A HUMAN CENTRIC APPROACH TO CAPTURING PROJECT MEMORIES FOR LEAN IMPROVEMENT

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1. Project Details

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Project Sponsor: Steve Williams, Highways England.

Project Administration: Steve Matthews and Greg Longley, WSP.

Project Planning and Execution: The proposal for this project was submitted during June 2016, and was agreed in early 2017 contributing to the broad agenda to drive improvements in knowledge transfer and learning systems. Background reading, establishing collaborations, team discussions and exploratory interviews were conducted over 2017, while contracts between WSP, HE and Universities were set up. The majority of the investigative activities were carried out over 2018, and the final report was written, and commented on by stakeholders, over December 2018 and January 2019.

Note on Project Deliverables: in addition to this project report, the other deliverables for the project included 1) a slide pack of the storybook approach and project findings for communication to stakeholders 2) a knowledge transfer pack and 3) a full project proposal submitted to a research council. Deliverables 1) and 2) were submitted to accompany the report. At the time of writing, a project proposal was submitted to the EPSRC, but had not yet been funded.

2. Executive Summary

Highways England (HE) is delivering an ambitious plan as set out in the phases of the Road Investment Strategy, including some of the largest major projects across Europe within the Complex Infrastructure Programme (CIP), and significant regional upgrades and maintenance. Consequently, HE will need to reflect considerably on its capability, expertise and opportunities to deliver the efficiency savings for the final stages of RIS1, as well as for RIS2 and beyond. This project report explores the role and capability of learning and knowledge management in contributing to these goals. The project was undertaken through workshops, interviews, systems demonstrations, analysis of documents, a desk-based review, presentations and feedback sessions, as well as regular dialogue with HE and WSP.

The current knowledge system (including people, processes, technology and financial elements) is evaluated in this project report, and a vision for “Better learning within projects, between ongoing projects, and transfer to future projects” is established. Through the project, we found islands of excellence as regards learning and knowledge management, but also considerable inhibitors and barriers that stand before this vision. Perceptions of the latter by different stakeholders are set out in the report. To achieve the above vision, a systems approach is required, which connects people, processes, technology, and financial/commercial elements to an overall knowledge system, including the supply chain. Based on the findings of the project, 10 Key Recommendations are identified in relation to the vision, which are summarised in the table below.

The recommendations in italics are shorter terms and less strategic, while the recommendations in bold are medium term. Longer term strategic recommendations are shown in blue highlighted text. It can be seen that the different elements of the vision, including project learning, feedback to existing projects, and then transfer to future projects, becomes progressively longer term and more strategic. The capabilities for each stage are envisaged as building blocks, leading to greater capability to establish foundations for the longer term recommendations. A foundational activity to establishing this capability building
will be the development of a strategy, which is informed by this report and other relevant work threads and endorsed at leadership level.

<table>
<thead>
<tr>
<th>Vision Elements</th>
<th>Ten Key Recommendations</th>
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<tbody>
<tr>
<td>To Facilitate Project Learning</td>
<td>• Key Recommendation 1 is to streamline the number of repositories and standardize the approach to learning and knowledge capture.</td>
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<td>• Key Recommendation 2 is to modify Governance frameworks to include a structured, systems-based approach to learning lessons, which builds on innovative forms of knowledge capture.</td>
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<td>• Key Recommendation 3 is to incentivise and raise the profile of learning and knowledge as a strategic capability for industry.</td>
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<td>To Facilitate Knowledge Feedback to Existing/Ongoing</td>
<td>• Key Recommendation 4 is to form knowledge champions within existing routes to market.</td>
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<td>Projects</td>
<td>• Key Recommendation 5 is to increase visibility and transparency of learning that is taking place.</td>
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<td>• Key Recommendation 6 is to develop a strategy, which is linked to long term goals such as learning legacies and the strategic imperatives.</td>
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<tr>
<td>To Facilitate Knowledge Feedforward to Future</td>
<td>• Key Recommendation 7 is to analyse patterns and synthesize the knowledge base to create an ontology (a defined set of concepts/categories showing properties and relationships in a particular domain) which can provide a platform for innovation.</td>
</tr>
<tr>
<td>Projects</td>
<td>• Key Recommendation 8 is to use the knowledge base to feedforward into the opportunity and risk planning of new projects.</td>
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<td>• Key Recommendation 9 is to strive for consistency of successful teams across projects.</td>
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<td>• Key Recommendation 10 is to empower and connect Communities of Practice and working groups.</td>
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3. Background and Context

