old management culture, for example by removing the team leader's involvement in the procurement process. This change could help reduce resources allocated to the procurement process, improve process efficiency, enhance employee autonomy, and improve morale, which is linked to positive project delivery outputs (Kerzner, 2013), and thus could lead to improved RWSW management.

Policies and Rules

It is recognised by theorists and practitioners that inter-organisational knowledge sharing is a critical success factor for increasing performance, innovation, and competitive advantage, and

should include both explicit and tacit knowledge (Khvatova and Block, 2016). Indeed research by Chen et al., (2013) found that the intra-organisational coordination of tasks, procedures and activities positively enables more effective delivery to external partners. However, limited organisational and cross-organisational working was evident throughout the DCC processes. Officers acknowledged that intra-organisational communication was poor, and therefore efforts should be invested in improving it. Furthermore, coordination meetings were acknowledged as weak, providing little value to the authority, tying in with findings from the stakeholder study (Appendix B and discussed in Chapter 4.2.2.2). DCC should work with stakeholders, particularly the HAUC and NJUG to devise a gold standard for coordination meetings, which should subsequently be adopted for independent Derby meetings.

The Network Management team's process found little inefficiency; this is likely to be because the process was heavily driven by statutory regulations. Furthermore no bottlenecks in the process were found because one officer would handle an application throughout. Process experts reported that individual meetings occurred with applicants for larger impact works, and where Provisional Advance Authorisation (PAA) were submitted. Conversely, HA experts felt that they were rarely communicated with irrespective of project size, which reinforces previous findings of poor institutional communication.

In summary, Table 4.8 details the problems identified (based on the theoretical underpinnings described in Chapter 3.4.4 by Sharp and McDermott, 2001) and makes recommendations for their management. The table is split into recommendations based on the strategic, tactical and operational levels. Strategic changes are those which would require approval at Corporate/Council Cabinet level such as purchasing new IT; tactical changes would require approval at the middle management/director level such as improving departmental

communication, whilst operational changes would need approval at Group leader/team level such as improving local communication.

Table 4.8 Recommendations for addressing process issues

<i>Team and enabler</i>	<i>Problem</i>	<i>Recommendation</i>	<i>Required resources</i>	<i>Timescale</i>
Strategic Level				
HM/HE/ NM - IT	Fragmented and outdated IT system. Duplicate data entry required across modules.	Update fragmented IT system with an IHMS	IT	Short
HM - Workflow Design	Technical Support Team directs incoming enquiries. Investigating officer requests more information from client if incomplete.	New enquires should be received through an online form integrated with the IHMS with compulsory fields. Enable photo uploads by customers.	One Off DCC IT Specialist IT Provider	Medium
HE - IT	There are numerous Highway Design related IT systems used by differing disciplines.	Integrate the design software applications onto a single collaborative cloud based construction platform.	IT	Long
NM - Policies and rules	Not enough coordination with utility companies/superficial coordination meetings	DCC to hold independent coordination meetings. DCC to work with stakeholders to re-vamp current of coordination meetings to become a beacon authority.	DCC	Long
			HAUC	Long
HM/HE /NM - Policies and rules	Fragmented and silo working between teams at operational level	Teams to have departmental work programme meetings and produce departmental newsletters.	DCC Teams	Medium
HM/HE - HR	Work promoters are unaware of duties under Permit Scheme	Provide training on the Permit Scheme and underpinning legislation.	HR	Medium
HM/HE /NM - IT	Technical problems with the IT system, for example: <ul style="list-style-type: none"> • Early start requests get lost in variation requests • Unclear if web transactions are sent • Hard to produce simple data reports • No warnings provided for expiring notices 	Provide an IT system which meets user's needs, specifically: <ul style="list-style-type: none"> • Alerts for Permit applications/variation/early start request • A clear audit trail of activity • Easy to produce performance monitoring and bespoke reports • Provide alerts based on user type requirements 	IT	Medium

Investigating the business process implications of managing road works and street works

<i>Team and enabler</i>	<i>Problem</i>	<i>Recommendation</i>	<i>Required resources</i>	<i>Timescale</i>
Tactical Level				
HM - Workflow Design	Programme Monitoring cause bottleneck – unclear of meetings value.	Abandon programme monitoring meetings	None	Short term
HM - Workflow Design	Paper work-packs used for approval	Make process paperless and authorisation electronic	None	Short term
HM – IT	Insufficient IT access rights- the Technical Administrative and Asset Management teams check work dates and input orders respectively on behalf of others.	Works issuing staff should have access to the IHMS to programme and issue works – Technical Administrative Team and Asset Management teams should be removed from the process.	HR and IT	Short term
HM - Policies and rules	Storage of case related material in personal email.	All works to be stored in a central accessible location.	None	Short
	It is unclear what value Framework meetings add to the process.	Abandon Framework Meetings	None	Short
	Schedule of rates is not documented which causes bottlenecks.	Formalise schedule of rates and add to IHMS for all staff to be able to devise a cost	One off Confirm IT	Medium term
	Operational programme of works is manually documented and not easily accessible	Operational work programme should be accessible on IHMS and visible across service area	One off Confirm IT	Medium
	Requesting drainage asset/street lighting locational/ Traffic Regulation Order (TRO) information from another team	Open up access for drainage design, street lighting and TRO drawings to Design Engineers on corporate GIS	Confirm	One off Medium
	Team Leader is involved throughout contractor procurement process, unclear of value.	Remove team leader involvement	None	Short
Operational Level				
HM – IT HM - Workflow Design	Print enquiry and take on site. Take photographs and upload to case.	Use portable electronic devices on site with camera facility and full IT access to the IHMS.	Confirm IT	One off Short term
	Manually check system for Permit authorisation.	IHMS creates prompts/alerts of correspondence from SA.	One off – Confirm	Medium term
	Submit Permit/Variation request.	The officer submits permit application – remove Technical Administrative from process	One off – Confirm	Medium term
	Obtain 3 external quotes for traffic surveys.	Use the preferred traffic survey company used by the Traffic and Transport section.	Traffic and Transport	Short

<i>Team and enabler</i>	<i>Problem</i>	<i>Recommendation</i>	<i>Required resources</i>	<i>Timescale</i>
HE - Policies and rules	Bus stops and traffic signal infrastructure require ordering outside of Principal Contractor agreement.	DCC to design bus stop and traffic signal infrastructure, but procurement to be assigned to Principal Contractor	None	Short
HE - Policies and rules	Obtain quotes for trial holes, topographical and ground radar surveys where costs exceed £1000.	Increases tender costs to £5000.	None	Short
	Unclear whether plant/utility data and future works information requests are being sent to the right teams.	Confirm point of contact for utility asset records and future works for individual utility companies regularly	None	Medium
NM - Policies and rules	SA does not have enough foresight of proposed works, preventing co-ordination with others. PAA are often submitted with less than 3 months advance notice.	Submit PAA for all business plan items at the beginning of the year with approximate dates.	All teams	Medium
		Set up a 'safe-guarded for future works' hatch on a GIS plan for PAAs submitted (HA or SU)	IT	Medium
	Not enough coordination with utility companies/superficial coordination meetings	G3 - Report 'major' works proposals, with all potential sites and approximate dates at coordination meetings at the beginning of each financial year. Provide updates at each quarterly meeting. G4 - Highways Engineering Team to attend quarterly co-ordination meetings.	None None	Medium

4.4.4 CONCLUSION AND RECOMMENDATIONS

The aim of this study was two-fold; firstly it investigated how existing highways processes could be streamlined, and secondly it considered how coordinated working could be enhanced in accordance with Chapter 1.2, and the method described in Chapter 3.4.4. The findings of this study are reported in Chapter 4.4.2, and presented in Appendix A.

The study found that there were a number of problems throughout the LA's road works process. Whilst Table 4.8 details a number of specific recommendations which have been validated by stakeholders, the following overarching recommendations are made to the Council:

- IT systems should be symbiotic, fit for purpose, reduce bottlenecks and assist in the efficient delivery of a process. Consideration should be given to integrating highways design through a cloud-based collaborative working/document management platform to enable design and view of drawings collaboratively.
- Internal communication needs significant attention as opportunities to collaborate and coordinate works are being missed. High level attention should be given to this matter due to its departmental implications.
- Coordination meetings are failing to meet their purpose. DCC should work with stakeholders to review the purpose of, and revamp these meetings to ensure that they actually facilitate joint working.

Of course the implementation of the above recommendations will have a number of resource and financial implications which will need to be considered.

CHECKPOINT!

HOW HAS THE STUDY HELPED TO UNDERSTAND THE RESEARCH PROBLEM?

Overall, this study has helped to understand that a number of DCC's internal processes were badly managed which could inadvertently lead to poor delivery of on-site RSWs. Specifically this study found that:

- Poor IT systems can contribute to process inefficiency, with fragmented IT systems being a particular issue in the AEC sector, of which RSW are a part of. Evidence of poor functioning and fragmented IT was also evident in DCC's process, which restricted access to data, causing bottlenecks, and thus delays in the process – badly managed internal processes may be contributing to poor management of RSW management on-site.
- Inter-organisational communication and knowledge sharing is very important for improving organisational performance, and also to improve external partner...

CHECKPOINT!

Continued...

working. However, data sharing at DCC was regularly compromised because of limiting IT systems and poor intra-departmental communication creating silos. Poor internal communications can have the ability to undermine overall process success and outcome, which is likely to impact on on-site RWSW management. Furthermore, poor internal communications mean that the SA are not prepared enough to coordinate road works, still less street works.

- Open access to forthcoming works data meant that the HA were able to re-schedule works if they appeared to ‘clash’ with others working on the highway – this was done without the knowledge of the SA who are responsible for coordinating RWSW activity.

4.5 OBJECTIVE 5 - EVALUATE PROPOSED PROCESS MAPS AND DEVELOP A RWSW MANAGEMENT LOGIC MAP

Objective 5 required the evaluation of the ‘to be’ proposed process maps and the development of a RWSW logic map as proposed in Chapter 1.2. Firstly, the ‘to be’ processes were subject to validation from industry experts through a focus group (see Chapter 3.3.1.3 for information about focus groups) and individual semi-structured interviews (see Chapter 3.3.1.2 about interviews). Industry validation aided objective and expert view of the recommendations made, based on the participant’s RWSW expertise (see Appendix G for validated ‘to be’ maps). Secondly, based on the findings from objective 4, as detailed in (Sections 4.4.2 and 4.4.3), and the validation exercise (to be discussed in the proceeding section), the ADMINISTER logic map was developed which was validated by industry experts. This section will start by providing a brief context, followed by the findings, the development of the logic map and ending with a conclusion and recommendations. The findings from this

study were presented in a Journal paper as attached in Appendix B, in accordance with the method detailed in Chapter 3.4.5.

4.5.1 CONTEXT

Objective 5 built on from objective 4, whereby the ‘as is’ and ‘to be’ maps developed to examine the Permit application process, were validated by industry experts (see method in Chapter 3.4.4). In addition to this, a logic map was also developed and validated to transfer lessons learnt from this study to interested parties, particularly LAs.

4.5.2 FINDINGS

Based on systematically examining each stage of the Permit process as part of Objective 4, a number of problems were identified, as detailed in Table 4.8 of Chapter 4.4.3. To make these problems more logical and manageable for the validation exercises, the process problems were refined and categorised sequentially into the stages of the project. Validation exercises were executed with DCC managers, peer LAs and HAUC to review the proposed processes based on the ‘to be’ maps.

Expert validation from RWSW industry practitioners was sought to review the ‘to be’ process. Experts were in agreement about most of the recommended changes to improve DCC’s Permit application process, for eg.: the adoption of cloud based collaborative construction platform, more open access of asset management data, and more improved communication amongst others. However, the experts did not agree with 5 key recommendations which subsequently required amendment. Firstly, examples of commonalities in opinion amongst RWSW experts include:

- Coordinated working was challenging both in the utility sector and LAs, due to complexities and inherent challenges from individual team processes and circumstances beyond employee control, such as, poor IT systems and limited data access.
- Cross-organisational communication was difficult because systems and processes were designed to be formal, which made flexible communication difficult.
- Coordination meetings were not meeting participant expectations which meant that little actual coordination occurred. The scope and membership of the meetings was unclear; HAUC proffered that it could be more productive if LAs met SUs in their offices to discuss their plans. Experts agreed that meetings should be limited to focusing on major impact projects, potentially cross-boundary schemes with neighbouring LAs. It was agreed that discussions about individual streets (which is currently common) should be addressed outside coordination meetings.
- Highways IT systems were fragmented and unproductive, which meant that internal processes were slow and laborious, which reduced internal and external coordination. Highways IT systems should be synergistic and web-hosted to provide slick processes. Ideally, IT systems should be procured regionally to reduce operational costs, particularly in the current financial climate.
- Organisational collaboration was considered crucial, albeit with differing degrees of effectiveness amongst LAs. To improve collaborative working, there was consensus that a broader appreciation of departmental activities was needed, which could be facilitated if work programmes were shared and discussed. Additionally, some experts felt that dedicated coordination personnel were highly successful in aiding internal and inter-organisational collaboration which help to manage RWSW significantly better.

Validation experts also expressed contrary views to the proposed recommendations in the 'to be' maps, as follows:

- That the Permit application submission process is a technical process, and therefore, should be executed by the Technical Administrative team. This was to prevent higher paid staff from devoting time to complex administrative functions which undermined their professional expertise and did not provide value for money.
- Most stakeholders agreed that in general, processes should not be micro-managed; team leader involvement should be limited to providing officer advice and approval. However, DCC felt that team leader involvement in the tender and procurement process was critical, given the officer's specialist knowledge and contracts experience. Therefore the involvement was considered 'quality assurance' (QA) which provided "exceptional value for money", and should remain. Discussion in Section 4.4.3 details the negative impact of micro-managing, such as poor knowledge management, reduced employee autonomy and reduced morale (Doran, 2016; Perott, 2002). The reluctance to change practices and maintain hierarchal decision structures is common culture and practice prevalent in the public sector (Kamal et al., 2015; Thong et al., 2000), furthermore, government employee autonomy is recognised as a fundamental ingredient for successful public organisations through the successful management of processes (Thong et al. 2000). Therefore, whilst reduced micro-management of the tender and procurement process in isolation may not undermine the Permit process, the hierarchal culture where employees have less decision making autonomy and undermined morale can have a negative cumulative effect on overall RWSW are management, which can impact on-site operations.
- Similarly, the overall expert consensus was that the HA's schedule of rates should be formally documented to provide instant costs, and prevent officer time wastage

involved in a customised quote. However, DCC felt that a published rate does not accurately reflect the true cost of an in-house work-force, and thus does not provide best value. As a compromise, the HA proffered an indicative published schedule of rate, however this compromise does not improve the process significantly, as the final price remains subject to change which presents problems such as time wastage and additional accountancy works (see Chapter 4.4.2)

Table 4.9 details the RE's validated recommendations for improvements as part of the 'to be' maps. The table also includes updated recommendations based on the validation exercise.

Table 4.9 Recommended and validated improvements to road works management process - items marked with * refer to additional changes proposed by stakeholders as part of the validation process

<i>Stage of project</i>	<i>Problem</i>	<i>Recommendations</i>
1. Receive enquiry	Duplicate entry of enquiry across CRM system and Highways IT systems.	Update programs to support vertical integration across IT systems (in progress).
2. Investigate enquiry	Duplicate system of enquiry across modules of single Highways IT system.	Update fragmented Highways IT system with a state-of-the-art system. *This proposal could be advanced by procuring IT across regional HAs for collaborative procurement.
	Manual process requiring paper work and camera.	Update to portable electronic tablets to use on site, with remote access to Highways IT System (in progress).
3. Detailed design	Numerous design software used by different teams and disciplines across designers.	Integrate the highways design software applications onto a single cloud based collaborative construction platform.
	Poor response rate for information about utility assets and utility future development plans.	Confirm point of contact for utility asset records and future works for individual utility companies regularly.
	Asset management data (lighting, signals, drainage etc. is not freely available, and must be obtained by contacting individual officers.	Store asset management data in a central location in an accessible format, for instant retrieval.
4. Submit PAA	Not enough advance notice is given about future works, with less than the minimum 3 months sometimes.	Furnish advance information for large impact and major works on the business plan at the beginning of the year (or earlier) with approximate dates. Set up a 'safe-guarded for future works' hatch on a GIS plan for future works (HA or utility companies).
5. Produce work schedule and costs	A schedule of rates is not published and the Works Manager must be emailed for quotes for all works.	*Formalise an indicative schedule of rates for staff to be able to devise an indicative cost.
6. Procure contractor	Team leader micro-manages procurement process.	*Team leader involvement should remain to facilitate quality assurance checks.
7. Programme works	Programme Monitoring meetings are considered a bottleneck which provide no clear value.	*Meetings should remain in order to facilitate joint decisions.
	The ability to check road space availability is restricted to Technical Administrative staff.	Staff should have direct access to road space data removing Technical Administrative Team staff from the process entirely.
	Operational programme of works is not available for common view.	Operational work programme should be accessible on IHMS and visible across the service area.
8. Book works with contractor	No problems identified.	N/A

<i>Stage of project</i>	<i>Problem</i>	<i>Recommendations</i>
9. Submit Permit application	Produce paper works packs for approval and submission. Permit applications submitted by Technical Administrative staff.	Make process paperless and authorisation electronic (in progress). *The permit submission process is best placed with the Technical Administrative team.
10. Assess Permit application	Not enough coordinated working with others.	Report proposals, with potential sites and approximate dates for all major works at the Quarterly Coordination. *Significant coordination efforts should be made outside of coordination meetings by a dedicated road works planner. HA to be represented at quarterly coordination meetings.
11. Advise applicant	Manually check IT system for a response from NM.	Update fragmented Highways IT system with a state-of-the-art system (in progress).

This section provided an overview of the validation exercises undertaken with RWSW management experts, based on the ‘as is’ maps (see Appendix G) and ‘to be’ maps (see Appendix H) developed with DCC process experts.

4.5.3 DEVELOPMENT OF A LOGIC MAP

RWSW management policy is considerably under-researched (Fisher, 2012; Tseng et al., 2011); furthermore, literature on LAs administrative RWSW management techniques are further sparse. Therefore, to capture and share the learning from this project, and also to provide a point for further research to build on, a logic map was developed. The logic map is based on the learning from documenting ‘as is’ road works processes for objective 4 (see Chapter 4.4) and from the ‘to be’ expert validation exercises as part of objective 5 (see Chapter 4.5.2). A logic map can be described as an important road map for focusing on key and overarching system attributes and can be used to document internal management functions and processes (McLaughlin and Jordan, 2004). Logic maps depict how organisations’, processes or strategies should work, typically incorporating the underlying context, principals, and activities/practices necessary for short, medium and long-term outcomes (Knowlton and Phillips, 2013; McLaughlin and Jordan, 2004; WK Kellogg

Foundation, 2004). The proposed logic map enabled the documentation of a strategy for administrating RSW activity through Administrating Street works Events and Road works (ADMINISTER). The ultimate purpose of the logic map is to facilitate a minimally disrupted transport network through a well-managed RSW process.

ADMINISTER is a high-level logic map, intended to aide LAs in their duty to manage and coordinate RSW management processes under S59 of NRWSA 1991 (see Figure 4.17). Specifically, it considered the key processes in road works management, and identified the key input factors required, associated key strategic supporting activities and highlighting possible participants. The logic map is presented in the journal paper in Appendix A. The logic map is purposefully high-level to ensure transferability, with individual recommendations being illustrative rather than exhaustive to enable amendment and additions as appropriate. ADMINISTER is aimed at senior managers in LAs with regulatory highway maintenance and network management functions to provide a high level system overview. The map could be used for bench marking to compare management approach, or as a basis for process review. Principally, ADMINISTER considers that skilled staff, efficient work flows, efficient data flow and using technology, equipment and resources, could be one way to bring about a streamlined and value adding process.

The logic map is depicted in Figure 4.17. More information about the key inputs and activities featured in the logic map are available in Appendix A.

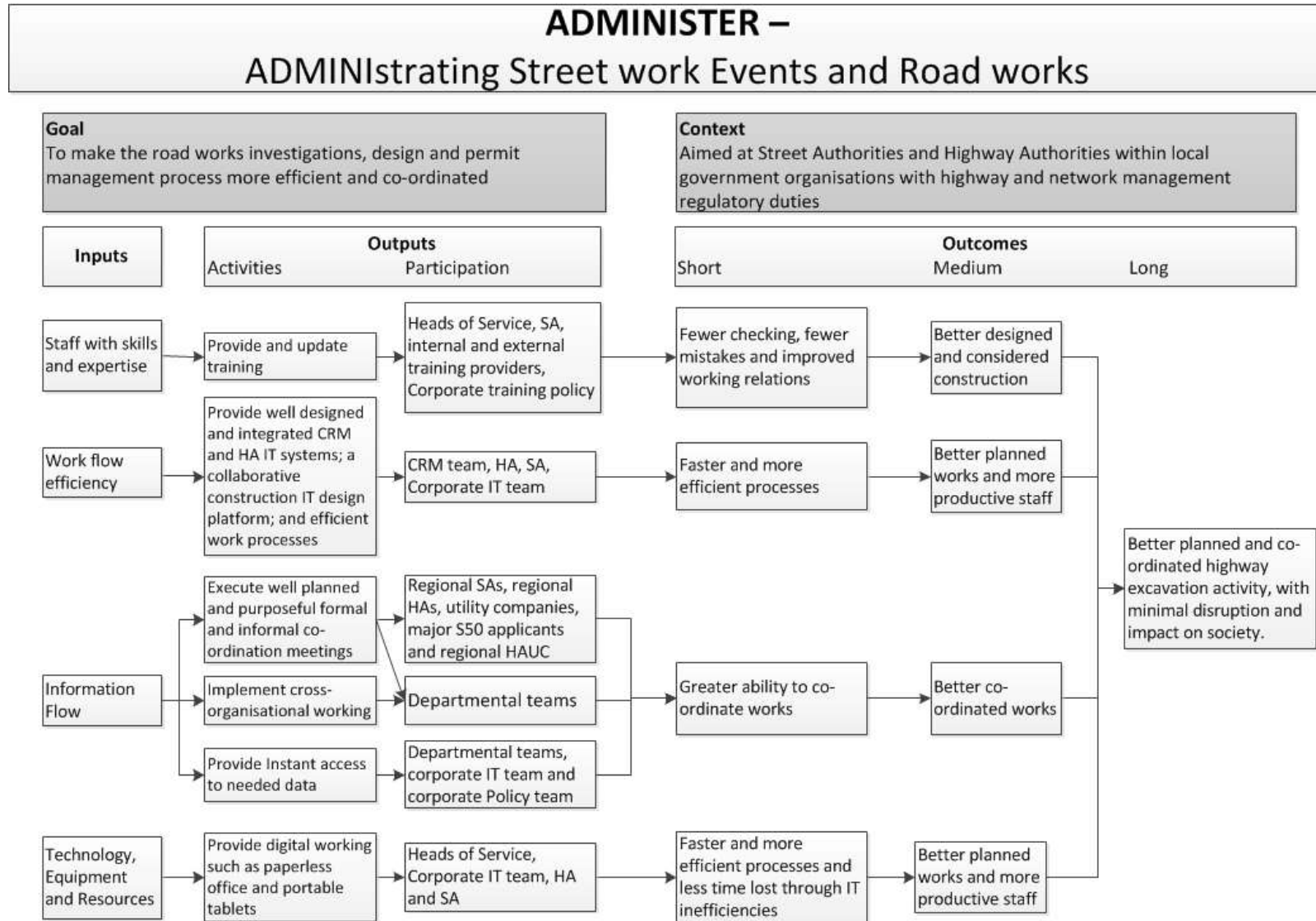


Figure 4.17 ADMINISTER logic map

A worked example of the logic map could be interpreted as follows:

If: an organisation has staff with skills and expertise, → supported by updated training, →with the possible involvement of Heads of Services, the SA, internal and external training providers and corporate training policy, → it is likely to lead to better planned and coordinated highway excavation activity, with minimal disruption and impact on society.

Figure 4.18 details the anticipated outcomes over the short, medium and long term.



Figure 4.18 Anticipated outcomes of adopting ADMINISTER

4.5.5 DISCUSSION

The logic map proposes an approach to manage road works administrative processes efficiently and effectively, whilst taking into account the inputs and outputs from a range of different activities from different stakeholders. The map can aide LAs to identify the key attributes to enable a well-managed RSW administrative process. It is acknowledged that there are likely to be many and wide ranging implications of adopting the logic map: finance and resource availability are two such key factors. The validation exercise with industry experts identified that DCC’s problems and issues were rather typical of other LAs in the country, and beyond (see Appendix A) and required addressing. Further impetus for change is necessitated by the overwhelming financial challenges faced by the public sector (Lepert

and Brillet, 2009) and sustained cuts in highways budgets and staffing levels (CIHT, 2016). However any change would require full consideration to be given to change management, because of embedded cultural practices prevalent in the public sector such as a culture of inertia, risk aversion and resistance to innovative practices (Kamal et al., 2015; Janssen and Cresswell, 2005; Thong et al., 2000). Change would also need to be championed and led by senior managers, who have the greatest control over re-orienting embedded culture.

In summary, based on the quality of the ‘inputs’ already in place, it is inevitable that each LA will be at different stages of ‘readiness’ for comprehensively administering road works. Dependent of the readiness of the LA, there may be a number of resource and financial implications which need to be considered, therefore, LAs should examine the inputs and consider their implications on a case by case basis.

4.5.4 CONCLUSION AND RECOMMENDATIONS

Objective 5 sought to evaluate the proposed process maps, and to develop a RWSW logic map. To meet this objective, firstly, the ‘to be’ processes were validated by industry experts through a focus group and individual semi-structured interviews. Industry validation sought to provide an objective and expert review of the recommendations made, (see Appendix H for validated ‘to be maps). Secondly, based on the findings from objective 4, as detailed in (Chapters 4.4.2 and 4.4.3), and the validation exercise, the ADMINISTER logic map was developed and validated by industry experts.

In conclusion the following recommendations are made:

- That DCC adopt an action research approach to test the ‘to be’ process maps through operation, observation and amendment until DCC are satisfied with the process.

- Councils adopting ADMINISTER must consider change management strategies to overcome embedded culture, otherwise processes are likely to remain inefficient.
- Where reduced organisational ‘readiness’ prevents full ADMINISTER adoption, an action plan is made to address readiness shortcomings, supported by high level buy-in and senior level ownership.
- Change needs to be championed by senior organisational managers to be effective, and backed by commitment, strategy, resources, employee support and training; otherwise improvement efforts could fail.

4.6 CHAPTER SUMMARY

This chapter discussed the research undertaken to meet the EngD aim and objectives as detailed in Chapter 1.1. It provided results of the findings for each objective, as well as check point summaries of key insights into RWSW management, and how the projects helped to address the research problem as appropriate. Chapter 5 details key study findings as well as the overall conclusions of this research.

‘Check point’ summary which provides a snapshot of how the project has contributed new insights to RWSW management knowledge and in some cases how the project has helped to address the research problem described in Chapter 1.1.

5 FINDINGS & IMPLICATIONS

This chapter presents the key findings for this EngD, along with its impact on DCC and implications on the wider RWSW industry. The chapter is structured to firstly present the key findings of executing the objectives detailed in Chapter 1, to meet the overall research aim. The chapter goes on to present the contribution to existing knowledge and practice as well as critically evaluating the research. Finally, a number of recommendations for industry and further research are made.

5.2 A REVIEW OF THE OBJECTIVES

Chapter 1 identified that RWSW were regarded as a necessary but highly disruptive activity, which needed improved management to mitigate their impacts. Undesirable impacts included damaged highway infrastructure from repeated cuts, as well as highly undesirable social effects such as congestion, poor air quality, and increased social and economic costs amongst others. This EngD set out to examine the efficiency and effectiveness of managing the business processes of RWSW, using a triangulated approach, incorporating qualitative and quantitative techniques (as detailed in Chapter 3) to help to move closer to addressing the research problem. A number of objectives were presented in Chapter 1, which will be examined in turn, detailing the findings that emerged as a result.

Objective 1 - Review related work on managing road works and street works.

Objective 1 focused on examining related literature on how RWSW were being managed, as this was an important factor in managing the research problem detailed in Chapter 1. Literature (as detailed in Chapter 2) highlighted that RWSW internationally tended to be managed through technology or policy based measures; although the latter was significantly

less researched (Fisher, 2012; Tseng et al., 2011). Whilst the literature found high level data about RWSW management, such as scheme types, a distinct knowledge gap existed in both academic and grey literature about the operational and day-to-day management. Whilst there was clear acknowledgement for RWSW management to mitigate its negative impacts (Abdelmohsen and El-Rayes, 2016; Weng and Meng, 2013; Walker and Calvert, 2013), there was little supporting evidence of policy measures or their performance.

In addition, a detailed review of available academic and grey literature was undertaken (see Chapter 3.4.1 for method) of the RWSW industry (as detailed in Chapter 4.1.1) highlighted that the utility industry was a profit driven industry subject to either high levels of regulations (monopoly industry), or high levels of competition (free market), specifically related to the telecoms industry, which made it especially vulnerable to corporate theft. These respective reasons present key motivators for SUs to work quickly, and singularly, to maximise profits. This secondary and inadvertent impact of silo SU working contributed to the negative impacts of RWSW, as identified in Chapter 1.1. The profiteering nature of SUs was considered adversarial to the LAs two statutory duties; firstly the HA's duty to manage and maintain the structural life of its highways, and secondly the SA's coordination and network management duties (see Chapter 1.5). Therefore this first objective enabled establishing that the research problem (Chapter 1.1) can be attributed to divergent priorities of the two main stakeholders involved in RWSW management, namely the SUs profiteering nature and the LAs public service nature.

Objective 2 – Establish the current working practices to identify RWSW operation

Objective 2 (see Section 1.2 for scope) required the establishment of current industry workings, to establish potential contributors to the research problem. To capture current

working practices, expert stakeholders were interviewed on the operational and strategic working levels (see Chapter 3.4.1 for method, and Chapter 4.2 for findings).

On the strategic level, stakeholders acknowledged that differing priorities led the industry to operate in a divergent manner. HAs and SUs were reported as complex industries, with fragmented intra-organisational operations and communications creating process barriers, which in-turn impacted on on-site RWSW management. The need to reduce RWSW and its negative impacts (see Chapter 1.1) was acknowledged by utility stakeholders, however, there were firm expectations that SAs should own and lead this effort in accordance with their statutory duties. Indeed, a number of interviewees felt that LA management processes were traditionally weak, lacked impact and evaded full responsibility for coordinating works. Whilst this was considered culturally embedded, national austerity cuts exacerbated this through reduced resources. Quarterly prescribed coordination meetings led by SAs were particularly criticised for being weak, poorly planned, inefficient and superficial, where little coordination actually took place (as detailed in Appendix B, and confirmed in a subsequent study in Appendix A). Stakeholders identified a range of key drivers and opportunities for improved working, such as the value of good communication, improved quality of reinstatements and improved public image. However, the industry faced a number of key barriers, which included complex legislation which created financial risks for utilities, perceived conflicts with industry legislation and limited ownership of the coordination effort (see Appendix B).

Furthermore, the construction workforce played a major role in the management of RWSW, as HAs and SUs were highly dependent on their workforce. High numbers of small specialist contracting constructions firms, driven by an adversarial working and profiteering culture,

meant that the construction industry financially benefitted from uncoordinated and fragmented RWSW as detailed in Appendix B.

On the operational level, the EToN system was generally seen as simply a data transfer mechanism as opposed to an aide to coordination (as intended by underpinning legislation). Alerts for coordinated working opportunities were generally seen as ‘work clashes’ which needed to be avoided. Instead, SUs focused on meeting their core business pressures, such as providing and maintaining essential utility supplies within specified regulated timescales to maximise profits. SU organisations were found to be generally structured in a fragmented fashion, which meant silo working was common and undermined intra-organisational working (See Section 4.2.2). Coordinating works was not a part of SU processes or psyche, as it was expected to be under LA control, therefore this presented little commitment to RWSW management.

In summary this objective assisted towards establishing extant industry working practices, and demonstrated that there were various cultural, institutional, legislative and practical reasons obstructing SUs and LAs from coordinated RWSW management. Recommendations to help improve practices in the RWSW industry, are detailed in Chapter 4.2.3 and Appendix B. Key recommendations include:

- SAs taking full ownership for the RWSW management process, and providing strategic vision and direction,
- Works promoters pro-actively managing contractors through a performance measurement and management framework to review performance;
- To amend NRSWA legislation to use terminology that supports and recognises multi-agency working instead of placing the entire onus on the works executer;

- HAs should undertake highway reinstatements commercially on behalf of undertakers, but simultaneously discharge undertakers of reinstatement performance guarantee obligations (this should however be subject to scrutiny from anti-competitive policies and regulations); and
- That SAs work with their HAs to adopt policies which champion longer highway structural life such as increasingly adopting trenchless techniques and trench charging (see Chapter 2.2.1).

Objective 3 –Assess the effectiveness of managing RWSW at a local level

Objective 3 required the assessment of the effectiveness of managing RWSW at the local level to measure how effective policy tools were in reducing RWSW activity. Accordingly, a quantitative time series analysis of HA and SU works in Derby was undertaken to measure mean works durations before and after policy interventions (see Chapter 3.4.3 for method). The key study focus was examining the Permit Scheme impact on works durations; although the HA study additionally included the WOMS intervention (the JCB Pothole Master and in-house construction workforce interventions were excluded for occurring too close to the Permit Scheme - see Chapter 3.4.3). Independent ARIMA HA and SU models identified that the Permit Scheme reduced SU works durations by 5.3%, which was equivalent to around 727 days, equating to cost savings of between £2.2-£7.7m annually (see findings in Section 4.3.2).

WOMS had the most detectable impact on reducing HA works durations by approximately 34%, which was equivalent to around 6,519 days and cost savings of between £8.25-£48.3m annually. Conversely the Permit Scheme made no statistically significant or detectable impact on works durations. Key reasons proffered for this are that:

- The SA may not have increased its management efforts in-line with additional powers the Permit Scheme affords (see Chapter 3.4.3) ;
- The HA may not have increased works pre-planning significantly to match Permit Scheme endeavours, instead, making minimal/enough efforts to secure Permits (see Chapter 3.4.3); and
- The recorded Permit works duration data do not accurately reflect on-site works durations, as a minimum of one day must be recorded under the Permit/Notification statutory process; whereas in reality a minor pothole repair can take as little as 30 minutes to complete.

In summary this study has critically demonstrated that whilst the Permit Scheme was successful in reducing SU works durations, it did not noticeably reduce HA works, and therefore should not be seen as a panacea for improving RWSW in isolation. WOMS successfully demonstrated that improving the business process could lead to improved performance of works on-street. Notwithstanding this, some caution should be applied, as WOMS is not a construction tool; therefore it is likely that WOMS has improved works reporting as opposed to reducing works durations in isolation.

Key recommendations for the effective management of RWSW as a result of this study are:

- That work promoters should focus on pre-planning works to help realise better outcomes on-street. Greater pre-planning involves greater communication with the SA, submission of robust site information, plans, methods, techniques, and detailed traffic management information.
- The SA should incentivise behavioural and process changes by periodically publishing performance data detailing works durations to induce high level public accountability

as an appropriate incentive. Outputs should be transferred to meaningful data that are easy for the public to interpret, for example:

- how many hours of congestion was saved compared to a previous period;
 - what this equates to in monetary values; and
 - What this equates to in air quality savings (Derby is due to be designated a Clean Air Zone in 2020 due to illegal exceedances in nitrogen oxides (NO_x) and particulate matter (PM) (Defra, 2016)).
- That more effort is made to reduce the volume of HA works occurring, through greater internal communication, and improved planning and coordination of works;
 - That SAs can minimise RWSW impacts by conditioning Permits so that minor works execution cannot take place during peak travel hours.
 - In consideration of the WOMS impact, to invest in process improvement to make processes more efficient.

Objective 4 - Develop business process maps to identify opportunities for the improved management of the RWSW sector.

Objective 4 required a detailed analysis of DCC to investigate how to make back office RWSW processes more efficient, and to improve intra-organisational working. This objective was met through the development of business process maps of the Highways Engineering, Highways Maintenance and Network Management teams. ‘As is’ process maps were developed in consultation with process experts to accurately document existing business processes. A number of key problems undermined process efficiency. Critically, IT systems were poor, which meant that inefficient processes were created to fit around the capabilities of

these systems, therefore opportunities to improve IT systems were identified. In terms of workflow design, staff did not always have access to needed data, thus creating bottlenecks which prolonged processes and created inefficiencies, therefore the opportunity to improve data access across the teams was identified. Planned works information was not shared until late stages, because it was perceived that the SA was uninterested until finalised construction dates, which tended to be late in the project. This meant that the SA's ability to coordinate works was significantly compromised – therefore an opportunity to improve coordination through improved communication was identified. Accordingly, 'to be' process maps were developed incorporating a number of changes to improve the RWSW management.

The study found that there were problems throughout the LA's road works process which undermined the entire process. Whilst Chapter 4.4.4 details a number of specific recommendations, the following overarching recommendations are made to the Council:

- IT systems should be symbiotic, fit for purpose, reduce bottlenecks and assist in efficient delivery of a process. Consideration should be given to updating IT where needed.
- Internal communication needs significant attention as opportunities to collaborate and coordinate works are being missed. High level attention should be given to this matter due to its departmental implications.
- DCC should work with stakeholders to review the purpose of, and revamp coordination meetings to ensure that they actually facilitate joint working, and meet stakeholder expectations.

Of course the implementation of the above recommendations will have a number of resource and financial implications which will need to be considered.

Objective 5 - Evaluate proposed process maps for their effectiveness, and develop a logic map for the management of road works and street works activity for transferability to other local authorities.

Objective 5 firstly sought the evaluation of the process maps developed as part of objective 4, and secondly, the development of a logic map. As detailed in the method provided in Chapter 3.4.5, this objective was met firstly through executing validation exercises with industry experts, and secondly by using the findings from objective 4, and the validation exercises to develop a logic map for transferability to other LAs as detailed in Chapter 4.5.3

Initially, key recommendations as part of ‘to be’ proposals which were put forward for validation included:

- Improving IT systems by adopting vertically integrated systems for improved synchronicity between systems, the integration of highway design software applications into a single cloud based collaborative construction platform, and providing greater access to data amongst others.
- Formally documenting the schedule of rates on the Highways IT system to remove the resource implications and delays caused by sending emails for bespoke quotes.
- To report all proposals for major schemes at quarterly meetings (irrespective of planned dates), and undertake significant coordination outside formal quarterly coordination meetings.

The ‘to be’ process maps were then subject to validation by industry experts through a focus group and individual interviews. The final ‘to be’ process maps incorporating the validated comments are included in Appendix H. A small number of counter-recommendations were made by the experts based on their contextual experience which were incorporated.

Finally, a logic map was developed and subjected to validation by DCC experts, and an expert at Kent County Council. The logic map sought to represent how the road works management process could be effectively and efficiently administered whilst taking into account the inputs and outputs from a range of different activities from different stakeholders. Amongst other factors it considers that skilled staff, efficient work flows, efficient data flow and the use of technology, equipment and resources could be one way to bring about a more streamlined and value adding process.

It is inevitable that each LA will be at different stages of ‘readiness’ for comprehensively administering road works based on the quality of the inputs the organisation already has in place. Therefore, LAs should examine the inputs and consider the implications on resources and costs on a case-by-case basis. Change needs to be championed by senior managers to be effective, and must be backed by commitment, strategy, resources, employee support and training; otherwise BPR could fail.

Key recommendations made include:

- That an ‘action research’ approach is adopted to review and amend the ‘to be’ processes. Action research involves a cyclic study of planning, implementing, observing and reflecting on the study. See Costello (2011) for more information;
- Councils adopting the logic map must consider change management strategies to overcome embedded culture (as discussed in Chapter 4.5.2 by Kamal et al., 2015; Thong et al., 2000), otherwise processes are likely to remain inefficient;
- Where lack of organisational ‘readiness’ prevents full adoption of ADMINISTER, an action plan is made to address issues. This will require high level buy in and senior level ownership (as discussed in Appendix B); and

- Change needs to be championed by senior organisational managers to be effective, and backed by commitment, strategy, resources, employee support and training; otherwise improvement efforts could fail.

5.3 CONTRIBUTION TO EXISTING THEORY AND PRACTICE

As the RWSW policy domain is wholly under-researched, this study has contributed significantly through one published journal paper, one ‘accepted’ journal paper, one journal paper currently under review, and three presented conference papers to the academic field.

More specifically the following new and innovative contributions to knowledge were made:

- The anecdotally discussed RWSW industry stakeholder views were consolidated and formally documented, providing an evidence base for long held assumptions as detailed in Appendix A and B. This provided a state of the industry, identifying common issues, problems and features, nationally and in some cases internationally, to effective RWSW management and joint working.
- The stakeholder study (Appendix B) added to the existing body of construction management literature by including the role of the construction industry in the RWSW supply chain.
- Time series intervention analysis using ARIMA was applied to statistically test policy interventions on RWSW durations. The method used can be adopted by other LAs to test the impact of the Permit Scheme, or other interventions over a time period as detailed in Appendix D.
- A method and calculation for estimating the daily cost of RWSW was estimated, building on the limited existing knowledge of RWSW costs (Appendix D).

- ‘As is’ road works administrative process maps provide a state of practice, to literature which is currently not available; conference feedback found these maps to be useful for benchmarking other LAs internationally. The associated conference and journal publications (Appendix A) detailed day-to-day issues and practices, representing a typical medium sized urban LA. The ‘to be’ process maps recommended revised ways of working to address common poor practices for LAs nationally and internationally.
- A logic map was developed to put forward a way to manage the road works investigation, design and Permit issuing process, providing key resource considerations as detailed in Appendix A.

5.4 IMPLICATIONS/IMPACT FOR THE SPONSOR

This study has helped the sponsor by providing:

- A logic map providing a strategy to improve the overall management of the RWSW administrative process (see Section 4.5 and Appendix A).
- An empirical time series analysis (as detailed in Chapter 4.3, Appendix C and D), enabling independent and robust testing of an important and controversial policy intervention - the Permit Scheme. The results proved that the Scheme helped reduce RWSW impacts, just shy of initial business case predictions of a 5.5% reduction in works durations (MVA Consultancy, 2012). Whilst the HA did not show a negligible reduction, the SA remains confident that impacts have been masked by other simultaneously occurring interventions which would have been expected to increase

volumes of road works – namely the DLO of the HA’s workforce, JCB pothole master purchase.

- Empirical testing of the WOMS intervention which was found to significantly reduce work durations by 34% (see Chapter 4.3 and Appendix C), providing impetus to investigate internal business processes as part of objectives 4 and 5.
- An investigation of DCC’s ‘as is’ business processes highlighting significant weakness in intra-organisational communication, which has the effect of undermining internal coordinated working, staff morale and prolongs processes (See Chapter 4.4 and Appendix A). Steps are being taken at the senior organisational level to address this as part of wider divisional communication.
- Identified the need for a more sophisticated IT suite to manage multiple IT design systems, such as a single cloud based collaborative construction platform to address identified process inefficiencies (See Chapter 4.4 and Appendix A). Whilst the Council’s financial position cannot justify the investigation of such at present, it may be considered in the future.
- A greater awareness of utility industry operations; whilst the SA enjoyed good working relations with SU partners, the stakeholder study (see Chapter 4.2 and Appendix B) provided access to fresh perspectives, experiences and practices of their industry and also other LAs. Importantly, the study helped to consolidate and provide an evidence base for long held assumptions and beliefs which is especially valuable to the sponsor.

- An important realisation of the limitations of joint working SUs. Despite the adversarial nature of the LA and SUs, the study has helped to clarify the position of the SUs in respect of RWSW management, through providing insights into their operations, perspectives, concerns and barriers. This has helped the authority to be more realistic in managing their expectations of the utility industry, and helps improve areas of working which are likely to be more fruitful (see Chapter 4.2 and Appendix B).
- Appreciation that SUs have firm expectations from the authority for greater direction, leadership and ownership of coordination (see Chapter 4.2 and Appendix B).

5.5 IMPLICATIONS FOR WIDER INDUSTRY

This study has brought attention to implications for the wider industry as follows:

- Through the findings of this study as detailed in Chapter 4.1, 4.2 and Appendix B, this research has highlighted the adversarial nature and relationship of the utility industry and local government; which are considered key barriers to effective RWSW management.
- Adversarial working was entrenched as a result of the profiteering nature of the utility industry and construction industry supply chain as detailed in Chapter 4.1, 4.2 and Appendix B. However, the NRSWA legislation and associated regulations exacerbated adversarial working because of the onus they placed on the single works executor, which discouraged joint working, and thus worsen RWSW impacts. This research highlights the need to amend NRSWA so that it supports joint working.

- This research has also highlighted that there is a significant need to reconsider the purpose and scope of prescribed coordination meetings, as stakeholders (including LAs and SUs) did not find them to be fit for purpose as detailed in Chapter 4.4.4, 4.4.2, Appendix A and B. HAUC UK should lead the effort for a detailed study with LAs and SUs to improve the current format by investigating why current meetings are failing, and agree steps to overcome these in order to improve RWSW management. Furthermore, coordination should not be restricted to formal quarterly meetings; smaller informal discussions should be held on an individual project basis to improve management and works coordination– these meetings should be held in an advanced and timely manner to maximise forward planning.
- LAs with current and proposed Permit Schemes should recognise that the Scheme in isolation is not a panacea to managing RWSW, and needs to be matched by motivations that encourage change. In the case of the utility industry this motivation is provided by Permit Scheme costs, however a similar behavioural change mechanism needs to be found to reduce HA works.

5.6 RECOMMENDATIONS FOR INDUSTRY/FURTHER RESEARCH

In addition, the study has shed light on general issues and practices in RWSW management; for which the following stakeholder recommendations are made:

National Government

- Longer budget cycles are needed as annual budgetary cycles can create difficulties for HAs to plan long term works, and thus carry out long term coordination as detailed in Chapter 4.2.2 and Appendix B.
- Government needs to have a stronger role in influencing types of construction methods to minimise utility cuts, or alternatively utilities need to be incentivised to use trenchless technologies where possible (see Chapter 2.2.1), as this could dramatically minimise RWSW disruption.
- NRSWA was considered complex and ambiguous by SUs, and cited as a major barrier (amongst others - see Chapter 4.2.2 and Appendix B) to collaborating with other SUs. Accordingly, in consultation with HAUC UK, NRSWA should be amended to recognise and promote joint working.

Local Government

- Intra-organisation and inter-organisational communication was found to be weak which meant that collaborative working opportunities were lost as reported in Appendix A and B. Concerted efforts and strategies are required to improve intra-organisational and inter-organisation communication to reduce silo working, maximise coordinated working and thus minimise highway disruption;
- The stakeholder study (Appendix A) found that SUs were highly critical of LAs for failing to manage RWSW, particularly as works coordination is prescribed on SA's under S59 of NRSWA. Accordingly, genuine senior level ownership and

commitment to improving highways management is needed to help motivate and drive cultural change within LAs as detailed in Chapter 4.2.3;

- Poor functioning IT systems were found to cause delays and reduce productivity in back office administrative processes (see Chapter 4.3.2), whereby processes were constructed around poor functioning IT systems. Consequently, IT systems, should be reviewed for their performance, with significantly under-performing systems being updated to improve process efficiencies. Indeed the stakeholder study found that well managed works from the outset, often led to well executed works on-site, thus reducing RWSW impacts; and
- Whilst there is a general industrial resistance to investigate efficiency in minor works (less than 3 days duration) due to their perceived insignificance, minor works accounted for the highest proportion of works amongst the combined categories (see Chapter 4.3.2). Indeed, DCC's minor works grow substantially following the move to an internal DLO and the JCB Pothole Master purchase, and therefore their increase should be managed through increased intra-organisational collaboration to reduce RWSW impacts.

Utility sector

- In investigating the stakeholder study, it was evident widespread departmental fragmentation was evident within SUs (as also reported in Appendix B and detailed in Chapter 4.2.1) where interviewees reported limited knowledge about other departmental works. Therefore, this fragmentation requires addressing strategically to enable joined-up organisational thinking and working, to mitigate RWSW impact where possible.

- Although at a strategic level there is an acknowledgement and acceptance for the need to manage RWSW to reduce their impacts, this was lost at an organisational level (See Chapter 4.2.3). Accordingly, genuine senior level ownership and commitment to reduce highways cuts needs to cascade through the organisation, to raise awareness of the impact of utility cuts, and thus help drive institutional cultural change.