3.1 Aims of the Project

Highways England (HE) currently sits at a transformational stage in its development, and faces considerable challenges. It is in the infancy of its journey as an independent government owned company, having transitioned from the Highways Agency to HE in April 2015, with regulatory oversight from the Office of Road and Rail (ORR). HE is also nearing the final stages of the first Road Investment Strategy (RIS1), which sets out a longer-term approach to improve and manage England’s strategic road network. RIS1, which runs between 2015-2020, establishes high level objectives, an investment plan, and ambitious efficiency targets. RIS1 included a £15 billion programme of investment, covering new major projects, enhancements to existing infrastructure, as well as maintenance of the network. The ORR set out a target for savings of at least £1.212 billion on capital expenditure by 2019-20. Hence, HE has an ambitious programme of work planned and challenging targets. Consequently, HE will need to reflect considerably on its capability, expertise and opportunities to deliver the efficiency savings for the final stages of RIS1, as well as preparing and planning for greater efficiency challenges in RIS2 and beyond.

This project report investigates the role of learning and knowledge management in contributing to the above challenges. There is clear evidence of ‘islands of excellence’ with regard to business improvement projects to be found in many corners of HE and its supply chain: lean projects, knowledge transfer packs, documented examples of efficiencies through the efforts of teams and individuals to show continuous improvement. Within HE, there are also ongoing efforts to reflect on strategies for sharing knowledge between complex projects. Despite all this, it is clear that it is difficult for project teams to mobilise a meaningful knowledge base and that the big picture approach to knowledge management is perceived to be unconnected, unsystematic, with feedforward and feedback issues encountered.

A report from our previous project, ‘Principles for appropriate contracting’, highlighted the fundamental importance of the capability of contracting systems to learn from the past and develop strategies that feed this knowledge forward into future projects. Having built on the previous work, this current project report aims to:

- Understand and explain the current systems and processes for capturing knowledge and ‘lessons learned’ across HE and its supply chain
- Identify the industry barriers and challenges that inhibit knowledge sharing and implementing lessons learned
- Propose new and / or improved learning mechanisms
- Provide recommendations for information capture, archiving, retrieval, visualisation and sharing.

3.2 Project Overview and Sources of Evidence

Although many sectors have invested in knowledge management initiatives, the construction sector is widely recognised to struggle to effectively capture and transfer lessons learned and new knowledge (Almeida and Soares, 2014; Carrillo et al., 2013; Duffield and Whitty, 2015; Hansen et al., 1999). HE sponsored this project to review their approach and reflect strategically on future knowledge management efforts across the organisation, and it was administered by WSP. The project ran from 2017-2018. Evidence gathering was undertaken via the following forms:
• Interviews with a wide range of HE staff and members of its supply chain, including knowledge managers, consultants, members of delivery teams, technical engineers and systems specialists, lean specialists, as well as Health and Safety experts. Input was gathered from HE representatives from the Smart Motorways Programme, Complex Infrastructure Programme, the Lower Thames Crossing Team, members of the Lean Group, Project Control Framework Specialists, and Efficiency Specialists. Staff who contributed form organisations from across the supply chain include WSP, Costain, Mott Macdonald, Balfour Beatty, Geldards and Constructing Excellence.
• Systems demonstrations of knowledge repositories used at HE and across the supply chain, including DAS, SHARE, Business Collaborator, HAGIS, CIP Programs, Lean tracker and the Knowledge Bank.
• Inspection and analysis of documents, including lessons learned logs, PCF templates, efficiency registers and reports, Health and Safety audits and alerts, draft strategy documents and presentations, bright ideas reports, and knowledge transfer packs.
• Interrogation of data held in repositories, including the lean tracker and the knowledge bank.
• A workshop, hosted by Constructing Excellence, and with presentations from HE, Cardiff University, and contractors from the HE Supply Chain. 30 Constructing Excellence members attended the event, representing clients, contractors, consultants, and subcontractors. Facilitated sessions were held in between presentations to gather views on lessons learned and knowledge management across the industry.
• A desk-based review of relevant academic literature and government reports.
• Presentations and feedback sessions
• Regular brainstorming and progress discussions with WSP and HE

4. Lessons Learned and Knowledge Management: a brief introduction

Effective learning and knowledge management have long been acknowledged as both problematic, but also as a source of competitive advantage (Alavi and Leidner, 2001; Senge, 1990). The 1990s, in particular, led to a proliferation of high-profile books and publications promoting knowledge management (Davenport et al., 1998; Senge, 1990). This section will briefly outline some core concepts from the literature which will form useful background knowledge for the recommendations set out herein.

Some principal knowledge related problems have been observed in the academic literature, which can be summarised as below. In the context of organisations that proceed primarily through complex projects of various types, knowledge management and learning is particularly challenging:

• **Communication barriers.** Blame culture and fear of penalties for disclosure, lack of trust and strong relational ties, as well as a lack of defined communication processes can contribute to an overall barrier to sharing lessons learned (Love et al., 2016). Further, there is a general tendency to avoid ‘violating’ or speaking out against organisational or industry expected norms (Argyris, 1977). This becomes particularly sensitive when analysing or detecting failure.

• **Time and resource.** Learning and knowledge require resource, and very often this is not something that is in abundance (Carrillo et al., 2004). Time remains a major challenge, particularly if employees are expected to undertake knowledge
management activities in addition (or on top of) all other everyday roles and responsibilities (Carrillo and Chinowsky, 2006).

- ‘Black hole repositories’ and ‘information limbo’. Information is typically structured according to project needs, losing its meaning and entering limbo once the project is concluded (Almeida and Soares, 2014). Hence it is common to find ‘black hole repositories’, where the documents go into a ‘black hole’ without any retrieval by anyone (Carrillo et al., 2013).

- Abstraction and causality. Firstly, abstract generalisation of knowledge, away from any particular learning context, is very difficult. Hence, when learning is separated from its context it can lose meaning, relevance and interest for others. Secondly, cause and effect of decisions and actions is often separated by time and space, so it is difficult to see any learning and how it affects other people (Senge, 1990).

In addition to the difficulties outlined above, there is also a wealth of understanding in the published literature concerning the fundamental processes and characteristics of learning. Some key terms and insights are summarised below.

- Knowledge has explicit and tacit forms. Explicit knowledge can be articulated in formal language, and can be transmitted across individuals. Tacit knowledge, which is hard to articulate with formal language, refers to personal knowledge that is embedded within individual values, perceptions, experiences and interpretations (Nonaka, 2008). These two forms interact to show how knowledge conversion takes place (Nonaka, 2008).

- Knowledge has a hierarchy – the well-established data-information-knowledge-wisdom hierarchy, sometimes referred to as the knowledge hierarchy, is a fundamental model of knowledge management (Ackoff, 1989). The assumption is that data can be used to create information, information can be used to create knowledge, and knowledge can be used to create wisdom, and these progress up a pyramid with wisdom as the pinnacle (Rowley, 2007).

- Learning has key processes, levels and phases. Learning is intimately intertwined with knowledge. While it is beyond the scope of this report to analyse different types of learning, it is useful to establish key constructs and processes. Huber (1991) suggests that “more organizational learning occurs when more of the organizations components obtain this knowledge and recognize it as potentially useful” (p90), and that it may be broken down into knowledge acquisition, distribution, interpretation and organizational memory. Prencipe and Tell (2001) highlight different phases of learning that occurs at different levels. For instance, learning may take place at individual, group, project, or organisational levels. Processes include experience accumulation, knowledge articulation and knowledge codification.

- Organisations can have a memory, but it needs cultivating. Knowledge has to be embedded within a complex range of entities, including organisational culture, routines, policies, systems, documents, as well as individuals. It requires a knowledge infrastructure – a web of connections, tools and encouragement among people and the technical systems to interact and collaborate over time and space (Alavi and Leidner, 2001). This memory is also intricately related to organisational routines, and the intimate social or collective understanding of ‘who knows what’ (Ren and Argote, 2011).