5.7 CRITICAL EVALUATION OF THE RESEARCH

This section provides some of the limitations of the research project:

- The focused nature of the intervention analysis enabled the exercise to be undertaken in a detailed manner afforded by case studies. However, whilst the findings of the Permit Scheme impacts can be generalised to a degree, a number of characteristics make the case unique, such as the additional significant interventions by the HA (DLO and JCB Pothole Master purchase) at the same time. It is possible that these interventions have skewed outputs; therefore masking the true Permit Scheme impact, and thus under-representing any potential reduction of HA works durations.
- Due to time constraints only one external expert could validate the ADMINSTER logic map. Therefore, it would be beneficial if further expert assessments could have been made.
- Despite tenacious attempts to engage utility companies to participate in the BPR exercise, engagement was limited. It is felt that the lack of involvement included a combination of reasons such as protecting commercial secrets, limited resource availability, and unfortunately limited commercial interest in the subject. The utility industries involvement would have been invaluable for this project providing a view of their processes.

- Both the time series study (objective 3) and the BPR study (objective 5) were case studies, undertaken to examine DCC's operations. It is arguable that the case studies are therefore unique and not generalisable.

5.8 RECOMMENDATIONS FOR FURTHER RESEARCH

The research presented in this thesis contributes to the strategic process of improving the RWSW management of DCC. It has established current practices, identified areas for improvement, and developed the ADMINISTER logic map with input from stakeholders. Findings from this research project add to the limited body of academic knowledge, and demonstrated the potential for improvements in RWSW management. This research can be developed further in the following ways by:

- Repeating the Time Series Analysis study in another LA to test the performance of the Permit Scheme. The selected authority should not have any other major policy interventions introduced within a close period as this could create difficulties in differentiating the independent impacts of interventions.
- Although the construction work force were briefly discussed in the stakeholder study (Appendix B), there is a need for further research to investigate their perspectives and issues faced, for a more holistic study of the industry. Green (2011) and Green and May (2003) strongly oppose BPR as they feel it has a highly negative impact on the construction industry, whereby people in the construction supply chain are treated as 'passive objects' and forced to lower costs whilst improving delivery, which exacerbates entrenched adversarial working cultures. It is important to therefore learn more about the construction industries perspective to improve RWSW management.

- Providing more studies into the value of RWSW. The most recent and most robust street works study costs was undertaken by McMahon et al. (2005) – at least 12 years ago. No similar study could be found for estimating the impact of road works. This information is important as evidencing the financial impact of RWSW on the economy helps to pressure work promoters into taking steps to mitigate their construction activities.
- Anecdotally, DCC is aware that RWSW can have a significant impact on social exclusion, particularly for those who are disabled, old, and for whom English is not a first language. RWSW can create physical displacements, which vulnerable groups of people are not always able to overcome leading to important activities being missed such as school, medical visits and in some extreme cases, social interaction. Therefore further research is needed to investigate how to reach out to and minimise RWSW impact on the most vulnerable people.

Notwithstanding these suggested lines of further research, it is important to point out that RWSW policy is generally wholly and frustratingly under-researched. The impact of RWSW such as congestion, air pollution, and local businesses amongst others is significant and expensive (see Chapter 1). Therefore significant research into all areas of RWSW management policy is advocated.

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APPENDIX A (PAPER 1)

JOURNAL PAPER

Title

Process mapping for road works planning and coordination

Full Reference

Hussain, R. S., Ruikar, K., Enoch, M., Brien, N., Gartside, D. (2017) Road works planning and coordination: a management logic map, Built Environment Project and Asset Management, accepted 1 February 2017.

Abstract

Purpose - Diminishing local government budgets coupled with the need to reduce highway works activities drive an increasing need to deliver cost effective and efficient processes. The aim of this paper was to investigate how road works administrative processes could be streamlined to enhance coordinated working opportunities at Derby City Council.

Design/methodology/approach - Case study research was undertaken, using Swimlane analysis to reengineer business processes of three key teams, from the design stage, to issuing a road works permit. Process improvement recommendations were expertly validated through a focus group and semi structured interviews. A logic map was developed for transferability to other local authorities, identifying key attributes of a successful administrative road works management process.

Findings - Research revealed that silo working was inherent and that processes were built around fragmented IT systems creating inefficiency. Validation found that certain practices and management styles were culturally embedded and common across local authorities. Peer reviewed recommendations are made to improve working practices, including improving IT systems, removing process bottlenecks, and providing staff training.

Research implications - Whilst road works management policy is generally under-researched, its strategic and major negative impacts are widely acknowledged. This study highlights the day-to-day operational problems which are interconnected to the strategic impact, bridging an important gap in knowledge, as well as adding to Business Process Reengineering literature.

Originality/novelty - The research adds to a limited of body of road works management policy research, and also presents a high-level framework for road works managers to adopt as appropriate.

Keywords – Business Process Reengineering, public sector, highways, policy

1. INTRODUCTION

Public highway works (utility works and highway maintenance) management increasingly requires enhancement to minimise its negative impacts on society including, congestion, depleted structural life, compromised air quality, local business losses, general public inconvenience and aesthetic depreciation (Brady et al., 2001; Hussain et al., 2016; Lepert & Brillet, 2009; Matthews et al., 2015; TRL, 2009; Walker and Calvert, 2015). Moreover, UK utility construction cost around £1.5 billion annually, whilst wider societal costs are estimated far higher - around £5.6 billion annually, of which £5.1 billion comprises driver time alone (McMahon et al., 2006). More recent utility construction costs by the National Joint Utility Group (NJUG) lie at around £2 billion (Bennett, 2014).

Derby City Council (DCC) recognises the aforementioned undesirable symptoms and adopted a Permit Scheme in 2013 to exercise greater control of planning and coordinating highway activities. However, industry stakeholders regard that inefficient back office business processes hold back efficient on-street operations (Hussain et al., 2016). Therefore, the study rationale is to investigate whether process efficiencies can be gained through reviewing business process activities. Although highway works incorporate both road works (highway maintenance works) and street works (utility works), DCC seeks to investigate internal business processes given the greater ability to influence intra-organisational change, before encouraging utility stakeholders' participation. A logic map is also developed for wider adoption by other local authorities (LA). This research is timely, because sustained HA (Highway Authority) budget cuts force additional powerful incentives for efficient working. The remaining paper details the literature review, method, findings, a road works planning logic map, discussion and a conclusion.

2. PROCESS EFFICIENCY IN HIGHWAYS MANAGEMENT

Great Britain's local road network comprising around 238,000 miles is statutorily managed by LAs; the strategic road network (SRN) of around 7,600 miles of mainly motorways and trunk roads is controlled by Highways England, Transport Scotland and the Welsh Government respectively (DfT, 2016). However, communities living and working in LA areas necessitate basic utilities such as energy, water and telecoms, leading to more highway cuts on local roads (Marvin and Slater, 1997). Whilst a structured and efficient approach for managing highway works is clearly required (Brady et al., 2001; Zhang, 2016), English LA highway works coordination processes are reported to be weak, superficial, and lacking ownership and coordination effort (Hussain et al., 2016).

One way of reviewing works is through business process reengineering (BPR), comprising radical process re-design to make significant organisational service, quality and cost improvements (Hammer and Champy, 2001). BPR distinguishes value adding and non-value adding activities, which assist process streamlining. Despite manufacturing origins, BPR is increasingly popular in office environments, and now government (Niehaves et al., 2013). However, unique public sector characteristics make removing non-value adding activities, and adopting private sector BPR lessons difficult. Unique characteristics include their non-profit driven nature, legal/formal constraints, accountability and honesty expectations, bureaucratic hierarchal structures, political influence, and reduced decision-making autonomy amongst personnel (Janssen and Cresswell, 2005; Kamal et al., 2015; Thong et al., 2000). Nevertheless, stakeholder expectations for efficient processes, and enhanced process and information technologies (IT) synchronicity, mean that government BPR remains advocated (Gulledge and Sommer 2002; Weerakody et al., 2011; Weerakody and Dhillon, 2008).

Process efficiency in highways management has been sought previously. For example, process improvements have made lengthy business processes faster and cheaper for Pennsylvania Department of Transport, who automated parts of the highways defect management process to hand-held mobile inspection devices leading to significant cost savings (Tomassini 2014). Separately, Highways England adopted an alliance and partnering framework - the Construction Management Framework (CMF), to improve procurement processes and collaborative working arrangements in major maintenance projects. Applying partnering principals of mutual trust and cooperation, the CMF emphasised the importance of communication and close working (Ansell et al., 2009). Additionally, 'lean' helped improve process efficiency and added value to highways projects. For example, the UK's Highway Maintenance Efficiency Programme (HMEP, 2013) report a lean review of pothole response activities, leading to revised processes, practices and equipment at Walsall Council. Ansell et al.'s (2007) study on Highways England's maintenance project (construction phase) found that lean working enabled greater emphasis on advanced formal planning, encouraging workforce discipline and focus on forthcoming tasks. The study stressed the importance of training operatives on lean principals to ensure wider understanding and sustained buy-in, and critically effective leadership to ensure project ownership. Indeed, lean construction was considered 'the biggest opportunity for improving operational productivity' (Wolbers et al., 2005). However, construction sector BPR and lean have been criticised as damaging rhetoric for efficient and streamlined working, which actually undermine the construction workforce. To enable process 'optimisation', people in the construction supply chain are treated as passive objects. Furthermore, contractors are forced to lower costs whilst improving delivery, which exacerbates entrenched adversarial working cultures (Green, 2011; Green and May, 2003); therefore the entire impact of process improvement activities requires consideration.

Whilst high-level process improvement cases are highlighted, literature at the tactical and operational levels, particularly in LAs is scarce. Therefore, LA operational level research issues is required, because it has a direct impact on on-site works execution, and currently this complex arena is under-researched.

3. METHOD

A case study approach was most suited to investigating the business processes of an LA because it enabled immersive and in-depth understanding of the authority's processes, whilst also providing rich subject data access in its contextual setting (Yin, 2014). Derby city was selected as representative of a fairly typical medium sized urban English regional city, of around 250,000 with a Permit Scheme. For this study three team processes were examined: Highways Maintenance and Highways Engineering teams, as the Highway Authority (HA) who were 'work promoters', and the Network Management team as the Street Authority (SA) who regulators.

As a key BPR component, business process mapping (BPM) was utilised to document DCC's administrative processes. BPM enables the understanding, investigation and evaluation of complex business processes for efficiency and effectiveness, supporting redesigned processes for improved outcomes (Biazzo, 2000). Amongst various BPM techniques considered, Swimlane diagrams (Sharp and McDermott, 2001) were selected for their ability to map complex, multi-actor processes (and sub-processes) simply. The study relied on DCC experts for process knowledge, thus snowball sampling was used to select two 'core' process experts from each team. Workshops were undertaken with process experts, where processes were

recorded on large sheets using sticky labels - additional comments were manually recorded. Processes were subsequently documented into Swimlane diagrams and subjected to an iterative process of amendment and approval, until process experts approved final versions. Detailed analysis of comments were undertaken using Bryman's thematic content analysis, comprising: text analysis, coding and categorising salient terms, and theming codes together (Gibbs, 2011).

The validation exercise required convenience and purposive sampling to invite middle and senior Highways Managers from eight LAs (constituting neighbouring LAs, or LAs regarded highly for road works management), and representation from the Highways Authority and Utilities Committee (HAUC). Three LAs, a senior HAUC member and six DCC managers ultimately participated in the study. 'Experts' constituted those with interpretative and technical process orientated knowledge (Miles and Huberman, 1994). The author developed a sequential eight step path to conduct this study, as detailed in Table 1.

Table 1 – Research Design

Stage	Purpose	Method and approach	Sources	Participants
1	To understand the strategic business context and position	Documentary analysis - analysis of literature and organisational reports.	Yin (2011)	-----
2	To secure management commitment	Meetings – To promote leadership and ownership of process re-engineering efforts	Hunt (1996)	Derby City Council – Service Director (1), Heads of Service (2)
3	To identify the parameters of the study	Project definition document and meetings – to understand which teams were involved and to agree the terms of reference.	Yin (2011)	
4	To document core functions and processes with process experts	Snowball sampling, Semi structured interviews and business process mapping using Swimlane analysis - two process experts from three team were put forward by their managers to assist in documenting processes. Interviews took place to understand the steps and tasks involved in completing team processes, and were documented in Swimlane process maps.	Bryman (1988); Miles and Huberman (1994); Flick (2014) Sharp and McDermott (2001)	Derby City Council Highways Engineering team (2) Highways Maintenance team (2) Network Management team (2)
5	To assess current processes with experts	Business process mapping using Swimlane analysis and literature analysis - Current processes were examined for strengths/weaknesses and obvious problems through brainstorming and individual assessment steps for its value to the overall process. Literature analysis was also undertaken to contextualise and corroborate the process issues found.	-----	
6	To develop revised processes based on stages 4 and 5	Business process mapping using Swimlane analysis - feedback from stages 4 and 5 was used to develop proposals to streamline processes and increase coordinated working.	Sharp and McDermott (2001)	-----
7	Process validation by expert peers	Focus group, semi structured interviews – a focus group and individual meetings were held to enable experts to discuss the proposals and exchange ideas about their value and their workability.	Collins et al. (2010)	Highways management experts: Derby City Council (6), Sheffield City Council (1), Kent County Council (1) and HAUC (1)
8	To develop a logic map for road works planning and management	Logic Map and semi structured interviews – feedback from stages 4-7 enabled the development of a logic map for transferability to other local authorities.	WK Kellogg Foundation (2004)	Highways management experts: Derby City Council (2), Kent County Council (1)

4. FINDINGS

This section reports findings from the eight step approach adopted to conduct, analyse and draw recommendations for this study.

Stage 1 – Understanding the Business Context and Position

Derby is a fairly typical English regional city of around 250,000 people, with a unitary LA. Central government's sustained national budget cuts have created unprecedented financial pressures in Derby. The Council strategically aims to be a modern and resilient authority ensuring that "every pound and hour is productive" (DCC, 2016a). Departmentally, Streetpride report £19m annual savings to date, and propose a 'lean' review of highway services seeking further efficiencies and savings (DCC, 2016b). Since 2013, the Council provides an in-house direct labour organisation (DLO) for highway works to maximise value.

The Council is dutybound to maximise road capacity through managing the highway network expeditiously and minimising road works and street works activity, thus the Derby Permit Scheme was introduced to take greater control over highway occupation (DCC, 2013). All works executers must now have a Permit to work on 'traffic sensitive streets,' which are free to HAs.

Stage 2 – Securing Management Commitment

High levels of management commitment is required to mobilise change and reduce project failure, particularly in LAs where organisational culture is entrenched, risk averse and change resistant (Cresswell, et al., 2013; Lines, et al., 2015). Therefore, buy-in was secured by the Departmental Director, and the relevant divisional Heads of Service, due to their positions and ability to direct change.

Stage 3 - Parameters of Study

Business process review spanned the Highways Maintenance, Highways Engineering and Network Management teams, as they were directly involved in road works (comprising road maintenance and rehabilitation, and breaking or excavation activities). The study was limited to back office processes, from scheme design to Permit issuing stage, and included 'standard' (3-10 days) and 'major' (over 10 days) works, as these facilitated greatest scope for collaborative working. Minor (less than 3 days), 'emergency' and 'urgent' works were excluded as it was considered disproportionate, inconvenient and potentially unsafe to delay these works.

Stage 4 – Analysis of Core Functions and Processes

Core experts assisted in the iterative exercise of process mapping as defined in stage 3. Highways Engineering's projects were found to be large and recorded on the annual work programme, whereas Highway Maintenance works were more routine, reactive and smaller natured. The headline stages of highway design and maintenance consisted of receiving enquiry, investigation, detailed design, work scheduling and cost production, contractor procurement, programming works, submitting a Permit application and awaiting an outcome. The Network Management team, as a Street Authority, processed Permit applications and sought to coordinate highway activities. Figure 1 details the high level process maps documenting the hand-off between the actors across the current team processes

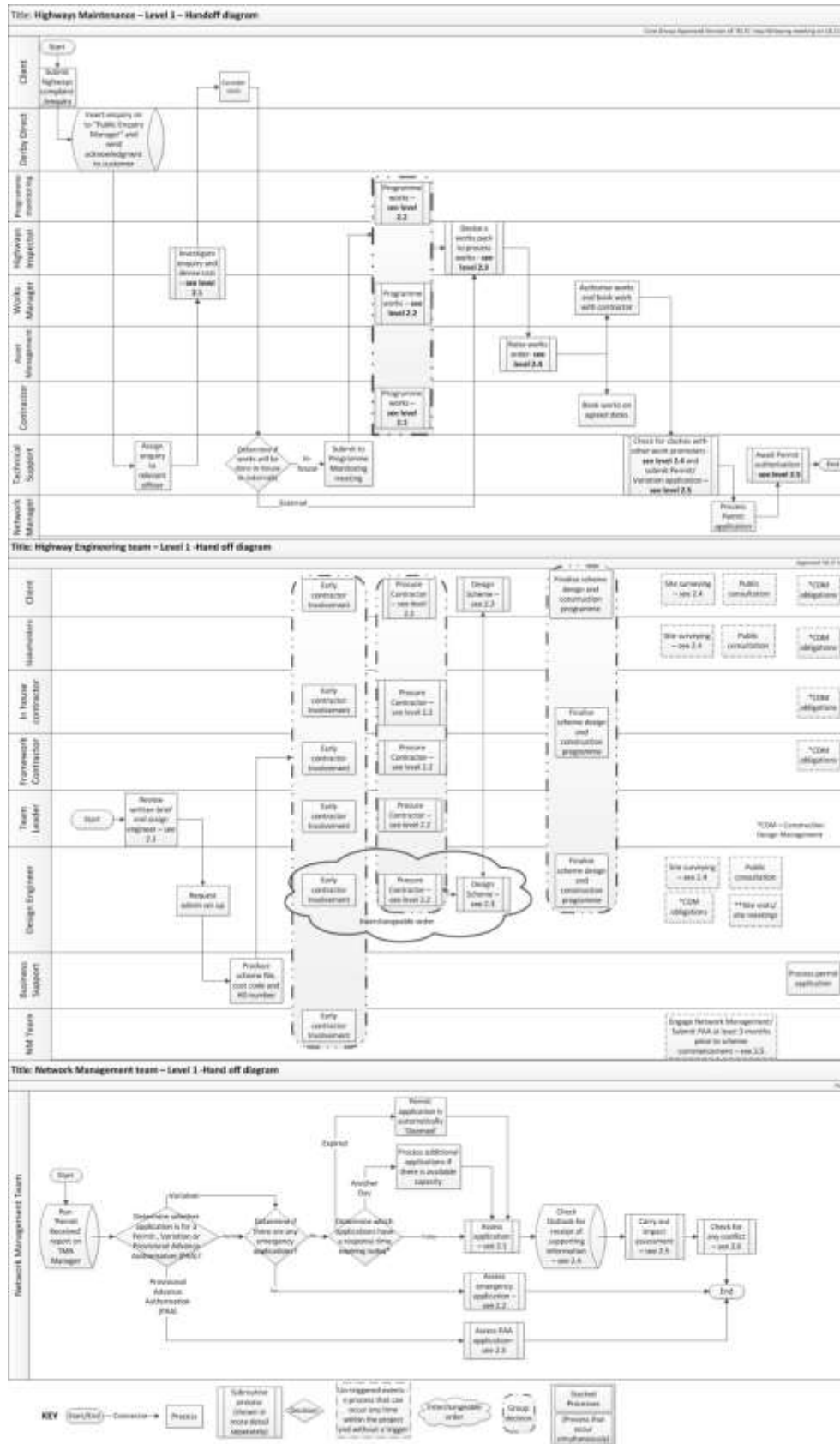


Figure 1 – High level process maps for Highways Maintenance, Highways Engineering and Network Management teams

Stages 5 and 6 – Assessment of Current Processes and Development of New Processes

This section examines the issues found across the teams. Although findings have been categorised into IT, workflow design and human resources (HR), and policies and rules (Sharp and McDermott, 2001), in reality, the themes overlapped each other.

Information Technology

Throughout the study, IT was a key bottleneck in multiple ways. Firstly, all three teams directly or indirectly relied on a combined Highways IT programme. The dual system recorded enquiries, raised works orders, and incorporated 'EToN' (Electronic transfer of notices – a statutory specification to enable electronic Permit exchange (Department for Transport, 2013). Staff had varying data access levels, with little or no formal training. The combined IT programme lacked synergy between modules, requiring duplicate data entry which created opportunities for error. Officers reported a number of issues including:

“There is no efficient way of checking EToN feedback for work promoters”

“We need access to EToN to check the status of Permit applications. Permits can be rejected and the Design Engineer is unaware as we are not informed. We have to rely on Tech Support to manually check the system daily.”

Other key system problems included: the inability to store documents, no prompts or warnings of incoming EToN correspondence, and no simple way to produce reports. The Highways IT system was aged (over 10 years old) and not fit for purpose, accordingly DCC operationalised a replacement system over the study period.

Separately, six different IT packages were used to draw/view scheme designs in the Highways Engineering team, which interrupted seamless design. An officer reported:

“We need a single storage location. Currently there are different software's, IT formats and drawing versions which can be highly problematic. People working from old drawing versions is not unheard of.”

Fragmented IT is symptomatic of data management within the engineering and construction sector, characterised by high data volumes, developed by different professionals, using different IT systems (Beach et al., 2013). Poor IT system architecture and poor integration commonly contribute to process inefficiency (Edwards and Peppard, 1994). Therefore, fractured IT systems should be replaced with a single cloud based collaborative working/document management platform enabling stakeholders to design and view drawings collaboratively (Beach et al., 2013).

Workflow Design and Human Resources

IT limitations meant workflows were modelled around IT systems creating bottlenecks; bottlenecks stem from compulsory information being unavailable to staff (Sharp and McDermott, 2001). Highways Maintenance team processes were particularly fraught with bottlenecks; for example, technical administration staff would check highway availability for proposed works instead of works promoters due to restricted data access. Indeed, unnecessarily restricted data access is an outdated LA practice, which should be replaced with wider data access to expedite works (Weerakkody et al., 2011). A further example is the

schedule of rates for internal DLO works which was not documented, therefore, cost estimate requests were emailed to a single Works Programme Manager. This practice is not only a significant bottleneck, but also undermines organisational knowledge management. Instead, the schedule of rates should be documented ideally within the Highways IT system and be readily available on demand.

In terms of external tender and contract procurement, a team leader was heavily involved in the process, presumably to oversee it and provide advice. This example of ‘managerialistic model’ where managerial involvement and monitoring is assumed to provide greater service, product, or behaviour, can be considered an outdated culture still common in the public sector. Instead the ‘professional model’ should be adopted, where the assumption is that trained and qualified staff lead to high quality and professional service, products and behaviour (Perrott, 2002). It is recognised that government employee autonomy is restricted, however it remains a crucial ingredient for successful public organisations (Thong et al., 2000); consequently, better value could be provided if employees are trained to the same level as the team leader.

Policies and Rules

Limited organisational and cross-organisational working was evident throughout the process. Statutorily prescribed quarterly coordination meetings have historically been held jointly with Derbyshire County Council, an upper tier LA responsible for numerous smaller rural councils. Although the Network Management team attended these meetings, the Highway Maintenance/Engineering teams were rarely represented. The meetings were acknowledged as weak, providing little value to the Authority, tying in with Hussain et al.’s (2016) findings that coordination meetings tended to be contrived and superficial. To address this, DCC should work with stakeholders, particularly HAUC and NJUG to devise a gold standard for coordination meetings, which should subsequently be adopted for independent Derby meetings. The meetings should also be attended by all stakeholders involved in highway works.

In terms of work planning, there was a culture of retaining planned scheme information until construction dates were more definitive, as it was perceived that stakeholders, particularly the Network Management team, were otherwise uninterested. An officer commented:

“Unless we have dates and sufficient plans, Network Management don’t want to hear from us”

Conversely, the Network Management team wanted more foresight of proposed works to plan network activity. Highway works can be significant undertakings, combining multi-disciplinary design, planning, materials, procurement, specialist machinery and on-site construction, requiring high level of planning, involving numerous supply chain actors. It can therefore be challenging accommodating or coordinating works in later stages of planning, particularly after finalised construction dates. Accordingly, work programmes should be available to interested stakeholders at the beginning of each financial year (or earlier if possible) to enable wider coordination notwithstanding firm construction dates. This could be advanced by plotting future works on a map-based system incorporating scheme information and contact details for works promoters.

Stage 7 - Validation of Road Works Management Issues and Recommendations

A validation exercise took place to review the processes and proposals with DCC managers, peer LAs and HAUC. Table 2 presents the problems found in the Derby road works process along with validated recommendations for improvements. The commonalities and conflicts in opinion amongst stakeholders are provided below.

Table 2 – Recommended actions for issues identified at Derby City Council - items marked with * refer to changes proposed by stakeholders as part of the validation process.

Stage of project	Problem	Recommendations
12. Receive enquiry	Duplicate entry of enquiry across CRM system and Highways IT systems.	Update programs to support vertical integration across IT systems (in progress).
13. Investigate enquiry	Duplicate system of enquiry across modules of single Highways IT system.	Update fragmented Highways IT system with a state of the art system. *This proposal could be advanced by procuring IT across regional HAs for collaborative procurement.
	Manual process requiring paper work and camera.	Update to portable electronic tablets to use on site, with remote access to Highways IT System (in progress).
14. Detailed design	Numerous design software used by different teams and disciplines across designers.	Integrate the highways design software applications onto a single cloud based collaborative construction platform.
	Poor utility response rate when requesting information about utility asset locations and future programmed works.	Confirm point of contact for utility asset records and future works for individual utility companies regularly.
	Asset management data (lighting, signals, drainage etc) is not freely available, and must be obtained by contacting individual officers.	Store asset management data in a central electronic location in an accessible format, for instant retrieval.
15. Submit PAA	Not enough advance notice is given about future major works, with less than the minimum prescribed 3 months sometimes.	Furnishing advance information for large impact and major works on the business plan at the beginning of the year (or earlier) with approximate dates. Set up a 'safe-guarded for future works' hatch on a GIS plan for future works (HA or utility companies).
16. Produce work schedule and costs	A schedule of rates is not published therefore the Works Manager must be emailed for quotes for all individual works.	*Formalise an indicative schedule of rates for staff to be able to devise an indicative cost.
17. Procure contractor	Team leader micro-manages procurement process.	*Team leader involvement should remain to facilitate quality assurance checks.
18. Programme works	Programme Monitoring meetings are considered a bottleneck which provide no clear value.	*Meetings should remain in order to facilitate joint decisions.
	The ability to check road space availability is restricted to Technical Admin staff.	Staff should have direct access to road space data removing Technical Admin Team staff from the process entirely.
	Operational programme of works is not available for common view.	Operational work programme should be accessible on IHMS and visible across the service area.
19. Book works with contractor	-----	-----
20. Submit Permit application	Produce paper works packs for approval and submission. Permit applications submitted by Technical Admin staff.	Make process paperless and authorisation electronic (in progress). *The permit submission process is best placed with the Technical Admin team.
21. Assess Permit application	Not enough coordinated working with others.	Report proposals, with potential sites and approximate dates for all major works at the formal quarterly coordination meeting.

22. Advise applicant	Manually check IT system for a response from NM.	<p>*Significant coordination efforts should be made outside of formal coordination meetings by a dedicated road works planner. HA to be represented at quarterly coordination meetings.</p> <p>Update fragmented Highways IT system with a state of the art system (in progress).</p>
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The validation exercises confirmed that road works design and management was complex and that collaborative working was challenging. The key commonalities in opinions were that:

- Coordinated working was challenging due to complexities and inherent challenges arising from individual team processes and circumstances beyond employee control, including poor IT and limited data access.
- Coordination meetings needed an improved format. Meetings should focus on large and major impact projects, whilst issues about individual streets should be addressed outside coordination meetings. Furthermore, coordination meetings should conjoin with neighbouring regional authorities to maximise effectiveness. An interviewee commented: *“Co-ordination is very difficult – who do you send plans to as different teams represent different purposes; it can become too complicated. This discussion should be a part of wider discussions as to what co-ordination meetings should achieve.”*
- Highways IT systems were generally poor, fragmented and unproductive. Highways IT systems should be synergistic, web-hosted and procured regionally to reduce costs.
- Organisational collaboration was considered critical, albeit with differing degrees of collaborative working effort amongst LAs. There was consensus that work programmes should be shared and discussed to facilitate collaborative working and a broader understanding of departmental activities. In addition, there was evidence that dedicated coordination personnel were highly successful in internal and inter-organisational collaboration.
- The annualised nature of highway budgets mean that local authorities cannot adequately plan in advance. An interviewee commented that *“this is a major issue across the country”*

Examples where conflicting opinions were expressed about some recommendations are as follows:

- Although most stakeholders felt that team leader involvement in the tender and procurement process should be limited to advice and ultimate approval, DCC felt that the involvement was quality assurance (QA) which provided exceptional value for money, and thus should remain.
- The view that the Technical Admin team were best placed to manage the Permit application process and this function should remain with them.
- Overall consensus was that the schedule of rates should be formally documented; however DCC felt that this would not provide best value as it could not accurately reflect the true cost of an in-house work-force. As a compromise, an indicative published schedule of rate was preferred by the HA.

Stage 8 - Development of Transferable Logic map for Road Works Planning Management
 Statutory legislation and funding cycles underpin road works practices, making processes and procedures fairly universal across LAs. Accordingly, a high-level logic map for wider transferability was developed, which is intended to aide LAs in their duty to manage and coordinate road works and street works management process under section 59 of NRWSA 1991. Logic maps depict how organisations’, processes or strategies should work, typically incorporating the underlying context, principles, and activities/practices necessary for short,

medium and long-term outcomes (WK Kellogg Foundation, 2004). The ADMINISTER logic map (Figure 2) was based on findings from this study, validation exercises and academic literature. Specifically, it considered the key processes in road works management, and identified the key inputs required, leading to key activities, and the support

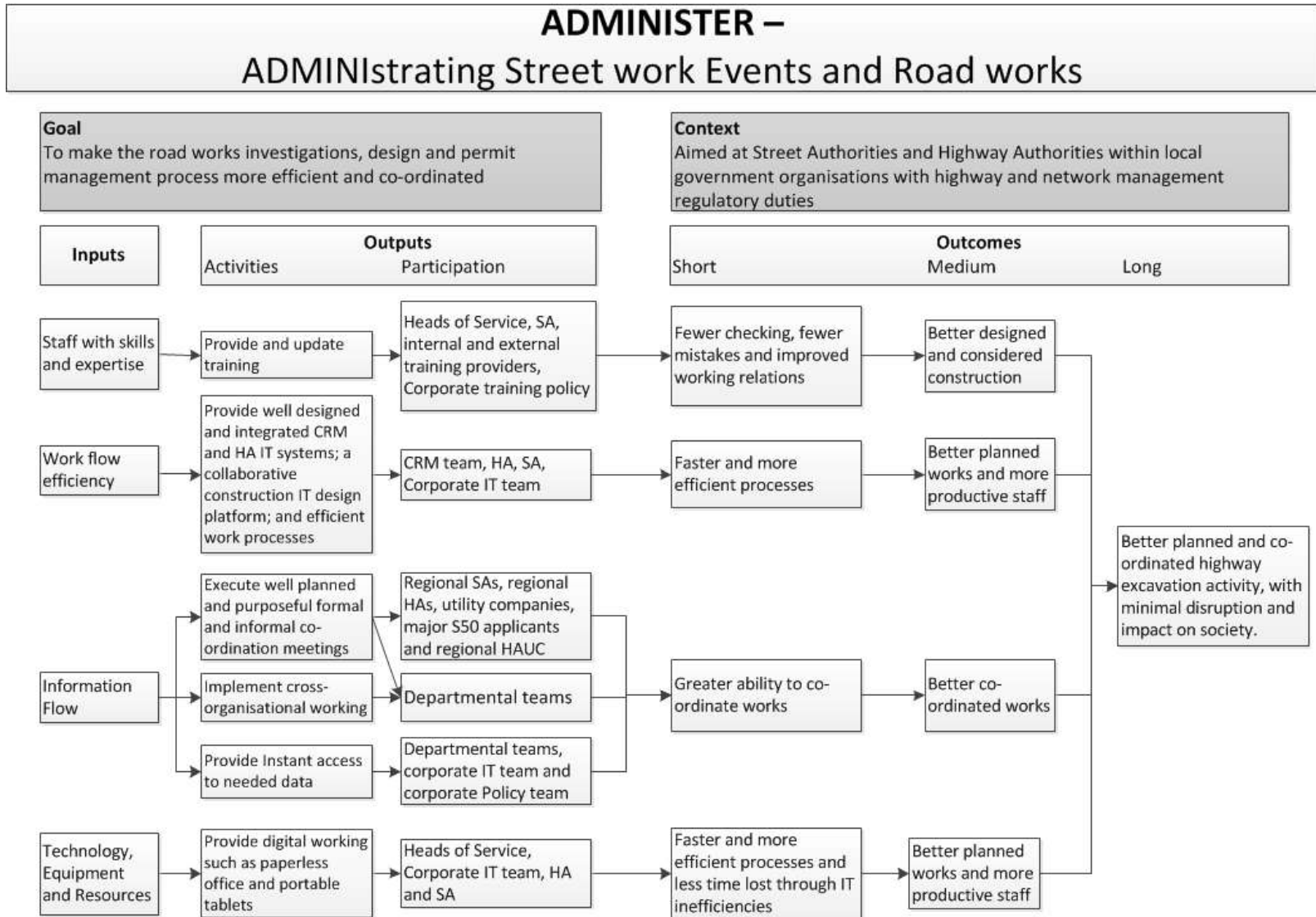


Figure 2 – Logic map for roadworks investigation, design and permit management process

required. The logic map seeks to represent how the road works management process could be effectively and efficiently administered whilst taking into account the inputs and outputs from a range of different activities from different stakeholders. Amongst other factors it considers that skilled staff, efficient work flows, efficient data flow and the use of technology, equipment and resources could be one way to bring about a more streamlined and value adding process. It is acknowledged that there are likely to be many and wide ranging implications of adopting this logic map, of which finance and the availability of resources are two such key factors. Furthermore it is inevitable that each LA will be at different stages of 'readiness' for comprehensively administering road works based on the quality of the inputs the organisation already has in place. Therefore, LAs should examine the inputs and consider the implications on resources and costs on a case by case basis.

A worked example of the logic map could be interpreted as follows: if an organisation has staff with skills and expertise, as a result of providing and updating training, with the possible involvement of Heads of Services, the SA, internal and external training providers and corporate training policy, it is likely to have the following effects:

Short term – empowered officers requiring fewer checks, leading to fewer mistakes and improved working relations;

Medium term – well trained officers producing well designed and considered construction projects;

Long term – well trained officers leading to better planned and coordinated road works with minimal disruption and impact on society.

The logic map is suitable for senior managers in LAs with regulatory highway maintenance and network management functions; it seeks to achieve well planned and coordinated road works activities to provide a minimally disrupted transport network. The logic map has purposefully been kept at a high-level to ensure transferability, with individual recommendations being illustrative rather than exhaustive to enable amendment and additions as appropriate. This section will briefly consider the key inputs and activities featured in the logic map.

Staff with Skills and Expertise

The process review highlighted that staff were not always clear of their roles and responsibilities, and sometimes did not have the skills or training to undertake tasks correctly which can reduce morale and cause mistakes. It is important that “the right people, with the right skills, in the right jobs, are performing the right tasks” (Sharp and McDermott, 2001), therefore senior managers should ensure that staff are fully trained for example, of regulatory responsibilities and IT system usage.

Efficient workflow

The study highlighted inefficiencies in various processes, therefore business processes should be analysed for efficiency with buy in, ownership and leadership from senior managers (Kamal et al., 2015). Further, IT enables a large proportion of processes in local government, but their inefficiency and fragmentation causes significant unproductivity and frustration. A cloud based collaborative document management portal for improved accessibility and document management for project design could be beneficial (Beach et al., 2013). IT

changes usually require appropriate financial investment and corporate approval by senior managers to integrate with wider strategic LA IT initiatives.

Resources and Equipment

Staff should have appropriate resources and equipment to undertake works, which includes access to functional IT systems. In addition, the construction industry is becoming increasingly automated and there is evidence that mobile computing devices have improved accessibility and operational efficiency, and could assist in the road works investigatory process (Son et al., 2012). The shift to digital working and paperless office should form part of a wider organisational strategy and would thus require senior manager approval.

Shared works information

The absence of shared information was a crucial barrier to communication, exacerbating internal and external silos; accordingly, staff should have convenient access to needed data (Weerakkody et al., 2011). Communication of works inside and outside formal coordination meetings was crucial as it provided appropriate forums to discuss and negotiate works; which is crucial for collaborative working (Lu et al., 2007). Therefore, formal coordination meetings should be well planned, purposeful, and limited to major and large works; smaller works should be discussed with appropriate parties outside coordination meetings as emphasised by the validation experts. There is also value in widening the scope of meetings to wider geographic areas to maximise value. Re-orienting coordination meetings would require working with utility partners and neighbouring local authorities.

In general, organisational culture in the public sector is deeply entrenched. Organisational change requires a culture which supports it, but this is difficult in LAs because the entrenched culture is risk averse and change resistant (Cresswell et al., 2013, Kamal et al., 2015). Councils adopting the logic map must consider change management strategies, otherwise processes are likely to remain inefficient. Change needs to be championed by senior managers of the organisation to be effective, and must be backed by commitment, strategy, resources, employee support and training; otherwise improvement efforts could fail.

2. DISCUSSION AND CONCLUSION

The aim of this study was two-fold; firstly it investigated how existing highways processes could be streamlined, and secondly it considered how coordinated working could be enhanced. Whilst several recommendations have been made to meet these aims, and despite the overwhelming financial challenges faced by the public sector, the value of BPR could be undermined by a culture of inertia, risk aversion and resistance to innovative practices common in local government (Thong et al., 2000; Janssen and Cresswell, 2005, Kamal et al., 2015). To address this, concerted change efforts are required, particularly by senior managers who have the greatest control over reorienting embedded culture. Further, intra-departmental collaborative working was undermined by inherent silo working, which is already a significant problem when also taking inter-organisational working with utility companies into account (Hussain et al., 2016). Sagacious concerns by Green (2011) and Green and May(2003) about the impact of BPR on the construction supply chain are acknowledged and would need to be considered prudently in any extension works directly involving construction workers. Furthermore, to provide LAs with a way to manage their statutory duty to coordinate highway works, a high-level logic map was developed for wider transferability. The map can be used as an aide to LAs to understand the key attributes to enable an efficient and

effectively managed process. Of course dependent of the readiness of the LA, there may be a number of resource and financial implications which will need to be considered.

In addition, the study has shed light on general issues and practices in road works management; for which the following stakeholder recommendations are made:

National Government

- Longer budget cycles are needed as annual budgetary cycles can create difficulties for HAs to plan long term works, and thus carry out long term coordination.

Local Government

- Greater organisational and inter-organisational communication is needed to reduce silo working, maximise coordinated working and minimise highway disruption;
- Genuine senior level ownership and commitment to improving highways management is needed to help motivate and drive cultural change within organisations;
- Technology needs to fit the needs of a service, instead of processes being developed around inadequate technology.

Utility sector

- Widespread departmental fragmentation within utility companies needs to be addressed to enable joined-up organisational thinking.
- Genuine senior level ownership and commitment to reducing highway cuts is needed to bring awareness of the impact of utility cuts, and help drive cultural change within institutions.

Highway works policy is generally under-researched with significant need to research the operational dynamics of LAs and utility companies in planning and coordinating excavation activity. This study is important because it bridges a key gap in knowledge by drawing attention to the day-to-day operational management of road works, which precede and lead to the widely reported negative impacts of highway works. The study also adds to BPR literature by acknowledging the public sector need for BPR, whilst accepting the embedded culture of local government and severe challenges to change, reinforcing findings by previous scholars. The findings are important because they make recommendation to practitioners about road works operations and issues based on robust validation from industry experts. The study is novel as it presents a high level transferable logic map for road works managers to adopt. The limitations of this study are that it is based on a single case study of a medium sized urban LA, therefore whilst the case study may arguably not be generalizable of all local authorities, the headline issues presented are likely be regular discussion points of HAUC meetings across the country, and indeed similar platforms globally.

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APPENDIX B (PAPER 2)

JOURNAL PAPER

Title

Street works policy in England – insights from stakeholders

Full Reference

Hussain, R. S., Brien, N., Gartside, D., Enoch, D., Ruikar, K. (2016) Street Works Policy in England, UK: insights from stakeholders, Proceedings of Institute of Civil Engineers: Infrastructure Asset Management, 3:2, 61-70

Abstract

Road works and street works can be highly disruptive, expensive and deleterious to highway structures and infrastructure planning, yet these activities must take place if modern societies are to continue to function. In helping to strike this balance, this study investigates the public policy landscape of highway excavation management in England. Semi-structured interviews with industry stakeholders highlighted the complexity of the industry and revealed that a number of issues compromise effective management. Principal problems included Street Authorities failing to take enough ownership of the coordination process, highway legislation not encouraging joint working due to inherent challenges arising from reinstatement guarantees, and entrenched attitudes and adversarial practices in the construction industry encouraging silo working. Key recommendations include amending highway legislation to support and recognise multi-agency working and Street Authorities undertaking reinstatements on behalf of undertakers, thus helping to reduce fragmentation and discharge undertakers of onerous guarantees which contribute to silo working.

Keywords

Roads and highways; infrastructure planning, public policy.

1 INTRODUCTION

An estimated 1.5 million utility excavation works (street works) with a direct construction cost of around £1.5 billion were estimated to occur in the UK annually in 2008 by Parker (2008). The Asphalt Industry Alliance (2015) estimated 1.9 million excavations in 2014, increasing to 2.2 million in 2015. Unsurprisingly, the volume of street works in urban areas is considered to have a negative impact on the road network causing disruption and premature deterioration (House of Commons, 2011) compromise the street scene (House of Commons, 2011; Goodwin, 2005), and significantly increase social, economic and environmental costs (Jordan et al., 2009; Parker, 2008). The social costs of utility works is estimated to be around £5.5 billion annually of which £5.1 billion of it is road user delays alone (McMahon et al., 2005). Comparative figures for highway works (road works) are not readily available but are likely to be similarly significant. Such impacts, coupled with yearly increases in excavation activity (Goodwin, 2005) warrant better highway management to reduce highway excavations and their associated impacts. Under the New Roads and Street Works Act (NRSWA) (1991) ‘road works’ are undertaken by Highway Authorities (HAs) to maintain, rehabilitate and reconstruct highways. ‘Street works’ are undertaken to install, inspect, maintain, repair or replace utility apparatus in the highway by utility companies. However, for the purpose of this paper, street works will be used to describe both terms given that the public are affected in the same way.

This paper aims to provide the sector’s views about street works performance in order to identify where improvements can be made. The paper comprises a literature review providing a state of the art of street works management, an outline of the methods used to perform this study, findings from the study, discussion, and conclusions with recommendations to help improve the management of street works.

2 LITERATURE REVIEW

Conventionally, utility apparatus is housed underground in modern densely populated urban cities in the United Kingdom (UK), United States (US), China and Japan (Jaw and Hashim, 2013). In order to manage street works activity technological and policy based approaches are typically used (Wilde et al., 2003).

2.1 Technological based approaches

Open cut excavations, also known as trenching have been in operation for around 200 years. Trenching entails cutting and excavating the ground to place utility apparatus underground (Asphalt Industry Alliance, 2013). Trenching is considered disruptive, expensive and as having high social costs (Lepart and Brillet, 2009). An alternative to trenching is the use of trenchless technologies, necessitating little or no use of open cut trenching. Trenchless methods include, amongst others, horizontal directional drilling, micro tunnelling, pipe jacking, auger boring, pipe bursting and robotic spot repairs which are being used extensively internationally. Trenchless technologies can require greater capital outlay than open-cut methods and thus discouraging wider take-up (Shukla and Karki, 2013; Ariaratnam et al., 2014). Utility assets can also be stored in tunnel systems known interchangeably as Multi-Utility Tunnels, Utility Corridors and Pipe Subways. These tunnels can house single or multiple utilities within purpose built enclosures constructed for human entry; examples can be found in London, Barcelona, Paris, Athens and Tokyo (URS, 2009; Canto-Parello et al.,

2009). Tunnels negate the need to trench the highway, but are associated with relatively high initial capital investment and long-term maintenance costs, making them unattractive propositions for extensive use (Hunt et al., 2014).

2.2 Policy based approaches

Whilst street works policy has received relatively limited attention in literature (Tseng et al., 2011), in practice, several schemes exist around the world. For example, Permit Schemes in the UK, Singapore and New York enable regulatory authorities to issue permits for works in the highway (Transport Research Laboratory, 2012). Further, Lane Rental schemes in London and Sydney enable highway authorities to rent out highway lanes for specified periods (Department for Transport, 2012; City of Sydney 2014).

Examples of localised street works policy restrictions include:

- One for One lane replacement – work promoters in Singapore are required to provide a temporary lane for any lane lost to street works (Land Transport Authority 2014);
- Works embargo – any works involving a road closure are generally restricted to a Sunday in Sydney. Singapore prohibits peak hour working and Hong Kong prohibits works between 7am – 7pm daily (Land Transport Authority 2014; City of Sydney 2014; Transport Research Laboratory, 2012).

The literature review has established techniques used to manage street works, however a knowledge gap exists about stakeholder views of street works policy.

3 METHOD

This study was undertaken through conducting 28 semi-structured interviews, whereby interviewees were given the flexibility to guide and expand discussions within set parameters (Bryman, 1988). Interviews were conducted in two stages. Stage one comprised exploratory interviews focused around the following discussion themes:

1. Performance of street works management system.
2. Factors affecting street works management.
3. The future of the street works industry.

Participant selection was initially targeted by using ‘snowball sampling’ initiated by Derby City Council as the sponsoring organisation. Subsequently, ‘purposive sampling’ was used to identify experts. Stage 1 involved 18 traffic management experts from various government agencies and utility companies as well as general managers. ‘Experts’ were considered as those with interpretative and technical process orientated knowledge (Miles and Huberman, 1994).

Stage one interviews provided a developed understanding which meant more defined questions could be asked in stage 2 as detailed in Table 1. Here, ten interviews were undertaken comprising government, regulatory and business/public representatives. Purposive sampling was adopted to target appropriate expertise from local authorities and the regulator (Flick, 2014). Expert knowledge was not sought from business/public interviewees as this was not considered necessary. Table 2 provides a breakdown of the interviewees.

Interview findings from both stages were analysed using a Thematic Analysis approach involving an iterative process of reading, annotating, and coding of data. Commonly occurring themes were labelled, and were then analysed, compared and contrasted (Braun and

Clarke, 2006). Interview findings were subsequently blended with literature to place them in context of existing knowledge and provide a comprehensive study.

Table 1: Design of stage 2 interviews

Theme	Question
Design of overall process	What is your understanding of the process of managing street works? Who are your stakeholders and what challenges does their management present? Do you work with others and how does this influence what you do?
Performance	How do you see the street works process performing generally? What is the current method for measuring street works performance? Does any incentives/penalties framework exist in your sector?
Context	What are the main issues, constraints and difficulties facing your stakeholders when faced with street works? What are the issues, constraints and difficulties of your organisation on the utility sector? What do you consider is working well in street works management?
Future	What current trends are likely to influence the future of street works, and what will their impacts be? What are the future challenges and opportunities for the road works and street works sector? What recommendations would you make to improve the sector?

Table 2 - Breakdown of interviewees and codes

Group	Subgroup	Interviewee Codes	Interview stage	
			1	2
Government	Central	NG1-2	✓	
	Local	LA2	✓	
		LA1, LA3-5		✓
Regulator		R1-2		✓
Utility	Electric	UE1-3	✓	
	Water	UW1-4	✓	
	Gas	UG1-3	✓	
	Telecoms	UT1-2	✓	
	Miscellaneous	UM1-2	✓	
	Industry representative	UR 1	✓	
Business and Public	Business	B1-2		✓
	Public	P1-2		✓

4 FINDINGS AND DISCUSSION

This section discusses the interview findings and seeks to corroborate them against existing literature where available. It begins with describing the key players to aide understanding of the industry. Subsequently, the interview findings are split into the following themes: performance of street works management processes, factors affecting street works management and future challenges and opportunities; and further subthemes. To guide the reader the structure of the analysis is provided in Table 3.