- Communities of practice play an important role in learning and knowledge transfer. Communities of practice (CoP) have become an increasingly influential model of learning within organisations (Wenger et al., 2002). It must be noted that this is a distinctive learning context, and differs from traditional notions of learning (such as
teacher student). It involves learning via participation in a community, which takes responsibility for a specific learning agenda. They may be defined in broad terms, such as large defined professions where participation is structured and may lead to becoming an accredited member of a community. However, it may also be conceived via a narrower view, including small tight knit groups with a more specific focus (Rowley, 2007). Individuals may belong to a variety of CoPs, and learn from crossing the boundaries of those different CoPs.

Before moving onto the investigative elements of the project, a few core ‘lessons learned’ concepts are summarised. Lessons learned are an important part of the knowledge debate, especially in construction projects, where the term is widely used and recognised. Some key features of our understanding of how lessons are learned is summarised below.

- **Processes can be put in place for auditing project learning** – Schindler and Eppler (2003) identify four key processes in project auditing for the purposes of knowledge management: the project review or audit, postcontrol processes, post project appraisals and after action reviews. The first two phases focus on the particular project of interest and the latter two phases concern the broader mission of learning from mistakes and knowledge transfer to other scenarios. These processes may be conducted in a range of formats, which are covered in the following item.

- **Lessons learned can be undertaken in a systematic and structured way.** Studies show that it is possible to implement a systems approach to lessons learned, finding that behavioural differences, reduction in rework, and safety improvements can be obtained (Duffield and Whitty, 2015; Duffield and Whitty, 2016; Love et al., 2016). However, knowledge across people and system elements of an organisation need to be carefully aligned and structured (Duffield and Whitty, 2016).

- **Narrative forms may help to capture learning in complex environments.** A range of studies have argued that narratives are more effective in complex environments (Williams, 2008). Testimonies and interviews suggest that staff would prefer to hear a few first-hand accounts of similar situations to the problems they are trying to solve, rather than to work through documentation (Snowden, 2002). In particular, learning diaries, oral stories, project histories, micro narratives, mapping and collective brainstorming and stories appear to be more important to deriving enduring lessons from projects (Schindler and Eppler, 2003; Williams, 2008). This also includes visualisations, video diaries and documentaries, and a range of types of written stories.

5. Analysis and Findings

5.1 Industry Barriers and Challenges

The intention in this section is to establish the broader industry challenges and perceptions of lessons learned, according to different type of organisations. To do this we report the findings of an interactive workshop, hosted by Constructing Excellence in Cardiff (See http://www.cewales.org.uk/events/event-presentations).

The first question debated in the workshop was:

*Why is it that we still don't seem able to do “lessons learned”, and then apply those lessons into future projects?*

Thoughts by subgroups were recorded on flip charts, and were then debated as a whole group with the help of a facilitator. They have subsequently been categorised in Table 1.
<table>
<thead>
<tr>
<th>Theme</th>
<th>Processes and Systems</th>
<th>Technology</th>
<th>People and Culture</th>
<th>Financial and Commercial</th>
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</table>
| Practical inhibitors | - Unsure of who is responsible and/or accountable for learning  
- Unsure how to share the knowledge effectively and what the lessons should be shared | - Lack of sharing mechanisms within teams, organisations, and projects  
- Closed information systems | - Lessons are distributed across the supply chain  
- Fear of professional embarrassment | - Too busy doing the day job  
- Pressure for delivery and the need to move on to the next project |
| Resource inhibitors | - Incomplete project reviews due to lack of resource and/or incentives | - Who pays for infrastructure for knowledge sharing? | - Lack of continuity of teams and people  
- Lack of skills and knowledge champions | - No budget for lessons learned and carryover from project to project |
| Industry Inhibitors | - "Pigeon holing" of improvement initiatives  
- Knowledge not within typical job descriptions / remit  
- No process that stipulates need to consider lessons learnt  
- Lack of formalized methods for sharing lessons learnt | - Lack of tools for diffusion, adoption and communication of knowledge | - Lack of a long-term collaborative working  
- Fear/blame culture  
- Lack of open and honest culture  
- People not 'allowed' to fail  
- People don't like concept of failure but focus on success  
- Lack of senior level priorities / sponsorship  
- Lack of examples  
- Lack of proactive steps by larger clients | - Lack of focus on learning legacies in budgets  
- Lack of understanding of value of lessons learned  
- Perceived reputational risk  
- Barriers to sharing due to competitive / power advantage |
| Mitigating Measures | - Building lessons learned into stage gate and/or governance models  
- Better governance of supply chain  
- Simplify processes | - Improve contractors design capability  
- Improve transparency of lessons learned through open systems | - Continuous improvement mindsets throughout the project stages  
- Collaborative approaches, and honest dialogue  
- Training and champions for lessons learned | - Clients lead by example and procure effectively  
- Incentivize learning and knowledge sharing |