Table 3 – Structure of interview findings

Themes	4.2 Performance of street works management	4.3 Factors affecting street works	4.4 Practical coordination barriers	4.5 Future challenges and opportunities
Sub-themes	4.2.1 Network Management End user satisfaction 4.2.2 Process performance Quality Functionality 4.2.3 Construction performance Efficiency Quality Costs	4.3.1 Permit schemes 4.3.2 Regulatory structure Regulation and timescales Conflict in industry and highway regulations Commercial sensitivity in the telecoms industry 4.3.3 Industry standards Highway reinstatement standards HA as guarantor 4.3.4 Working relationships	4.4.1 Scheduling constraints 4.4.2 Physical constraints	4.5.1 Asset management 4.5.2 Silo working

4.1 Key actors

This section identifies the key actors involved in the street works management industry in England:

- ‘Street Authorities’ (SA) are part of a Council authority and have a statutory duty to manage and co-ordinate road works and street works activity on their road network.
- ‘Highway Authorities’ (HA) are part of a Council authority with a statutory duty to repair and maintain the fabric and structure of their highways.
- ‘Statutory Undertakers’ (SU) are those involved with the execution of works related to utility apparatus. They have a statutory duty to make efforts “to co-operate with the street authority and other undertakers” to assist with the execution of street works (New Roads and Street Works Act, 1991).
- ‘Regulators’ typically refers to financial regulators in this study who closely monitor the monopoly utility industries of water, electric and gas. Multiple regulators monitor other industry activities and also the telecoms industry.
- ‘Construction Industry’ refers to the network of contractors and subcontractors that the utility industry rely on to deliver their physical works.
- The ‘general public’ are consumers of utility services and users of the highway

4.2 Performance of street works management processes

This section discusses the performance of street works management systems as identified by interviewees. Findings have been categorised into three main areas of performance, namely, network management performance, process performance and construction performance. In order to rationalise interviewee comments, discussions have been split into a number of construction performance indicators (Chan and Chan, 2004) and adapted accordingly as follows:

- quality – the degree to which a street works system or process satisfies user’s needs;
- functionality – the degree to which a street works system or process fulfills its intended function;
- efficiency – the minimal degree to which a system or process expends time and effort;
- cost - the degree to which street works activity provides value for money;
- end user satisfaction – the level of satisfaction of those who ultimately experience street works operations or systems;

4.2.1 Network management

Network Management performance is concerned with the over ground impacts of street works activity and therefore feedback focused on public impact.

End user satisfaction - Satisfaction levels were low because communication about street works, particularly those directly affecting road users and businesses was considered unsatisfactory (R1, R2, P1, P2, B1, B2). It was felt that “utilities should be held to account” for the negative social and financial impact they had (B1). Businesses felt that street works were damaging, and despite being significantly affected, they had little influence on street works operations. Wong et al., (2012) stress that limited communication with the public about construction projects can result in a negative image of companies executing works, which should be avoided.

4.2.2 Process Performance

Process performance is concerned with the operational element of street works and focuses mainly around the interactions of SAs and SUs. Interviewees generally discussed the quality and functionality of the processes and collaborative/partnership working. Collaborative working within this context means co-ordinated multiagency working.

Quality - Undertakers felt that SAs compromised the effective management of street works by failing to take ownership of the co-ordination process and lacking the motivation to drive it, despite this being their legal duty (UG1, UW2). Interviewee UG1 stated “collaboration doesn’t happen unless local authorities make it happen.” Interviewee NG2, a government agency asserted the SA’s role; “it is incumbent on local authorities to coordinate and not utilities.” Undertakers (UE3, UE2, UW2) expressed a desire to work with others but found it hard to initiate multi-utility working because of the logistics of seeking and contacting other undertakers. It is recognised that inter-organisational collaboration is intrinsically difficult due to the involvement of multiple actors (Calamel et al., 2012; Johnson et al., 2012). SAs should therefore seek to facilitate collaborative/co-ordinated working through taking ownership of street works management, providing genuine leadership, vision, strategy and engaging organisational buy in (Lu et al., 2007; Shea et al., 1987; Hackman 1998).

Functionality - Interviewees alluded to the statutory prescribed Coordination meetings tending to be poorly planned, inefficient, and superficial (UM1, UM2). In fact, Engstrom et al. (1997) and Bishop et al. (2009) found that coordinated working in the construction industry tended to be scripted with little genuine collaborative effort. To help address this, SAs should plan and manage co-ordination meetings diligently to maximise potential multiagency working opportunities. Further, undertakers felt that SAs were not interested in long term coordination plans (UM1, UM2, UW2, UW3). UW4 stated “Local Authorities don’t have very long term plans in comparison with utilities who may plan for 30 years.” Awareness of long term plans is particularly valuable for Authorities with long term infrastructure management plans known as Highway Asset Management Plans. Two key reasons may explain why SAS may not have long term plans:

- HA budgets – local government funds are awarded annually and are no longer ring-fenced to highways maintenance; this means shorter maintenance cycles, with no guarantee of spending on highways. Further, austerity cuts have meant reduced budgets and uncertainty over future spending allocations (Lowndes and Prachett, 2012).

- Elections cycles - frequent elections can cause changing political structures, again, promoting short term objectives (Fenwick et al., 2003). The allocation of HA budgets and election cycles are factors outside of the control of the SA – changes would be required at central government level to address these issues in order to have a positive impact on street works.

4.2.3 Construction performance

This section considered interviewee views on construction performance which focuses around on-site operational issues and factors including silo working, street works quality and financial penalties.

Efficiency - Interviewees generally accepted that undertakers sought to work individually. Silo working was considered more convenient than integrating work with others, which could undermine individual goals and priorities. LA5 explained “utilities are tied into contractors who then sub-contract. Two contractors agreeing to work together does not happen as companies want to maximise their profits.” The construction industry is well documented as an industry symptomatic of fragmentation through its processes, procurement and working practices (Greenwood and Wu, 2012; Xue et al., 2010) and driven by entrenched adversarial relationships where there is not a natural desire to work collectively and for the common purpose (Wong et al., 2012). Further, the construction industry workforce was considered a key party in enabling/restraining advancement of street works (LA1, UG1, R1, R2). The regulator summarized: “a lot of control is with the site operatives; it’s difficult to change. The age profile of the workforce is high; some have been there since pre-privatisation when costs weren’t an issue. A change of mind-set is needed for the old timers” (R2). Ideally, construction firms should seek to modernise culture by managing contractors through performance measurement and management frameworks to evaluate, control and improve performance (Xue et al., 2010). Carefully planned communication and contractor management strategies would help change behaviour and culture.

Quality – the quality of street works standards was considered as being driven down by SAs who were seeking to minimise street works durations: “operatives may spend less time on the quality of the work to speed things up, which in the long run is not good” (LA3). Indeed the HA and SA can be considered as having ‘adversarial duties,’ insofar as the HA’s priority is highway maintenance, which operationally disturbs the flow of traffic, and therefore conflicts with the SAs network management duty. Therefore in seeking to manage its duty, SAs may cause undertakers to accelerate works, potentially causing substandard works (notwithstanding prescribed standards) which could undermine structural life and the HA’s statutory duty. The local authority must therefore be mindful of both duties and balance network management with high quality highway structures.

Costs – Undertakers felt that SAs were using the NRSWA legislation to unnecessarily financially penalise undertakers through section 74 (overstay) charges and fixed penalty notices (UW1, UG1, UW2, UW3, UW4, UR1). Interviewee UW2 felt that the utility sector was being used to substitute local authority austerity cuts with UW4 remarking that “street works are seen as a cash cow.” The regulator supported undertaker concerns; “utilities feel that they can get penalties easily. They (SA) see it as an opportunity for raising money” (R2). In contrast, LA1 and LA3 expressed unapologetic views suggesting that financial penalties were avoidable and often calculated: “it may be cheaper for undertakers to receive a fine from us than the logistics of stopping and starting works again on another date....The consequences

of work promoters not following the rules are felt by road users and businesses; the fines are minor compared to the cost of disruption” (LA3). Trust is an important component for inter-organisational working; however an environment where parties feel suspicion and mistrust is unlikely to support a conducive environment for collaborative working (Lu et al., 2007; Shea and Guzzo, 2007; Hackman, 1998; Shelbourn et al., 2007; Patel et al., 2012).

4.3 Factors affecting street works

This section considers those factors that interviewees considered had an indirect impact on street works management namely, the Permit scheme, regulatory structure, industry standards and working relationships.

4.3.1 Permit Schemes

Interviewees had mixed views about the Permit scheme, a relatively new approach in England which gives SAs greater ability to control and direct works on the highway; the scheme is chargeable to utility companies and free to HAs. Most of the utility interviewees did not feel that the Permit scheme was justified or necessary. Interviewees UE1, UW2, UW3, UW4, UR1, UM1 and UM2 felt that there was nothing within the new enabling legislation (The Traffic Management Act 2004) that wasn't contained in NRSWA, with respondents 6, 7 and 8 stating that the key difference was the ability to charge utilities to undertake works. Utilities were also dissatisfied with the additional work generated by the scheme creating in-direct costs (UW1, UG1, UW2, UW3, UW4, UT2 and UR1). Further, interview UR1 felt that SAs did not exercise parity, and that HAs 'got away' with not applying for Permits. In contrast respondent UE1, NG1 and NG2 felt that the Permit scheme had come about because of local authorities' failures to 'co-ordinate' street works and the utilities' duties to 'co-operate'. Respondent UR1 suggested that both parties should work together to remove the permit scheme.

The regulator acknowledged that SUs had complained that the Permit schemes were affecting productivity and were a greater financial burden; however the regulator saw this as an opportunity to review their processes and make them more efficient (R1). The regulator confirmed; “the Permit scheme has driven a behaviour change in utility companies; they see it as a big issue. They now pay more attention to planning street works; street works have benefited and so has the general public. They have risen to the challenge.” Whilst there is some acknowledgment of the need for the Permit Scheme, the SUs was generally opposed to the scheme and did not consider it a value for money exercise; no literature could be found on the empirical evaluation of the Permit Scheme to corroborate this argument (with the exception of some grey literature).

4.3.2 Regulatory structure

Undertakers reported allegiance to industry regulations and its associated timescales, conflicts between highway legislation and industry regulation, as well as competitiveness effecting their commitment to street works management. These discussions will be elaborated on further.

Regulation and timescales – The telecoms industry reported to operating in a 'free market' motivated by fast facilitation of contractual commitments (UT2). Conversely, water, electric and gas undertakers were a part of a monopoly market subject to high levels of financial regulation. Failure to meet regulator deadlines attracted fines and impacted on profits and subsidies awarded. Regulators rewarded undertakers for high customer service and efficient

customer facilitation, particularly in terms of faults and new connections (UW1, UG1, UE2). The regulator (R2) reported “the regulations constantly require efficiency and demonstrating efficiency.... we may not fund unless they can demonstrate efficient cost.” The pressure to deliver works in a timely manner meant that undertakers’ business goals often took precedence over street works management. Conflicting goals and timescales can make coordinated working difficult (Patel et al., 2012) further; delaying works to synchronise with others can also lead to negative financial expenses (Johnson et al., 2010). As speed of service delivery to customers was considered critical by all undertakers particularly in the case of small works such as connections, SAs should direct coordination efforts on longer duration works, namely ‘standard’ (3-10 days) and ‘major’ (over 10 days) works.

Conflict in industry regulation and highway regulation - Some interviewees reported significant ‘clashes’ between the obligations of NRSWA legislation and respective monopoly industry regulations (UE2, UM1, UG1, UW1, UW2, UW3, UW4, LA1, LA4). Interviewee UE2 summarised: “neither regulation has any regard for the other.” Interviewee UW1 revealed that sometimes these conflicts compelled them to work against NRSWA which meant that they risked receiving small fines by SAs, as opposed to being ‘fined millions’ by their regulator. Working in conflict with street works legislation requirements shows an unnecessary compulsion faced by undertakers, which transposes into a lack of trust and openness between parties which are significant barriers to effective communication and thus effective joint working (Shelbourne et al., 2007). The regulator (R1 and R2) expressed surprise about perceived conflicts, and advised that any specific conflicts brought to their attention would be thoroughly investigated. NG1 and NG2 proposed that Permit Schemes were solutions for any perceived conflicts.

Commercial sensitivity in the telecoms industry - As part of operating in a free market, the telecoms industry reported to be operating in a highly competitive industry with high levels of secrecy to protect commercial dealings (UT1, UT2, UR1). Unlike the monopoly industry, there was a distinct hesitation about openly discussing works in the presence of competitors to prevent theft of clients. Like the construction industry, organisations working in the telecoms industry are profit driven where a culture of secrecy is common practice (Bishop et al., 2009). Trust is an important component for nurturing collaborative working (Shelbourn et al., 2007; Hashim, 2012), however joint working with competitors is regarded as ‘adversarial collaboration’ (Patel et al., 2012). These issues appear to be barriers in the telecoms sector which restrict sharing of information, which in turn has the effect of reducing joint working opportunities.

4.3.3 Industry standards

Interviewees felt that highway reinstatement standards and HAs being lead work promoters had a significant impact on street works management. These issues will be looked at further below.

Highway reinstatement standards - The reinstatement procedure requires works executors to reinstate and subsequently guarantee reinstatements for a period of at least two years (Department of Transport, 2010); this guarantee period was typically referred to as a ‘liability’ by undertakers (UE2, UW1, UG1, UT1, UW2, UW3, UW4). Issues around the guarantee period center around the responsibilities of the ‘last noticer’. Interviewee UG1 explained; “Collaboration is more of a problem in terms of sharing liabilities as only one of the two or more utilities can be the lead Notice provider - the lead organisation has to take the

most liability and there is reluctance as the company doesn't want to take liability for another utility's carelessness or mistakes." Undertakers were more willing to work together subject to legal contracts clarifying responsibilities, although this was considered a time consuming exercise (UT1, UW1). Respondent UE2 stated "there is no incentive and even a reluctance to collaborate...it is too risky." Indeed section 70 of NRSWA places the entire reinstatement onus on the executor and thus removing the option to share works. It would be beneficial if NRSWA legislation was amended to use terminology that was supportive of and recognised multi-agency working. Different working cultures and practices make inter-organisational working difficult, thus parties are motivated by incentives to work together as opposed to risks (Calamel, 2012; Patel, 2012) which the 'liability' is seen as.

HA as guarantor - Undertakers proudly cited examples of participation in multiagency working led by HAs as part of their highway maintenance works. In such instances it is highly likely that the HA would be the executor, reinstator and thus guarantor of works (UE1, UG4, UW2, UW7, UW8). Undertakers showed a distinct difference in attitude and enthusiasm to multiagency working once the onus of the reinstatement guarantee had been taken away by the HA (see highway reinstatement standards). Tapping into undertakers' willingness to work with HAs, the HA could potentially carry out reinstatements on behalf of undertakers, and discharge them of guarantor obligations at a cost. This would encourage increased multiagency working and encourage consistency in materials and standards across areas. This will be similar to the predecessor legislation, Public Utilities Street Works Act 1950, where SAs compulsorily undertook all reinstatement works at a cost on behalf of undertakers. It would be important however to take account of previous mistakes to ensure that those issues which led to the original legislation being repealed are not repeated.

4.3.4 Working relationships

There was a great emphasis on the importance of good working relationships between undertakers and SAs. UW1, UG1, UM1 and UM2 commented that they operated throughout the country with various SAs and each had slightly different approaches to managing street works. Frustratingly these subtle differences made it difficult for undertakers to adopt a consistent approach. Nevertheless, good working relationships with all local authorities were seen to be vital for successful partnership working as confirmed by Hashim (2012). Respondents UG1, UM1 and UM2 also felt that 'people relationships' were critical. Interviewee UW1 stated; "some authorities are helpful, others are very prescriptive which is usually not helpful." The interviewee referred to a SA that would only accept communication in writing, which made it difficult to negotiate changes to planned street works. Formal and informal communication through meetings or discussions, as well as the ability to negotiate is regarded as 'vital' for collaborative working (Lu et al., 2007). To assist with peer co-operation in negotiation, an argumentation based negotiation approach could be adopted to facilitate discussion (see paper by Sierra et al., 1998).

4.4 Practical coordination barriers

Interviewees discussed the working practicalities of joint working. Their views cover two issues namely, scheduling and physical constraints.

4.4.1 Scheduling constraints

Undertakers considered joint working to be resource intensive (UE1, UG1, UW2). Respondent UE1 stated, "coordination takes a lot of time, effort and planning." Utilities in England are profit driven enterprises therefore can be less inclined to spend time on limited-

value adding activities. Further, entrenched attitudes prevalent in the construction industry towards maximising individual gains and profiteering can make coordinated working 'economically irrational' (Bishop et al., 2009) and therefore reinforce silo working. In addition, disparate timing of works was considered a barrier to multi-agency working, "...expectations are unrealistic; coordination involves logistics, gangs and materials all to tie in" (UW3). Similarly UE2 felt; "... it would only work with seamless or consecutive working – it doesn't work with differing utilities having different regulator timescales." An available forum to plan and co-ordinate works exists through Co-ordination meetings; however these meetings have previously been described as ineffective (see Process performance - quality).

4.4.2 Physical constraints

Interviewee UW1 identified that "trench sharing is not easy." The interviewee referred to guidelines set by the National Joint Utilities Group (NJUG) which specify the sequence and depths of underground apparatus, which were considered a barrier to trench sharing. NG1 and NG2 referred to health and safety risks with UG1 corroborating: "it's not usually practically possible for two utilities to work simultaneously..... logistics and safety of the job come first; this can make collaboration very difficult." Whilst trench sharing simultaneously may not always be appropriate due to potential dangers, utilities may be able to reduce risk by working sequentially. This area requires further research to fully understand the risks and likelihood of incident, as well as the impacts of different utilities working together. This can then be advanced into creating a risk scale which could be used by undertakers to determine the differing levels of risk associated with collaborating with other utility industries.

4.5 Future challenges and opportunities

In looking to the future, interviewees identified asset management and silo working as key issues likely to affect street works management.

4.5.2 Asset management

Key challenges were considered around utilities requiring greater knowledge of the location of their assets (R1, R2). This issue is prolific and is currently being addressed through the Mapping the Underworld project (Rogers et al., 2014). Concerns were also expressed about ageing assets; R1 stated "buried assets are deteriorating, how do you deal with infrastructure that is over 100 years old?" Despite this concern, interviewees were optimistic about the rapid development of technologies to help prolong highway and utility asset life (LA1, LA3, LA4, R1, R2). LA4 and LA5 expressed concerns that repeatedly cutting the highway compromised the life of highway infrastructure and questioned whether a 2 year guarantee period was enough or if utilities should be subject to whole life charges? Indeed a charge structure has been developed for trenching in the highway (Jordan et al., 2009; Latham et al., 2011) which Street Authorities could use as an opportunity and adopt.

4.5.2 Silo working

Fragmented working amongst the construction industry was damaging as it undermined coordinated working (LA1, LA4). Non-local authority interviewees (P1, P2, B1, R1, R2) also desired increased multiagency working to minimise the impact of street works. A way of addressing this could be amending NRSWA legislation to encourage multiagency working by removing the reinstatement onus from the executer. Indeed interviewees commented that NRSWA was complex legislation open to interpretation (LA3, LA4, UM1, UE1); "if

legislation was clear and free from ambiguity then it would drive greater collaborative working" (LA4). LA5 also suggested adopting innovative ways of working such as undertakers working from Council offices, which would afford undertakers more proactive consideration in street works projects and thus increase multiagency working.

5 CONCLUSIONS AND RECOMMENDATIONS

This research set out to provide an insight into the management of the street works sector and provide the sector's views on its performance to identify where improvements can be made. Principal findings from the research reveals issues around:

Limited ownership of co-ordination process - Street works are part of a complex industry with direct actors comprising SAs and undertakers, with industry regulators and the construction industry having a significant role and influence, albeit indirectly. Non-local authority interviewees expressed firm expectations that SAs should take greater ownership of the management of the coordination of street works. Prescribed co-ordination meetings were considered ineffective and superficial.

Recommendation - SAs need to take more ownership and lead by providing strategic vision and direction to enhance street works management.

Long construction supply chains - Interviewees felt that the construction supply chain played a major role in hindering the effective management and advancement of the street works industry because of its entrenched attitudes, adversarial practices and profiteering culture.

Recommendation – undertakers should pro-actively manage contractors through a performance measurement and management framework to evaluate, control and improve performance.

Conflicts between industries - there was a perceived conflict between timescales prescribed by NRSWA legislation and industry regulations. In the circumstances undertakers tended to give greater priority to utility industry timescales as they were driven by financial rewards.

Recommendation – any perceived conflicts should be brought to the attention of Highways and Utilities Committee (HAUC) UK to own, investigate and provide remedial measures.

Onerous reinstatement guarantees - NRSWA was not considered to encourage undertakers to participate in joint working due to the inherent challenges associated with reinstatement guarantees placed on the primary executor of works.

Recommendation - NRSWA legislation should be amended to use terminology that is supportive of and recognises multi-agency working as opposed to placing the single onus on the executor of works.

The HA as the primary executor - Undertakers showed significantly greater willingness to participate in multiagency working where the HA was the executor and guarantor of works.

Recommendation – HAs should undertake reinstatement works on behalf of undertakers at a cost, and thus discharge undertakers of the guarantee period by becoming the guarantor of the reinstatement. This would also help to encourage consistent reinstatement standards throughout areas.

Future – key future concerns were particularly expressed around prolonging the life of highway and utility infrastructure, with technological innovations and the adoption of trenchless technologies and trench charging structures seen as potential opportunities in mitigation. The contemporary prevalent nature of silo working was also seen as an area which would benefit if NRSWA legislation was amended.

Recommendation – that SAs work with their HAs to adopt policies which champion longer highway structural life such as increasingly adopting trenchless techniques and trench charging.

Overall, street works are expensive for industry and society and need to be managed effectively. The significance of this study is that it has identified some of the current problems facing the industry which are impeding the optimal management and efficiency of street works practices. Failure to consider and address these issues will lead to sustained increases in street works which is an unsustainable scenario, particularly in the current climate of rising street works, decreasing local authority budgets and forecasted population and housing growth. This study contributes to a limited body of literature in street works policy, and is novel in that it is the first time a comprehensive study of stakeholder attitudes to street works management has been undertaken.

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APPENDIX C (PAPER 3)

CONFERENCE PAPER

Title

Evaluating the road works and street works management Permit Scheme in Derby, UK.

Full Reference

Hussain, R. S., Ruikar, K., Enoch, M., Brien, N., Gartside, D. (2016) Evaluating the road works and street works management Permit Scheme in Derby, UK. 95th Transportation Research Board Annual Meeting, 10th–14th January 2016, Washington DC

Abstract

Road works (highway works) and street works (utility works) activities are vital for society to travel, enjoy amenities, and to access essential services such as water, electricity, gas and telecommunications. However, road works and street works can be disruptive, inconvenient and have high social costs. The Permit Scheme is a relatively new management regime which seeks to reduce the disruption caused by highway excavations by giving English Street Authorities greater control of works in their areas. The Derby Permit Scheme commenced on October 2013. This research aims to understand whether the adoption of the Permit Scheme has resulted in any change to the city's road works and street works landscape. A time series model using an intervention variable was run. 61 months of average works duration data was analysed along with several independent variables including daylight hours, economic activity and precipitation. The results showed that the Permit Scheme had a positive effect on Derby by reducing the overall average duration of works by a third of a day. This is a 10% reduction overall, being equal to 8434 days per year, and in monetary terms equivalent to saving £769,048/\$1,179,777 in societal costs per annum. This research is significant as it provides impact information for policy makers and practitioners on a relatively new type of scheme, and it is original, in that this is the first time that an intervention analysis approach has been applied to this area of public policy.

Keywords

Permit Scheme, road works, policy, construction, time series analysis, pavements

1 INTRODUCTION

The UK transportation network has a dual purpose; over-ground it facilitates transportation which is fundamental for economic growth and to access key essential and leisure services, whilst underground it houses utility infrastructure critical for the smooth functioning of society. Problems can (and often do) arise when highway excavations occur as they can clash with over-ground demands for transportation, causing disruption and inconvenience to society. Road works are executed by Highway Authorities (HA) pursuant to a statutory duty to repair and maintain their highway assets. Street works are carried out by utility companies, also known as Statutory Undertakers (SU) who have a legislative duty to provide utility services and also rights to install, access and maintain their apparatus. Street Authorities (SA) have a regulatory role and are duty-bound to manage and co-ordinate excavation activity. For the purpose of this study, excavation activity has the same meaning as ‘registerable works’ under highway legislation - this primarily means any activity which necessitates breaking up or resurfacing the highway (1). Key emerging impacts of highway excavations include, congestion, negative environmental effects, loss of trade for local businesses, increased accidents, premature highway deterioration and aesthetic depreciation amongst others (2; 3). These factors demonstrate a clear need to manage highway excavations more effectively.

Along with many local authorities in England, Derby has introduced a Road Works and Street Works Permit Scheme (hereon known as the Permit scheme) on key city streets with the aim of minimising delays to road users through improved planning and execution of planned disruption to free flow traffic. Key scheme objectives are to:

- ensure parity between HA and SU works;
- improve co-operation between work promoters;
- reduce the adverse impact of highway excavations on residents and businesses and
- promote the adoption of minimally invasive works methods (4).

Permit schemes give SAs greater powers to manage and control excavations compared to the predecessor ‘Noticing’ regime, whereby, work promoters simply notified Councils of their intention to work (5). SAs have a duty to report on their Permit scheme performance, however reporting quality is inconsistent with little research into the effects of introducing Permit Schemes. Therefore, this study seeks to measure the extent to which the Permit scheme intervention has affected overall highway excavation activity in Derby.

2 LITERATURE REVIEW

Efficiently managed excavations are critical to maximise the integrity of highway infrastructure and to minimise the impact on the over-ground movement of traffic (including people) and society. Highway excavation activity can be enhanced in two ways: through the use of technological measures, or through using policy tools. Whilst extensive research underpins technological solutions such as trenchless techniques (eg, auger boring, pipe jacking and robotic spot repairs), multi-utility tunnels (6), subsurface utility engineering (SUE) (7) amongst others, policy based techniques have received less attention (8).

Nevertheless, some research can be found about policy tools and techniques employed, such as:

- Works embargo – works requiring road closures are generally restricted to Sundays in Sydney; Singapore prohibits peak hour working and Hong Kong prohibits works between 7am – 7pm daily (9;10). UK legislation enables SAs to place restrictions on excavations for up to two years after the completion of highway improvement works (8); whilst Japan and France are also known to prohibit re-excavation for up to five years (2).
- Legislative rights – UK undertakers have enjoyed legal rights to provide statutory utilities in the highways since the mid-nineteenth century. Conversely, Scandinavian utilities have no such rights and must seek authorisation from the highway owner/Road Authority (2).
- Lane Rental schemes – HAs in London and Sydney rent out highway lanes for specified durations to enable work promoters to execute works (9;10).
- Permit schemes - Authorities in the UK, Singapore and New York issue permits to work promoters to undertake works on the highway (12).
- Memorandum of Understanding (MOU) – In several Australian and US states, MOUs are agreed and signed between States and utilities to secure co-operative and co-ordinated working processes during construction (13).
- Transportation and Utility Corridors (TUCs) – As part of Calgary and Edmonton’s restricted development areas plans (RDA), TUCs formally designate ring road and utility alignments in advance (13).

In quantifying the costs of highway excavations, there is only a limited body of research (2). However, a comprehensive analysis by Halcrow used the Queues and Delays at Road Works (QUADRO) modeling program to estimate the cost of delay. A cost of delay to private and commercial motorists in England was estimated at £4.3 billion/\$7.1 billion (USD) in 2004 (14). However, a utility industry commissioned report challenged the assumptions, methods and values used in the this study and estimated that the true cost of delay lay between £0.5–1 billion/\$0.8–1.6 billion (15). This revised figure was further contested where reservations were expressed about the use of historical, geographically inaccurate and limited data in arriving at this lower figure. Instead, Halcrow’s social cost estimation was extrapolated to include the whole of UK with the revised social cost updated to £5.1 billion/\$8.0 billion. Additional social costs attributed to businesses, community, costs to HAs through premature damage and environmental costs were estimated at a further £0.5 billion/\$0.8 billion (16). Direct construction costs were valued at £1.5 billion/\$2.3 billion, with indirect costs (third party damage) estimated at £150 million/\$230 million, taking the overall cost of street works to be in excess of £7 billion/\$10.9 billion per annum. A Pennsylvanian (USA) study estimated social costs to be around 80 times the project contract cost (17). With such limited and diverse ranging costs and associated factors, it is difficult to determine a true cost of UK street works.

As the Permit scheme is in its relative infancy stage, there is little academic research into the quantitative evaluation of street works policy interventions. The one exception is a methodology proposed for the assessment of the Kent Permit scheme incorporating the use of fuzzy logic (18). Regulations require that SAs evaluate their Permit schemes after 12 months, and then subsequently 36 months to monitor their effectiveness (19). However, the utility industry does not feel that such evaluations are a comprehensive assessment as they do not reflect the true scheme costs borne by works promoters (20). Analysis of available performance reports from across the UK reveal the following reductions in highway excavations:

- London Permit Scheme - 2% reduction in average duration in the first year (21)

- Kent County Council - 18% reduction in ‘impact of road works’ over four years (22)
- Yorkshire Common scheme – 21% reduction in duration over two years (23)

3 CASE STUDY OF DERBY

Derby is a fairly typical English regional city of around 250,000 people, approximately 130 miles north of London (Figure 1). Derby is renowned for its strong engineering base across the aerospace, automobile and rail industries, housing celebrated businesses including Rolls Royce, Toyota and Bombardier (24).

Traditionally and primarily, highway excavations in Derby have been managed through a ‘Noticing’ system, whereby work promoters submit prescribed notices to the SA, pursuant to the New Roads and Street Works Act (NRSWA) 1991 (25). The NRSWA legislation encourages SAs and SUs to use their best endeavours to co-ordinate and co-operate with others to facilitate co-ordination. In 2008, the Traffic Management Permit Scheme gave SAs powers to adopt Permit schemes to exercise greater control over excavations on their highways (26). Permit applications and their variations incur costs for SUs, whilst HAs are subject to the same processes but exempt from fees. The Derby Permit Scheme commenced in October 2013 (4) and cost around £60,000 (\$92,044) to implement, but is subsequently intended to be cost-neutral. SU costs are unclear, but include upfront Permit fees as well as increased back office costs in greater pre-planning in producing supporting Permit information. Operating the Permit scheme on all streets was considered unnecessary and excessive, therefore the scheme operates on only traffic-sensitive streets, which comprise around 20% of Derby’s roads. Noticing applies to the remaining streets. Traffic-sensitive streets are formally designated subject to NRSWA criteria. They are essentially streets where works would be especially disruptive to road users, typically due to high vehicular, pedestrian, bus or commercial vehicle volumes (27).



FIGURE 1 A Map of the City of Derby and its Location in the UK

Key differences between the Permit and Notice regimes are:

- Permits enable SAs to be more proactive in managing and controlling activities on their road networks, whereas Notice schemes afford limited control.
- Permits are more aligned to applying to work on the highway, whereas under Noticing, work promoters simply notify the SAs of their intentions.
- Permits enable SAs to add specific conditions as standard to works, which is significantly less common under a Noticing regime.
- Permit applications carry a charge, and failure to comply with any conditions set can attract financial penalties (5).

THE STUDY

The study period lasted five years commencing October 2009 on only traffic-sensitive streets. During this period 42,171 individual works were registered with the SA. The mean volume of works was 8434 per annum (Figure 2). Around 54% of the works were executed by the HA, compared to 46% by SUs. The number of excavations occurred as follows:

- Year 1 – 8512
- Year 2 – 8201
- Year 3 – 8626
- Year 4 – 7678
- Year 5 – 9154

Interestingly, the highest volume of works occurred in year 5 of the study, when the Permit scheme was active. This increase may have been because of greater reporting compliance under the Permit scheme. Anecdotally there has always been a subtly cavalier attitude towards submitting Notices, with under-reporting acknowledged across the industry. Legal repercussions have been limited to cases of sustained failure of an SU to notify. Failure to apply for a Permit is considered a more serious offence than failing to give Notice, due to both failing to seek authorisation for works, as well as evading payment. Further, the volume of work undertaken is not necessarily a proxy of disruption; volumes of work can increase at the request of the SA who may encourage SUs to work at less disruptive times.

DATA

Study data was already routinely collected by the SA, however additional work was undertaken to create specialist reports pertaining to volume, duration and works promoter. Reports were run recalling monthly data from the SA's central database used to receive Notices and Permit applications. This data was collated in Microsoft Excel and transferred to IBM SPSS Statistics 22 (SPSS). 61 monthly entries between October 2009 and October 2014 were used to run an Autoregressive Integrated Moving Average (ARIMA) time series model on SPSS. Each entry was based on the mean duration of an excavation activity per month, which was calculated by dividing the total applications received, by the total days spent occupying the highway.

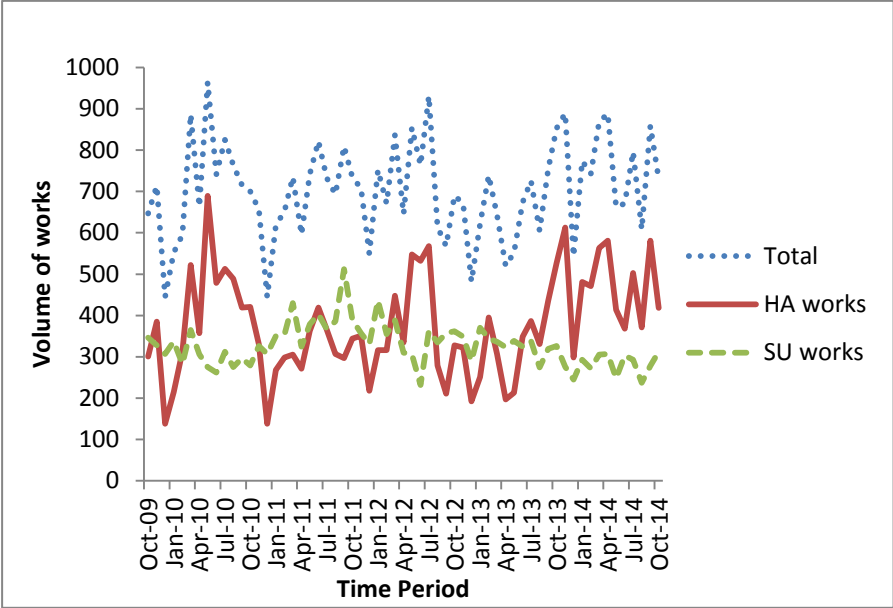


FIGURE 2 Derby Case Study – Volume of Works over 5 Years

Various externalities considered to effect excavation activity were picked as independent variables and measured (Table 1). In particular the Gross Domestic Product (GDP) showed an uneven trajectory until June 2012, after which it consistently increased. Construction infrastructure output meanwhile showed a small and steady increase whilst housing demand almost doubled over the five years. Data on vehicle miles travelled showed regular seasonal peaks (Jul-Sept) and dips (Jan-Mar) as expected, but was relatively static over the five year period. Note, that the Christmas Restrictive period identified is a period when the SA heavily restricts works on traffic-sensitive streets between mid-November and early January (except emergencies).

4 METHOD

The variables were first screened using a correlation coefficient process. This process tests how closely variables are correlated to each other. Gross Domestic Product (GDP), construction infrastructure and air temperature were found to be too closely correlated (over 0.80) to other variables and were consequently removed from the model (28). The remaining variables namely, vehicle miles travelled, daylight hours, overall construction industry output, construction housing, precipitation, school holidays, Christmas Restrictive period and daylight hours were retained as independent variables (IV). The dependent variable (DV) was the average duration of each work per month.

The method for devising the correlation coefficient was:

$$r_{xy} = \frac{\text{cov}(x, y)}{s_x s_y} = \frac{\sum (x - \bar{x})(y - \bar{y})}{(N - 1) s_x s_y} \tag{1}$$

TABLE 1 Variables Used in the Analysis and Descriptive Statistics

Variable Type	Variable	Variable Description	Variable format/unit	Source	Minimum value	Mean Value	Maximum value
Dependent variable	Average duration of work per month	Total number of works/total duration	Count/days	Derby City Council reports	2.19	3.05	4.42
Intervention variable	Regime	Type of management regime - Notice or Permit scheme	Binary/(0/1)	Derby City Council	0	-----	1
Independent variable	(GDP)	An indicator of economic activity. Based on 'current price' (CP) per month	Ratio/\$-USD	(29)	100.4	105.31	112.2
Independent variable	Construction industry output (overall)	An indicator of economic activity. Money spent on construction of new housing, infrastructure and 'other' works – commercial and private per month in UK (£ million)	Ratio/£-GBP	(30)	16,031	18,011	19,030
Independent variable	Construction housing output	An indicator of economic activity. Money spent on new public and private housing per month across UK (£ million)	Ratio/£-GBP	(30)	3,860	5,218	6,932
Independent variable	Construction infrastructure output	An indicator of economic activity. Money spent on public and private (industrial and commercial) infrastructure per month across UK (£ million)	Ratio/£-GBP	(30)	2,411	3,359	3,830
Independent variable	Daylight	An indicator of working conditions. Number of hours of daylight per day (hours: mins)	Count/hours	(31)	7 :51	12:38	16:39
Independent variable	Air temperature	An indicator of working conditions. Mean air temperature over month - °C	Ratio/Degrees Celsius	(32)	-0.3 °C	10°C	17.6°C
Independent variable	Precipitation	An indicator of working conditions. Based on amount of rain fallen	Count/millimeters	(33)	5.75	56.23	129.59
Independent variable	Vehicle miles travelled	Distance travelled on all roads in UK by all classes of vehicles per year (billion miles)	Count/miles	(34)	70.1	76.2	81.3
Independent variable	School holidays	An indicator of road activity. Based on the proportion of school holidays over week days per month	Count/%	(35)	0%	25%	100%
Independent variable	Christmas restrictive period	An indicator of a period of typically low excavation activity and high traffic volumes between mid-November and early January over Christmas period	Binary/(1/0)	(36)	0	-----	1

- r is the correlation
- X is the observed value 1
- Y is the observed value 2
- \bar{x} is the mean of the observed value 1
- \bar{y} is the mean of the observed value 2
- S_x is the standard deviation of the observed value 1
- S_y is the standard deviation of the observed value 2
- N is the sample size

TIME SERIES MODEL

A time series analysis model repeatedly measures a single variable over a regular and consistent period of time. This form of analysis can be employed to understand patterns and trends historically, and to extrapolate these into the future to make predictions. Time series analysis can also be used to measure the impact of one or more intervention. A minimum of 50 observations should be used for more reliable results (37). Time series analysis was used in this study to measure the impact of the Derby Permit scheme on excavation activity over a five year period.

The time series model can be defined as:

$$y_t = f(I, X_t) + N_t \quad (2)$$

- y_t is the dependent variable at a given time representing the mean duration of each excavation activity per month
- t is the discrete time (month in this case)
- f (function of)
- I is the intervention variable
- X is the deterministic effect of other independent variables
- N_t is the stochastic or noise component

INTERVENTION FUNCTION

Time series analysis can include an intervention variable which examines the effect of an event or occurrence in the dataset (38). This research sought to analyse the effect of the Permit scheme, which will be used as the intervention variable (I). The intervention in this case is a step function as opposed to a pulse function. Therefore prior to the Permit scheme the $f(I)$ value was 0, but with the onset of the scheme the $f(I)$ value changed to 1 (28). The intervention function is defined as:

$$f(I_t) = S(t) \text{ when } S(t) = \{0 \text{ when } t < T, 1 \text{ when } t \geq T\} \quad (3)$$

- $S(t)$ is the step function
- T is the beginning of the event

Diagnosis of any model residuals is regarded as white noise, whereby consideration is given to the correctness of the model, its parameters, and for all systematic variances (28). This study includes the possibility of noise within the ARIMA model, however no significant evidence of this was found, as will be detailed in the Ljung Box Q significance in the results section. ARIMA models employ lagged values for forecasting time series analysis. The models can be expressed as ARIMA (p, d, q); where p is the autoregressive element, d represents the seasonal trends in data, and q represents the lingering effect in the prediction equation (39).

IMPACT CALCULATION

As part of Derby City Council's business case for the Permit scheme, a cost benefit analysis predicted an overall reduction in highway excavation durations of around 5.5% (40), similar to Kent County Council's prediction of 5% (22). The following values have been identified for the daily cost of street works disruption per site:

- £868/\$1331 - based on road user delay only in England, in 2004 (14). (This rate is inflated (41) from source data rate of £633/\$971).
- £783 (\$1201) based on net consumer and business impact, accidents, fuel and carbon emissions in 2014 limited to Kent County in England (22).

Placing a daily value on highway excavation disruption is difficult due to the subjective and differing attributes used for calculations, such as user delay, loss of business, pollution etc (1). Of the two sources above, the value of £886 will be adopted to make impact calculations, given the comprehensive analysis and documented methodology provided by the authors.

RESULTS

Based on 61 monthly entries between October 2009 and October 2014, the overall mean duration of works was 3.06 days (minimum - 2.19 days and maximum 4.42 days).

In order to understand the effect of the Permit scheme (I) on the average duration of works per month (DV) and the other explanatory variables (IV), an ARIMA time series model was run. The SPSS Expert Modeller function was engaged to identify the optimal model. The results returned an ARIMA (0,0,0) model - this means that there was no evidence of any seasonal trend within the dataset.

Overall the model demonstrated that total excavation durations reduced over the five years with a generally downward trajectory. The average duration of works was highest in the first two years of the study with a sharp drop in October 2011. With the exception of October 2013 where there is a sharp increase, the duration of excavations reduced over the remaining three years and stabilised further with the Permit Scheme (Figure 3). It is considered that the stabilisation of excavation duration is linked to the greater pre-planning of activity as is necessitated by the Permit Scheme.

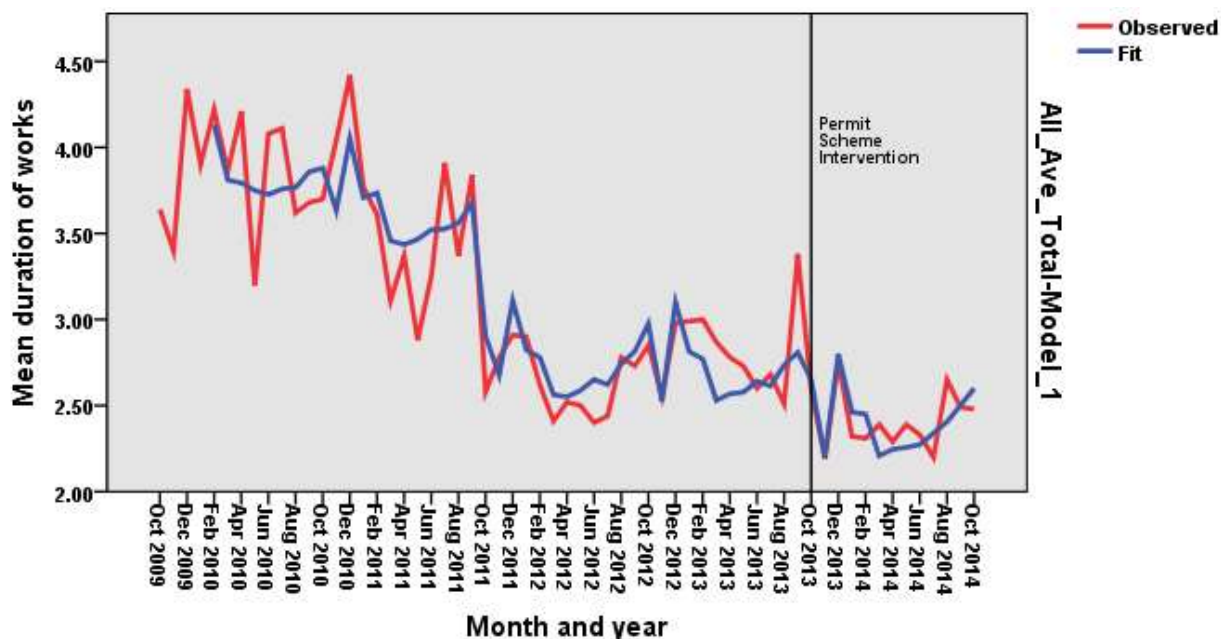


FIGURE 3 Total Highway Excavation Activity During Study Period

Model analysis shows that the intervention of the Permit scheme has reduced the average duration of highway excavations by 0.322 days, or approximately 1/3rd of a working day. ‘Daylight hours’ was the only variable considered a significant explanatory variable with results showing a lagged value, which means a relationship with the number of daylight hours in the current month, along with, to differing degrees, daylight hours of the two previous months (Table 2). This relationship may be related to the complex interaction with daylight hours due to the ‘frantic’ use of hours at the beginning of spring and less desperation to use the hours at the end of the summer. It may also be related to the hurried nature in which work promoters use their budgets towards the end of the financial year. Statistical analysis did not find that the country’s economic activity influenced the duration of excavation activity. Analysis over a longer duration, to include the period prior to the global economic recession from 2007 to further post permit scheme analysis would be helpful for deeper analysis. Unfortunately, this was not possible due to limited data availability.

TABLE 2 Results from the Time Series Intervention Model

Variable	Estimate
Average works duration	3.05
Permit Scheme Intervention	-3.22
Daylight hours	Lag 0 (current month) -1.75
	Lag 1(last month) -0.329
	Lag 2 (month before last) +0.186

In terms of model accuracy, the R squared value provided goodness of fit statistics – the closer the value is to 1, the greater the goodness of fit (38). The results gave an R-squared value of 0.855, therefore we can be 85.5% certain that the changes in activity are attributable to the variables identified in the model. The remaining 14.5% value is based on factors

outside of this model. The MAPE (mean absolute percentage value) of 6.039 means that across the series, on average, the forecasted/predicted value has a 6% margin of error. The MaxAPE value of 20.353 means that at worst, 20.4% of the variation was not explained at some point in the series. The Ljung Box Q statistic provides an indication of whether the model is correctly specified (38); with a value of 0.989 significance, we can be very confident that the model is correctly specified (Table 3).

TABLE 3 Results of Model Statistics

Descriptive statistics	Value
R-squared	0.855
MAPE	6.039
MaxAPE	20.353
Ljung-Box Q	0.989

The average duration of excavation works in Derby is 3.06 days; the model estimated that the Permit scheme reduced works by 0.322 days, which equates to a 10.5% reduction and is almost double the anticipated 5.5% reduction previously derived. This reduction is against a backdrop of increased volumes, but a simultaneous decrease in duration of works. Using the average volume of works of 8434 works per annum, and the estimated cost of road user disruption of £868/\$1331 (14), this equates to a reduction of excavation activity by 886 days per year, which is equivalent to a cost of delay saving to motorist of £769,048/\$1,179,777 in Derby. This does not include construction costs saved by work promoters, or costs related to business, community or environmental impact.

5 CONCLUSION

This study sought to evaluate the effects of the Permit scheme intervention on the average duration of highway excavation activity per month. An ARIMA time series analysis model positively demonstrated that the Permit scheme reduced the average duration of excavations by 1/3rd of a day per job; in Derby this is equivalent to around 886 days, equivalent to £769,048/\$1,179,777 per annum. The Permit scheme has played a positive role in reducing excavation activity which is valuable feedback for policy makers and practitioners. In rationalising why the Permit scheme has had this effect, a key explanation could lie with the greater pre-planning the scheme demands in order for application approval. Permit applications, resubmissions, and variations all attract fees for the applicant (except for HAs). Rejected applications waste time and create uncertainty; this is likely to be significantly more inconvenient and expensive than the Permit costs itself, especially if it involves re-programming works, plant and equipment, the labor supply chain, as well as informing stakeholders. Greater pre-planning involves submitting robust site information, plans, methods, techniques, and detailed traffic management information which leads to greater collaboration with SAs. In turn, this greater preliminary planning means that operatives go to site better informed and prepared, leading to less on-site problems and thus reducing the overall work duration.

Of the independent variables selected, only ‘daylight hours’ was found to have a significant relationship with excavation and was previously correlated to ‘temperature’. Both variables have obvious relationships with excavation activity, as longer daylight hours afford greater working time, whilst warmer temperature afford more stable ground conditions. In

considering the effect of economic activity, it is harder to draw conclusions as work promoters were likely to have been affected in different ways. With the exception of telecoms, regulated monopoly industries saw price increases for consumers during the recession. Water increases were modest (around 2% per annum between 2000-2013), however, contentiously, the energy industries saw significant price increases against stable spot wholesale gas markets (electricity - around 8% per annum between 2004-2011, no increase between 2011-13; gas – around 12% per annum between 2004-13). The perceived profit levels led to public and political accusations of profiteering (42) leading to the commencement of a high profile investigation by the Competitions and Markets Authority (43). Overall this indicates that utilities were financially comfortable during the recession. Further, greater capital works are advisable during an economic downturn to take advantage of lower costs of labour, equipment and raw materials (44). It is therefore conjectured that utility investment potentially increased; indeed anecdotal evidence showed that utility investment in Derby was certainly unaffected by the economic climate. In contrast, a change in central government and a political will to reduce national deficit in 2010, meant significant austerity cuts and changes to local government funding. Austerity cuts were combined with local authorities being granted freedom to spend their allocations on chosen local priorities, which meant highway budgets were no longer exclusive and could be spent elsewhere if the authority felt there was a greater need (45). These factors make it difficult to understand what role infrastructure investment had to play in highway excavations. A government drive to construct more houses in the UK could also be contributing to increased utility infrastructure. Additional research would benefit from more information about capital spend per year from the work promoters to increase understanding about its role on excavation activity.