Table 1: Inhibitors of lessons learned with mitigating measures

The second question was:

How do different industry organisations and roles across the industry perceive the issues and solutions with respect to lessons learned?

The workshop participants were divided into groups, based on their role within the industry to discuss the issues, and potential solutions, with learning lessons. There were four groups - Clients, Contractors, Consultants and Others. The emerging view of each is characterised below.
Clients’ view:

There was a level of frustration expressed that there is no systematic extraction of all the learning from previous projects for use in the current projects and programmes. However, clients acknowledged some of the challenges in making this a reality. Further, there was discussion around the extent to which the regular versus ‘once off’ clients can influence the knowledge and learning dimensions of a project. The latter group, in particular, may find it difficult. The need for continuous improvement mindsets throughout the project stages was highlighted, as well as the need for collaborative approaches.

Contractors’ view:

Contractors noted the main issues as lack of an agreed systematic approach, lack of early client / contractor discussion, lack of fruitful discussion between departments, no clear resource for learning lessons and carrying forward learning, and a skewed focus on what went wrong, or what did not go right. The view was that Clients do not take enough ownership of this critical issue. Suggestions for improvement included training and champions for lessons learnt, and building lessons learned into stage gate and/or governance models. Overall, there was agreement that there is a need for honesty in discussions over knowledge sharing (on perceived risk/personal risk/commercial risk), and regular dialogue with the client (i.e. not just one meeting at the end).

Consultants’ view:

Consultants began by questioning the level of transparency in learning between consultants, since this can often be a source of competitive advantage in the tendering process. This is a difficult commercial tensions to manage. There was also agreement that more could be done to share lessons across sectors and across knowledge workers. It was observed that many lessons that are shared tended to be technical learning. With regards to clients, the general view was that procurement processes do not encourage the sharing of lessons, and that clients rarely seem to lead by example and learn lessons for themselves. Cost was also identified as a key driver, rather that knowledge or learning that can be offered. With regards to contractors, there is a tendency to proceed without depth of understanding of the project documents or brief, and clear definitions of value, leading to problem further down the line. Better design management capability across contractors and subcontractors would allow more learning and knowledge to be fed into value engineering processes. Further, more active and controlled management of the supply chain would allow for innovative ideas to surface.

Others’ view:

Comprised, for example, of representatives from third sector, logistics, and academic organisations, this group noted the consistency of ‘black holes of information’, overcomplicated or non-existent processes, the lack of time to properly reflect on lessons learned and their meaning, and the unwillingness of many across the industry to share valuable lessons outside of close teams.

5.2 Highways England’s Knowledge System

5.2.1 The Current System

Figure 1 presents an ‘input-output’ diagram of the current explicit HE knowledge system. This was developed through the sources of evidence explained in Section 2.
Figure 1: Mapping the HE knowledge system
It is possible to see major sources of learning and knowledge flowing from a current project into various repositories. The figure shows flows of learning and knowledge derived from defined processes, moving into the various repositories used by HE and its supply chain. Each repository is shown as a ‘black box’ with inputs flowing in and outputs flowing from it. The figure then shows how (or if) learning and knowledge flows into other ongoing projects or future projects.

While these repositories and flows may traditionally have been considered as distinct work activities, this report will make the case that it would help to view these flows as connected, integrated work activities that all contribute in some way to the wider system of learning and knowledge. Building on research by Wang et al. (2011), the repositories of knowledge have been categorised as either open access, shared (but over a private network – i.e. by invitation only), and closed (i.e. only one organisation can access it).

Key processes and repositories can be summarised as follows:

**Project Control Framework (PCF) and SHARE** – The PCF establishes the governance framework for projects, and includes learning logs, lessons learned registers, and NCR reports, which should be logged on HE’s SHARE system during the various phases of the project lifecycle.