This research demonstrates that the Permit scheme is a positive scheme; therefore it is recommended that the Permit scheme could be extended to other busy urban areas. This study has made a reasonable assumption that the deduction in works duration is as a result of better pre-planning of works – it is recommended that the utility industry takes heed of the positive impact this has had. Whilst this study offers financial valuations of the potential scheme savings, these should be seen as indicative due to the varying opinions and estimations of street works disruption.

This is an important and novel piece of research because highway excavation management policy and particularly intervention impacts are under-researched. There is further value in developing this work in order to understand the separate impacts of the scheme on the HAs and SUs, and also on the various works categories. It would also be valuable to research the running costs of the Permit scheme to understand the cost implications on works promoters to get a more holistic understanding.

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APPENDIX D (PAPER 4)

JOURNAL PAPER

Title

Determining the impacts of local authority interventions on the duration of highway excavations

Full Reference

Hussain, R.S., Enoch, M., Quddus, M., Ruikar, K., Brien, N., Gartside, D. (201X) Determining the impacts of local authority interventions on the duration of highway excavations, Proceedings of American Society of Civil Engineers :Journal of Infrastructure Systems *Under review*

Abstract

Road works (highway works) and street works (utility works) are vital, yet can be disruptive, inconvenient and have high social costs, therefore it is critical to make efforts to manage them considerately to minimise their impacts. Despite their impact and costs, street works policy is an under-researched area. This case study sought to understand whether the adoption of two policy tools, namely a Permit scheme and an electronic work order management system (WOMS) reduced the duration of highway works activities in the city of Derby. Time series statistical analysis was run on two datasets to understand their impact on both Highway Authority works and Utility industry works.

The results showed that the Permit scheme reduced utility works durations by around 5.4%; which was equal to 727 days per year, saving between £2.2 - £7.7 million construction and societal costs annually. Conversely, whilst the Permit Scheme did not demonstrate a noticeable impact on HA works, the introduction of WOMS reduced work durations by 34% (6519 days) which was equivalent to between £8.3 - £48.3m per annum. This case study has shown that the Permit scheme can be an effective tool for reducing utility work durations, however more considered practices are required by the HA to support the Permit Scheme principals. This research is significant as it provides impact information for policy makers and practitioners on a relatively new type of scheme, and it is original, because this is the first time that an intervention analysis approach has been applied to this area of public policy.

Key words

Roads, highways; traffic engineering; policy, time series analysis, ARIMA

1 INTRODUCTION

Growing urbanisation and an escalation of internet dependence means there is an increased need for certain utility infrastructure to match commercial and residential needs; in the UK there is also a need to maintain and replace ageing Victorian utility infrastructure. Underground, a complex network of utility apparatus enable the delivery of essential services to properties for day to day domestic and commercial use, with at least seven main utilities underground (i.e. water, sewers, gas, electricity, telecommunications, street lighting and traffic cabling) owned by differing utility companies who manage, install, operate and repair their private networks independently of each other (e.g. Rogers et al., 2012). Problems can (and often do) arise when utility companies (also known as Statutory Undertakers (SU) need to install/access/maintain utility assets (known as street works) or when the Highway Authority (HA) needs to repair the fabric or structure of its highway (known as road works); these practices can disturb and clash with over-ground expectations for expeditious access and transport.

Unsurprisingly, road works and street works (collectively known as highway works or work zones) are considered disruptive and inconvenient to society (see Hussain et al., 2016 for more information). An estimated 1.5 million utility excavation works with a direct construction cost of around £1.5 billion occur in the UK annually (McMohan, 2005); which can substantially decrease lane flow capacity causing major congestion (e.g. Walker and Calvert, 2015). Further, repeated utility cuts have led to serious deterioration of road life, with several major cities reporting significant damage to infrastructure including Toronto, Vancouver, San Francisco, Phoenix (Arizona) and UK cities (e.g. AMEC, 2002; Jordan et al., 2009; Mouaket and Capano, 2013). Other key impacts include, negative environmental effects, loss of trade for local businesses, increased accidents, increased vehicle operating costs, elevated levels of frustration for drivers and aesthetic depreciation amongst others (Brady et al., 2001; House of Commons, 2014; Hussain et al., 2016; Lepert & Brillet, 2009; Matthews et al., 2015; Transport Research Laboratory, 2012; Walker and Calvert, 2015; Wilde et al., 2003). Annual societal costs of around £5.6 billion have been reported, of which £5.1 billion is attributable to lost driver time alone; suggesting that the cost of delay is actually higher than the cost of construction itself (Halcrow, 2004; McMohan, 2006). Whilst these studies have specifically looked at utility works, there is a significant gap in knowledge about the impact of HA works. There is a clear need to minimise highway excavation activity and their impacts to minimise disruption, inconvenience and to keep the over-ground transport network running as freely as possible.

In order to reduce the impact of excavation activity in the city, key policy interventions have been introduced by Derby City Council in its independent capacities of both Street Authority (SA) and HA as follows:

- The Street Authority, who is responsible for the over-ground management of traffic on the highway network has implemented a Road Works and Street Works Permit Scheme (hereon referred to as the 'Permit scheme') on critical streets in the city of Derby, with the aim of minimising delays to road users through improved planning and execution of planned disruption to free flow traffic. Any work promoter seeking to work on the highway must obtain a Permit (Derby City Council, 2013).

- The HA, who are responsible for maintaining the highway, introduced certain interventions which exclusively affect their works:
 - the introduction of a real-time electronic Works Order Management System (WOMS),
 - the purchase of a JCB Pothole Master machine, and
 - bringing in-house their highway maintenance service.

The objective of this paper is to examine the impact of introducing new policy interventions in an urban authority on the duration of highway works activity – namely the Permit Scheme, and the introduction of the electronic WOM system. A general examination of literature finds that highway excavation literature tends to be high level, and with focus weighted on technological tools to manage highway works, rather than policy tools (Fisher, 2012; Wilde et al., 2003). There is a dearth of literature about the macro/operational level of highway works management. Further, whilst literature recognises that Permit Schemes operate around the world, there is limited evidence about their performance. The Permit Scheme is a relatively new scheme in England, but is contentious because charges apply only to all except the HA. SUs consider the scheme an unnecessary financial burden and superfluous to needs (Hussain et al., 2016; National Joint Utility Group 2012).

This paper is important because it fills a gap in knowledge about an under-researched area of policy at a practitioner level. The paper is innovative because it uses time series analysis to measure the performance of a Permit scheme, and compares the performance of HA works with the utility sector. The remainder of this paper is structured in sections comprising a literature review, case study information about Derby, data, method, results, followed by a discussion, and conclusion with important policy implications.

2 LITERATURE REVIEW

Efficiently managed highway works are critical to maximise the integrity of highway infrastructure and to minimise the impact on the over-ground movement of traffic (including people) and society. Highway works and excavations can be enhanced either through technological measures, or policy and management tools. Whilst extensive research underpins technological solutions such as: trenchless techniques (eg, auger boring, pipe jacking and robotic spot repairs), multi-utility tunnels (Hunt et al., 2014) and subsurface utility engineering (SUE) (Kraus et al., 2012) amongst others, policy and management techniques have received less attention (Tseng et al., 2011). Some exceptions are as follow:

- Permit schemes - Authorities in the UK, Singapore and New York issue permits to execute works on the highway (Land Transport Authority, 2014; Transport Research Laboratory, 2012). Permit schemes in the UK give SAs increased powers to manage and control works compared to the predecessor ‘Noticing’ regime (House of Commons, 2014). The Permit scheme typically seeks to ensure parity between HA and SU works, to improve co-operation between work promoters, to reduce the adverse impact of highway works and to promote the adoption of minimally invasive technological approaches (Derby City Council, 2013; DfT, 2008).
- Works embargo – Local authorities can prioritise traffic management by restricting timings of highway works, for example, Singapore ban peak hour working whilst Hong Kong prohibits works between 7am – 7pm daily (Transport Research Laboratory, 2012). Where works require road closures, in Sydney for example, these

are generally restricted to Sundays (City of Sydney, 2014). UK legislation enables SAs to heavily restrict excavations for up to two years following completion of highway improvement works (Tseng et al., 2011); whilst Japan and France are also known to prohibit re-excavation for up to five years (Brady et al., 2001).

- Legislative rights – UK utility companies have enjoyed legal rights to store utilities in the highways since the mid-nineteenth century. Conversely, Scandinavian utilities have no such rights and must seek authorisation from the highway owner/Road Authority (Brady et al., 2001).
- Lane Rental schemes – HAs in London and Sydney rent out highway lanes for specified durations to enable work promoters to execute works (City of Sydney, 2014; Transport Research Laboratory, 2012; DfT 2012).
- Noticing – Traditionally and primarily, highway works in England were managed through a ‘Noticing’ system (unless superseded by a Permit scheme), whereby work promoters submit prescribed notices to the SA to notify of their intention to work (House of Commons, 2014).
- Memorandum of Understanding (MOU) – In several Australian and US states, MOUs are agreed and signed between States and utilities to secure co-operative and co-ordinated working processes during construction (Campbell et al., 2009).
- Transportation and Utility Corridors (TUCs) – As part of Calgary and Edmonton’s restricted development areas plans (RDA), TUCs formally designate ring road and utility alignments in advance in order to effectively manage works from the offset (Campbell et al., 2009).
- Works Order Management System – For increased efficiency, Derby have replaced their paper-based works order system with portable real time electronic tablets, which means they can work interactively from site (Derby City Council, 2012). A similar approach has been adopted in Gateshead (Total Mobile, 2013).

Whilst the above cases identify macro-level policy based techniques, there are few examples at a meso-level or micro-level; for example, the performance and impacts of specific policy interventions or how they affected an area or population is unclear. Although the Permit Scheme has caused a major paradigm shift in the English highways management industry, there is a dearth of literature analysing its performance possibly because the scheme is relatively new; the one exception is a study proposing the use of fuzzy logic for the Cost Benefit Analysis of the Kent Permit scheme (Shrivastava, 2010). Indeed regulations require that SAs evaluate Permit Schemes after 12 months, then subsequently 36 months to monitor their effectiveness (DfT, 2014). However, SUs feel that such evaluations are not comprehensive, as they fail to reflect the true costs borne by utilities (National Joint Utility Group, 2012). Analysis of Permit scheme performance reports from around the UK reveal the following reductions:

- London Permit Scheme - 2% reduction in average duration in the first year (London Permit Scheme operational Committee, undated)
- Kent County Council - 18% reduction in ‘impact of road works’ over four years (Kent County Council, 2014)
- Yorkshire Common scheme – 21% reduction in duration over two years (Yorkshire Common Permit Scheme, undated)

The reports are detailed, identify data limitations, and report on pre-agreed performance indicators agreed with the Department for Transport (DfT), UK. However, the reports lack robustness due to limited information about study methods, data analysis techniques, and

lacking appropriate statistical sensitivity testing of results. The results are not subject to peer review or feedback from the DfT which makes it difficult to understand the confidence levels of the results given. Therefore an absence of robust Permit policy analysis in literature remains.

2.1 The cost of street works

In terms of the overall cost of street works, since Brady et al.'s (2001) report detailing the small number of studies quantifying the cost of utility works, the following notable studies have taken place:

- Halcrow study - The DfT commissioned Halcrow (2004) to investigate the cost of delay to motorists using the Queues and Delays at Road Works (QUADRO) modelling program who estimated the cost at £4.6 billion in 2004.
- Goodwin study - A utility industry commissioned report challenged the assumptions, methods and values of the Halcrow study, and estimated that the “true cost” of delay actually lay between £0.5–1 billion (Goodwin, 2005).
- McMahan et al. study - The Goodwin report was further contested by the UK Water Industry Research (UKWIR), who expressed reservations about the use of historical, geographically inaccurate and limited data to calculate the value of £0.5 billion. Instead, UKWIR found that Halcrow's analysis drew on the most extensive set of data, and was the most comprehensive and methodical analysis to date. Consequently, Halcrow's costs were extrapolated to include the whole of UK, and the revised social cost of street works was updated to £5.1 billion. Additional social costs attributed to businesses, communities, premature highway damage, and various environmental costs were estimated to be around £0.5 billion, whilst direct construction costs were valued at £1.5 billion, with indirect costs (third party damage) estimated at £150 million, taking the overall cost of street works to be in excess of £7 billion per annum (McMahon et al., 2005).

Notwithstanding McMahon et al.'s (2005) estimate of £0.5 billion in environmental costs, the authors acknowledged that social costs are under-researched and difficult to calculate. Although Hunt et al.'s (2014) research identifies several cases of social costs derived from individual construction projects, as McMahon et al. (2005) found, no comprehensive, universal strategy could be found for calculating social costs. Further, literature focuses on utility related construction costs and the well documented negative impact on pavement life (Jordan et al., 2009, Wilde et al., 2003) with HA works receiving little attention even though they tend to be greater in volume and impact society in the same manner. Therefore the true cost of all highway excavation activity could be at least double the cost of only utility works.

3 CASE STUDY OF DERBY

Derby is a fairly typical English regional city of around 250,000 people, and is located approximately 200 kilometres north of London. Traditionally and primarily, highway works in Derby have been managed through a 'Noticing' system. The Derby Permit Scheme commenced in October 2013 (Derby City Council, 2013) replacing Noticing on key city streets. Permit costs can range from £60 – £231 per application, and £45 per variation. Permit

applications and their variations incur costs for SUs; whilst HAs undertake the same application processes, but Permits are free. The financial impact of the new scheme on SUs is unclear, but includes Permit fees, and increased back office costs through greater pre-planning and producing supporting Permit information, similarly, HA operational costs are also likely to have increased. The Permit scheme only operates on ‘traffic-sensitive’ streets, which comprise around 20% of Derby’s roads. Traffic-sensitive streets are formally designated subject to legislation, and are essentially those streets where works would be especially disruptive to road users (DfT, 2012). Noticing applies on the remaining streets. SAs must exercise parity of treatment between the HA and the SUs (DfT, 2008).

Key differences between the Permit and the predecessor Notice regimes are:

- Permits enable more proactive management and control of activities on road networks;
- Permits are more aligned to applying to work on the highway, as opposed to simply notifying the SA;
- Permit applications are chargeable, and failure to comply with any conditions set can attract financial penalties (House of Commons, 2014).

In addition to the Permit Scheme, the HA have also been actively working towards making highways maintenance more efficient and cost effective through the introduction of the following practices:

- Works Order Management System (WOMS) (October 2011) – this technological change involved replacing the paper-based system of recording works information with an app-based electronic system. Highways Inspectors were given devices to use remotely, interactively and in real-time, reducing delays caused by a manual system.
- Purchase of a JCB Pothole Master (3CX) (August 2013) – this technological purchase was made to enable in-house construction by a direct labour organisation (DLO).
- In-house construction activity (September 2013) – this policy change meant that after 16 years of contracting construction works to an external company the HA brought most services in-house, employing a DLO.

A time series statistical analysis model can be employed to evaluate whether the introduction of these interventions had any impact on the reduction of the mean duration of excavation activity while controlling for other factors that influence the work duration.

3.1 The cost of road works and street works in Derby

Street works costs are generally under-researched as detailed in the literature review of this paper. Whilst construction costs of street works are generally accepted as around £1.5 billion (McMahon et al., 2005), social costs are disputed and range from as little as £0.5 billion (Goodwin, 2005) to £5.6 billion (2002 values and market prices) (Halcrow, 2004; McMahon et al., 2005). The studies do not provide enough information to calculate a daily cost for street works, although Goodwin (2005) proposed costs of works of £633 per site, per day which are unsubstantiated. Therefore, a sliding scale of costs for excavation activity in Derby was devised using the construction costs (McMahon’s et al., 2005) and both Goodwin’s (2005) and McMahon’s et al.’s (2005) social costs by firstly applying inflation (Bank of England, 2015). Secondly, since the study, the UK population had grown by 8% from 59.6 million in 2005 (McMahon et al., 2005) to 64.5 million (Office for National Statistics, 2016), which was added to the respective inflated values. Thirdly the values were then divided by the English population size to calculate a per person cost for excavation activity per year. Fourthly, the

values were, multiplied by the population size of Derby (250,000), and finally divided by the volume of street works activity (see Table 1) to arrive at the daily cost of street works activity which can be considered between £2904 – £10,166 (see Appendix A for cost calculations).

TABLE 1 – Volumes, means and intervention data for time series analysis study

<i>Year (Commencing October)</i>	<i>Intervention</i>	<i>HA works volume</i>	<i>SU works volume</i>	<i>All works volume</i>
Year 1 – 2009-10	-----	4819	3693	8512
Year 2 – 2010-11	-----	3783	4418	8201
Year 3 – 2011-12	Oct – WOMS	4466	4160	8626
Year 4 – 2012-13	Aug - JCB Pothole Master Sept - In-house maintenance	3708	3970	7678
Year 5 – 2013-14	Oct – Permit Scheme	5771	3383	9154
Year 6 – 2014-15	-----	5662	3149	8811
Year 7 – 2015 – 2016 (6 months only)	-----	3658	1595	5253
Total works		31,867	24,368	56,235
Mean volume (year)		4902	3748	8651
Mean duration of works prior to Permit Intervention (days)		2.8	3.6	-----
Mean duration of works prior to WOMS Intervention (days)		3.9	-----	-----

The cost of road works on the other-hand is even less researched, and thus equivalent figures could not be found to match the cost of street works. Again, a sliding scale of costs for Derby was estimated. Firstly, the social impact of road works was considered similar to street works, therefore this was calculated for Derby as described previously. To estimate the cost of HA works, the Authority’s budget records were consulted and using available data covering a four year period, the average cost was calculated at £3.1 million per annum for design and construction (see Table 2). Accordingly Derby’s daily road works costs were calculated as between £1,266 and £7416 (see Appendix A for cost calculations).

TABLE 2 – Highway Authority spending on road works activity

<i>Year</i>	<i>Annual spend on road works</i>
2011-12	£3,258,560
2012-13	£2,953,484
2013-14	£3,119,115
2014-15	£3,203,057
Total spend	£12,534,216
Mean spend	£3,133,554

4 DATA

Two separate datasets were used to investigate the duration of HA and SU highway works. The separation was important to differentiate the performance of HAs who do not pay for Permits, compared to SUs who do.

The study period lasted 6.5 years commencing October 2009 on Permit applicable streets only. During this period 56,235 valid individual works registered with the SA were downloaded. The mean volume of works was 8651 per annum overall, whilst the HA and SUs

executed 4,902 (57%) and 3,748 (43%) works on average respectively (Table 2). Data was collated using the SA's central database used to receive Permit applications, and uploaded to IBM SPSS Statistics 22 (SPSS). The mean duration of highway works per month was calculated by dividing the total applications received, by the total days spent occupying the highway.

Figure 1 shows the time series plots of mean duration of works on a monthly basis for both datasets. SU works remained relatively smooth over the study period, whilst HA works took a dramatic drop in October 2011 coinciding with the introduction of the WOMS system. The surge in HA works evident in August 2013 ties in with the change-over period of the HA moving from a term maintenance contractor to bringing works in-house executed by a DLO. Notwithstanding this, the graph shows that the Permit scheme has potentially reduced the duration of SU works, however, the impact is not so distinct for HA works. Therefore it is hypothesized that the Permit Scheme reduced the duration of highway works for the SUs, but did not reduce HA works.

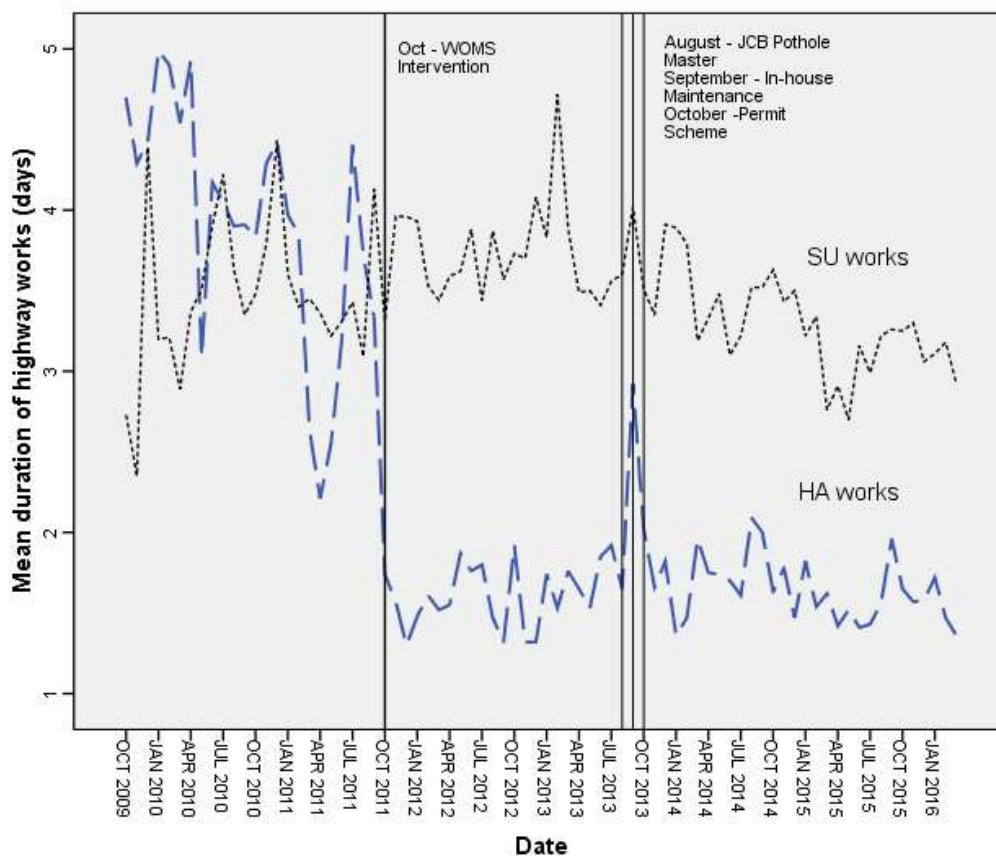


FIGURE 1 - A sequence of mean highway works activities (October 2009 – March 2016)

Further to this, control variables were also collated to account for external factors which could affect performance (Table 3). Examination of control data revealed that the Gross Domestic Product (GDP) showed an uneven trajectory until June 2012, after which it consistently increased. Construction infrastructure output showed a small and steady increase, whilst housing demand almost doubled. Vehicle miles travelled (VMT) showed regular seasonal peaks (Jul-Sept) and dips (Jan-Mar) as expected, but was relatively static over the five year period. Note, that the Christmas Restrictive period identified is a period when the SA heavily

restricts works on traffic-sensitive streets between mid-November and early January (except emergencies).

TABLE 3 - Variables used in the analysis and descriptive statistics

<i>Variable Type</i>	<i>Variable</i>	<i>Variable Description</i>	<i>Variable format/unit</i>	<i>Source</i>	<i>Mean Value</i>
Dependent variable	Average duration of work per month	Total number of works/total duration	Count/days	Derby City Council reports	3.05
Intervention variable	Regime	Type of management regime - Notice or Permit scheme	Binary/(0/1)	Derby City Council	---
Intervention variable (HA model only)	WOMS	Works Order Management System – Manual or real time electronic system	Binary/(0/1)	Derby City Council	---
Independent variable	Gross Domestic Product (GDP)	An indicator of economic activity. Based on household final consumption expenditure - 'current price' (CP) per month (£ million)	Ratio	(Office for National Statistics (2015a)	105.31
Independent variable	Construction industry output (overall)	An indicator of economic activity. Money spent on construction of new housing, infrastructure and 'other' works – commercial and private per month in UK (£ million)	Ratio/£-GBP	Office for National Statistics (2015b)	18,011
Independent variable	Construction housing output	An indicator of economic activity. Money spent on new public and private housing per month across UK (£ million)	Ratio/£-GBP		5,218
Independent variable	Construction infrastructure output	An indicator of economic activity. Money spent on public and private (industrial and commercial) infrastructure per month across UK (£ million)	Ratio/£-GBP		3,359
Independent variable	Daylight	An indicator of working conditions. Number of hours of daylight per day (hours: mins)	Count/hours	<i>Weather Channel (2005)</i>	12:38
Independent variable	Air temperature	An indicator of working conditions. Mean air temperature over month - °C	Ratio/Degrees Celsius	<i>Met Office (2015a)</i>	10°C
Independent variable	Precipitation	An indicator of working conditions. Based on amount of rain fallen – mm	Count/millimetres	<i>Met Office (2015b)</i>	56.23
Independent variable	Vehicle miles travelled	Distance travelled on all roads in UK by all classes of vehicles per year (billion miles)	Count/miles	<i>DfT (2015)</i>	76.2
Independent variable	School holidays	An indicator of road activity. Based on the proportion of school holidays over week days per month	Count/%	Derby City Council	25%
Independent variable	Christmas restrictive period	An indicator of a period of typically low excavation activity and high traffic volumes between mid-November and early January over Christmas period	Binary/(0/1)	Derby City Council	---

5 METHOD

This study sought to evaluate the impact of various policy relevant interventions on the duration of excavation activity using statistical analysis. This section will provide further information on time series analysis, the role of ARIMA and intervention functions.

5.1 Time Series Model

A time series model was used to evaluate the impact of policy relevant interventions on the duration of highway works, while controlling for other factors such as GDP, weather and other incidental and cyclic events. Since all of the variables were time-variant (as opposed to time-invariant for the case of a cross-sectional study), a time series regression model was preferred. A time series model repeatedly measures a single variable (i.e. dependant variable) over a regular and consistent period of time, thus can be employed to understand patterns and trends historically, and to extrapolate these to make future predictions. Time series analysis can also be used to measure the impact of one or more interventions on the dependant variable. An important criterion of employing a time series regression model is that a minimum of 50 observations should be used for more reliable results (Chatfield, 2004), accordingly this study aims to use 78 monthly observations (no future predictions are sought).

The time series model can be defined as:

$$y_t = f(X_t, I_t) + N_t \quad \dots\dots\dots (1)$$

In which t is the discrete time (month in this case), y_t is the appropriate Box-Cox transformation of Y_t , say in $\log Y_t$, Y_t^2 or Y_t itself (Box and Cox, 1964), Y_t is the dependant variable (i.e the mean duration of each highway work activity) for a particular time t , $f(l, X)$ is the deterministic part of the model which contains the intervention component (I) and the deterministic effects of independent control variables (X) and N_t is the stochastic or noise component.

The random component (N_t) follows an autoregressive integrated moving average (ARIMA) model that is normally denoted as ARIMA ($p.d.q$) in which p is the order of the non-seasonal autoregressive (AR) process, d is the order of the non-seasonal difference, q is the order of the non-seasonal moving average (MA) process. The ARIMA model can be expressed as (Box and Cox, 1964):

$$\phi(B)(1 - B)^d N_t = \theta(B)u_t \quad \dots\dots\dots (2)$$

In ϕ is the regular AR operator, θ is the regular MA operator, B is the backward shift operator, and u_t is an uncorrelated random error term with zero mean and constant variance (σ^2). The seasonal version of the models and their details can be found in Box and Cox (1964).

5.2 ARIMA Modelling

The process of the ARIMA model analysis entails the identification, estimation and diagnosis of data (e.g. Tabachnick and Fidell, 2006). Analysis firstly requires identification of stationarity in the time series; a stationary time series, or applying, for example, ‘differencing’ to achieve stationarity is critical for the ARIMA process (Box et al., 2016). Stationarity removes any linear/quadratic, or other trends to provide a series where means, variance and autocorrelations remain constant over time (Tabachnick and Fidell, 2006). Stationarity can be identified using autocorrelation functions (ACF) and partial autocorrelation (PACF)

correlograms. Analysis of the ACF and PCF is also used to identify a suitable autoregressive model (AR) or moving average (MA) model, or a combination of both (Chatfield, 2000). The second step is to run the model to test the lingering auto-regressive or moving average effect is more appropriate. This may include incorporating control variables (i.e. X). The final step is the diagnosis of the model to determine accuracy – this incorporates examination of the significance of parameter estimates, goodness of fit statistics, and testing white noise residuals for all systematic variances (Box et al., 2016).

5.3 Intervention function, $f(I_t)$

Time series analysis can include intervention variables which examine the effect of events or occurrence in the dataset (Box and Tiao, 1975). This research sought to analyse the effect of various interventions. Both models were subject to the Permit Scheme (October, 2013), therefore the SU model was singularly tested against this intervention. The HA model was however affected by three further interventions: WOMS (October 2011), the purchase of a JCB (August, 2013) and the bringing in-house of highway construction operations (September, 2013). However, as the former two interventions occurred within the preceding two months of the Permit Scheme, they were not incorporated in the model because of their step function nature (see figure 3). This means that prior to their onset, the value of the function (f) of the intervention (I) was 0, but with the onset the value changed to 1 (Yafee, 2009). It was inappropriate to examine three consecutive monthly interventions with step function because, they can distort the model thus presenting difficulty in confidently attributing change to either of the interventions. In the circumstances, only the Permit Scheme and WOMS interventions were tested for the HA model.

The intervention function is defined as:

$$f(I_t) = \vartheta_0 I_t \dots\dots\dots (3)$$

where ϑ_0 is a constant, and I_t is the intervention variable which takes a value of 0 for every month before the implementation date (i.e. t') of the policy intervention and a value of 1 for every month thereafter, i.e.,

$$I_t = \begin{cases} 1 & \text{for } t \geq t' \\ 0 & \text{elsewhere} \end{cases}$$

Therefore, the full ARIMA model can be presented as follows:

$$y_t = \vartheta_0 I_t + \beta X + \frac{\theta(B)u_t}{\phi(B)(1-B)^d} \dots\dots\dots (4)$$

The parameters of the model presented in equation (4) can be estimated by employing the maximum likelihood estimation.

6 RESULTS AND DISCUSSION

Analysis of the autocorrelation function (ACF) (Figure 2) revealed numerous lags of autocorrelation coefficients fell outside the 95% confidence limits, thus exhibiting serial correlation in both data models; however the HA model was significantly more non-stationary than the SU model. A log transformation was applied to stationarise the series, however this failed, instead, ‘differencing’ stationarised the series more effectively. As the data required first order differencing, this is indicated in the ARIMA (p,d,q) model by the ‘I’ (d), where d=1, as opposed to d=0 where no differencing is required (Yaffee, 2000). Different

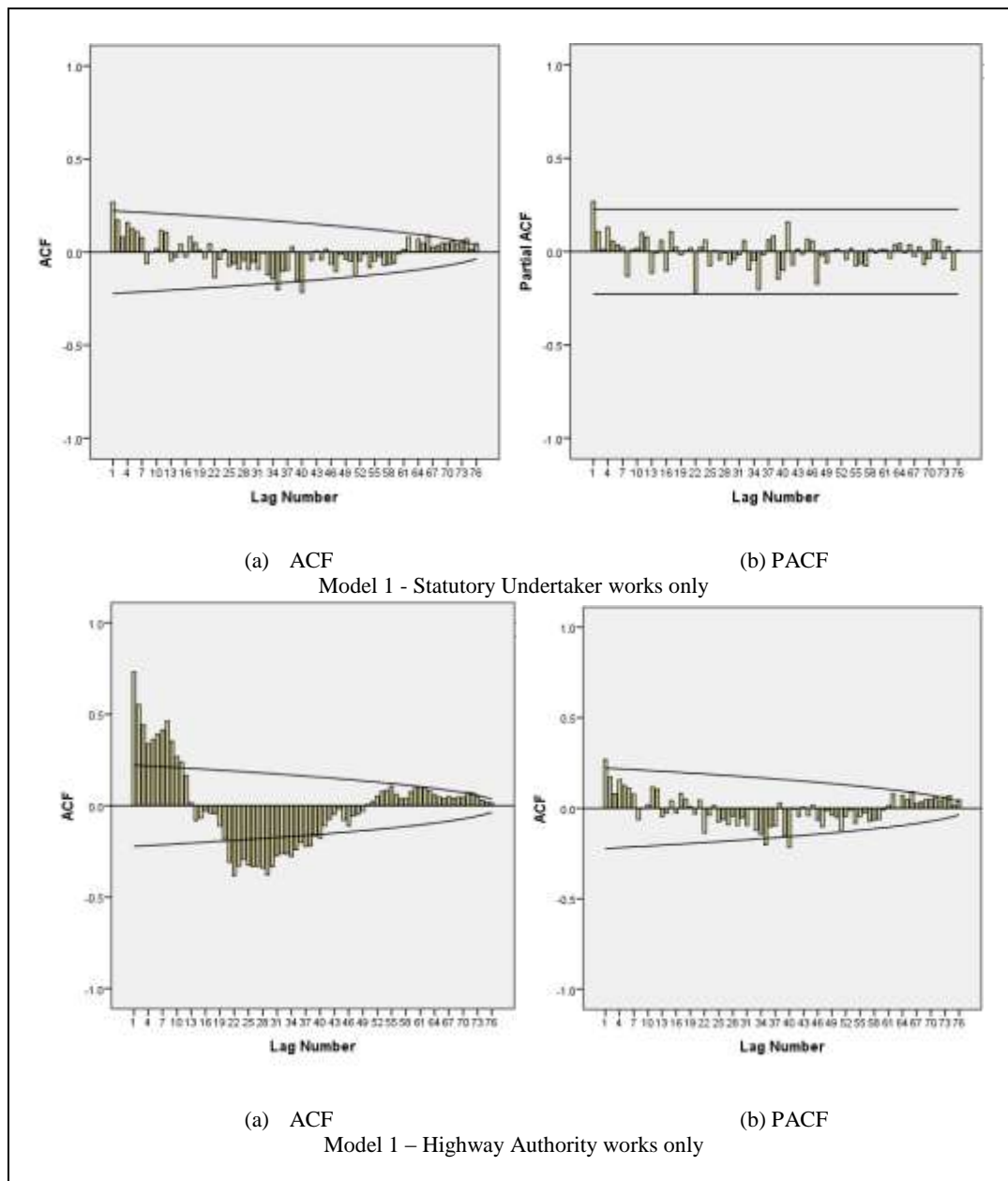


FIGURE 2 - Sample ACFs and PACFs with associated 95% confidence limits of monthly highway excavation durations showing non-stationary time series for SU works and HA works

variations of ARIMA models were tested to find the best-fit models for the datasets. In the models, the mean duration of works respective to the SU and HA model were the dependent variable (DP), the Permit Scheme was the single intervention variable (IV) in the SU model, whereas the Permit Scheme and WOMS were IVs in the HA model; additionally control variables (as shown in Table 1) which were not found to be statistically significant or relevant to a model were disposed of.

6.1 Model 1 – SU works only (1,1,0)

Optimum results for the SU dataset was found in the ARIMA (1,1,0) model (Table 4). The model is a non-seasonal autoregressive model with no indication of any lingering effect of

TABLE 4 - Results from the Time Series Intervention Models

<i>Model</i>	<u>2. SU works only</u>		<u>3. HA works only</u>	
<i>Intervention Model</i>	ARIMA(1,1,0)		ARIMA(4,1,0)	
<i>Noise Components</i>	<i>Coefficient</i>	<i>t-stat</i>	<i>Coefficient</i>	<i>t-stat</i>
Autoregressive (AR) 1	-.486	-4.723	-.277	-2.65
Autoregressive (AR) 1	-----	-----	-.339	-3.16
Intervention Variable				
WOMS – (October – 2011)	-----	-----	-1.33	-3.34
Permit Scheme (October 2013)	-.194	-2.55	-----	-----
Control Parameter				
Vehicle Miles Travelled	.051	3.117	-----	-----
Daylight hours	-.037	-2.34	-----	-----
Descriptive Statistics				
RMSE		.384		.420
MAPE		7.537		12.96
MaxAPE		36.169		48.47
Ljung-Box Q		.285		.085

works from previous months; this is statistically significant at the 95% confidence level. The model shows that the Permit scheme intervention variable reduced works duration by 0.196 days per activity on average, *ceteris paribus* (if all other factors remain constant); this was statistically significant at the 99% confidence level.

The goodness of fit indicators provide an RMSE value of 0.277 suggesting a root mean squared error. The mean absolute percentage error (MAPE) value of 6.215 indicates that across the series, on average, the predicted value has a 6.2% margin of error. The MaxAPE value of 22.6 suggests that at worst, 22% of the variation was not explained at some point in the series. The Ljung Box Q has a value of 0.439, which is over the specified minimum of 0.05, which demonstrates that the model is correctly specified (Yaffee, 2009).

Vehicle miles travelled and daylight hours were found to be statistically significant - both may be rooted in health and safety as road construction workers are disproportionately affected by injury and fatality than their counterparts (Harb et al., 2008). Firstly, should vehicle miles travelled increase by 1 billion miles, the duration of utility works is likely to increase simultaneously by 0.051 days per job on average (significant at the 95% confidence level). Increased vehicle miles travelled could be correlated with greater volumes of traffic, which is known to increase the safety risks to on-site personnel (Walker and Calvert, 2015)

and increase risks of crashes and fatalities at highway work zones (Debnath et al., 2013). The increased works duration could be reflective of work sites being managed more carefully to prevent accidents, and thus inadvertently increasing works durations. In terms of daylight hours, a one hour increase in daylight led to works durations decreasing by 0.037 days per activity (significant at the 100% confidence level). A disproportionate number and severity of accidents occur in dark hours (Harb et al., 2008), with fatalities 5 times more likely during night-time construction compared to day-time construction (Arditi et al., 2007). Night-time working can increase project costs due to increased personnel and traffic management costs, as well as compromise aesthetic considerations, and affect workforce productivity (McMahon et al., 2005; Rebholz et al., 2004). Daytime working generally affords improved working, making it a more productive working environment; therefore it is unsurprising that longer daylight hours reduce works duration.

Impact calculation for SU works

Based on the average volume of 3748 works (see Table 2), and multiplying it by the mean duration of highway works of 3.6 days prior to the Permit Scheme the typical number of utility work days per annum was around 13,492 days in Derby. The model estimated that the Permit Scheme reduced works duration by -0.194 days per highway works activity which is equivalent to 727 days or 5.4% reduction per annum. When multiplied by the daily cost of street works, (see section 3.1) the total cost of street works savings lies between £2.11m - £7.39m as shown in Table 5.

Model 2 – HA works only (4,1,0)

A visual examination suggested that the WOMS had a significant and sustained impact on the duration of works, whilst the impact of the Permit scheme was less clear (see Figure 1). To test this, a number of different variations of ARIMA models were run, however the model results were weak and the impact of the Permit scheme seemed exaggerated given the visual examination. It was considered that the inclusion of two intervention variables was disturbing the model, therefore the models were re-run examining the interventions separately. The Permit scheme was first tested using a 52 observation model which removed the observations prior to the WOMS intervention to ensure model consistency. Despite trying a number of varying ARIMA models it was not possible to find a statistically significant model which showed the impact of the Permit scheme. Using SPSS, a simple mean comparison of durations was run to check work durations before and after the Permit scheme. The mean comparison showed that works duration prior to the Permit scheme was 1.67 days, and with the onset of the scheme marginally improved to 1.68 day. As the change was so slight it corroborated the reasons a suitable ARIMA model could not be found from the onset.

The Permit scheme was introduced so that the Council could manage highway works better. Works durations is not the only proxy to measure success, therefore volumes of works were also examined. It was evident from Figure 3 that the overall volume of works had increased since the intervention, with minor works substantially increasing, along with urgent/emergency works (Figure 4). The in-house workforce and the deployment of the JCB Pothole Master which occurred around the same time as the Permit Scheme, could have caused the increase in the volume of minor works, because the HA can now be more reactive with works. This is positive for the HA because they are now executing more works than before, despite financially austere times, and positive for the public because they are experiencing improved road conditions. However this is not so positive for the SA, because it suggests that more highway works are taking place than ever before, and thus the societal

impact of these works is increasing. A caveat to this however should be that works are calculated by the day, therefore, even though a straightforward pothole repair can take around 30 minutes from start to site clearance, it will be recorded as 1 day's work which can misrepresent works durations. The recording of this information is governed by statutory legislation and thus is not easy to overcome in the short-term. However, in its regulatory role, the Street Authority could seek to minimise the impact of works by conditioning Permits so that minor works execution cannot take place during peak travel hours. Also as the Permit scheme is not chargeable to the HA, it does not create any incentive to reduce work volumes.

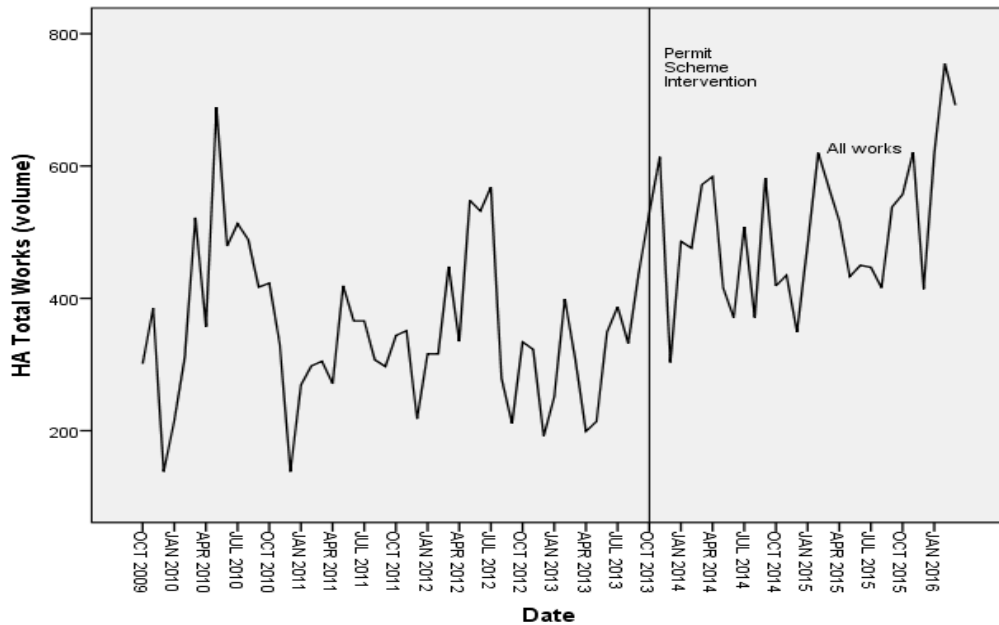


FIGURE 3 – Overall volume of HA works

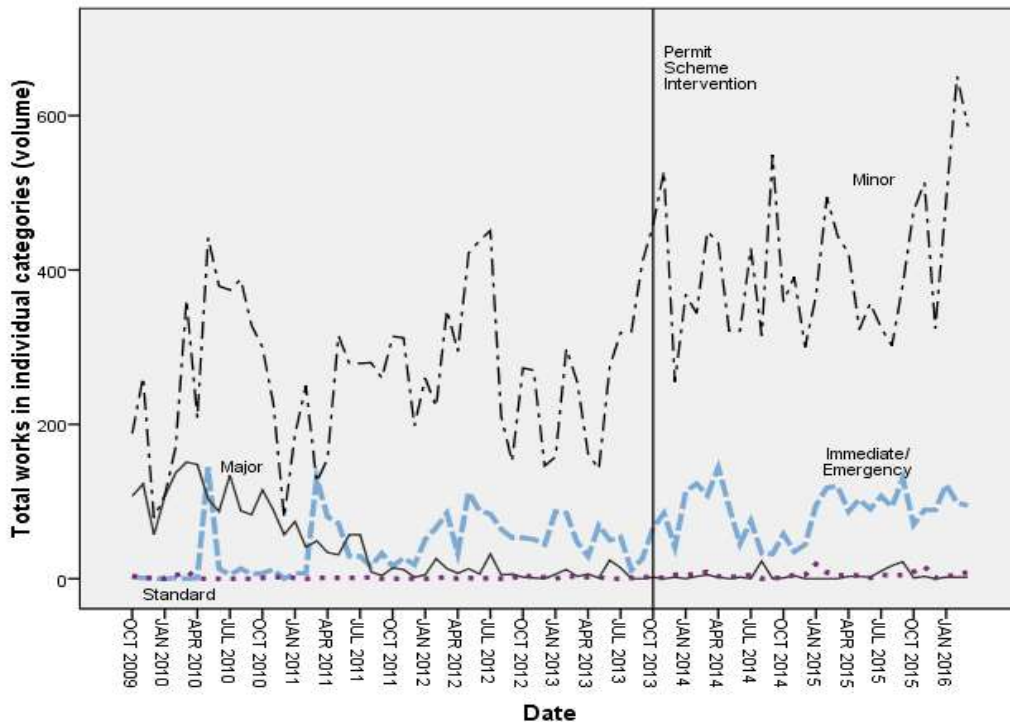


FIGURE 4 – Volume of HA works amongst different categories

The second model run examined only the WOMS impact using 78 observations. Optimum results for the HA dataset were found in the ARIMA (4,1,0) model (see Table 2). The model is a non-seasonal moving average model with a lingering effect from the previous month 4 (statistically significant at the 95% confidence level). The WOMS intervention was found to be significant by reducing works duration by 1.33 days per activity (significant to 99% confidence) *ceteris paribus*.

The goodness of fit indicators provide an RMSE value of 0.462 which suggests low mean squared error. The MAPE value of 12.96 means that across the series, on average, the predicted value has a 13% error margin. The MaxAPE value of 48.4 means that at worst, 55% of the variation was not explained at some point in the series. The Ljung Box Q has a value of 0.085 over the specified minimum of 0.05, which demonstrates that the model is correctly specified (Yaffee, 2009).

The WOMS system had the greatest impact on the duration of highway works, and was greater than the Permit Scheme which was not expected prior to the study. The WOMS enables the Works Manager to allocate and control works information sent to Highways Inspectors which reduced duplications that arose in a manual system. It can be deduced that efficient planning from the onset can lead to efficient execution of works on site, culminating in an overall reduction in on-site works duration. The adoption of WOMS also fits in with the wider Transformation Government strategy of using IT to transform government operations and processes (Weerakkody et al., 2011). The result however should be treated with caution, because, WOMS is not a direct construction tool, therefore it is more likely that WOMS has in fact improved reporting, and is thus reflecting actual works durations, which can be undermined due to delays prevalent in paper-based systems. Notwithstanding this, it is recognised that better planned road works and street works lead to better executed works on site, therefore its impact should not be disregarded.

Impact calculation for HA works

Based on the average volume of 4902 works, and multiplying it by the mean duration of highway works of 3.9 days prior to the WOMS intervention, the typical number of highway work days per annum was around 19,117 days in Derby. The model estimated that the introduction of WOMS reduced works by -1.33 days on average per works activity, which is equivalent to 6,519 days or 34% reduction per annum. When multiplied by the daily cost of road works, (see section 3.1) the total cost of road works savings lies between £8.25m - £48.3m as shown in Table 5.

TABLE 5 Impact calculations for time series analysis interventions

<i>Industry and Intervention</i>	<i>Days saved per excavation</i>	<i>Mean volume of excavation activity per annum</i>	<i>Days saved as result of intervention per annum</i>	<i>Cost (£) Incorporating Goodwin's (2005) social cost</i>	<i>Cost (£) Incorporating McMahan's (2005) social cost</i>
SU - Permit impact	-0.194	3748	0.194*3748 = 727	2,904*761 = 2.1m	10,166*761 = 7.4m
HA - WOMS impact	-1.33	4902	1.33*4902 = 6519	1,266*6519 = 8.3m	7,416*6519 = 48.3m

7 DISCUSSION AND CONCLUSION

This study sought to evaluate the effects of policy interventions on the duration of highway works. The effect of the Permit scheme was analysed in both HA and SU models, whilst the electronic WOMS was tested additionally in the HA model. The study found that the Permit scheme has played a positive role in reducing utility works duration by 5.4% (equivalent to £2.2 - £7.7m in costs annually), however the scheme had no meaningful impact on HA works. In rationalising why the Permit scheme has had this effect for SUs, a key explanation could lie with the greater pre-planning the scheme demands in order for application approval. Permit applications, resubmissions, and variations all attract fees for utility companies. Rejected applications waste time and create uncertainty; this is likely to be significantly more inconvenient and expensive than the Permit costs itself, especially if it involves re-programming works, plant and equipment, the labour supply chain, as well as informing stakeholders. Greater pre-planning involves submitting robust site information, plans, methods, techniques, and detailed traffic management information which can lead to greater collaboration with SAs.

Conversely, the Permit Scheme has not demonstrated the same impact on the HA. In this case, the Permit Scheme commenced at the same time as other major highway changes including bringing in-house highway maintenance, and the deployment of a JCB pothole repair machine to increase efficiency of highway works, which as a result has significantly increased the volumes of works now undertaken. Therefore in interpreting the HA findings, it is necessary to balance the purpose and impact of these different interventions, however these findings do highlight the adversarial nature of both the SA and HA, despite being a part of the same organisation. Hypothetically, if HAs were subject to permit costs like their counterparts, it is unlikely that Derby's road works would have increased at the same rate that they have done given the cost impact. Whilst the ad-hoc nature and small temporal durations of minor highway repair works is recognised, it is recommended that more effort is made to reduce the volume of works occurring. This case study has demonstrated that the Permit scheme can have an impact on reducing utility works durations, however greater effort is required to reduce HA works durations.

It is also considerable that the WOMS intervention led to an unanticipated 34% reduction in works durations (equivalent to £8.25-£48.3m saved per annum), as found in the HA model. Again, this is considered linked to the greater pre-planning that WOMS enables, as well as eliminating the duplication involved in a paper based system. The investment in IT to replace the paper based WOMS system, yielded positive results, suggesting that making back office processes more efficient can lead to more efficient working on site. However, caution should be exercised in the interpretation as it is likely that some credit lies in the improved reporting efficiency WOMS enables over a paper-based system.

Whilst this study offers financial valuations of the potential scheme savings, these should be seen as indicative due to the varying opinions and estimations of street works disruption, and also because works durations are always rounded up to the day. The limitations of this study are that the occurrence of major HA internal changes around the same time as the Permit scheme could affect analysis and interpretation of its true impact. In addition this study may not be representative of a non-urban local authority.

This is an important and novel piece of research because highway excavation management policy and particularly intervention impacts are under-researched. This research is valuable to policy makers, practitioners and the utility industry because it provides evidence that the Permit Scheme, as a policy intervention can be a successful scheme, and also that back office, business process improvement processes can have a key effect on improving on-site works execution. Highway excavation policy in general requires much greater research; however this study could be further enhanced by more current research into the costs of street works, and also examining the running costs of the Permit scheme for affected stakeholders.

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APPENDIX A

Table of cost calculations for road works and street works in Derby

	Street works (£) (Goodwin, 2005)	Street works (£) (McMahon et, al., 2005)		Road works (£) (Goodwin, 2005)	Road works (£) (McMahon et, al., 2005)
Base cost (incorporates £1.5b cost of construction)	2,000,000,000	7,000,000,000	Societal cost only	500,000,000	5,600,000,000
Add inflation (2015 costs)	2,693,780,536	9,428,231,876	Add inflation (2015 costs)	673,445,134	7,542,585,501
Add population growth – 8%	2,909,282,978	10,182,490,426	Add population growth – 8%	727,320,744	8,145,992,341
Divide by England population – 64,500,000 (per person cost)	45	157	Divide by England population – 64,500,000m (per person cost)	11	126
Multiply by Derby population – 250,000 (per person cost)	11,276,290	39,467,017	Multiply by Derby population – 250,000 (per person cost)	2,819,072	31,573,613
Divide by days of works per annum (3882) = total cost per excavation per day	2904	10,166	Add cost of construction (£3,100,000)	5,919,072	34,673,613
			Divide by days of works per annum (4675) = total cost per excavation per day	1,266	7,416

APPENDIX E - ETON INTERVIEW QUESTIONS

Semi-structured interview questions

Participant information

General

1. Which system do you use for EToN?
2. How many years have you had EToN/this system?

Context

3. How widespread is its use in your organisation and beyond?
Prompts: Internal teams, types of users DCC, other utilities?
4. What is the system used for and what key functions does it perform?
5. What additional functions does the system perform and what do you use them for?
Prompts: Reports, FOIs, monthly monitoring
6. On average how many notices does your system process annually?
7. What proportion of notices do you process manually? What method do you use?
Prompts: Fax, post

Design

8. Is the system easy to use?
9. If you didn't know how to use a feature, how easy is it to find an answer?
Prompts: Technical manual, online help etc
10. What are the strengths of the system?
11. What are the weaknesses of the system?
Prompts: Reliability, crashes etc
12. What are the limitations of the system?
Prompts: Co-ordinates not correct, non-compliant notices
13. What features need adding?
Prompts: Collaboration prompts
14. Does the system allow you to input data that would not be in keeping with the EToN code of practice?
Prompts: Reduced notice timescales, nonsensical data
15. Is the system integrated with GIS?
Prompts: How well does it work?
16. Which other software does the system integrate with?
Prompts: Oracle, Arcmap, Street Gazetteer
17. How adaptable is the system to accommodate new EToN changes?
18. Do you consider that the system provides value for money?

Performance

19. How well do you consider the system meet its intended purpose?
20. How easy is it to retrieve data?
21. How confident are you with the information retrieved?
22. How much information does the system give you about other agencies working in the same area?
23. What happens to information afterwards – is it re-used?

Prompts: Assessed and used for service improvement?

24. Does your system provide co-ordination prompts? If so, when?
25. What action would you normally take if you see such a prompt
26. Does your system flag up 'return path' comments from the local authority? Are these easy to ignore, retrieve and action?
27. What are the parameters for prompts?

Prompts: Specified numbers of days, location

28. Are you satisfied overall with the performance of the system?

Prompts: Specified numbers of days, location

History

29. How did you manage Notices prior to this system?

Prompts: Paper, post, fax, in house system?

30. What were the drivers for change? **Prompts:** Volume, efficiency, legislation

31. What were the push factors in getting this particular system?

Prompts: Cost, design, ease of use, features, value

32. What were your key aspirations from this system?

Prompts: Reduce duplication, efficiency

33. Have you received training on how to use the system? If so, in which areas? **Prompts:** Formal, informal, access to manuals, task specific training or aware of wider capabilities?

Future

34. Are there any proposals for the system to be changed in future?

35. Are there any new drivers for change?

APPENDIX F - WIDER STAKEHOLDER INTERVIEW QUESTIONS

Stakeholder interviews

Interviewee: Regulators

Design

1. What is the purpose of regulations?
2. How are the regulations driven? What are the motivations?
3. Who are the stakeholders? Upwards and downwards
4. What is the role of the regulator?
5. Who are the regulators governed by?

Performance

6. How is utility performance measured?
7. What are the rewards and penalties?
8. Overall how well are utilities performing?
9. What impact does utility performance have on regulations

Context

10. What are the constraints and difficulties of the regulation industry?
11. What kind of frustrations do you face from utility companies?
12. What pressures do regulators face by ministers?
13. Do you work with other regulators or international peers?

Future

14. What are the challenges to the regulators?
15. What future challenges do the utility industry face?

Interviewees: Local Authorities

Design

1. What is the purpose of coordination?
2. What is the role of the local authority?
3. How is coordination facilitated?
4. What internal policies exist? What are the motivations?
5. Who are the stakeholders?
6. Who are the local authorities governed by?

Performance

7. How is co-ordination measured?
8. What are the rewards and penalties?
9. Overall how well are utilities performing?

Context,

10. What are the constraints and difficulties of co-ordination?
11. What kind of frustrations do you face from utility companies?
12. What pressures do you face from stakeholders?
13. Do you work with other local authorities?
14. What issues are unique to your local authority area?

Future

15. Are there any long term proposals to improve street works management?
16. What there proposals to adopt lane rental?

Interviewees: Commerce/City Centre Managers

Design of overall process

1. What is your understanding about the process of managing street works?
2. Who are your stakeholders? And what are their roles and motivations?
3. What challenges does the management of multiple stakeholders present?
4. Do you work with others and how does this influence what you do?

Performance

5. How do you see the street works process performing generally? How well are utilities working with street works management processes?

Context

6. What are the main issues, constraints and difficulties facing your stakeholders when faced with street works?
7. What are the issues, constraints and difficulties of your organisation on the street works sector?
8. What do you consider is working well in street works management? Why is it working well?

Future

9. What current trends are likely to influence the future of street works, and what will their impacts be?
10. What are the future challenges and opportunities for the street works sector? How can innovation be used to improve the street works sector?
11. What recommendations would you make to help improve the street works sector?

APPENDIX G - BUSINESS PROCESS MAPS 'AS IS'

The 'as is' business process maps, are separated into teams in the following sub-appendices:

G1. Highways Maintenance

G2. Highways Engineering

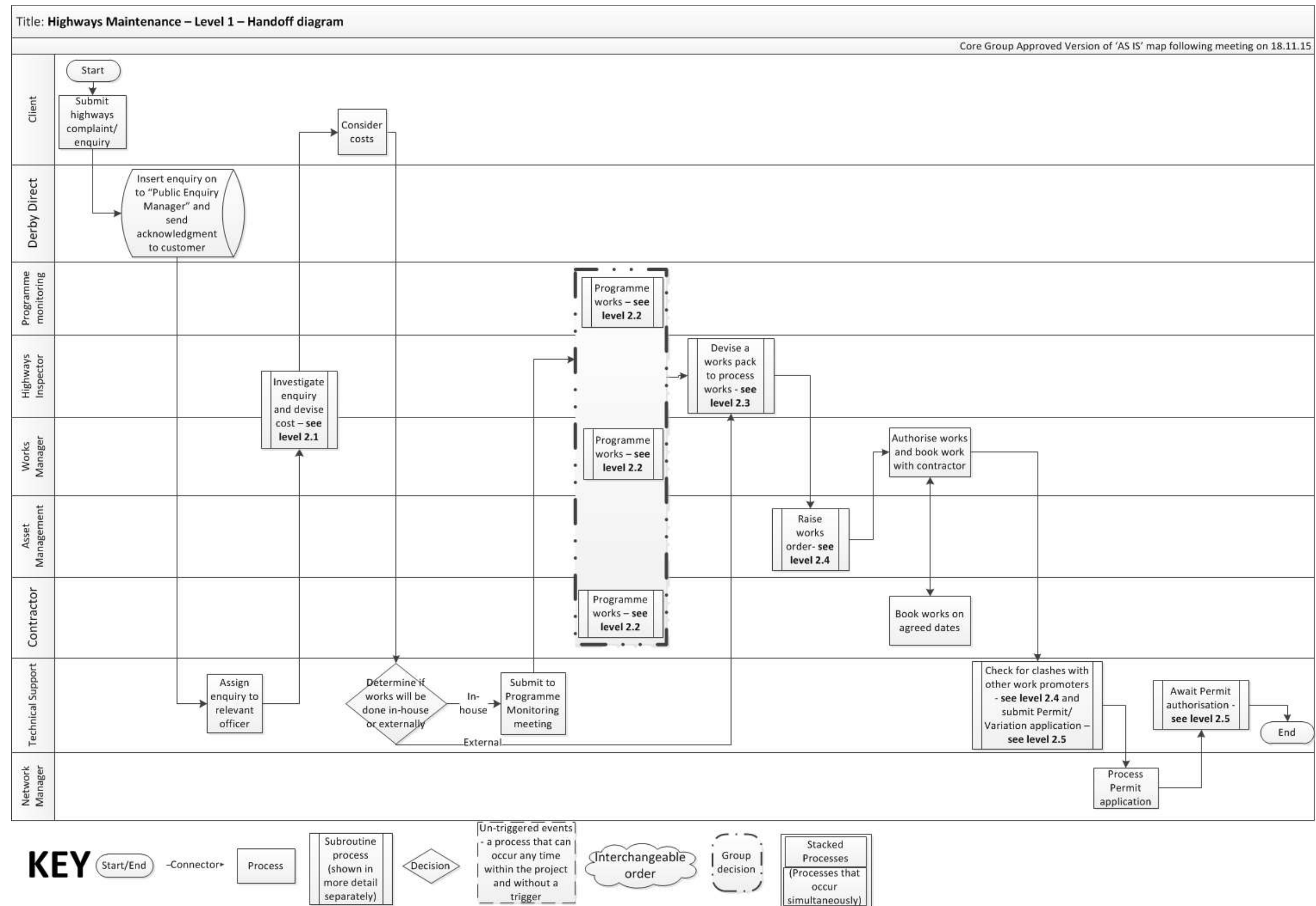
G3. Network Management

APPENDIX G1 - HIGHWAYS MAINTENANCE

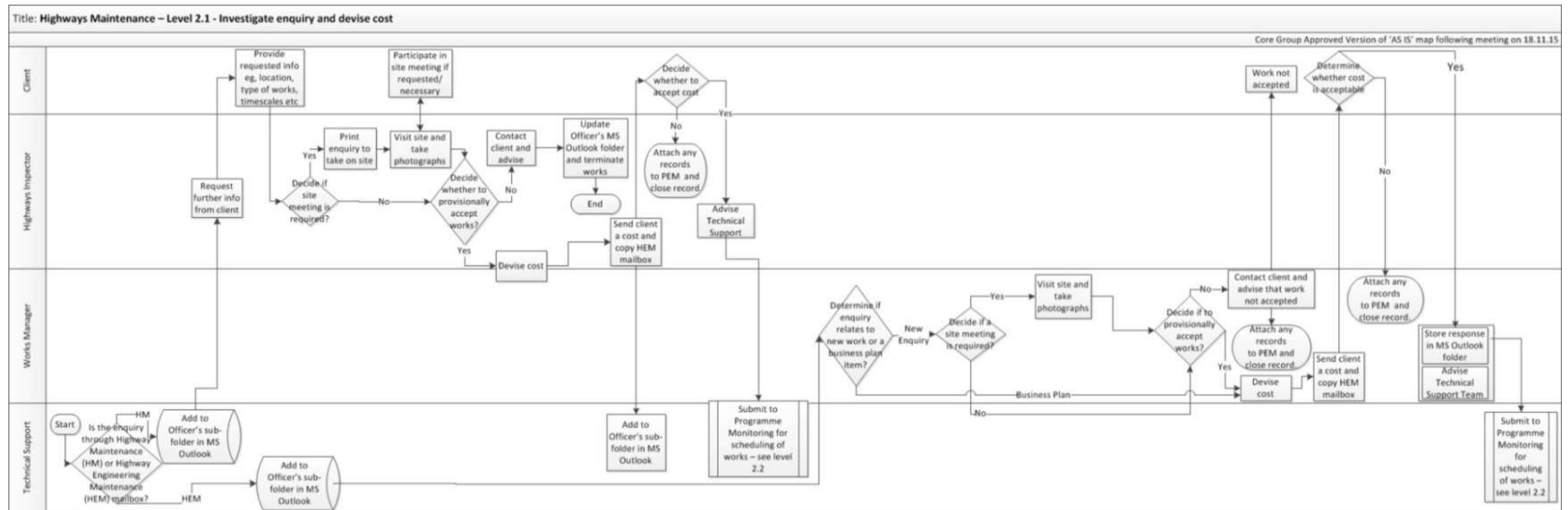
AS IS Swimlane Business Process Maps

1. Level 1 Hand-off diagram
2. Level 2.1 Investigate enquiry and devise cost
3. Level 2.2 Programme monitoring
4. Level 2.3 Devise a works pack to process works
5. Level 2.4 Check for clashes
6. Level 2.5 Submit Permit/Variation request
7. Level 2.6 Await Permit authorisation

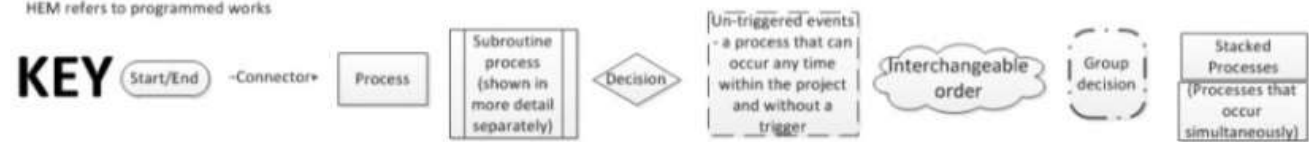
Highways Maintenance team – Level 1 ‘as is’ - Hand-off diagram



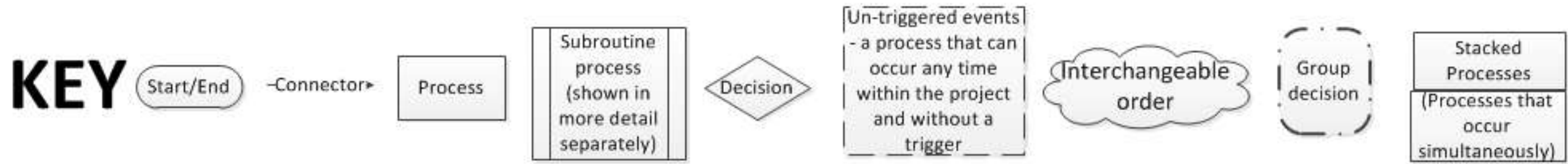
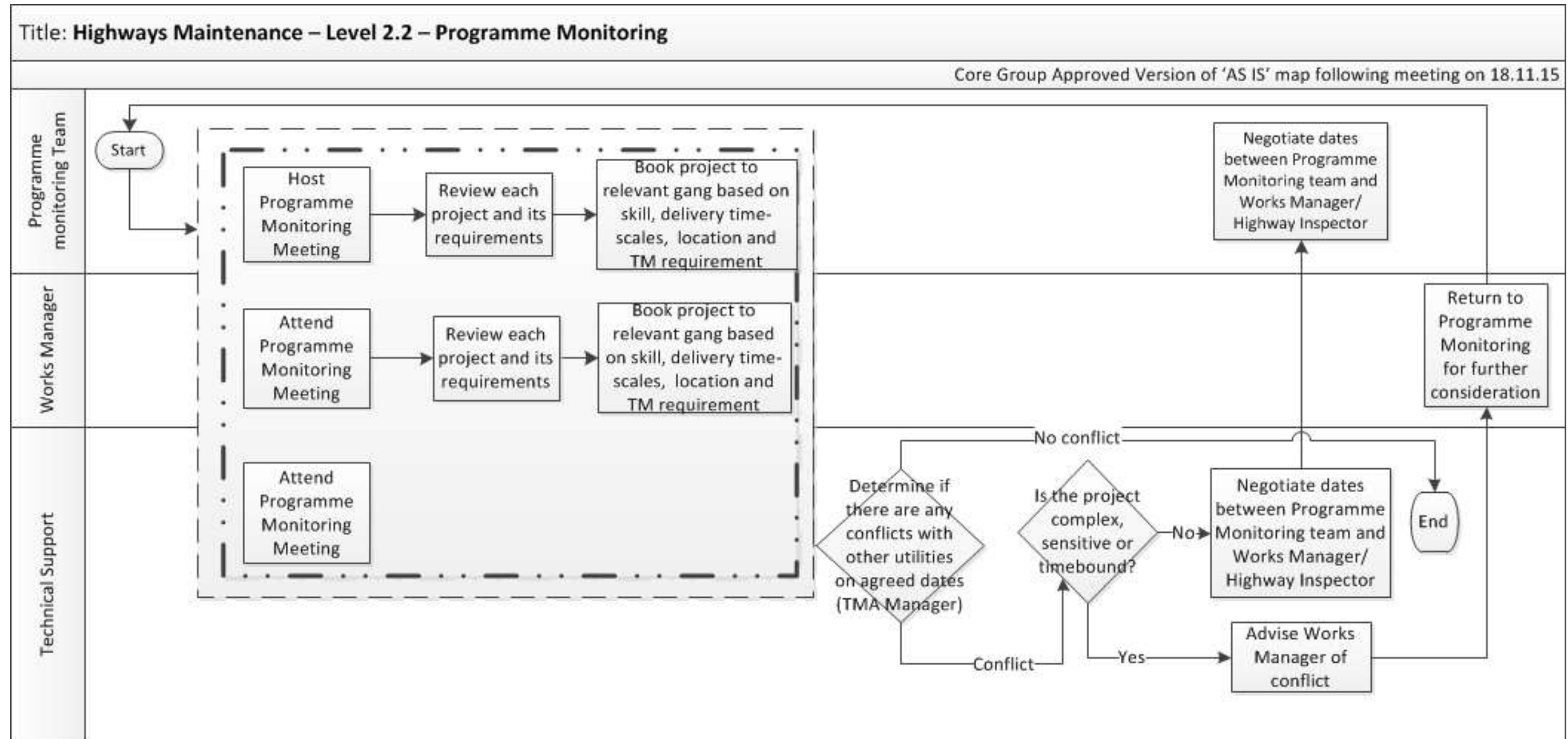
Highways Maintenance team – Level 2.1 ‘as is’ - Investigate enquiry and devise cost



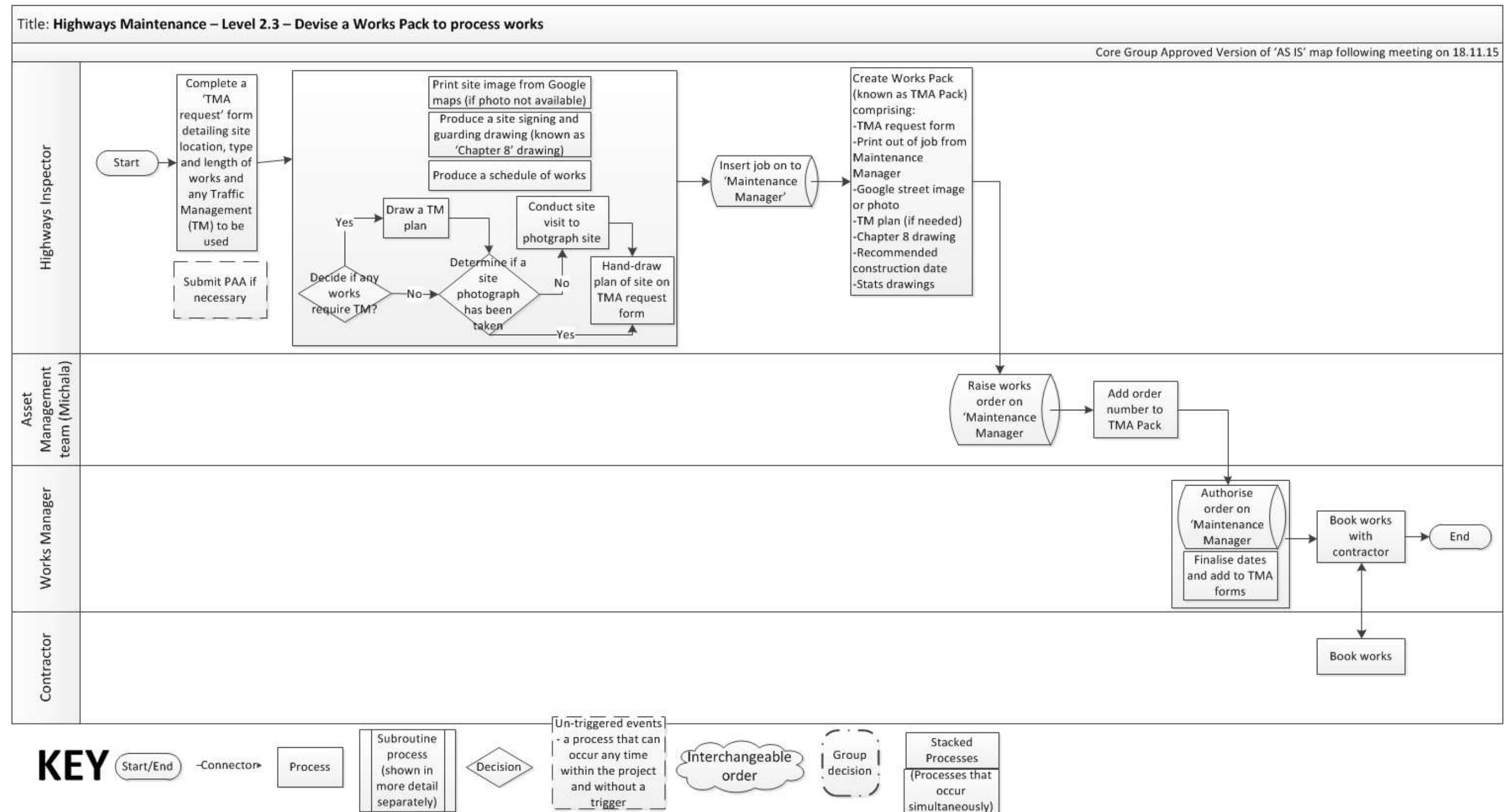
Comment
 HM refers to reactive works
 HEM refers to programmed works



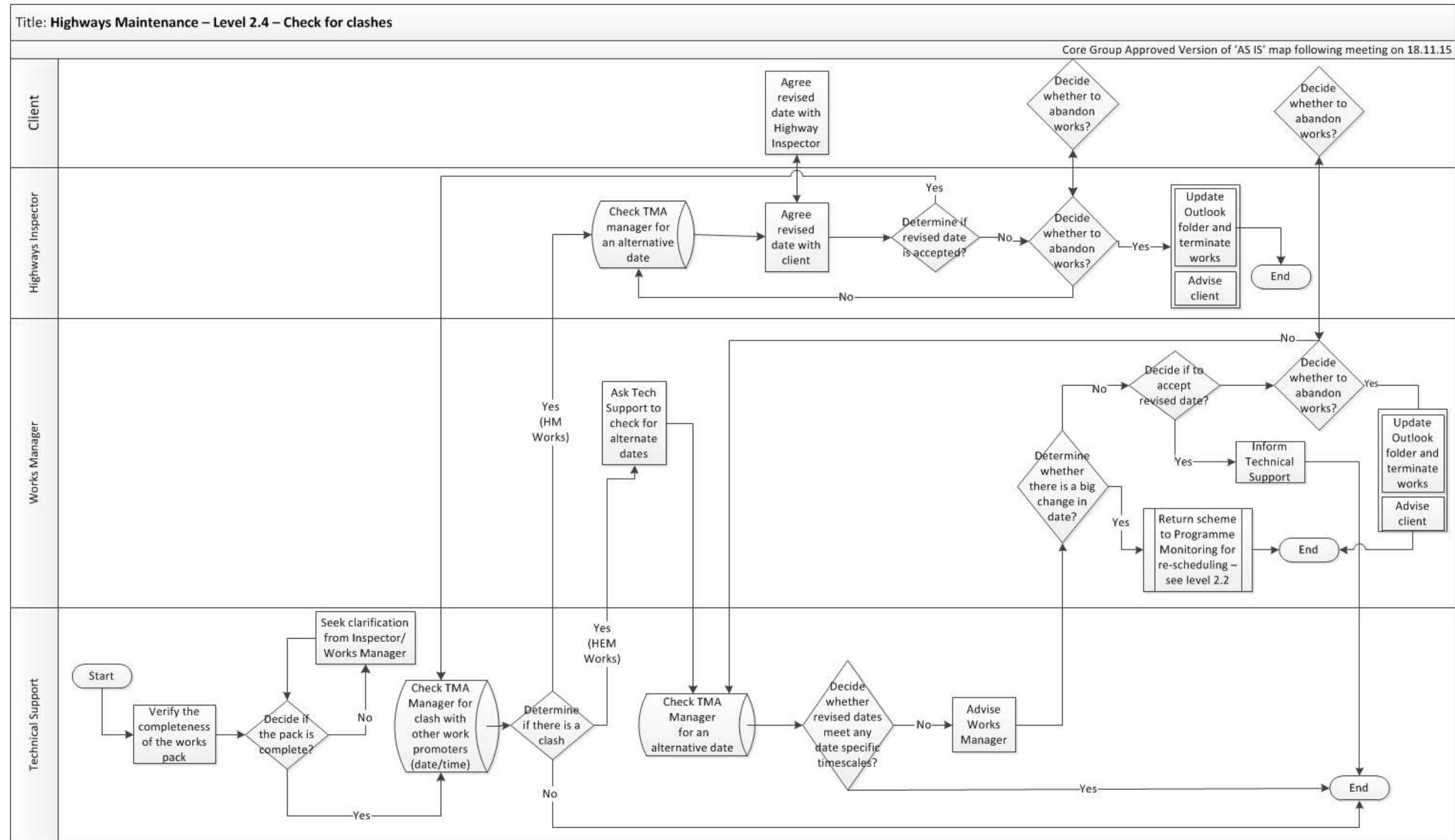
Highways Maintenance team – Level 2.2 ‘as is’ – Programme monitoring



Highways Maintenance team – Level 2.3 ‘as is’ Devise a works pack to process works



Highways Maintenance team – Level 2.4 ‘as is’ – Check for clashes

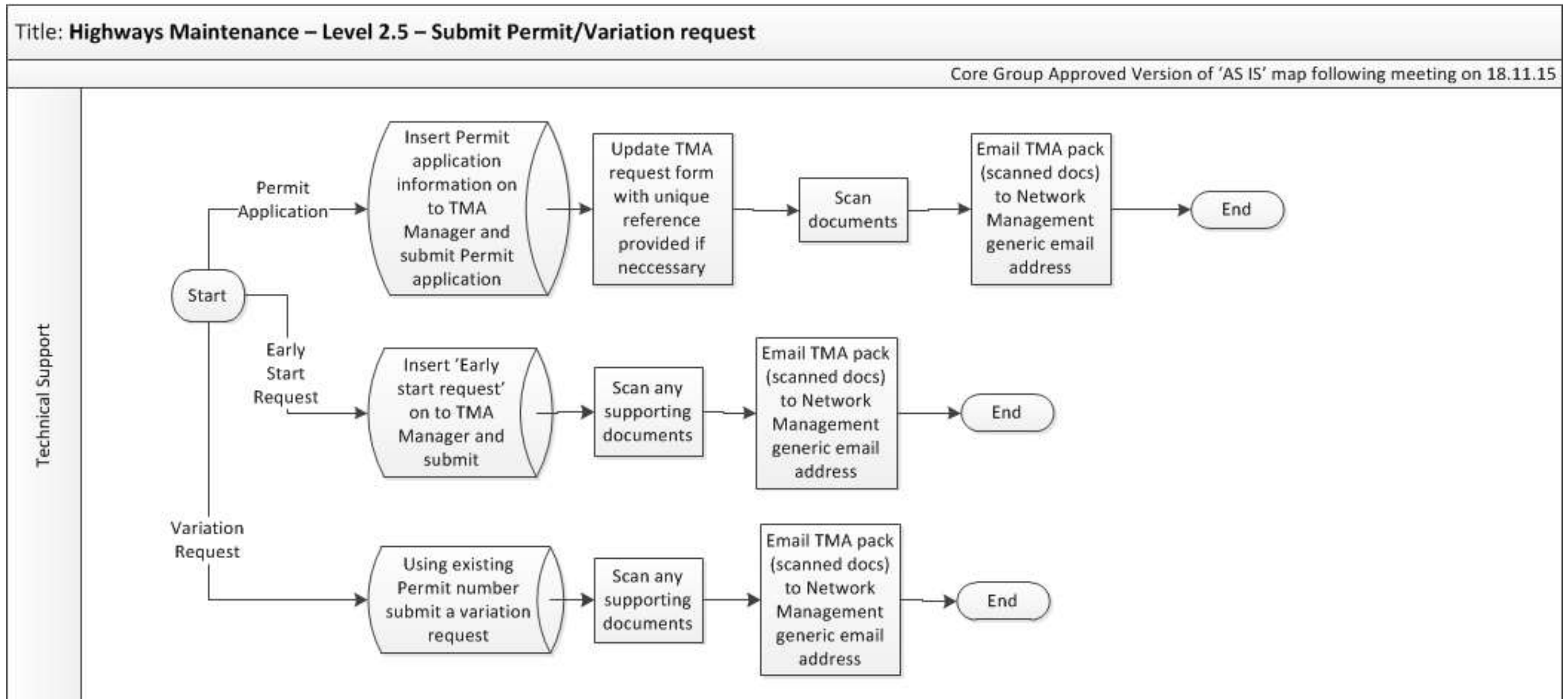


Comment

HM works refers to reactive works
HEM works refers to programmed works

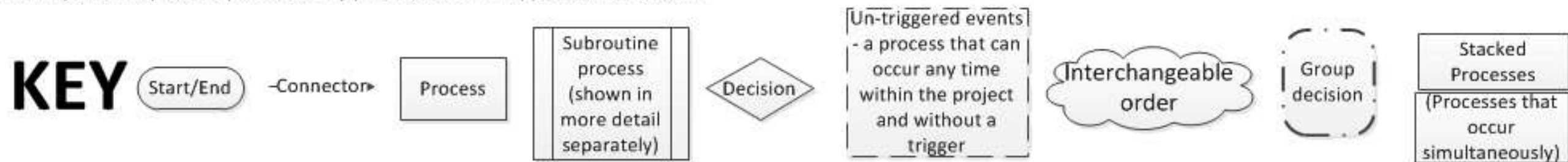


Highways Maintenance team – Level 2.5 ‘as is’ –Submit Permit/Variation request

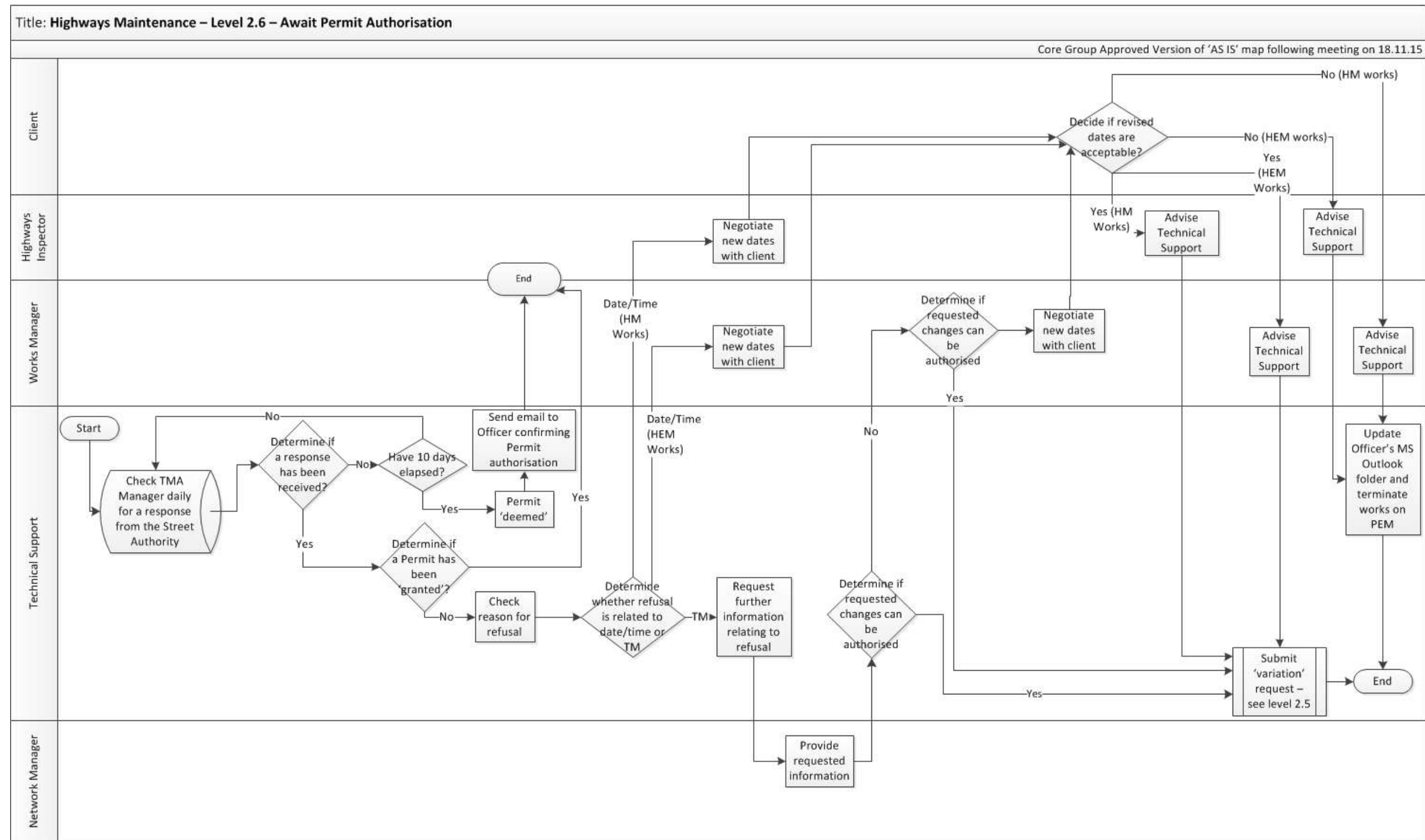


Comments

An Early Start Request may immediately proceed a Permit Application submission



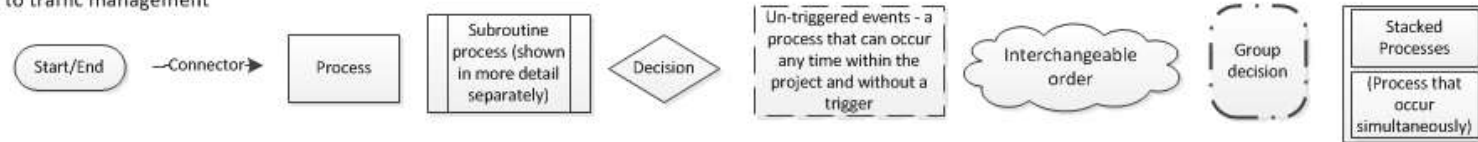
Highways Maintenance team – Level 2.6 ‘as is’ – Await Permit authorisation



Comment

HM works refers to reactive works
 HEM works refers to programmed works
 TM refers to traffic management

KEY

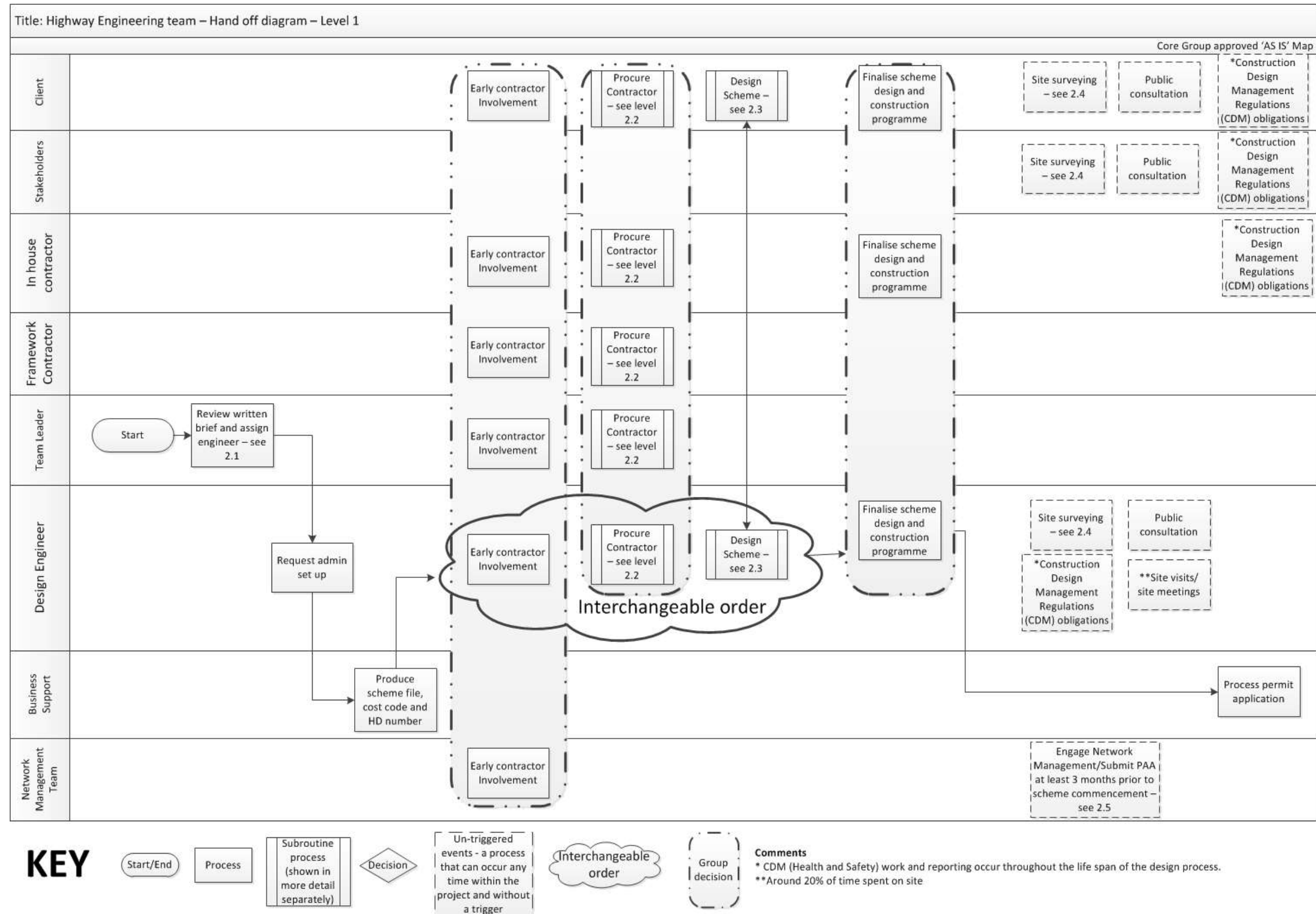


APPENDIX G2 - HIGHWAYS ENGINEERING

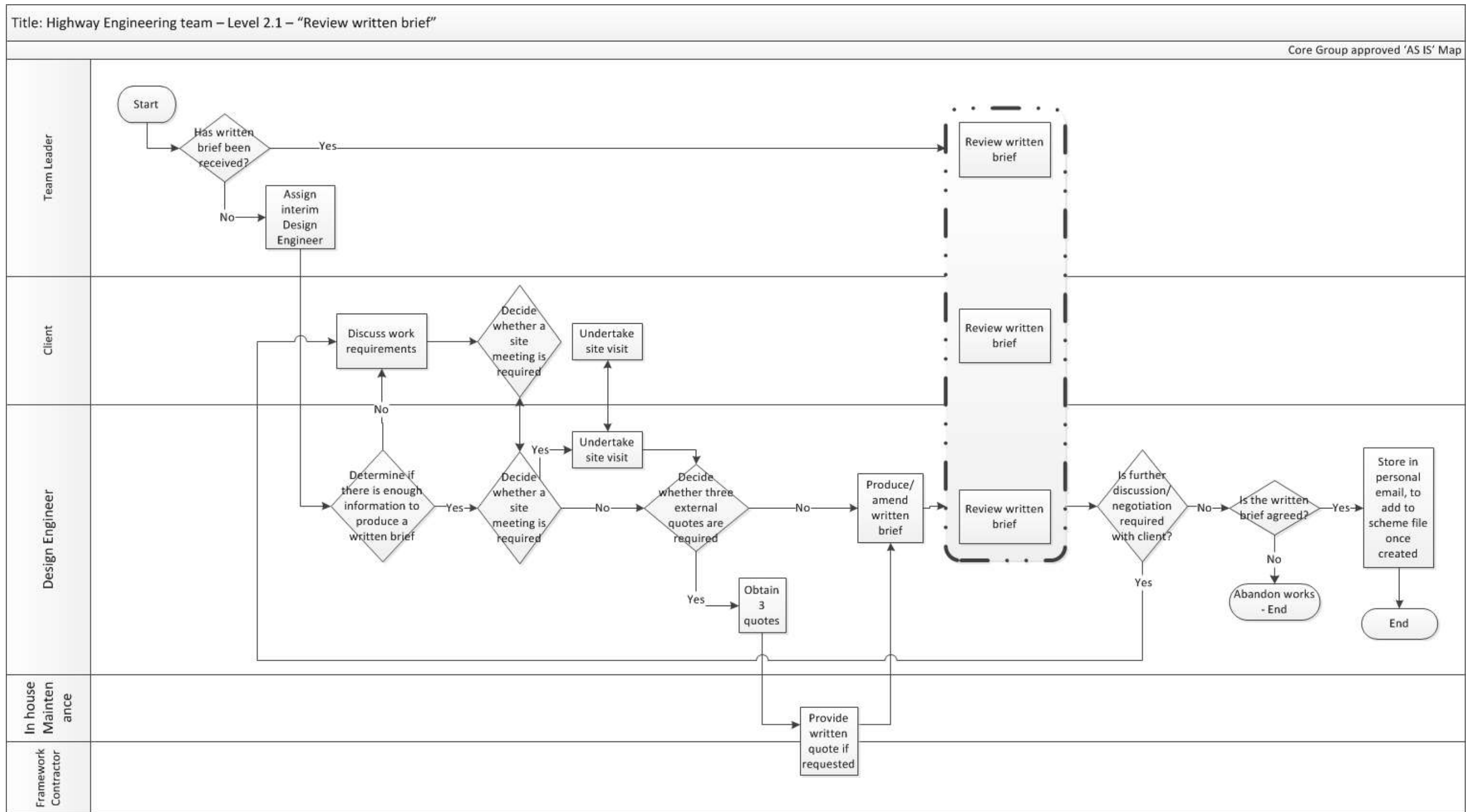
AS IS Swimlane Business Process Maps

1. Level 1 Hand-off diagram
2. Level 2.1 Review written brief
3. Level 2.2 Contractor procurement
4. Level 2.3 Design scheme
5. Level 2.3.1 Undertake detailed design (1)
6. Level 2.3.1 Undertake detailed design (2)
7. Level 2.3.1 Undertake detailed design (3)
8. Level 2.3.1 Undertake detailed design (4)
9. Level 2.4 Site surveying
10. Level 2.5 Engage Network Management Team

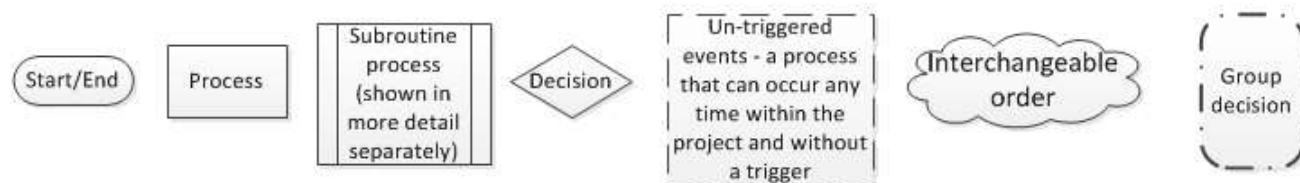
Highways Engineering team – Level 1 ‘as is’ - Hand-off diagram



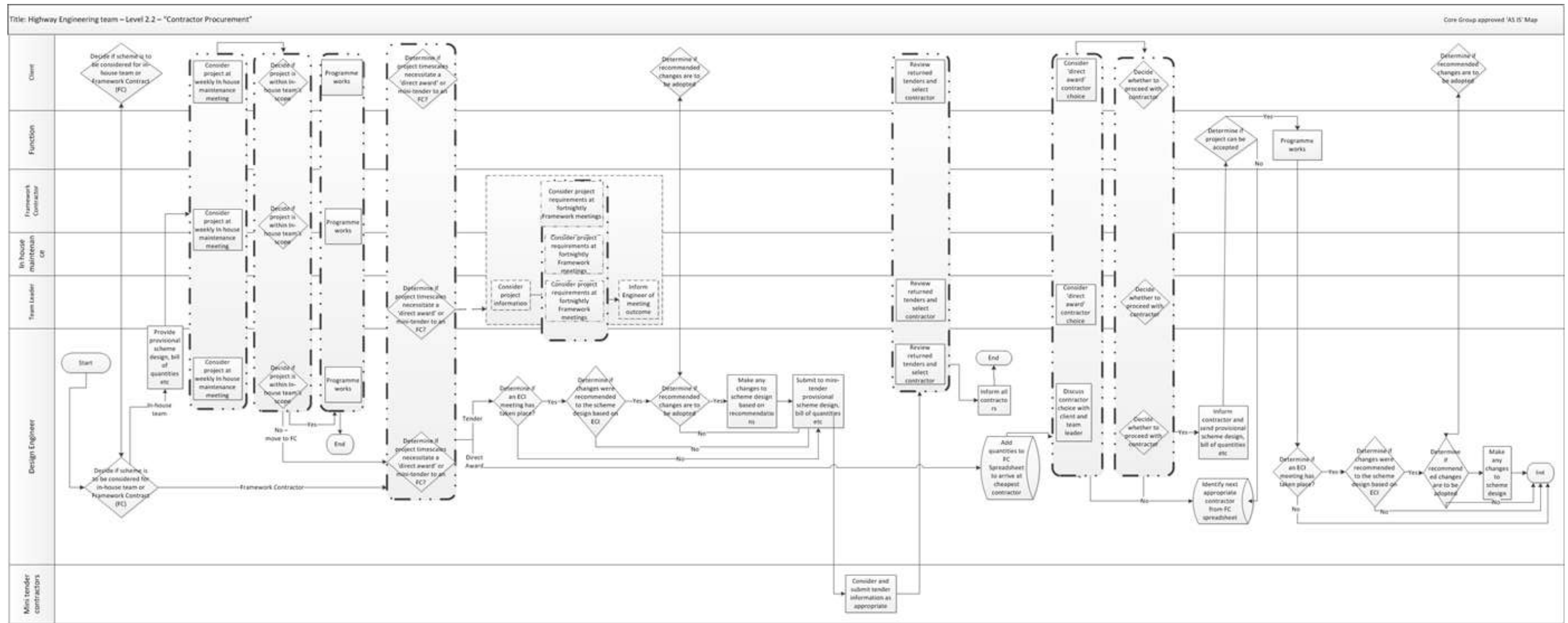
Highways Engineering team – Level 2.1 ‘as is’ - Review written brief



KEY

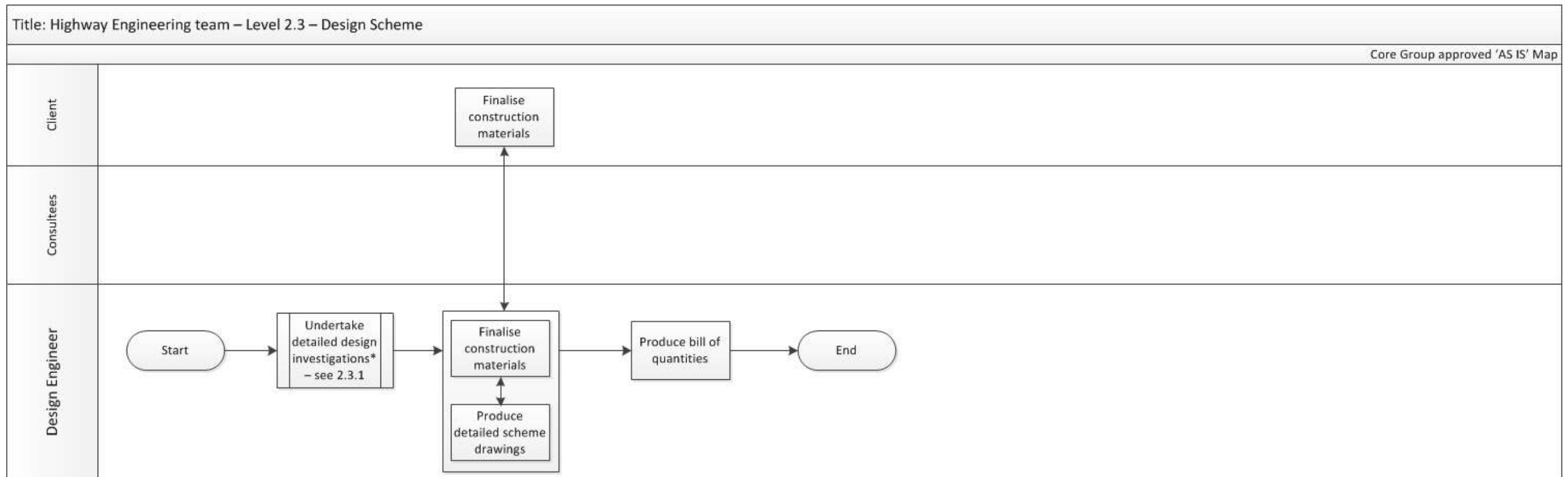


Highways Engineering team - Level 2.2 'as is' Contractor procurement

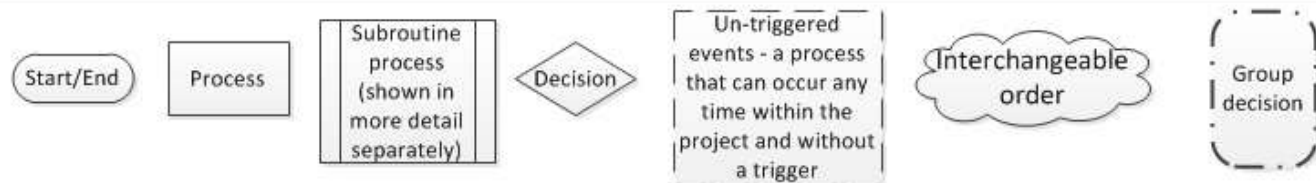


Comments
 ECI refers to 'early contractor engagement'
 Further procurement options include the Midlands Highways Alliance and open tender to the European Market – both are rarely used in practice.