**The Knowledge Bank and The Lean Tracker** – these include lean improvement projects (written up in DMAIC or A3 format for the tracker), or improvement projects submitted to the knowledge bank.

**Efficiencies** – pressures to report efficiencies have increased through the ORR and the Road Investment Strategy (RIS1). Hence, these are now recorded at a range of levels. The detail of the approach and the requirements have been published by HE in the Efficiency and Inflation Monitoring manual, which can be found at the link below.


Within the HE knowledge system, efficiencies are reported at project, regional and central levels in the form of efficiency registers. Initiatives are underway by central teams to further analyse these and develop a series of efficiency manuals.

**Departures Approval System (DAS) and the Design Manual (DMRB)** – the technical system DAS logs and tracks requests for departures from the standards set out in the DMRB. At the time of writing a new version of DAS (DAS 3.0) is preparing for launch, which will have some process changes and an updated software platform. Departures must be analysed and approved by technical teams before they can be approved, and if there is a pattern of departures these may be considered for more systematic changes to the DMRB.


A general observation is that the output flows from many of the repositories can be best described as ‘user led data mining’. Ultimately, this means that to extract any learning or knowledge from the system, a person will have to spend time searching through the various systems with some target learning in mind. Very often users will resort to their informal network, just ask questions and extract tacit knowledge. This is fine, but it assumes that a) there is an established informal network and b) people know who to ask. In some cases, for
instance with new starters, this may not be the case, and, further, expertise is notoriously difficult to catalogue and define.

The problems observed in the learning and knowledge system can be summarised as below. It is possible to see that they link closely with the typically observed problems in Sections 2 (i.e. theoretically noted problems) and 3 (i.e. those observed in the constructing excellence workshop). While there are significant barriers in overcoming these issues, and in some cases there may be no immediate solution, the role of this report is to develop a candid assessment of the deeper structural problems.

- Islands of excellence exist in terms of learning and knowledge projects, but there is no overall systematic approach or strategy to learning lessons. Further, there is a lack of a formal strategy to bring together and connect the threads of learning across time and space.
- Many legacy systems are closed, or private, rather than open and accessible. Hence, lessons are not open, transparent and available to those that would like to learn.
- There is little emphasis (or budget!) for legacy building and industry learning.
- Too many repositories have overlaps, so that there is likely repetition in production of knowledge, and also this adds to confusion about where to look for relevant learning. There are also unconnected processes, pioneered by different areas of HE and the supply chain, which are trying to achieve similar things.
- The search for relevant knowledge is difficult. There are black holes and an over-reliance on user led data mining.
- There is a fear of sharing sensitive information.
- Knowledge management and learning must compete with resource demands from many other initiatives and priorities.
- Much of the experiential learning resides in people’s minds, but is scattered over time, place, and the supply chain.

Figure 1 does not cover the various Communities of Practice (CoP) within HE’s knowledge system. HE, along with help from the supply chain, has established and facilitated a number of effective CoP. Within the scope of the project, it was not feasible to map all of these, and their respective roles and modes of working. However, building on the interviews, selected groups are summarised below for illustrative purposes, and some reflection is offered relating to the challenges, the way that knowledge and learning is developed, and positive results flowing from these groups.

- **The pavement efficiency group** – this community builds from previous work undertaken in the category management framework. It started out using the value chain plan approach, and building on ongoing work achieving efficiencies. The group helps analyse the market, what could be done differently, what is recognised as good practice, and the joint issues faced. It includes representation from CIP, SMP, regional programmes, finance, technical standards, design, and supply chain tier 1 as well as tiers 2/3. Notable successes have included improvements in the working window, and the management of standards. Work generally proceeds through workshops and subgroups focusing on particular issues (e.g. contracts, materials), and work has been undertaken to showcase efficiency ideas, and through the development of efficiency guides and manuals. The challenges for this group are to ensure the key messages right are diffused right across HE, and finding the appropriate levers of impact. Some outputs from this CoP are documented in SHARE.

- **The engagement council** – this is the primary forum for collaborative engagement between Highways England and its supply chain. This community is open to any member of the supply chain, but does have elected representatives who are tasked with taking forward specific
issues and commitments. There are a range of subgroups (e.g. Health and Safety, Productivity), which seek to promote innovation, improvements and good practice.

Peer-to-peer communities – There are a number of structural and technology peer to peer groups across HE. These include, for example, structures and geotechnical communities of specialists that meet to collectively discuss discipline issues, opportunities and risks across projects and programmes. While the technical remits vary, such CoP generally focus on resolution of common issues, management of common risks and the collective identification and planning of improvement opportunities. Key areas include developing technical specifications, standardisation and optimisation. Peer to peer groups typically upload their notes and working to Business Collaborator.

Lean community – the lean community at Highways England has formalised elements and less formal elements. For example, HE has published a lean strategy document (https://www.highwaysindustry.com/wpcontent/uploads/2016/04/Lean_Strategy_Document_2015-2020__2_.pdf) and has established the Lean Group within the Innovation and Continuous Improvement Division (ICID) who are part of the Safety, Engineering and Standards Directorate (SES). It has been responsible for developing a wide range of tools and techniques and support structures, including a structured methodology for sharing ‘knowledge transfer packs’. The division has worked hard to encourage the adoption of lean across the HE supply chain, offering support and tools for suppliers to adopt lean principles. Through the lean practitioner community, a network of specialists with interest in lean has been established, which is galvanised through a range of HE lean practitioner community events, as well as a range of micro groups which come together to address specific problems. The lean tracker has been established as a repository and efforts are being made to raise its profile.

As can be seen, many positive learning and knowledge transfer activities are undertaken within CoPs. This is a particularly good way of moving beyond project and organisational boundaries to discuss common issues and areas of practice. While CoPs are acknowledged as a very effective source of learning and knowledge transfer, the following issues were highlighted from the interviews in relation to CoPs. These have been aggregated and anonymised to enable more general points concerning CoPs in HE.

- While it is possible for an individual to be part of many CoPs and evidence that innovation can derive from this, there is a danger that there are so many forums and groups that it is either overwhelming and/or confusing as to which group to attend.
- The engagement points and methods for groups to interact with the broader HE knowledge systems and individual projects, as well as the different routes to market, is not clear. Should there be formalised points of engagement (e.g. through the control frameworks), or should the groups work informally?
- “We all have day jobs on top of this...” There is a difficult balance to be struck in terms of allowing time for everyday roles and responsibilities, whilst also allowing freedom to pursue collective reflection on issues that may yield very large system level improvements and hence huge gains towards hitting efficiency targets.
- Relevant people and knowledge needs to be suitably directed to the relevant discipline and groups. One view expressed was that specialist disciplines work well in spreading and developing knowledge, since they do not have to go up and down bureaucracy levels and speak directly to technical specialists. However, there is always a difficulty of getting the right membership and representation within the various CoPs.

Figure 2 shows selected CoPs mapped onto the HE knowledge system. It is interesting to consider CoP overlaying the infrastructure of the processes and repositories of the knowledge system. They take input from, and feed into it, in different ways. Through informal social networks, there is also a potential link to future projects where CoP are able to pass on tacit knowledge to members of new project teams.
Figure 2: Communities of Practice and the Knowledge Infrastructure
5.2.2 Ongoing HE initiatives

The CIP Team has acquired significant learning on the A14 project, and there is significant learning from this activity that can be captured and translated for other CIP projects. This has been recognised within CIP and a number of projects and initiatives have been put into place to facilitate knowledge sharing. A high level process has been developed, and this is being evaluated and assessed. This will focus on multiple areas, including people and behaviours, as well as processes and systems. Key characteristics include:

- A structured approach to learning and knowledge
- Proactive lessons learned capture and dissemination
- Knowledge sharing culture and behaviour embedded into the “way we work”
- A central repository with easy to find information fully accessible to HE and supply chain
- Identifying hot topics and understanding the potential benefits and value of our learning.
- Create a ‘blueprint’ for a standard approach to knowledge sharing and learning across complex projects.

At a practical level, current initiatives have begun, which experiment with case studies, HOW2 guides, 1 to 1 knowledge sessions, facilitated knowledge management workshops, and developing I.T capabilities.