Highways Engineering team – Level 2.3 ‘as is’ – Design scheme



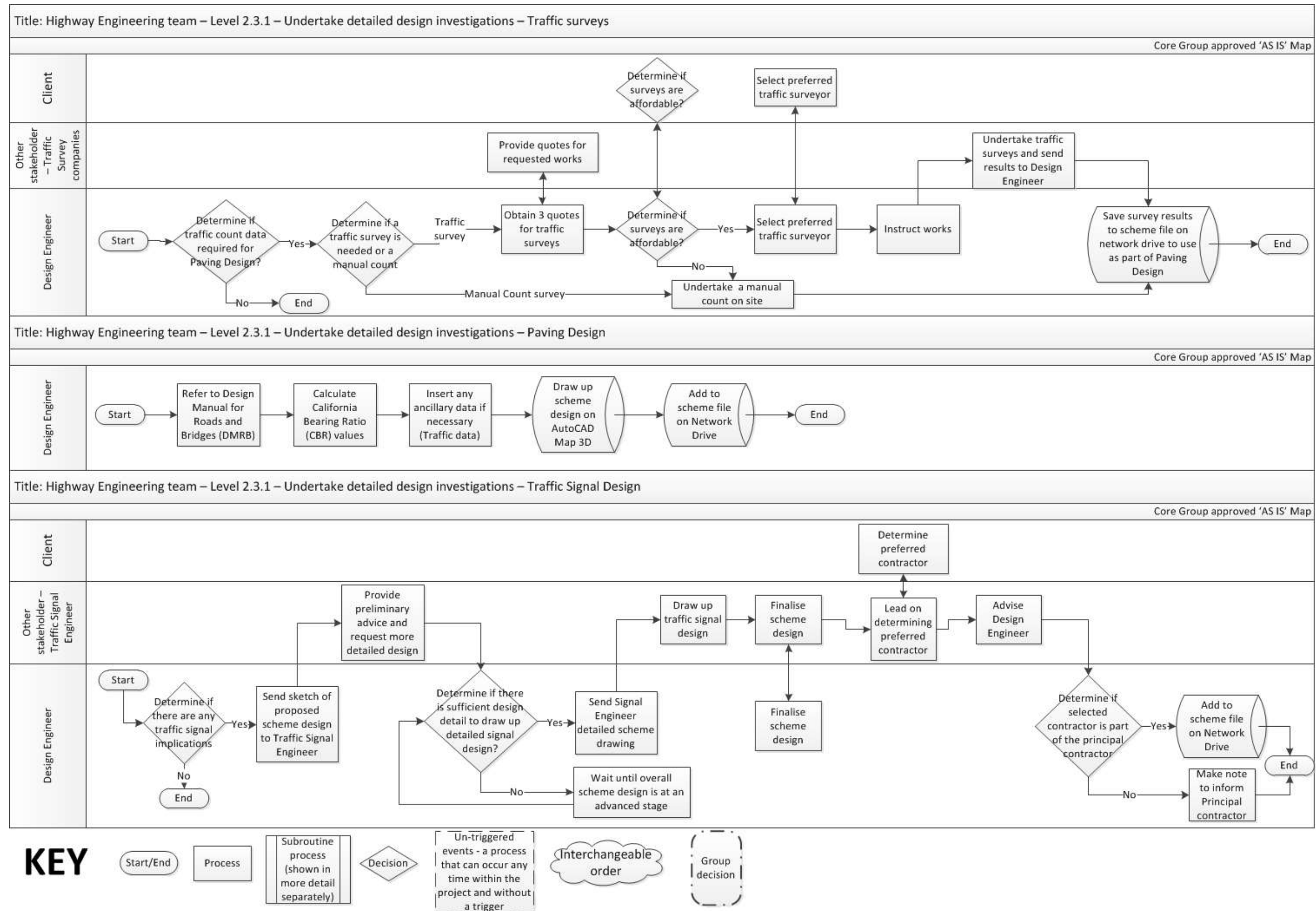
KEY



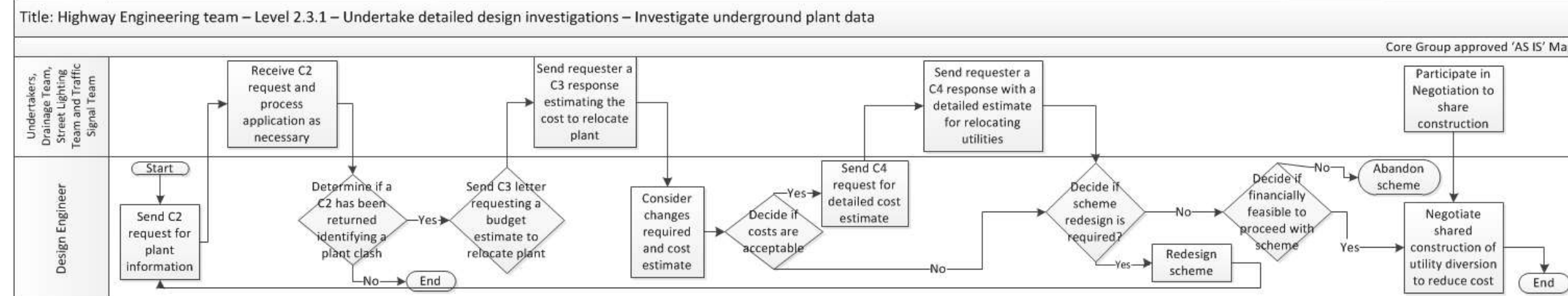
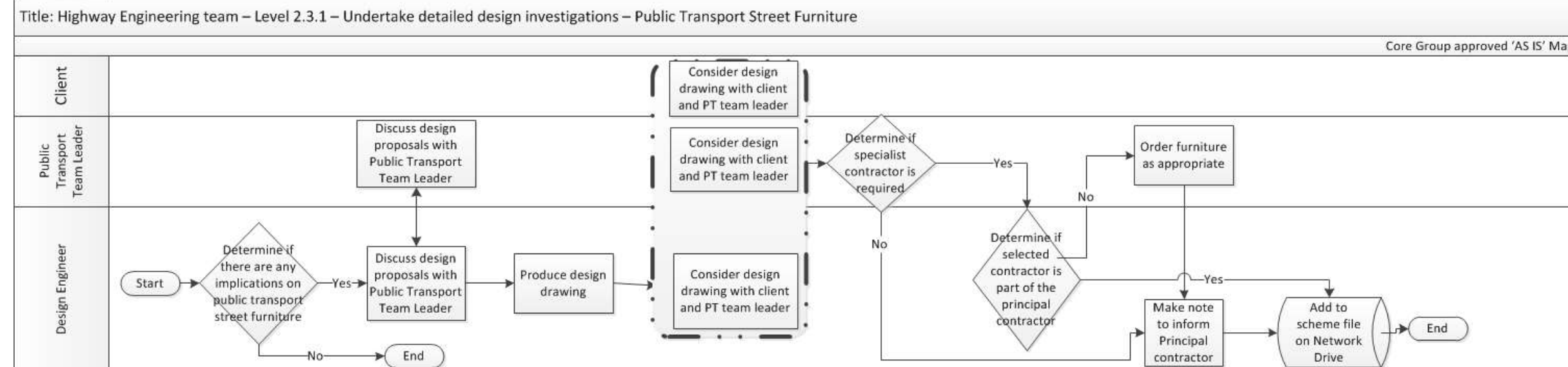
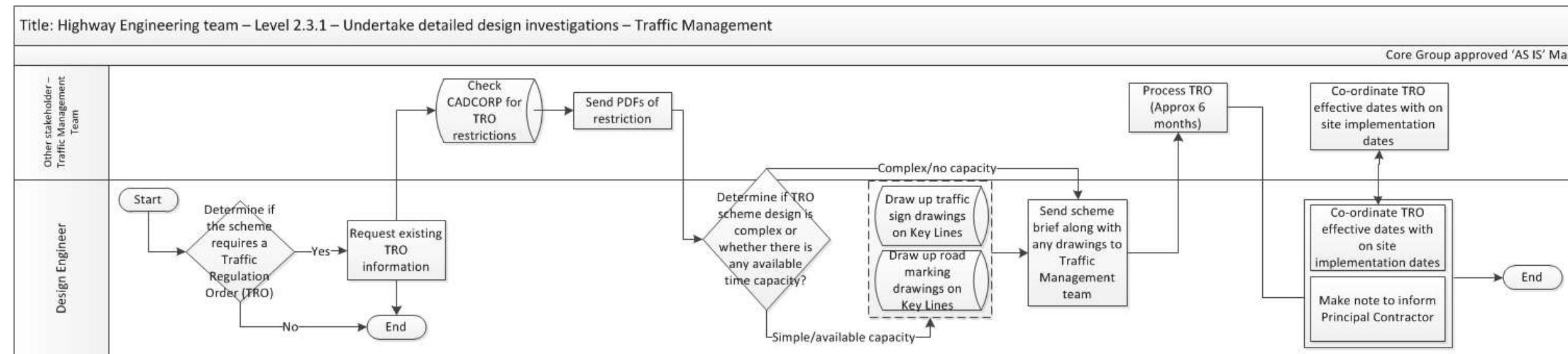
Comments

- *Stacked steps are independent and can occur simultaneously
- *Detailed design comprises: Drainage design, Level Design, Street Lighting Design, Paving Design, Traffic Signal Design, Public Transport Street Furniture Design, Traffic Management Design

Highways Engineering team – Level 2.3.1 ‘as is’ – Undertake detailed design (1)



Highways Engineering team – Level 2.3.1 ‘as is’ – Undertake detailed design (2)



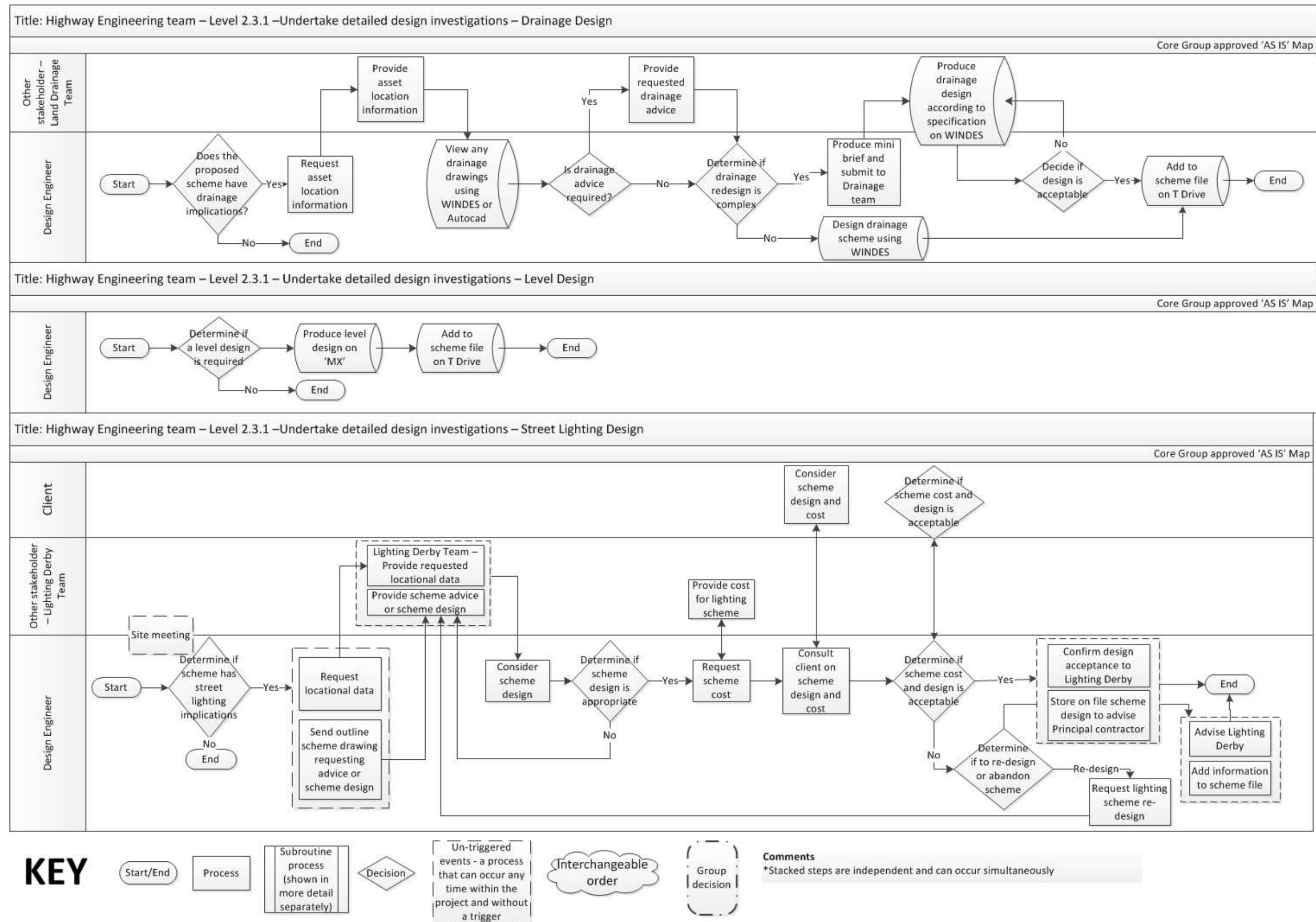
KEY

- Start/End
- Process
- Subroutine process (shown in more detail separately)
- Decision
- Un-triggered events - a process that can occur any time within the project and without a trigger
- Interchangeable order
- Group decision

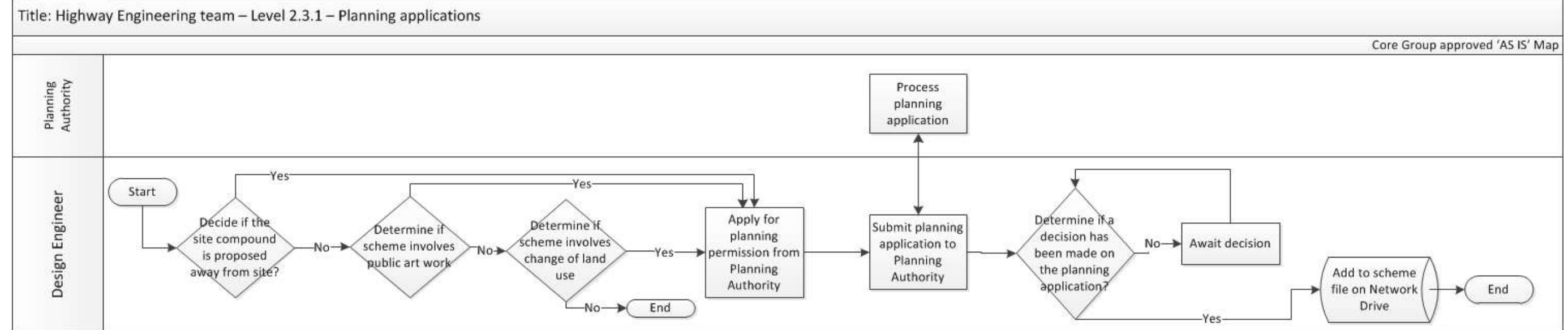
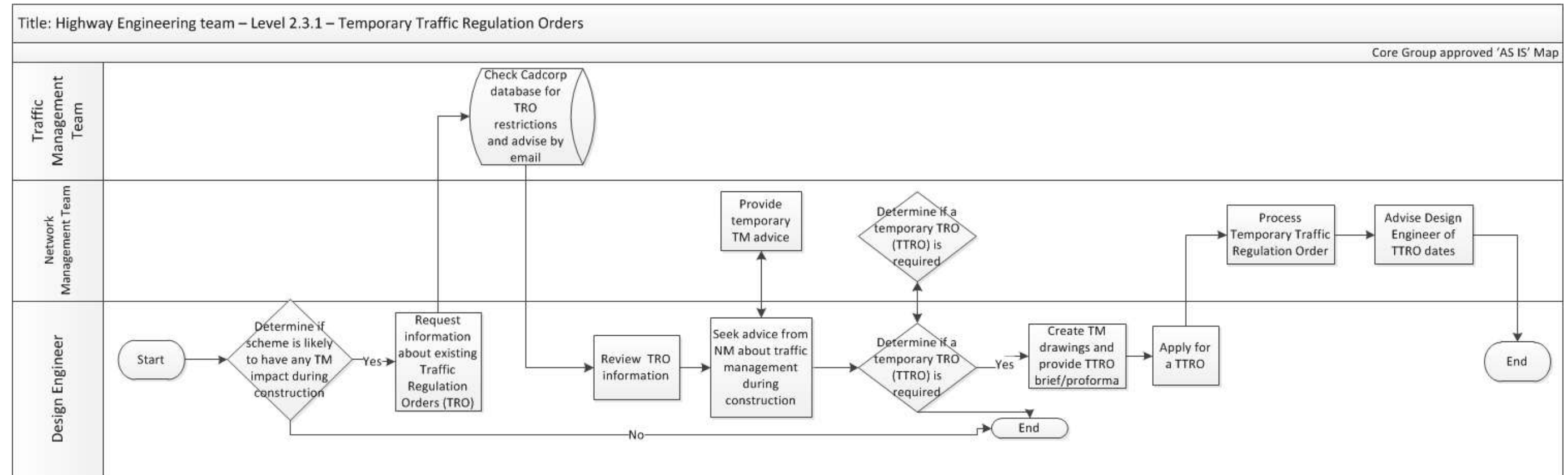
Comments

- C2 are statutory utility location enquiry requests
- C3 are statutory preliminary cost estimates for relocation of utilities
- C4 are statutory detailed cost estimates for relocation of utilities

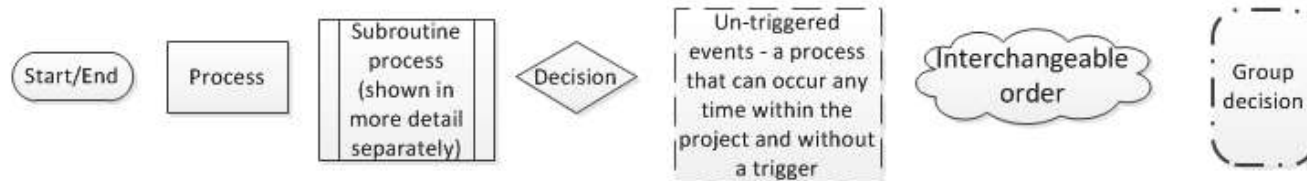
Highways Engineering team – Level 2.3.1 ‘as is’ – Undertake detailed design (3)



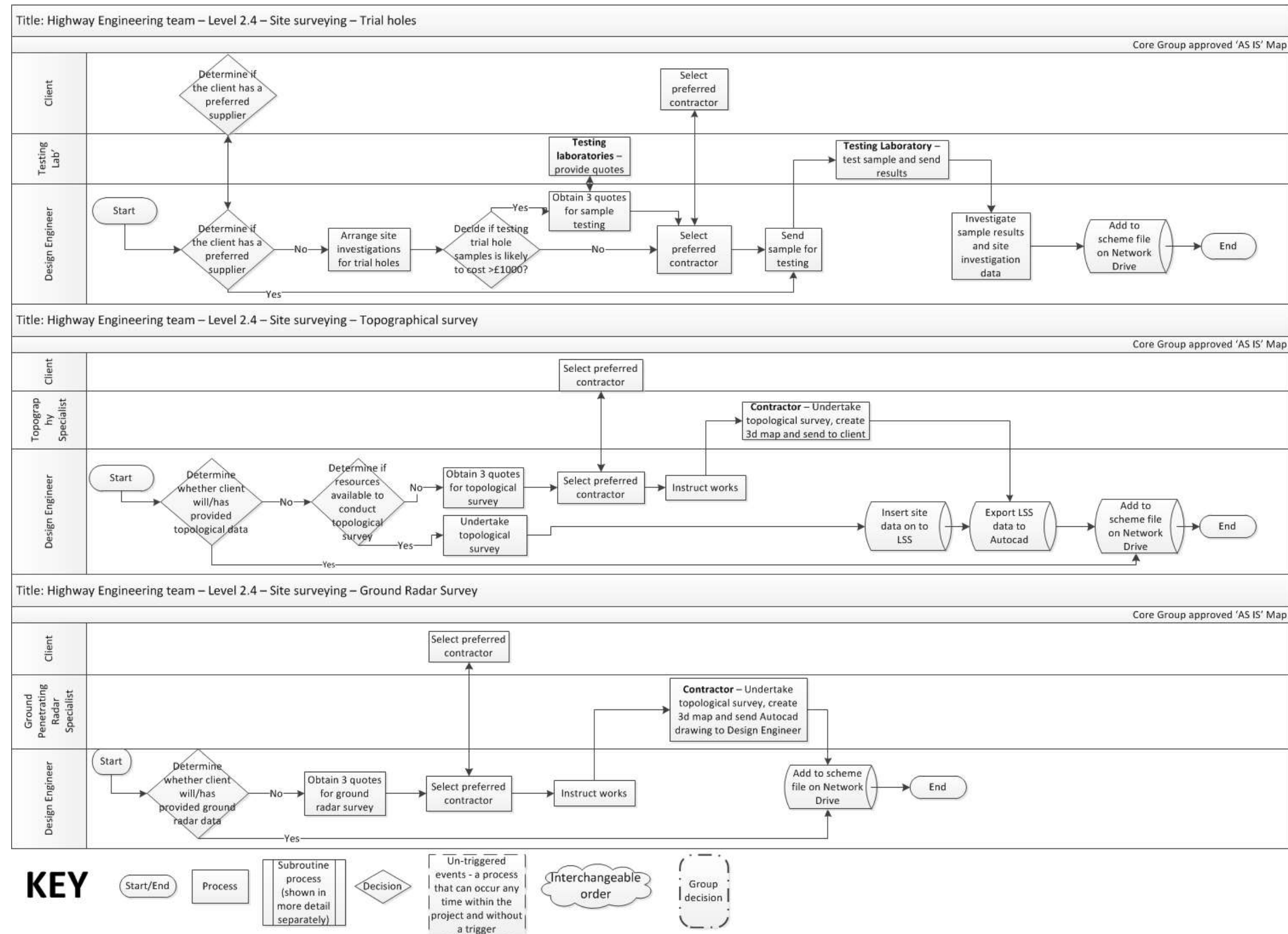
Highways Engineering team – Level 2.3.1 ‘as is’ – Undertake detailed design



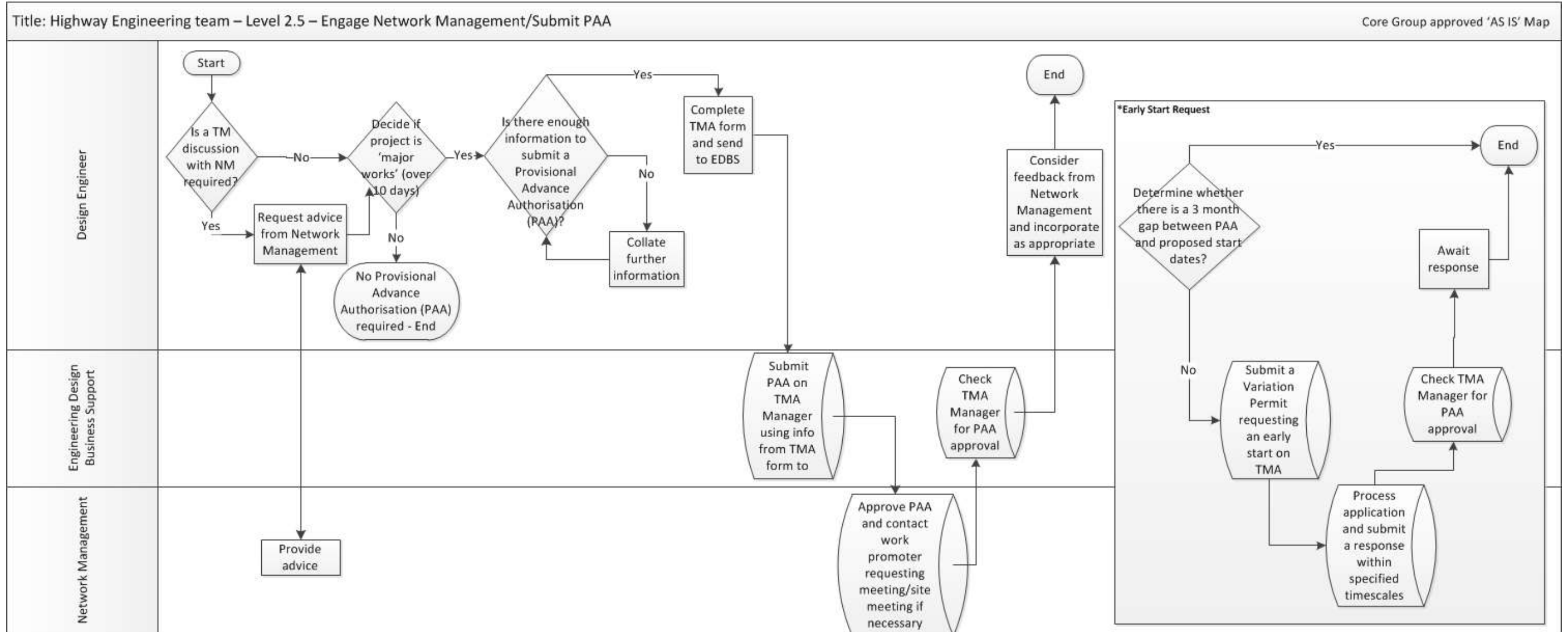
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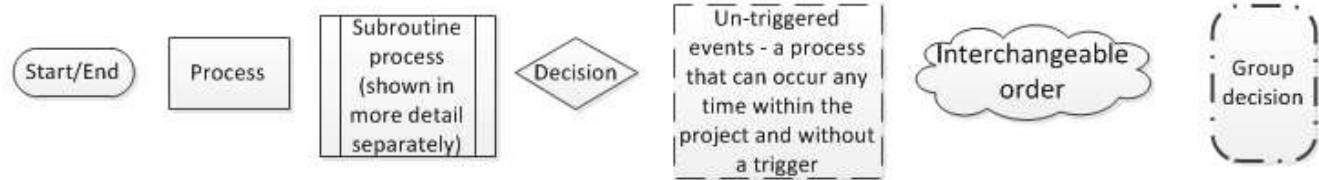
Highways Engineering team – Level 2.4 ‘as is’ – Site surveying



Highways Engineering team – Level 2.5 – Engage Network Management team



KEY



Comments

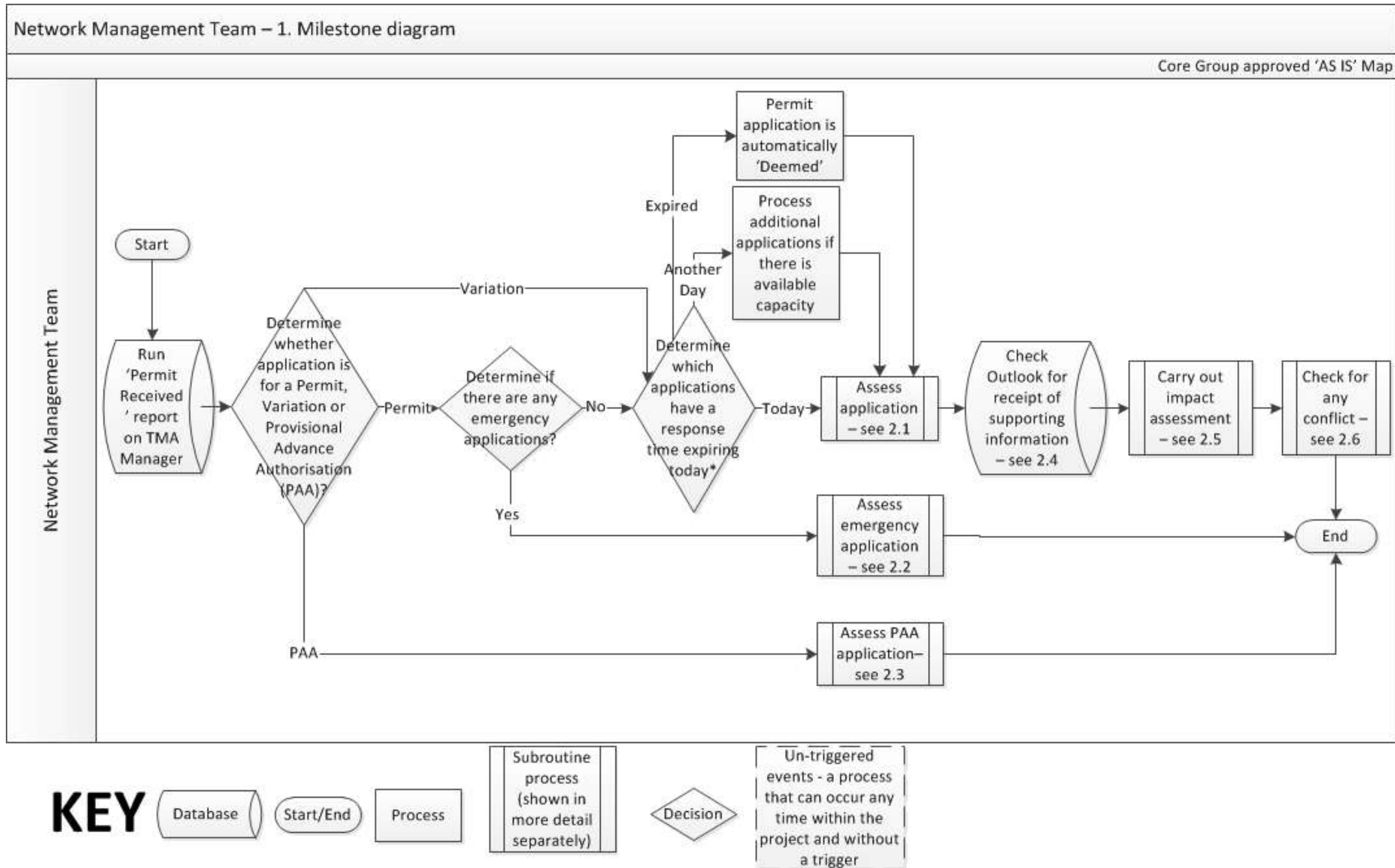
* Early start request – a request for an early start may be made at the same time as submission of a PAA or at a later date (less than 3 months before the proposed road work start date)

APPENDIX G3 - NETWORK MANAGEMENT

AS IS Swimlane Business Process Maps

1. Level 1 Hand-off diagram
2. Level 2.2 Assess application
3. Level 2.3 Assess Provisional Advance Authorisation application
4. Level 2.4 Check email for supporting information
5. Level 2.5 Impact assessment
6. Level 2.6 Check for any conflicts

Network Management team – Level 1 ‘as is’ - Hand-off diagram

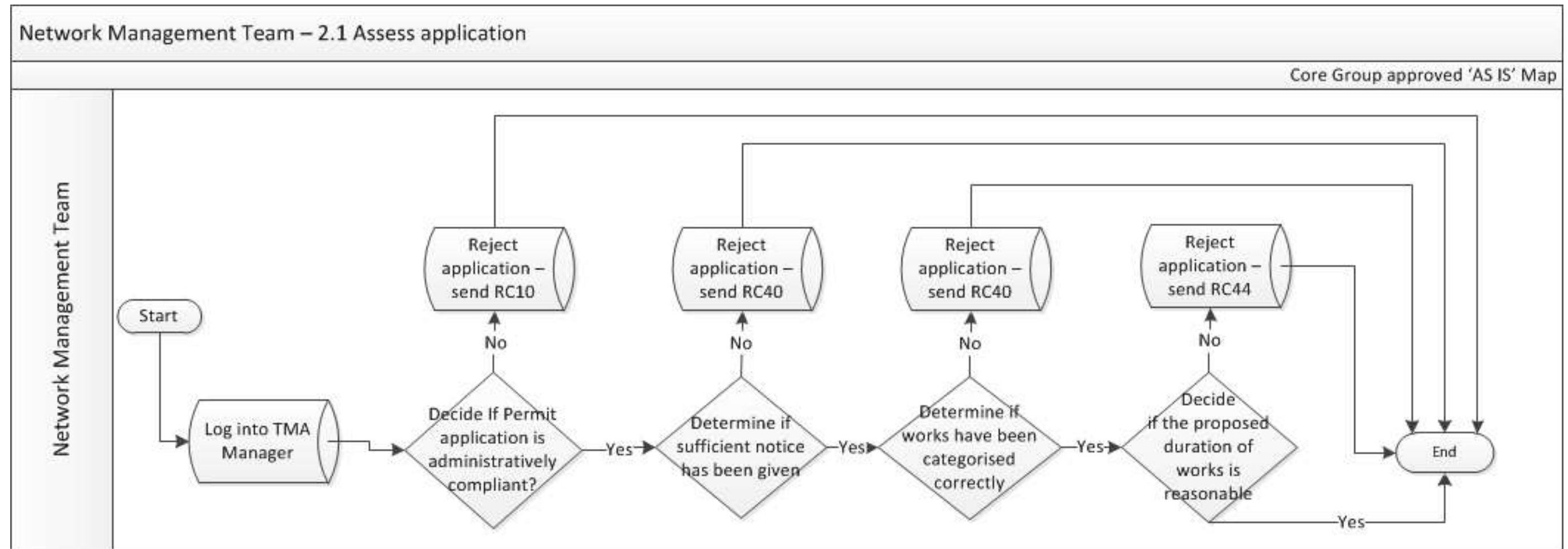


Comments

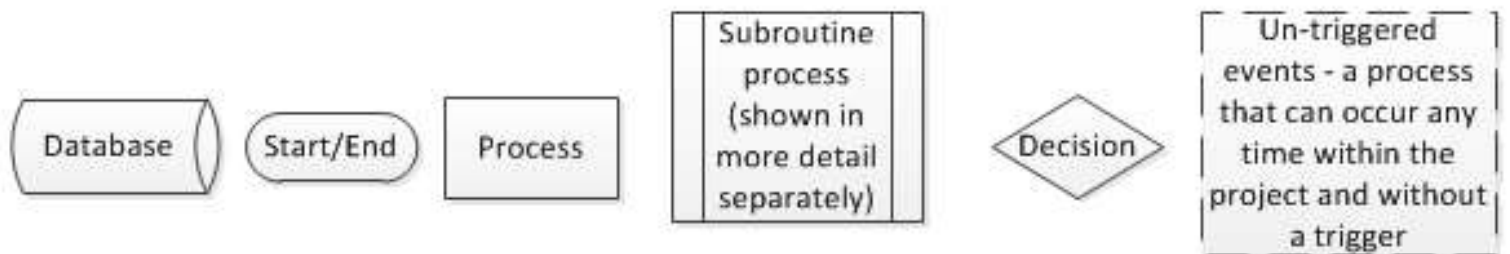
Unless stated otherwise, all steps are undertaken on TMA Manager module

*All applications have a response window of before they are automatically ‘deemed’.

Network Management team – Level 2.1 ‘as is’ – Assess application



KEY

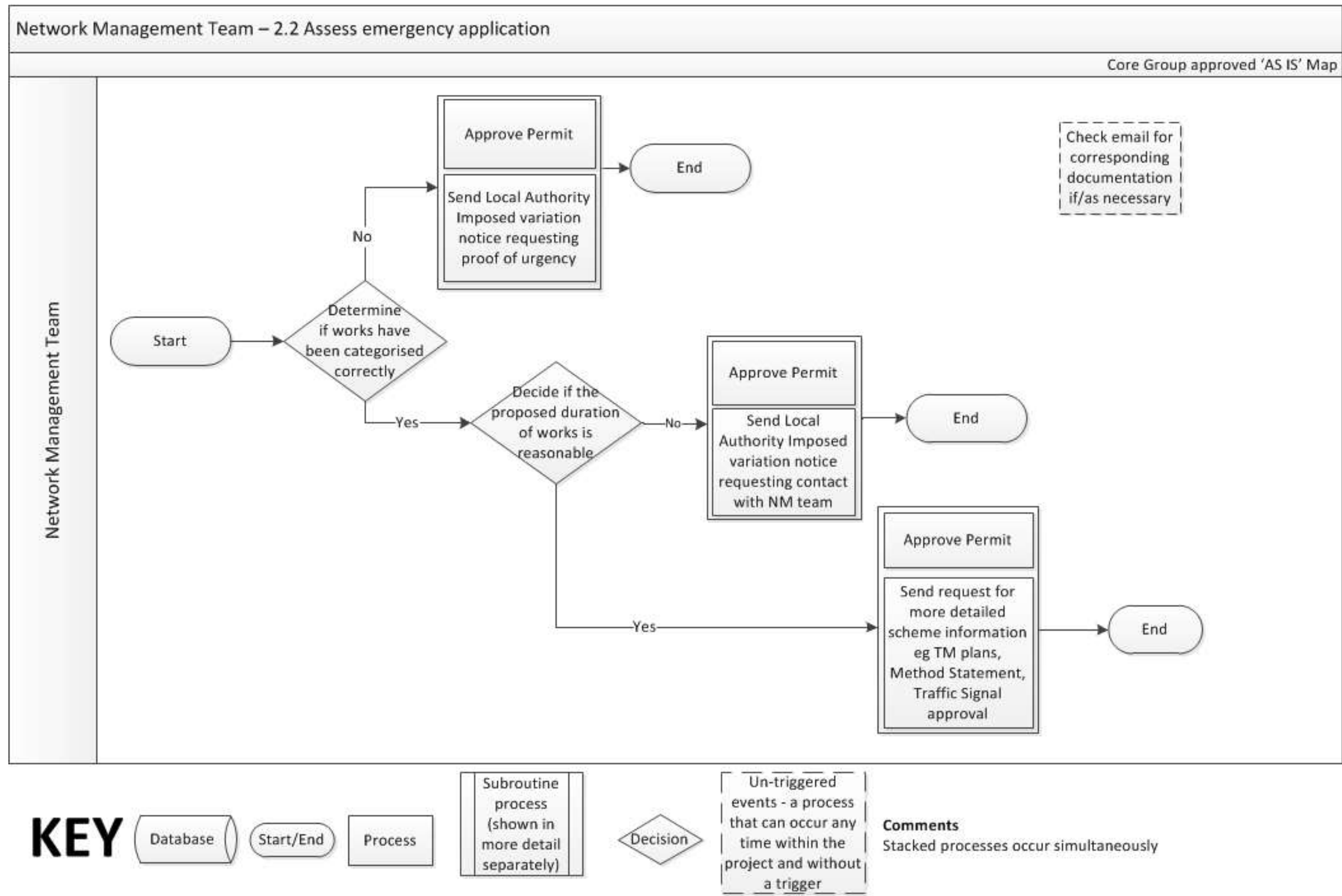


Comments

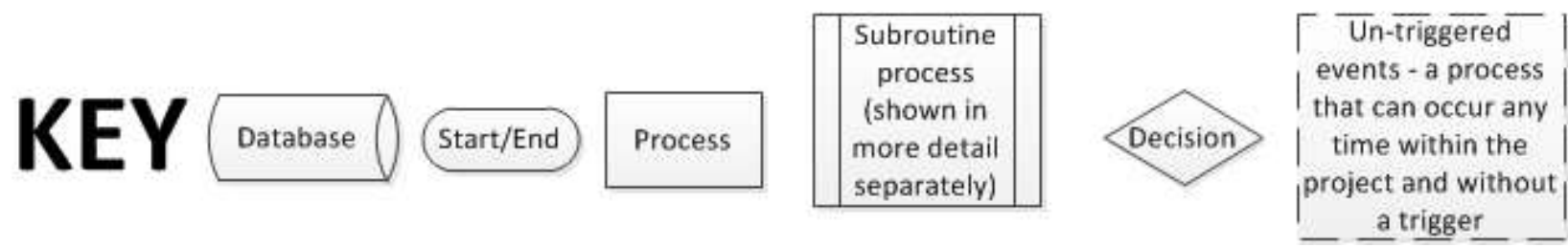
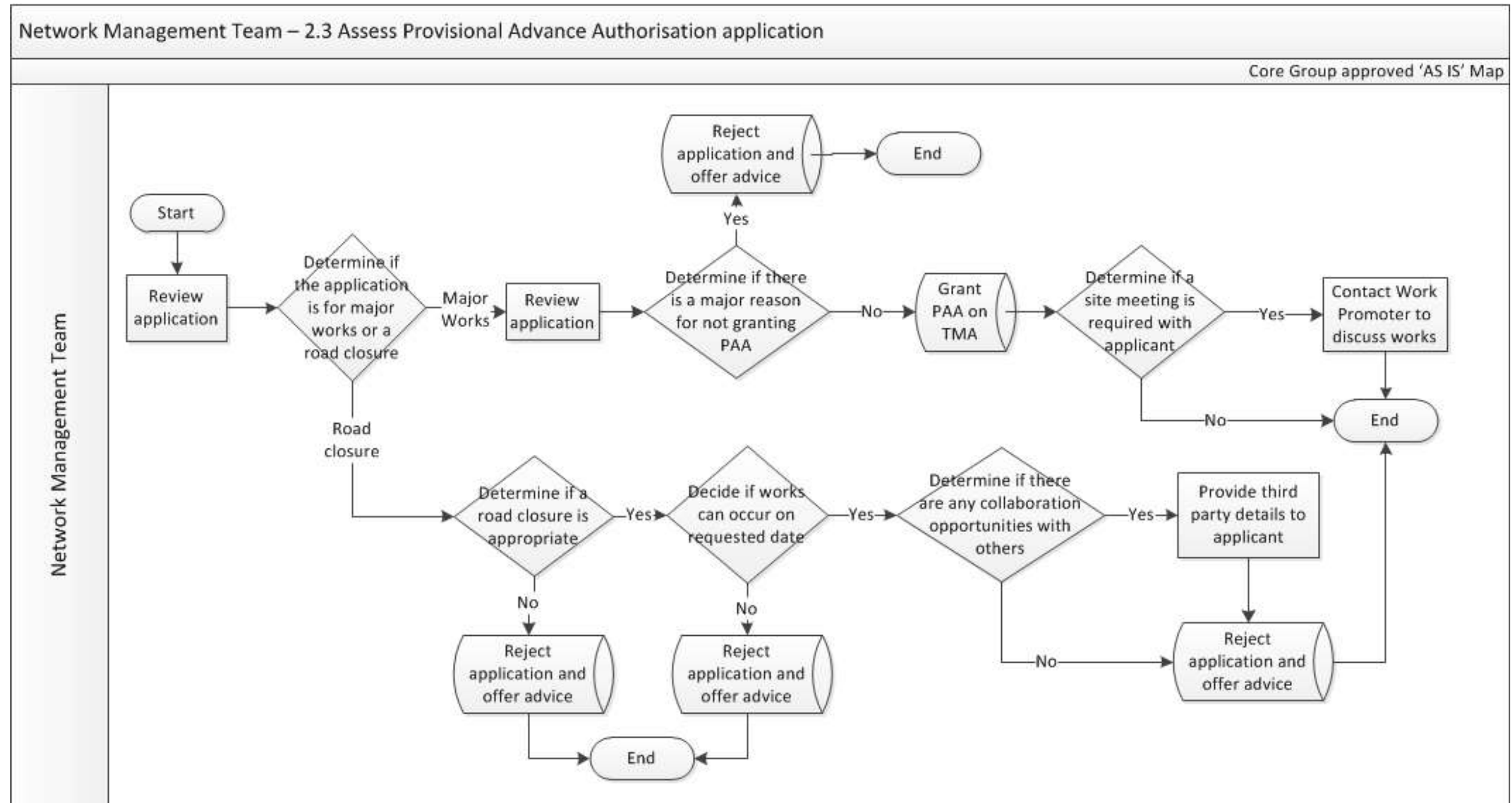
In the case of ‘Deemed’ permit applications, the application is assessed retrospectively. Deemed permit applications cannot be rejected, instead a ‘Local Authority Imposed Variation’ can be issued directing....

A rejected application will include guidance by Network Management on how to improve the application

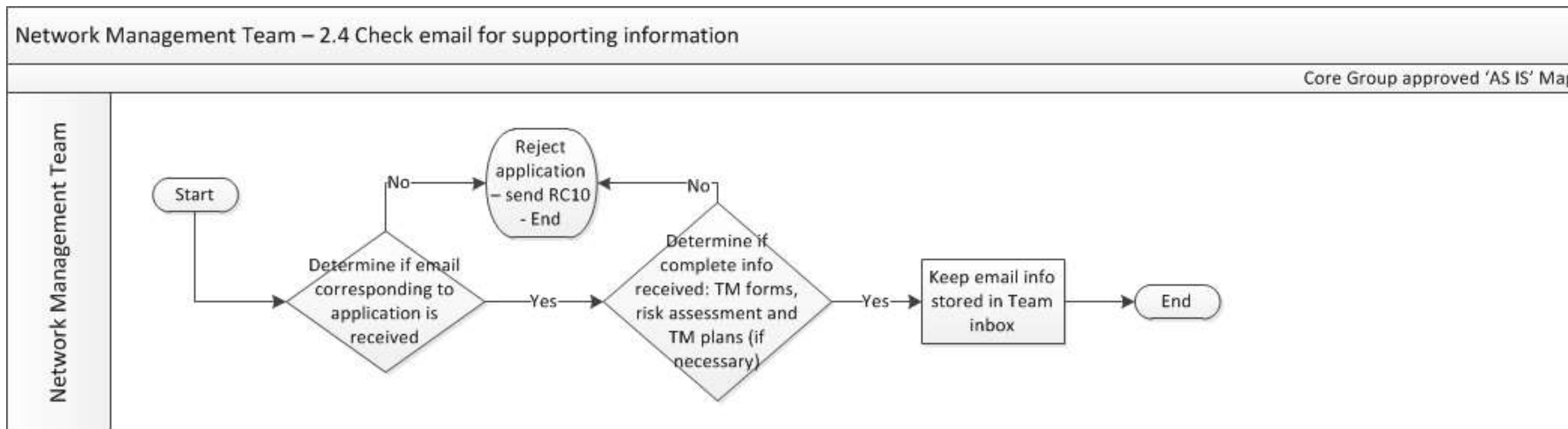
Network Management team – Level 2.2 ‘as is’ – Assess emergency application



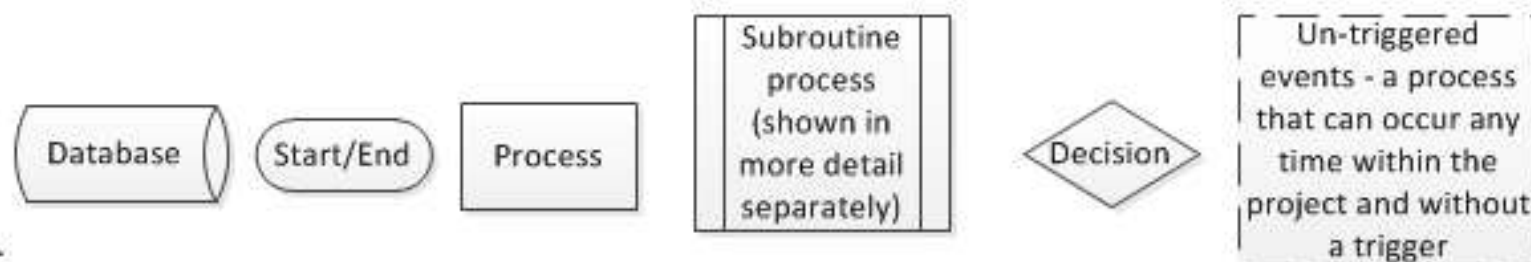
Network Management team – Level 2.3 ‘as is’ – Assess Provisional Advance Authorisation application



Network Management team – Level 2.4 - ‘as is’ Check email for supporting information



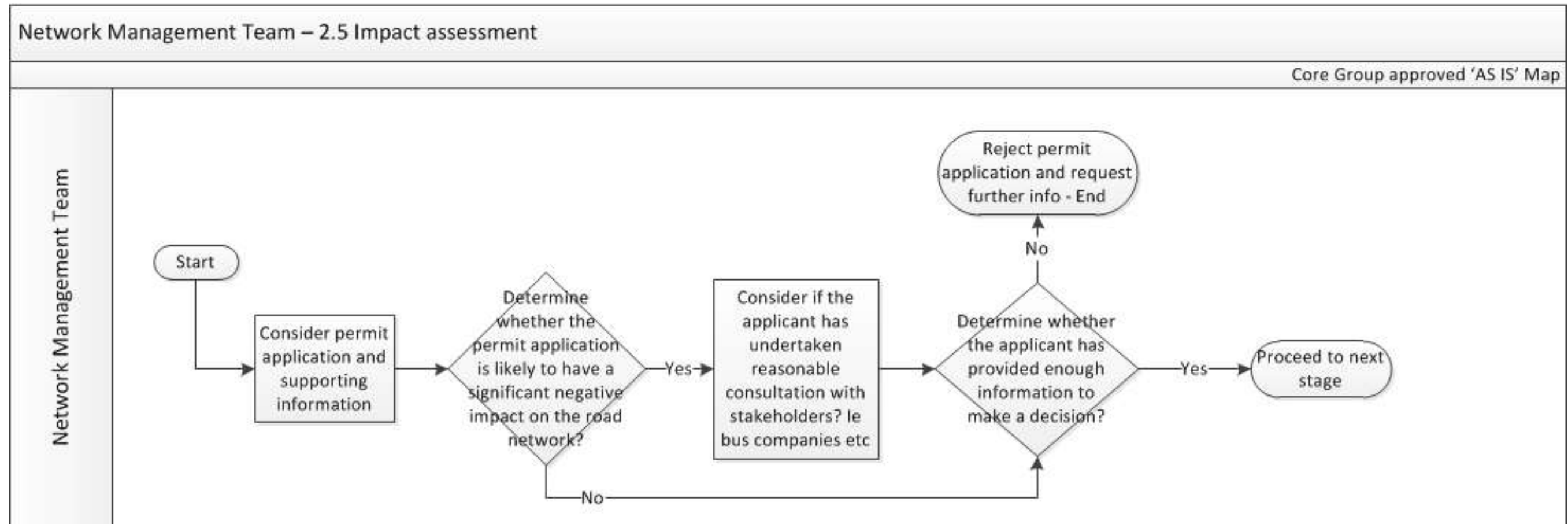
KEY



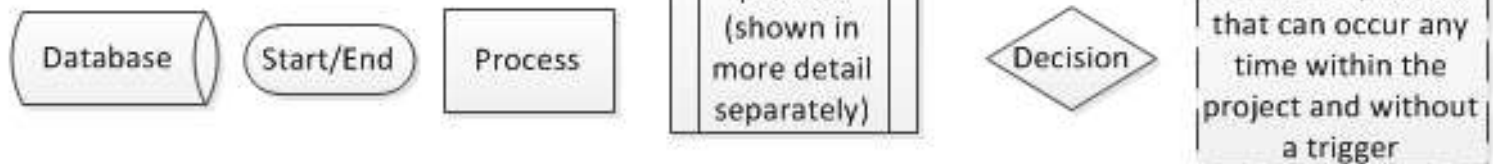
Comment

In the case of ‘Deemed’ permit applications, the application is assessed retrospectively. Deemed permit applications cannot be rejected, instead a ‘Local Authority Imposed Variation’ can be issued directing how remaining works are to be executed.

Network Management team – Level 2.5 - ‘as is’ Impact assessment



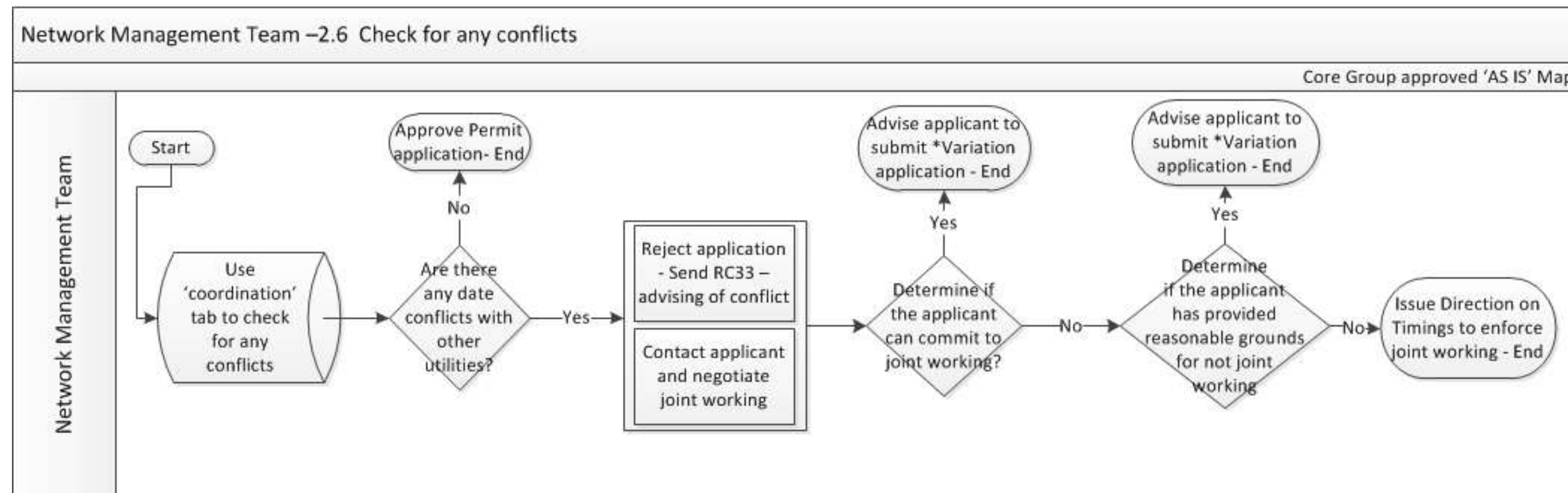
KEY



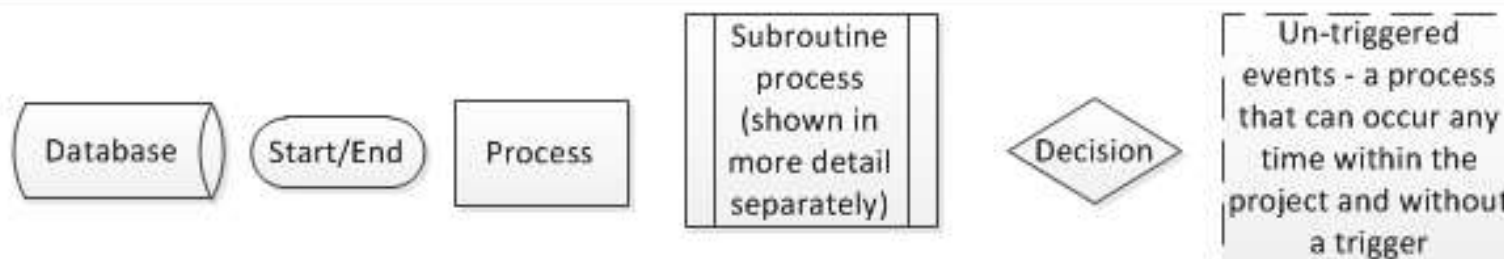
Comment

In the case of ‘Deemed’ permit applications the application is assessed retrospectively. Deemed permit applications cannot be rejected, instead a ‘Local Authority Imposed Variation’ can be issued directing....

Network Management team – Level 2.6 ‘as is’ – Check for any conflicts



KEY



Comment

In the case of 'Deemed' permit applications, the application is assessed retrospectively. Deemed permit applications cannot be rejected, instead a 'Local Authority Imposed Variation' can be issued directing....

*A Variation would start the approval process again.

APPENDIX H - BUSINESS PROCESS MAPS ‘TO BE’

The ‘To Be’ business process maps, are separated into teams in the following sub-appendices:

H1. Highways Maintenance

H2. Highways Engineering

H3. Network Management

All ‘As Is’ process maps detailed in Appendix G have been systematically reviewed by examining various overarching enabler categories as defined by Sharp and McDermott (2001), namely, IT, Human Resources (HR) and, policies and rules. Table H identifies examples of attributes considered in each enabling category. Following the consideration of the impact of these identified enablers, and feedback from process experts and validation experts as detailed in Chapters 4.4 and 4.5, the ‘To Be’ process maps in Appendix H have been re-designed accordingly and throughout by removing redundant and obsolete processes, to provide improved and more efficient processes.

Table H Reviewing 'as is' processes by considering enablers

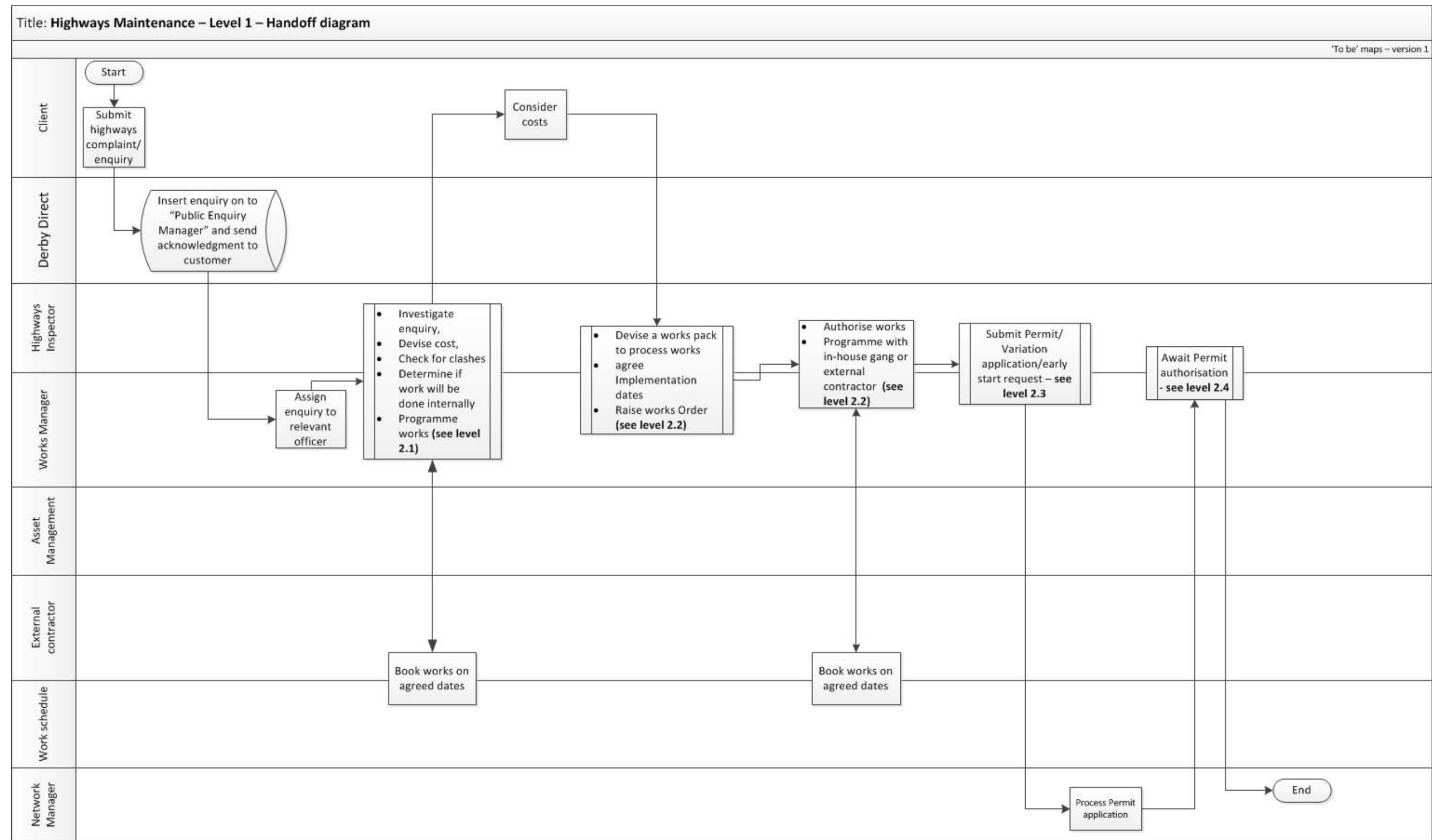
<i>Enabler category</i>	<i>Considerations when examining process</i>
Workflow Design	Are there too many actors/handoffs? Does the data yoyo between staff? Are there duplications/non-value adding step? Are there bottlenecks?
IT	Is information unavailable/ is there a lack of shared data? Are there duplications? Is there inconsistent formats/structures or semantics Are staff reconciling different information sources
Human resources	Are the right people, with the right skills, in the right jobs performing the right tasks? Are skills matched to job? Do staff have the right training?
Policies and rules	Why do we request 3 bids for values more than £1000? (It could cost more to solicit, review and select from bids) What are the constraints or requirements that impact on the conduct of the business or work flow?

APPENDIX H1 - HIGHWAYS MAINTENANCE

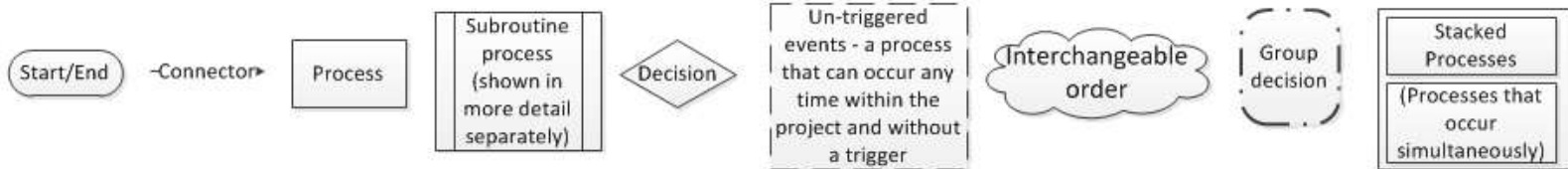
TO BE Swimlane Business Process Maps

1. Level 1 Hand off diagram
2. Level 2.1 Investigate enquiry and devise cost
3. Level 2.2 Devise a works pack
4. Level 2.3 Submit Permit/Variation request
5. Level 2.4 Await Permit Authorisation

Highways Maintenance team – Level 1 ‘to be’ - Hand-off diagram

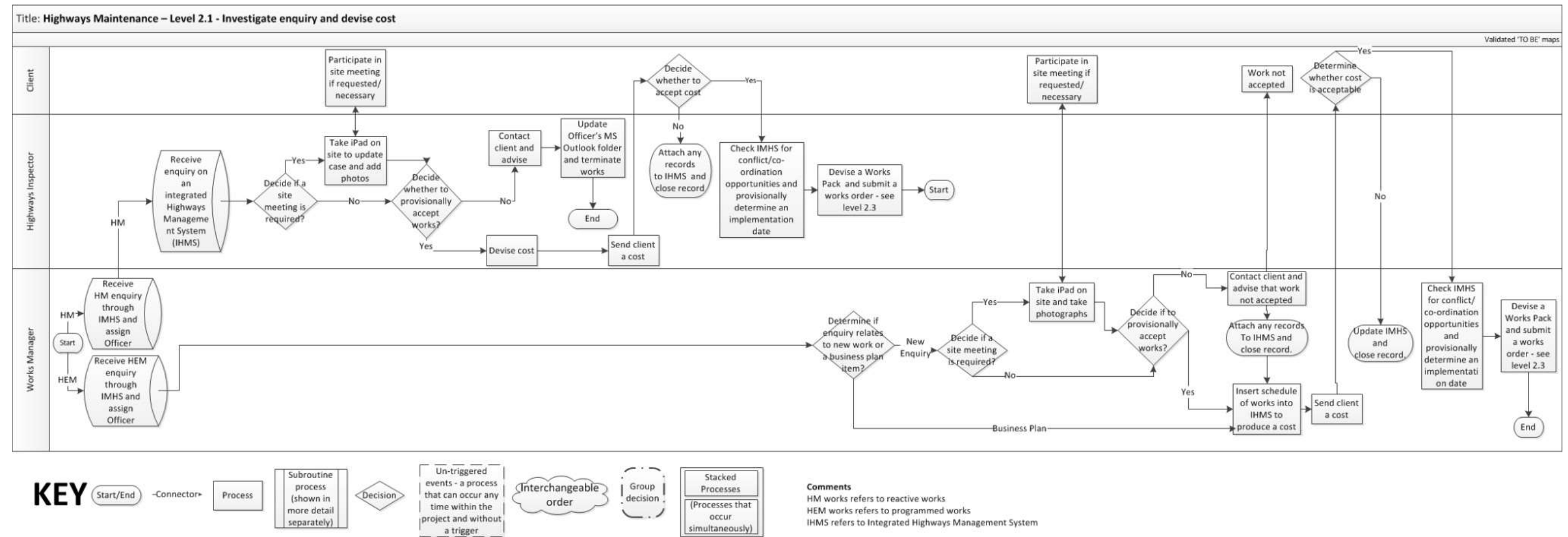


KEY

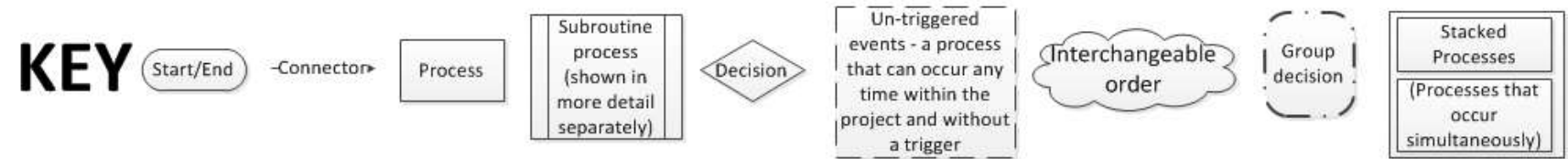
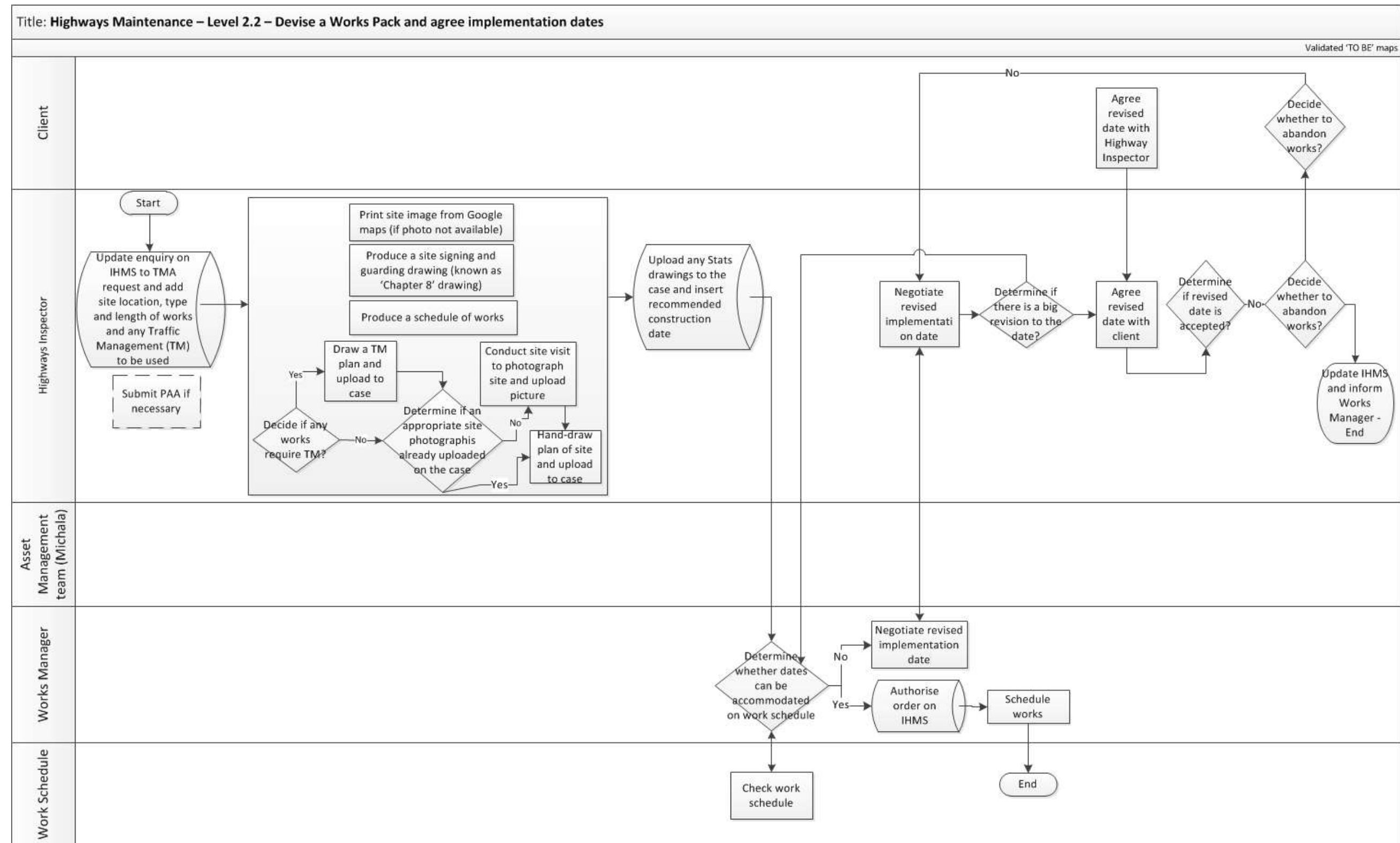


Comments
Permit applications are also processed on behalf of Highways Engineering

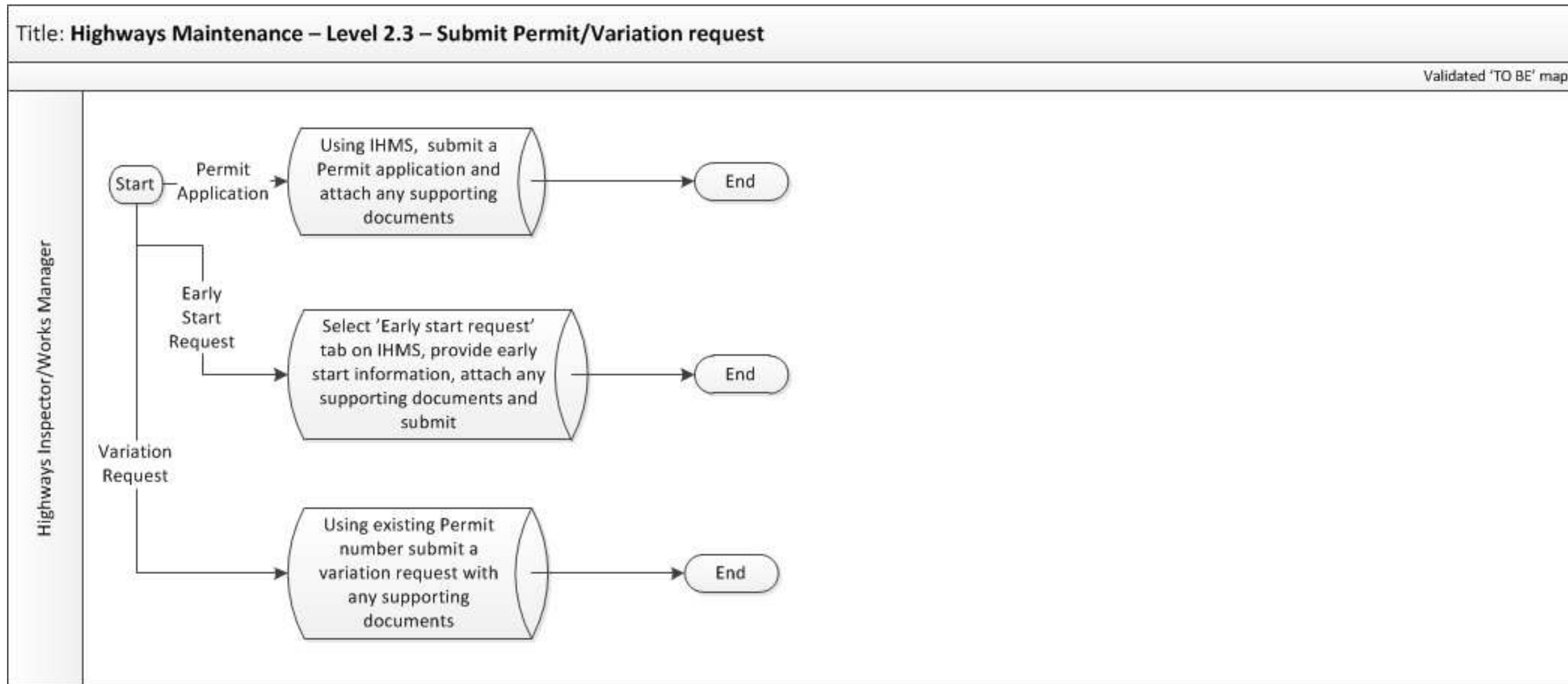
Highways Maintenance team – Level 2.1 ‘to be’ Investigate enquiry and devise cost



Highways Maintenance team – Level 2.2 - ‘to be’ – Devise a works pack



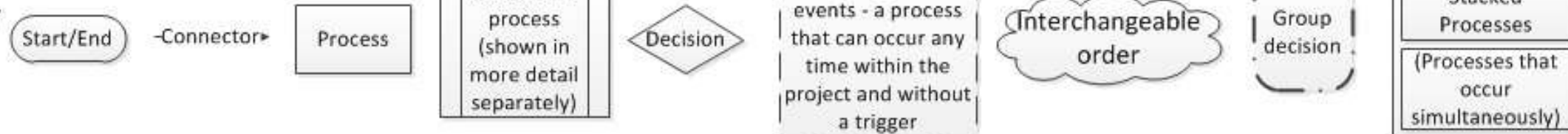
Highways Maintenance team – Level 2.3 - ‘to be – Submit Permit/Variation request



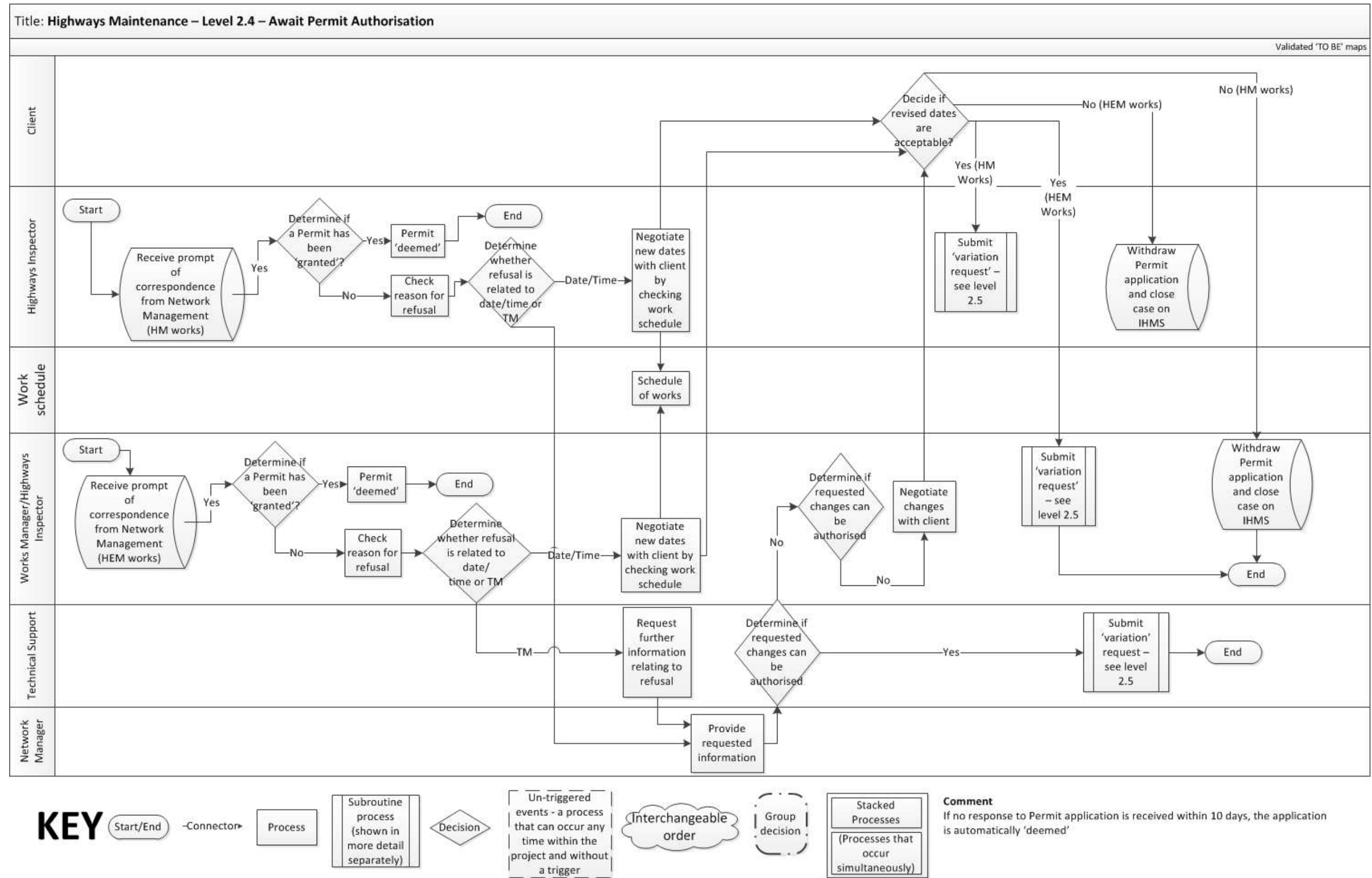
Comments

An Early Start Request may immediately proceed a Permit Application submission

KEY



Highways Maintenance team – Level 2.4 ‘to be’ – Await Permit Authorisation

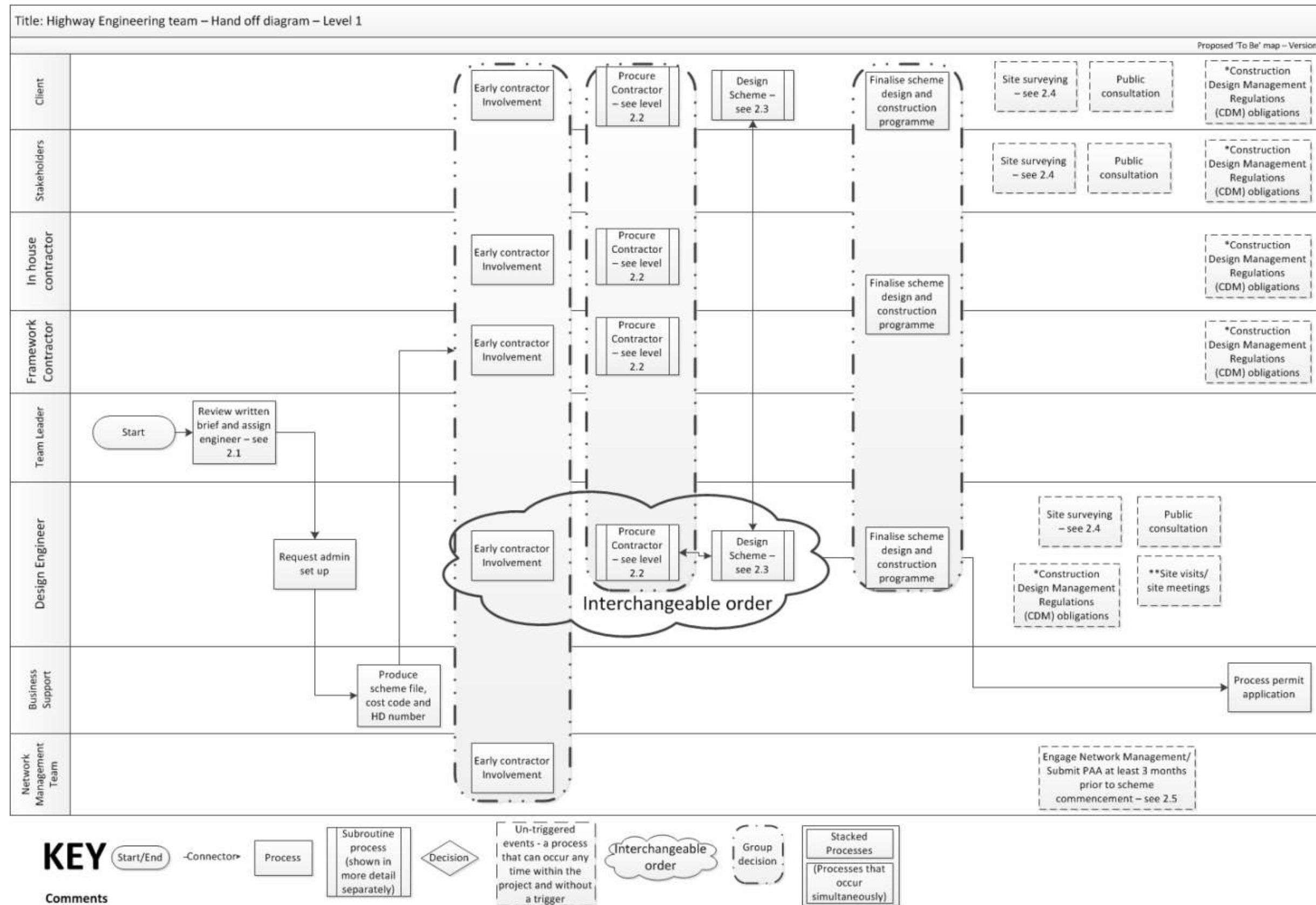


APPENDIX H2 - HIGHWAYS ENGINEERING

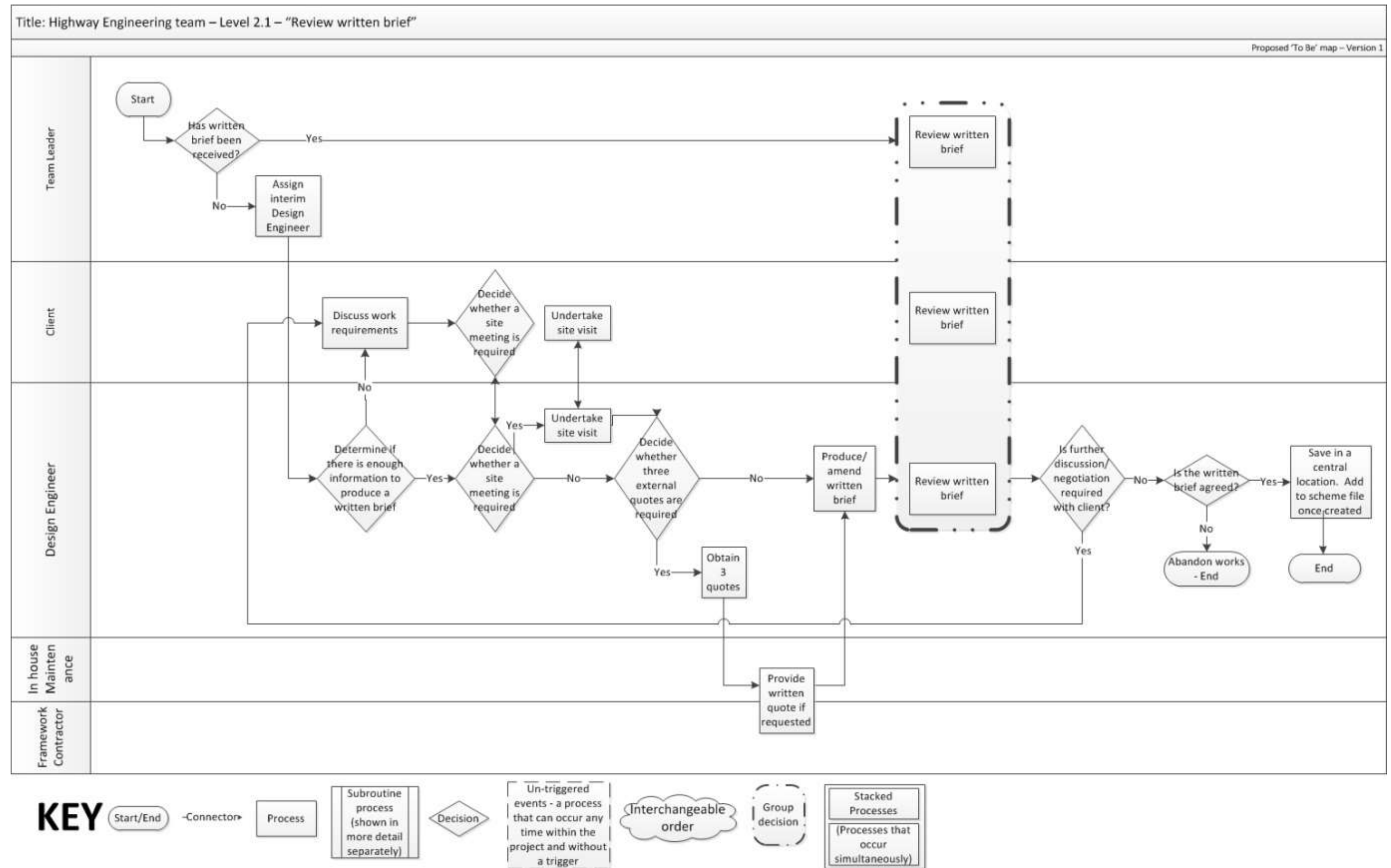
TO BE Swimlane Business Process Maps

1. Level 1 Hand off diagram
2. Level 2.1 Review written brief
3. Level 2.2 Procure contractor
4. Level 2.3 Design scheme
5. Level 2.3.1 Undertake detailed design (1)
6. Level 2.3.1 Undertake detailed design (2)
7. Level 2.3.1 Undertake detailed design (3)
8. Level 2.3.1 Undertake detailed design (4)
9. Level 2.4 Site surveying
10. Level 2.3.1 Engage Network Management

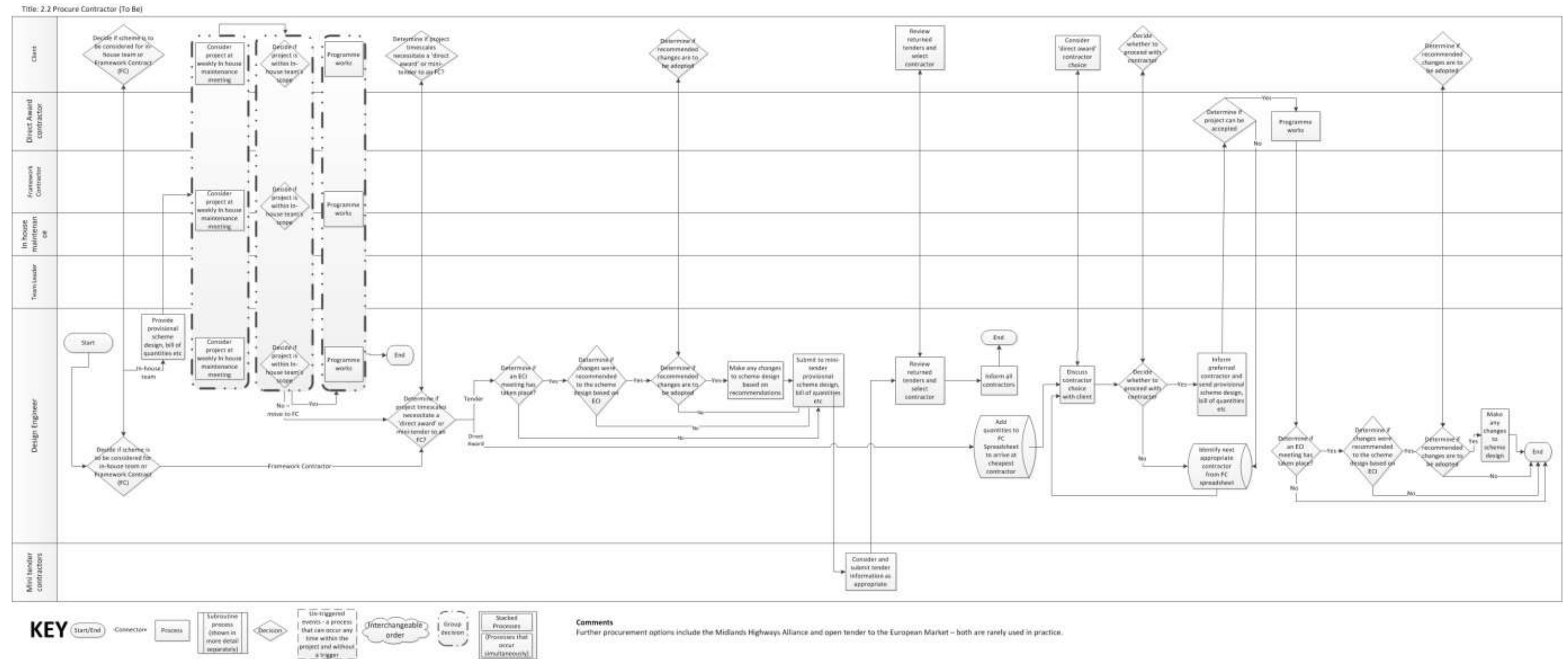
Highways Engineering team – Level 1 ‘to be’ – Hand off diagram



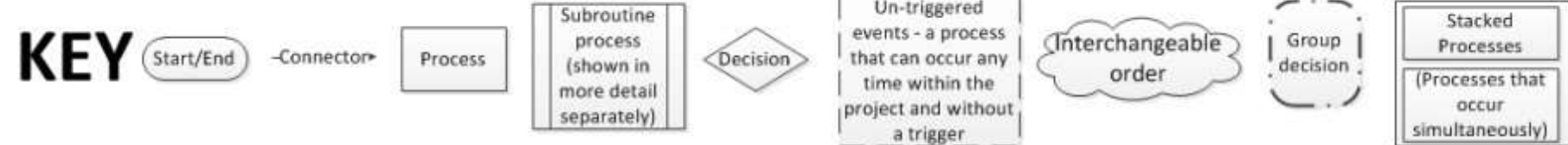
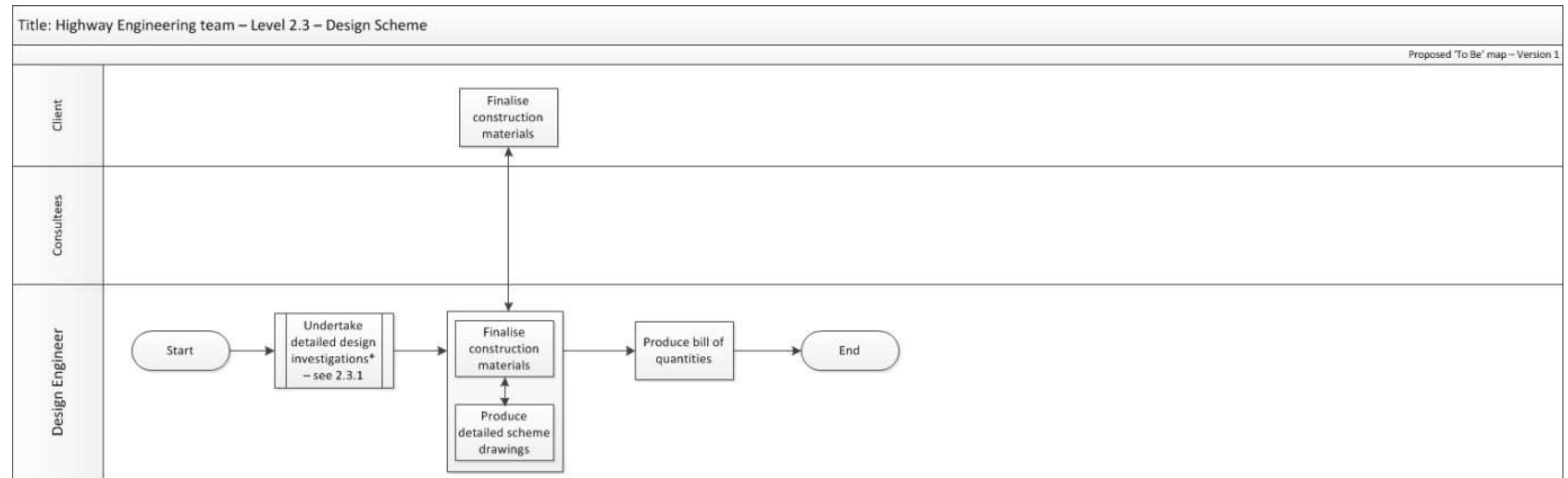
Highways Engineering team – Level 2.1 ‘to be’ – Review written brief



Highways Engineering team – Level 2.2 - ‘to be’ – Procure contractor

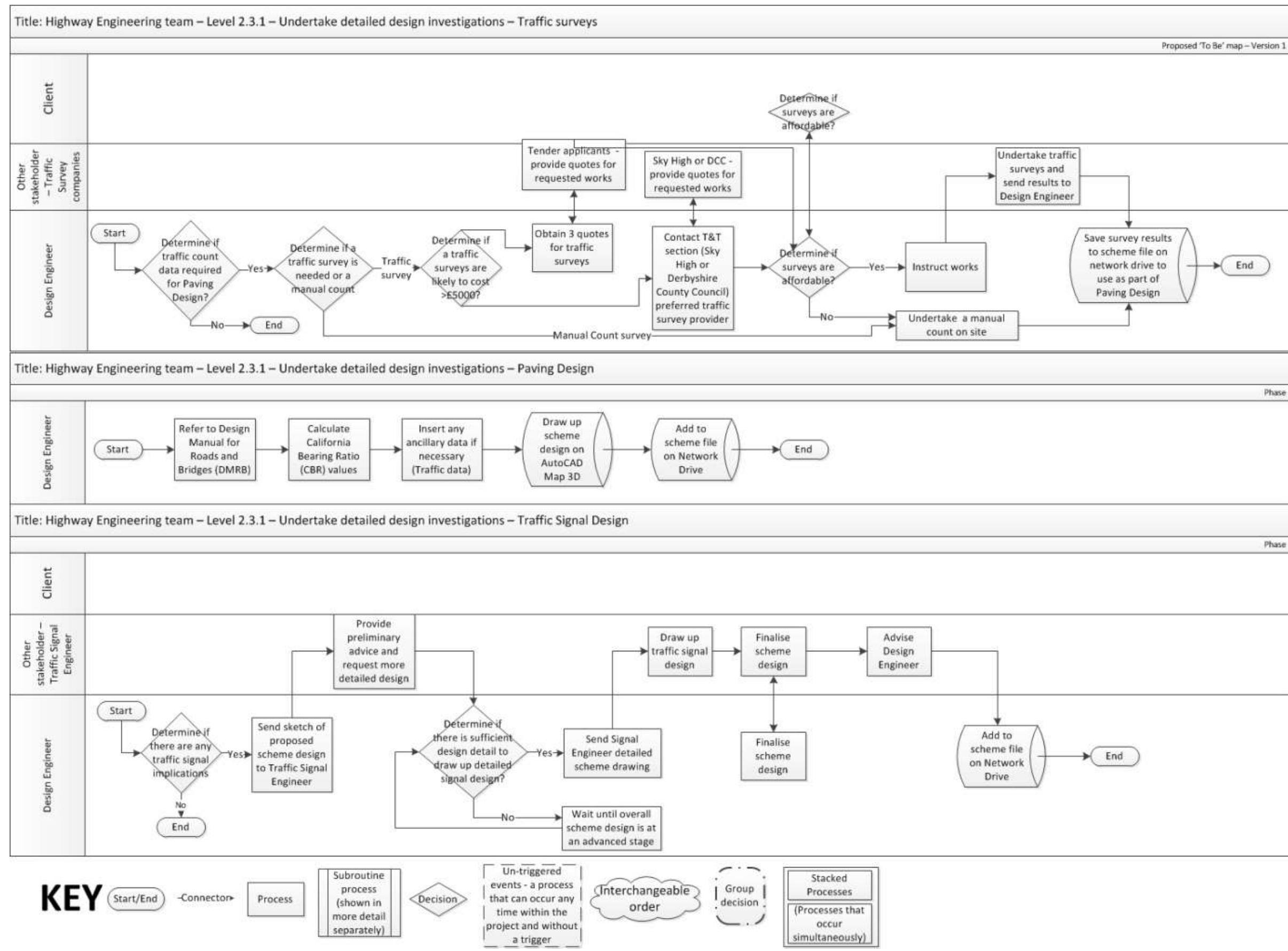


Highways Engineering team – Level 2.3 - ‘to be’ Design scheme

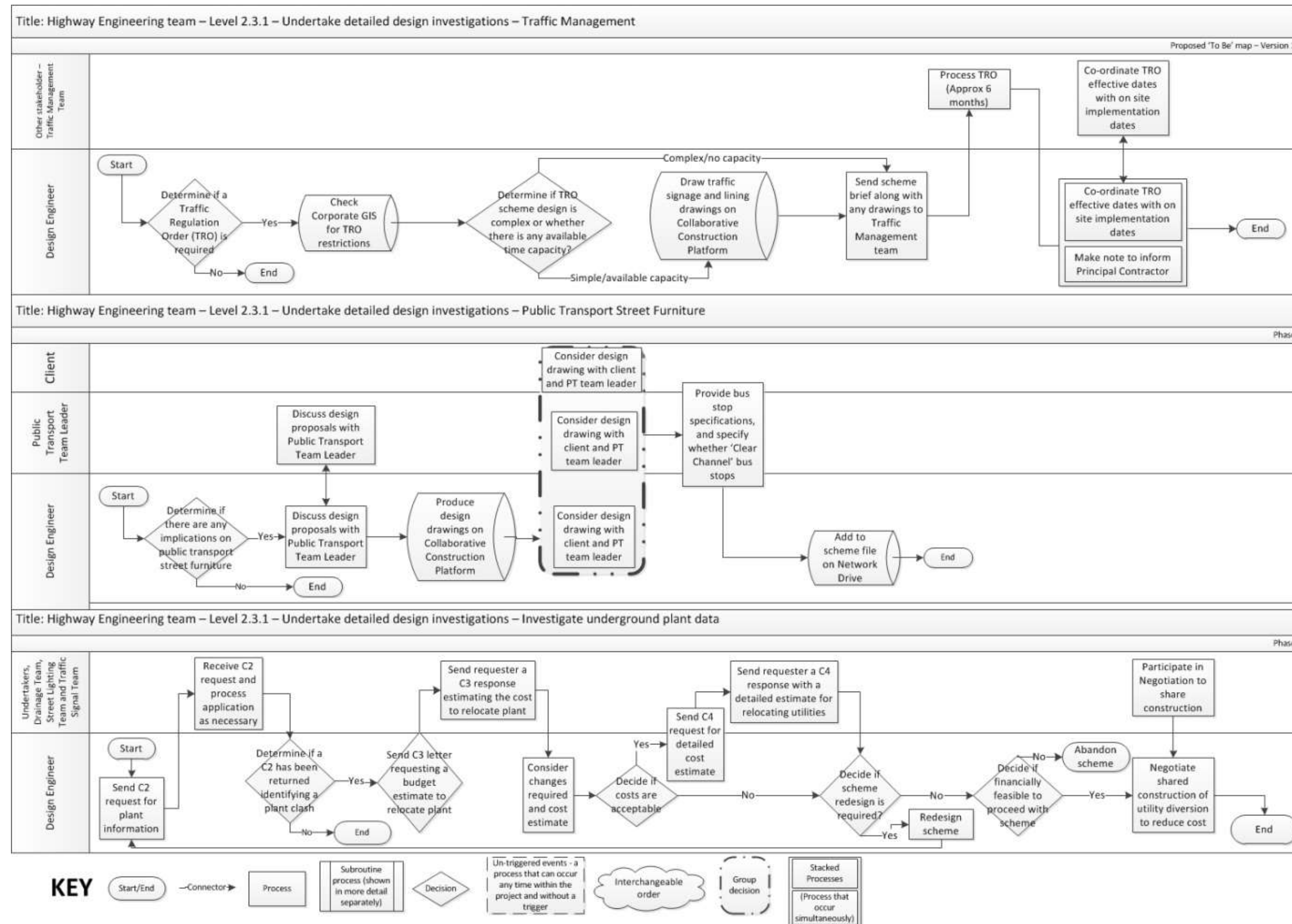


Comments
 *Detailed design comprises: Drainage design, Level Design, Street Lighting Design, Paving Design, Traffic Signal Design, Public Transport Street Furniture Design, Traffic Management Design

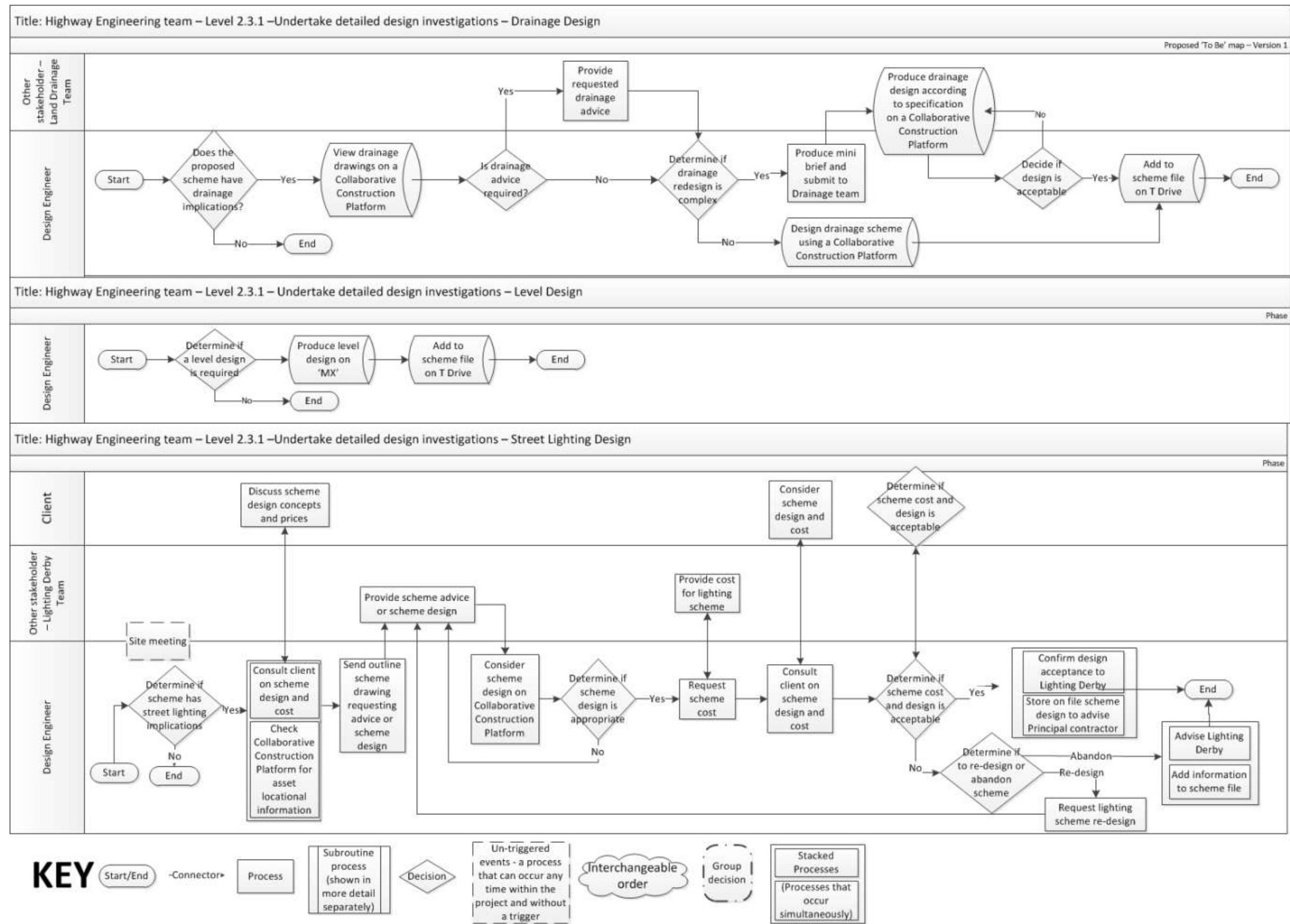
Highways Engineering team – Level 2.3.1 ‘to be’ Undertake detailed design (1)



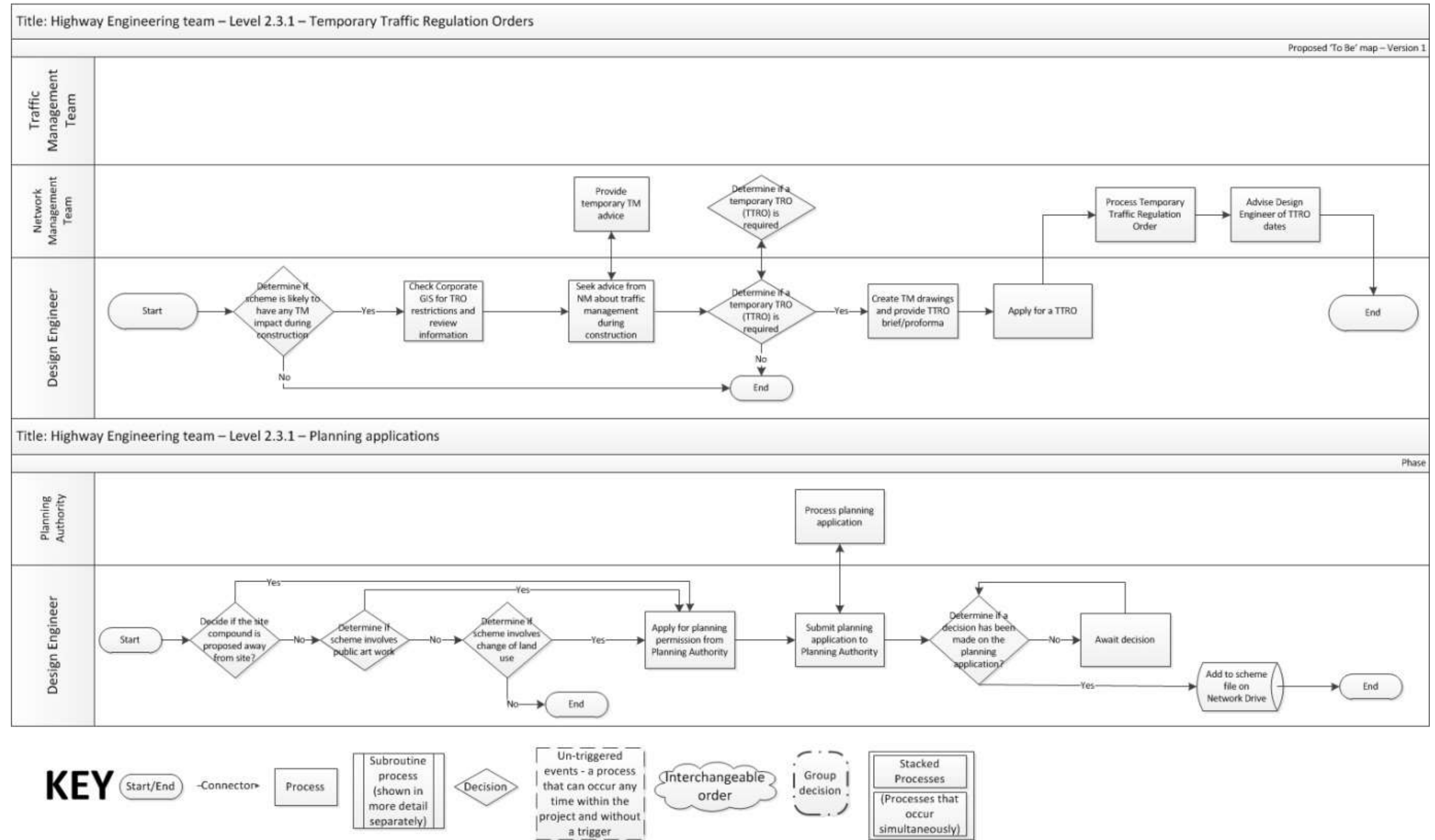
Highways Engineering team – Level 2.3.1 ‘to be’ Undertake detailed design (2)



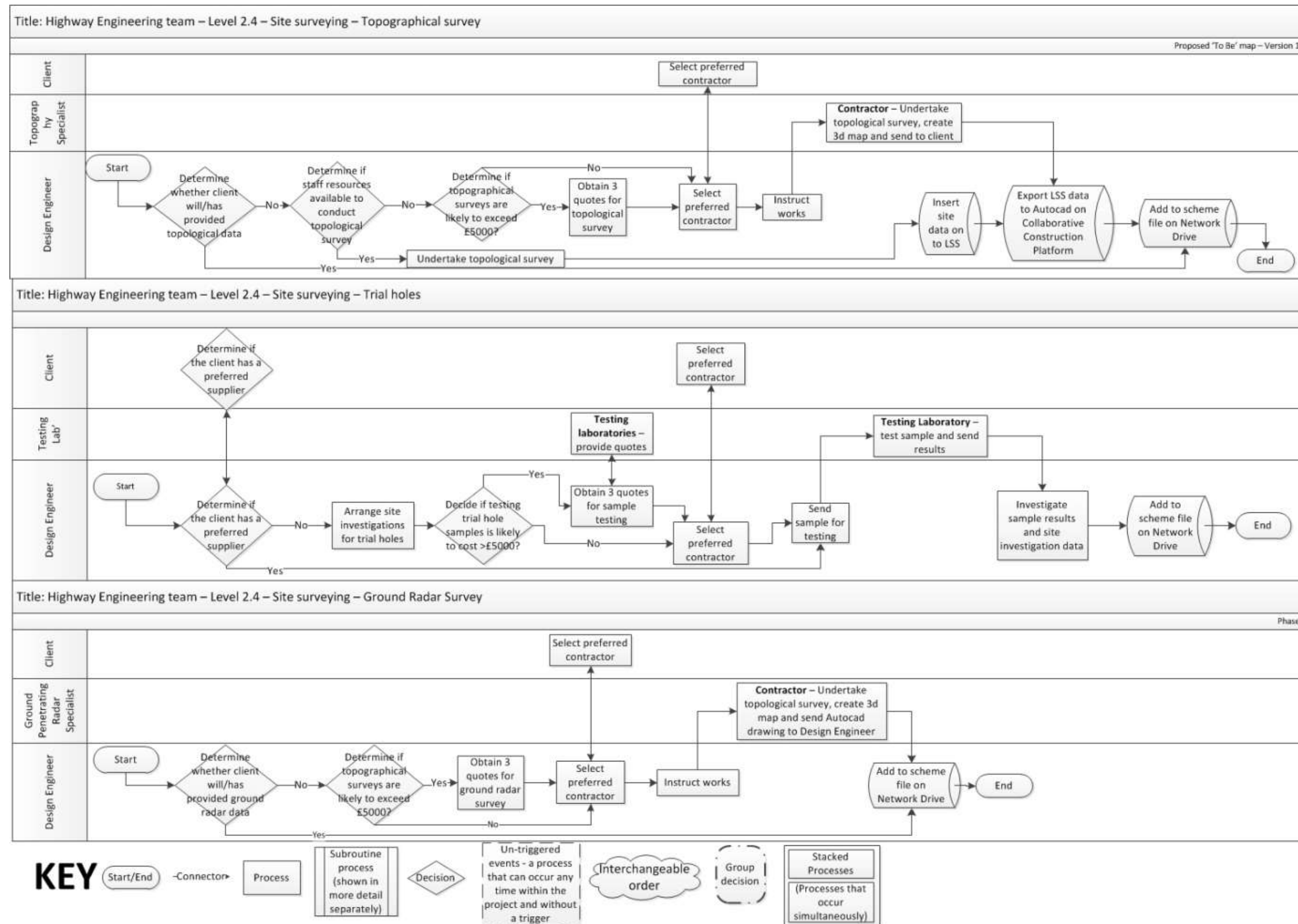
Highways Engineering team – Level 2.3.1 ‘to be’ Undertake detailed design (3)



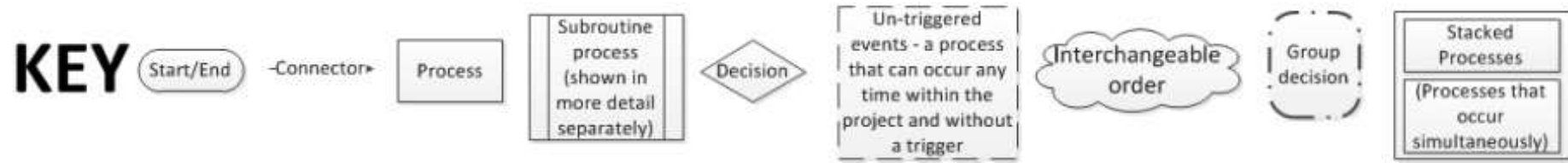
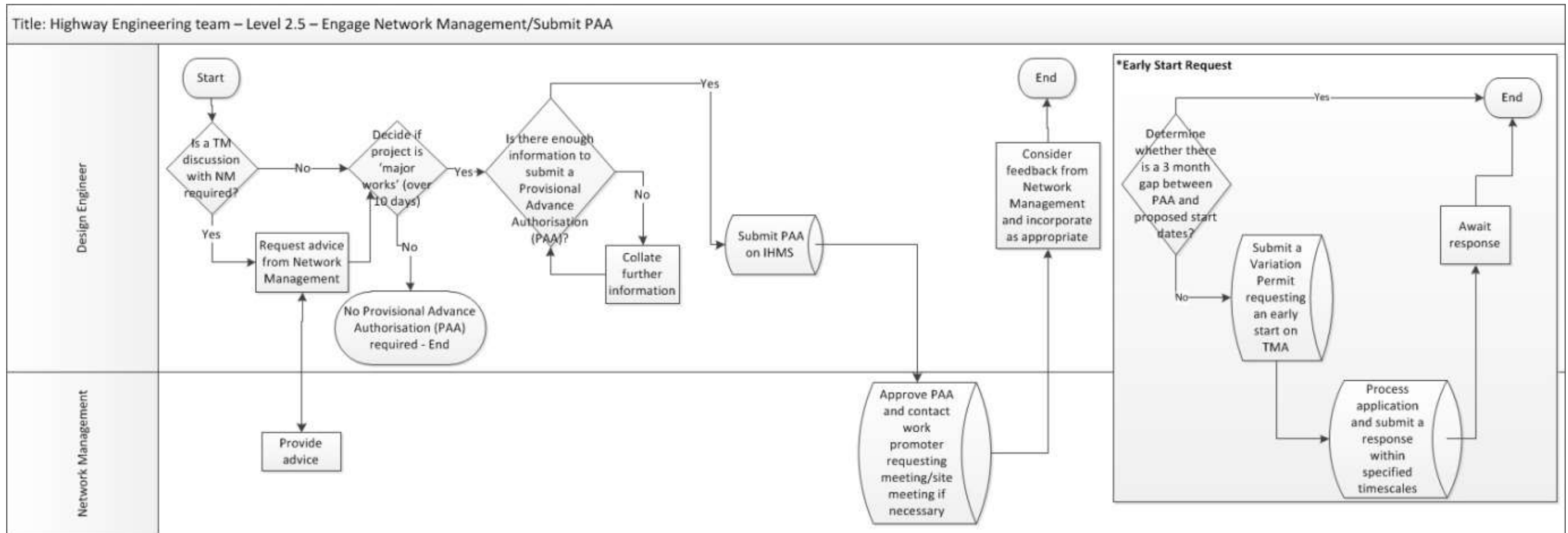
Highways Engineering team – Level 2.3.1 ‘to be’ Undertake detailed design (4)



Highways Engineering team – Level 2.4 ‘to be’ Site surveying



Highways Engineering team – Level 2.5 ‘to be’ Engage Network Management

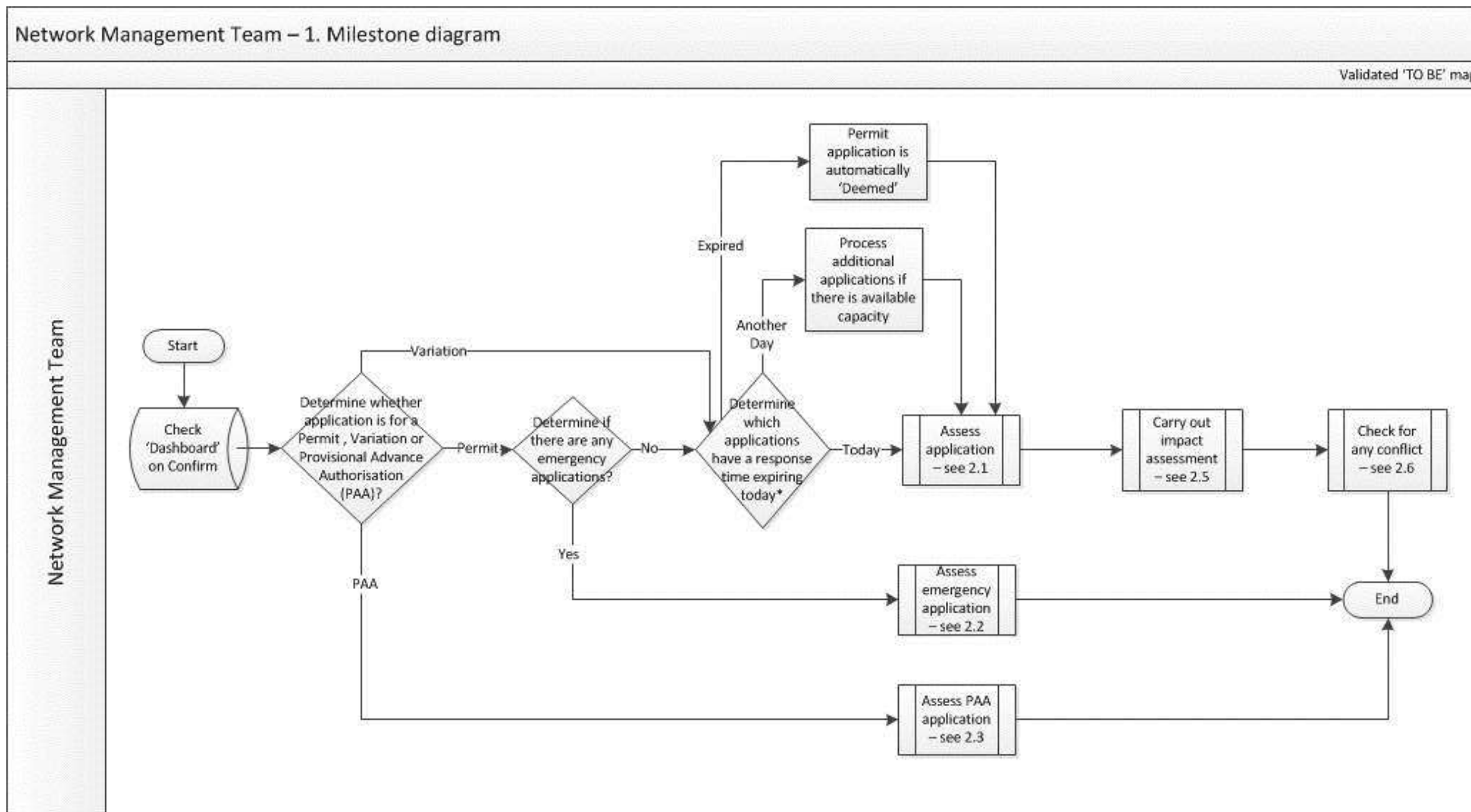


Comments
 * Early start request – a request for an early start may be made at the same time as submission of a PAA or at a later date (less than 3 months before the proposed road work start date)

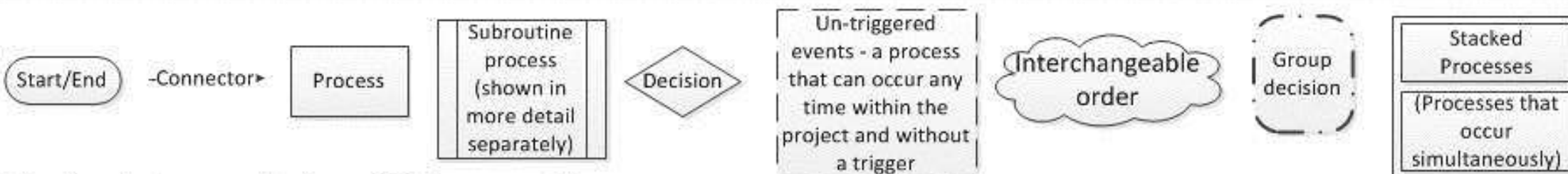
APPENDIX H3 - NETWORK MANAGMENT

1. Level 1 Hand-off diagram
2. Level 2.1 Assess application
3. Level 2.2 Assess emergency application
4. Level 2.3 Assess Provisional Advance Authorisation application
5. Level 2.4 Impact assessment
6. Level 2.5 Check for clashes

Network Management team – Level 1 ‘to be’ - Hand-off diagram



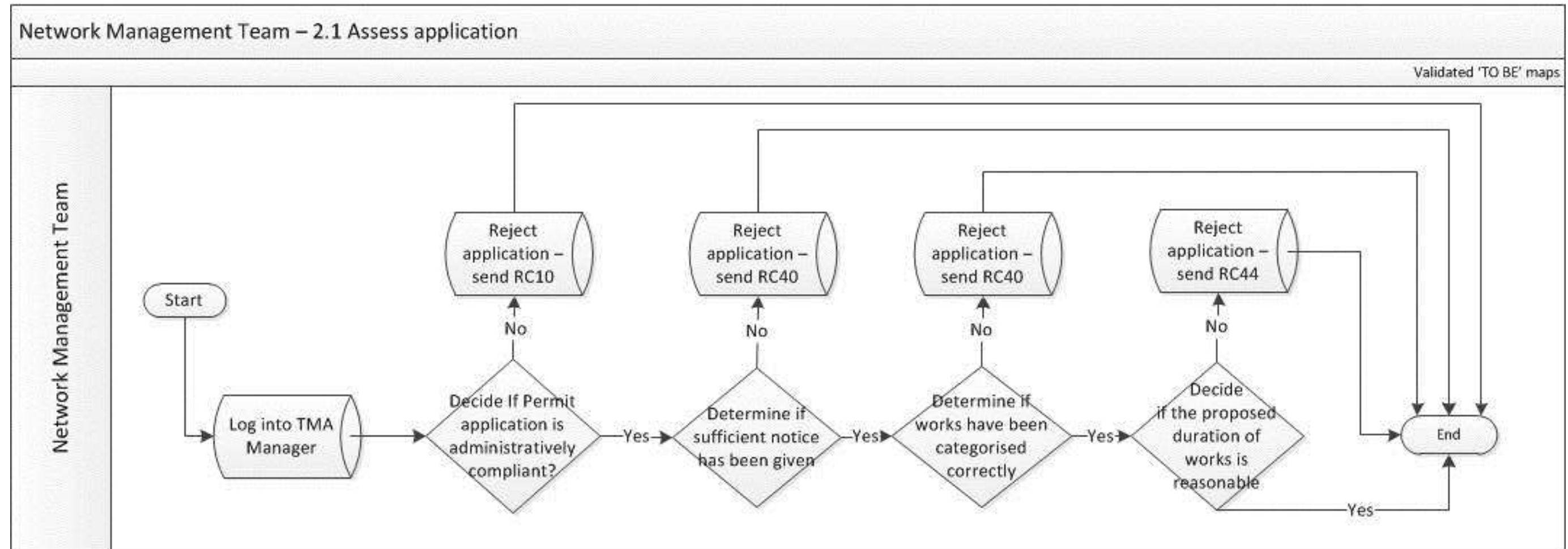
KEY



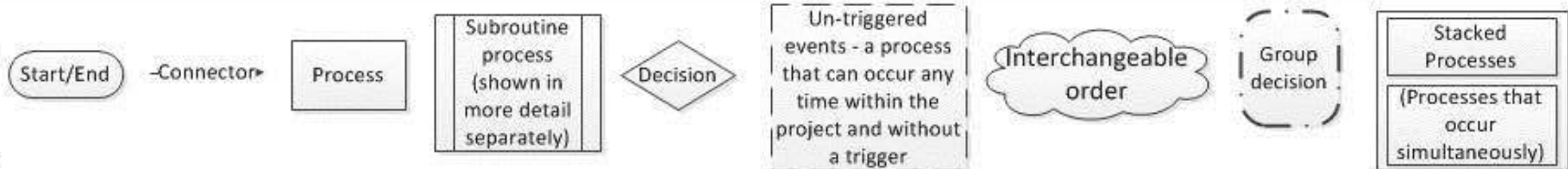
Comments

Unless stated otherwise, all steps are undertaken on TMA Manager module
 *All applications have a response window of before they are automatically 'deemed'.

Network Management team – Level 2.1 ‘to be’ – Assess application



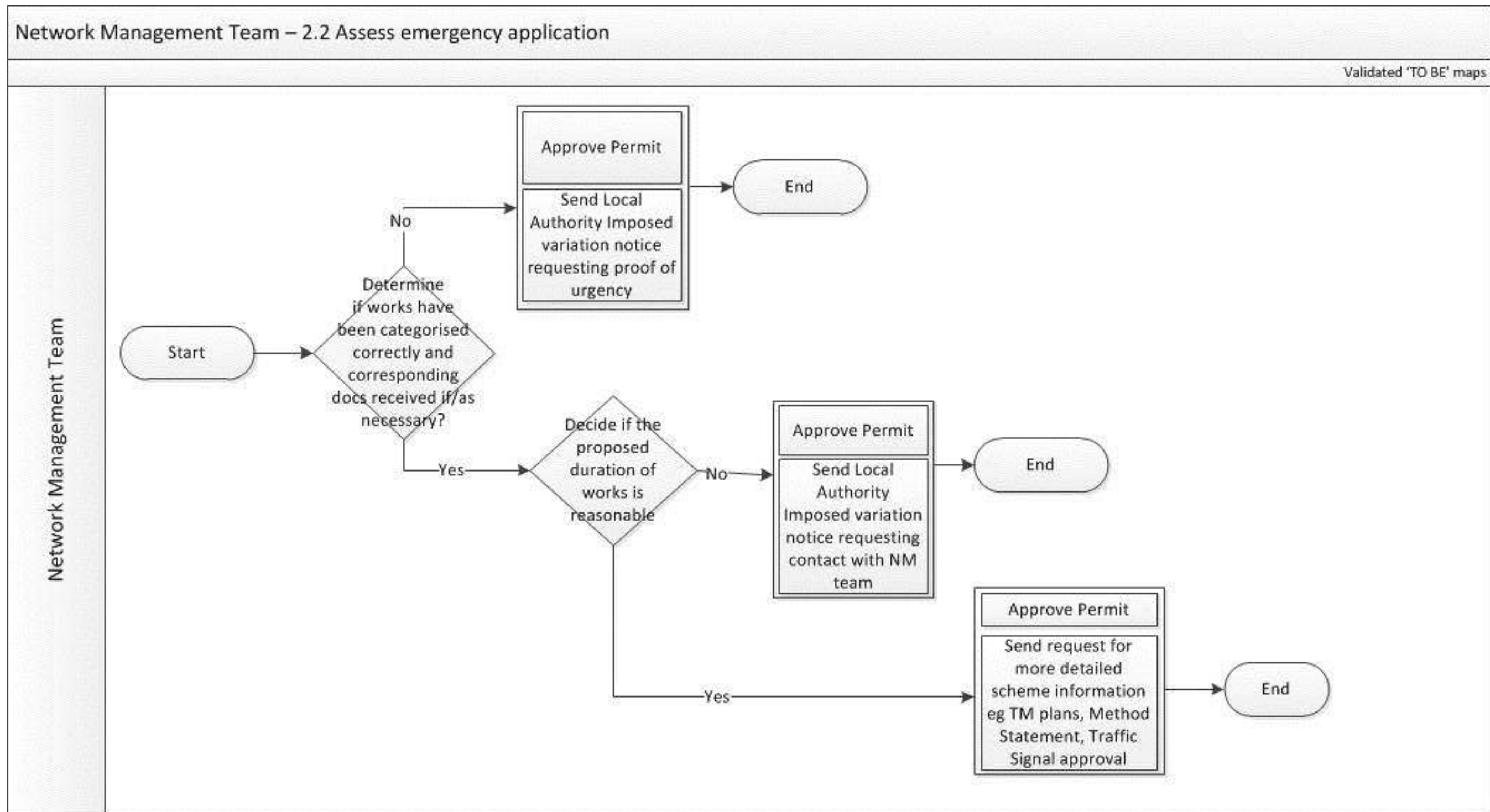
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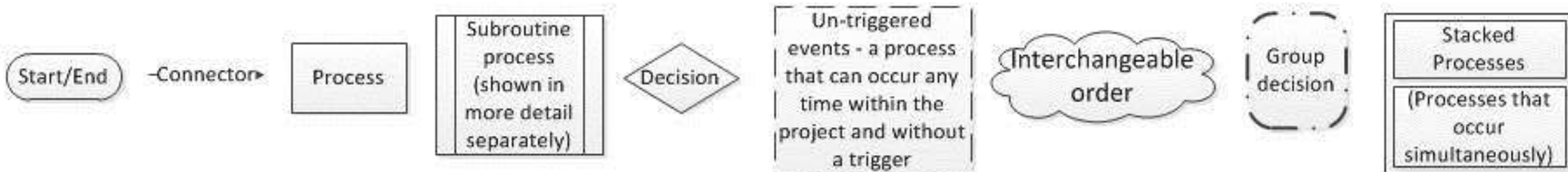
Comments

In the case of 'Deemed' permit applications, the application is assessed retrospectively. Deemed permit applications cannot be rejected, instead a 'Local Authority Imposed Variation' can be issued directing.... A rejected application will include guidance by Network Management on how to improve the application

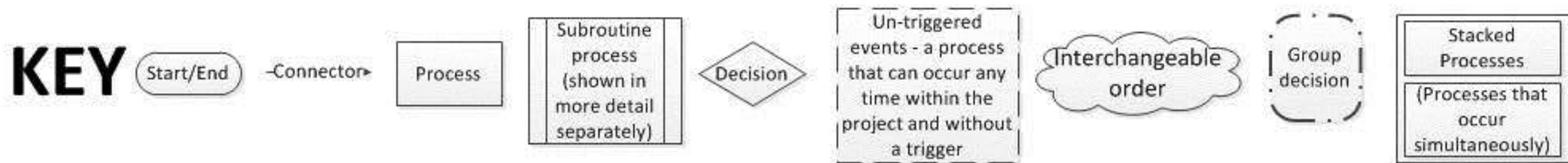
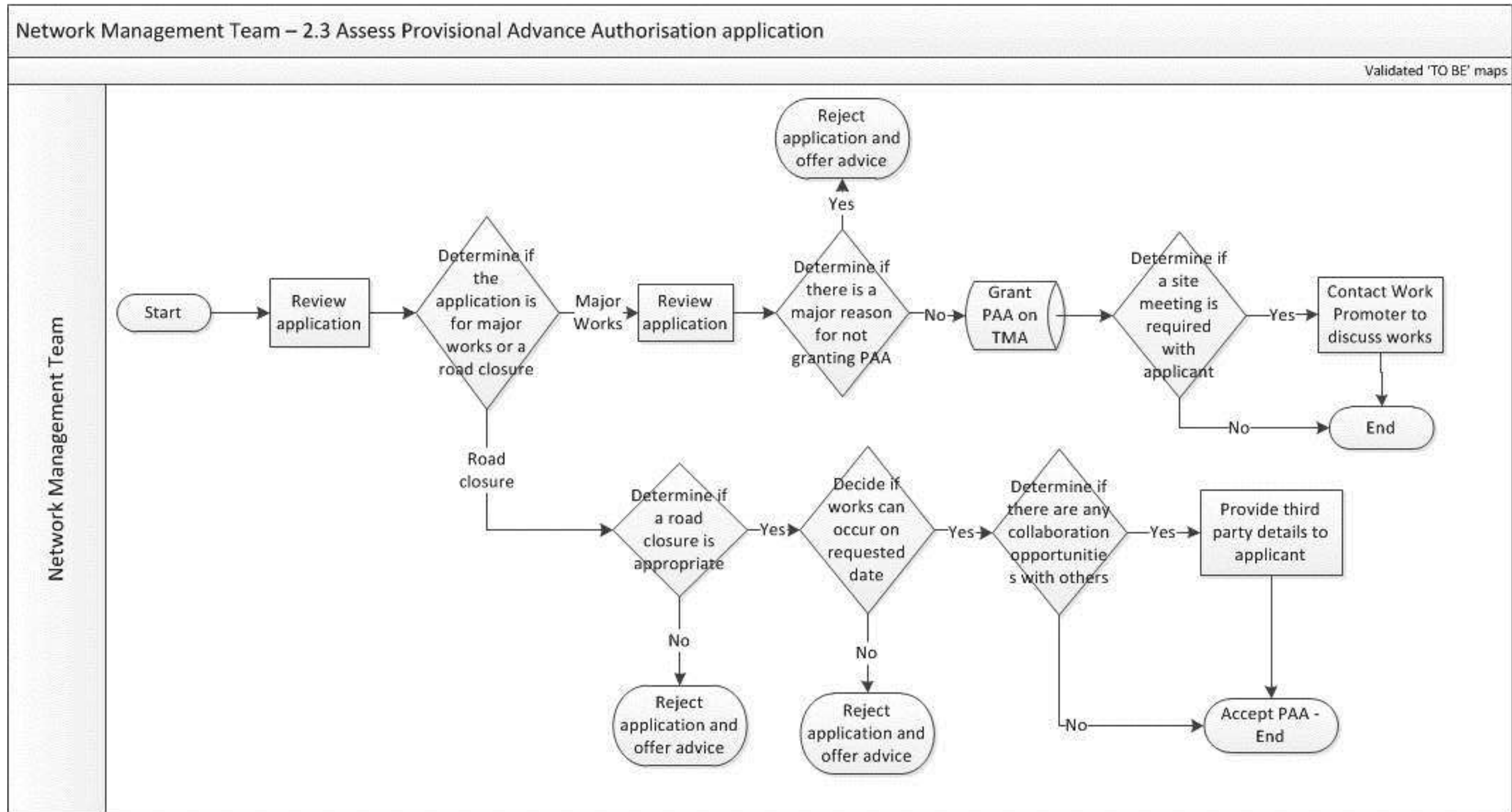
Network Management team – Level 2.2 ‘to be’ – Assess emergency application



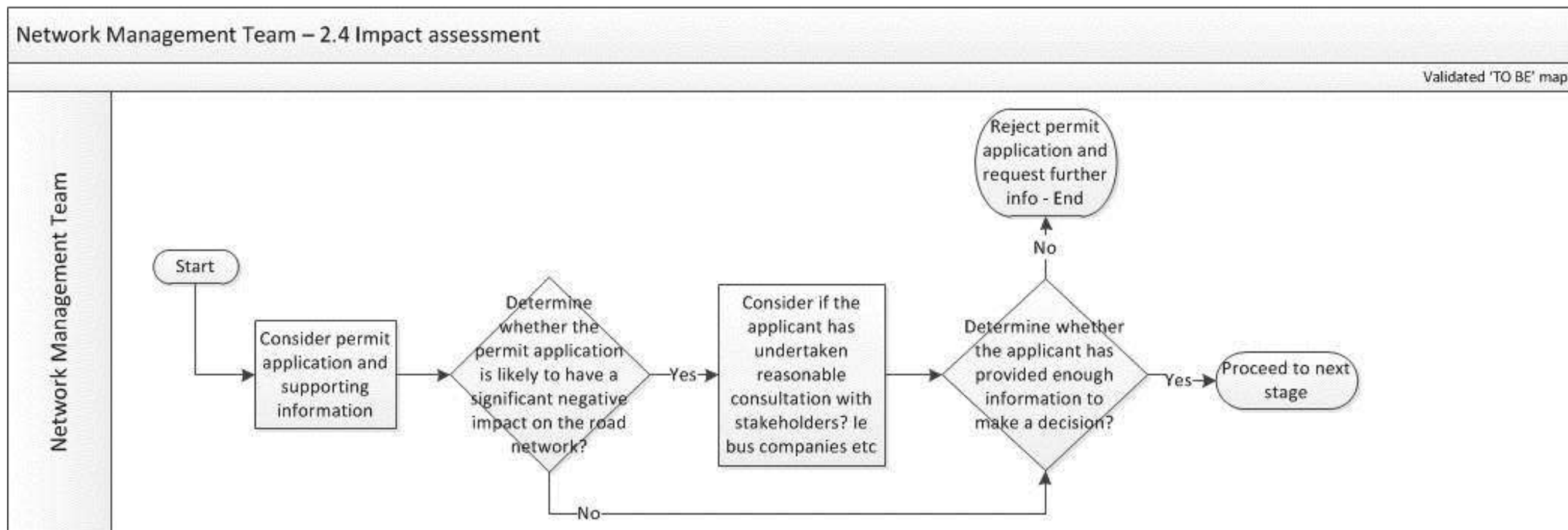
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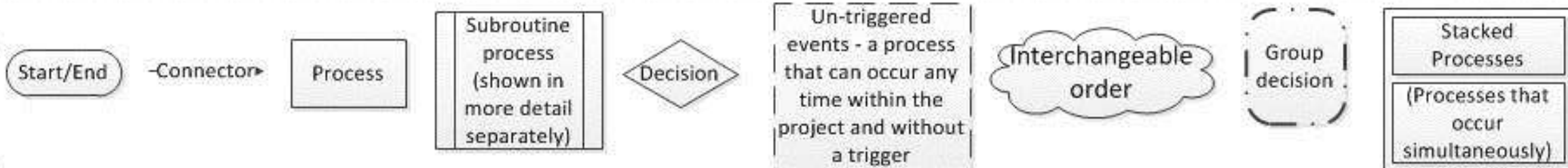
Network Management team – Level 2.3 ‘to be’ – Assess Provisional Advance Authorisation application



Network Management team – Level 2.4 ‘to be’ – Impact assessment



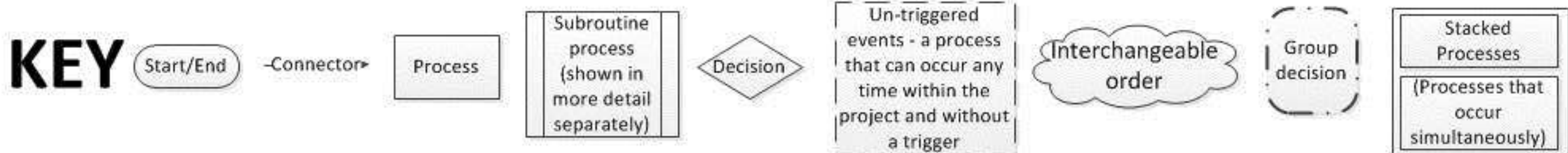
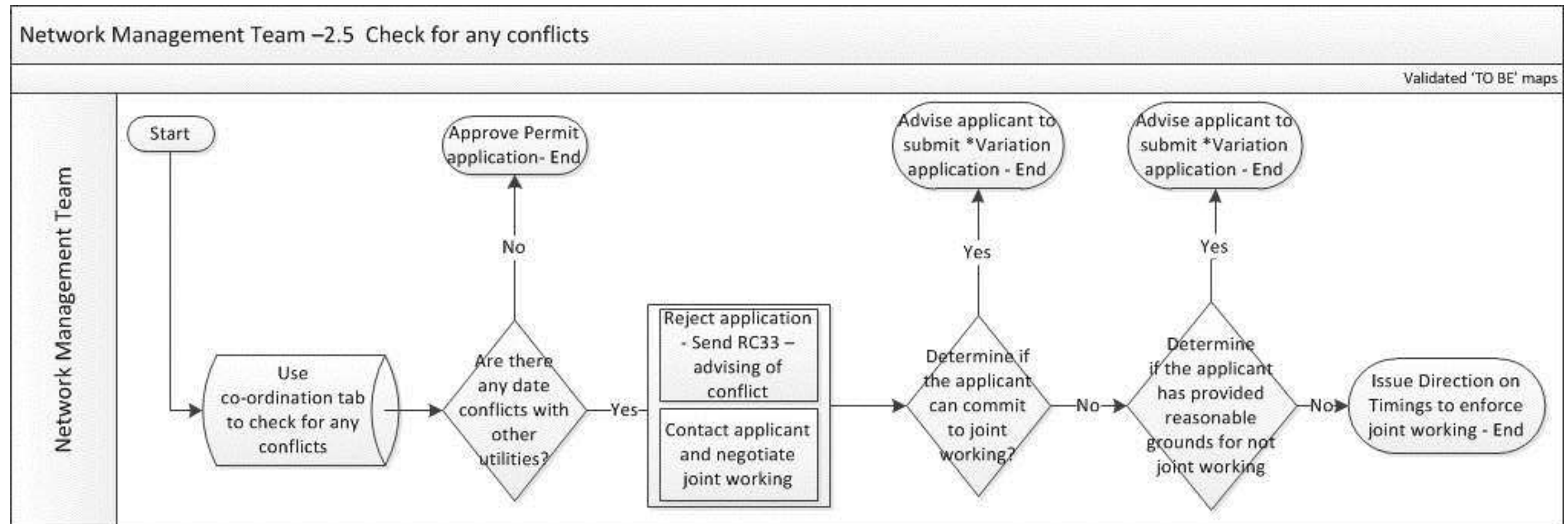
KEY



Comment

In the case of ‘Deemed’ permit applications the application is assessed retrospectively. Deemed permit applications cannot be rejected, instead a ‘Local Authority Imposed Variation’ can be issued.

Network Management team – Level 2.5 ‘to be’ – Check for clashes



Comment

In the case of ‘Deemed’ permit applications, the application is assessed retrospectively. Deemed permit applications cannot be rejected, instead a ‘Local Authority Imposed Variation’ can be issued directing....

*A Variation would start the approval process again.