5.3 Building Blocks for a Future Knowledge System

5.3.1 Principles for reimagining the system

We propose that the knowledge management system should enable “Better learning within projects, between ongoing projects, and transfer to future projects”. This vision is visualised in Figure 3. Learning must be acquired from current projects, allow feedback into ongoing projects, but also facilitated so that it can feedforward into future projects. As shown in Figure 3, this must acknowledge the different phases of project learning, as well as the need for analysis and adaptation of knowledge for different contexts along the way.
In striving to achieve this vision, a selection of principles can be used to establish the context for any recommendations.

- Link projects (and subprojects) through strategic long term goals as a context for transfer of knowledge.
- Commitment by leadership across the industry to support, encourage and endorse knowledge sharing endeavours.
- Open systems that enable the right people to find the right lessons.
- Incorporate innovative forms to capture lessons. In complex environments, it is increasingly acknowledged that narratives/visual based collaborative lessons learned exercises are more effective in capturing and transmitting learning.
- Enable, support and encourage CoPs.
- Promote ‘information to wisdom’ transformation. Facilitate personal development, learning, reflexivity, and journeys. Facilitate learning behavioural patterns and mental models.
- A systems approach, which connects people, processes, technology, and financial/commercial to an overall knowledge system. Where possible structures and strategies should link people to the whole system, rather than reinforce disconnectedness.

5.3.2 Stories, Narratives, Analogies and Risk
Forgetting is a common problem in organisational life. Memory loss is particularly pertinent to complex infrastructure projects where teams are created then disbanded, and organisations, teams and individuals move on to new challenges. An interesting analogy can be taken from therapy for dealing with human memory issues. For dementia patients and adopted children, memories are often facilitated by a ‘life story book’. The life story book organises information so that individuals with memory problems can review, recall, reflect and organise their experiences, usually with help of family members, carers and friends (Shi and Setchi, 2013).
It represents a cross between a diary, a photo album, a scrapbook, memory box, and a folder. Various benefits have been reported for a range of stakeholders: patients (enjoyment and increased reminiscence), relatives and friends (shared meanings, stimulation, basis for conversation), and staff (greater understanding of patient).

These have been used as the basis for user-oriented expert systems to create digital life stories based on an ‘ontology’, which acts as the structure to classify, cluster, and model information. A dynamically generated story like output is generated, which can help with recall and reflection (Shi and Setchi, 2012). Fundamental to this is developing a knowledge base. Every knowledge base is committed to some form of conceptualisation. An ontology is an explicit specification of this conceptualisation (Gruber, 1995).

Narratives, e.g. accounts or images of events, are particularly pertinent as we relax common assumptions in project planning and risk management of a well-ordered world that is analytically tractable, where cause and effect is precisely known and predictable. Social science research suggests narratives help managers make sense of the world but are difficult to archive and retrieve. Senior managers when solving problems commonly use analogical reasoning, allowing a current ‘target problem’ situation to be compared to a valid previous experienced ‘source problem’ from which a potential set of ‘candidate solutions’ may be identified (Gavetti and Rivkin, 2005).

Having set out the principles for such an approach, it is possible to reflect on how this may be used to reflect on potential implication for HE. This will require:

- Sense making of the underlying structure of explicit and tacit knowledge at HE to create an ontology
- Promoting the idea of ‘story book’ approaches to organise information so that individuals and project teams can review, recall, reflect and organise their experiences of a project.
- Clearly identify the types, linkages and formats for explicit documented knowledge to be sorted.
- Create a process for developing a storyboard of opportunities and risks to feed into future projects.

Figure 4 shows a potential conceptual outline or schema for a project story book. It shows the potential sources that may inform such a story book. An important addition is the narrative and reflection category, which build on some of the conceptual foundations introduced at the start of the report, and will be returned to in the final recommendations.
Finally, there is a need to link such an approach with opportunities and risk processes, so that stories, narrative and lessons can feedforward to future projects. The outline for a process to do this is given in Figure 5. This will require a core ontology consisting of interrelated entities consisting of opportunities, risks, events, places, and people, which all describe a project i.e. the sources of input highlighted in Figure 4. Then, a tool that processes narratives will be required, that also captures semantics associated with visual forms, and attaches them to entities within the ontology. This will facilitate the creation of idealised opportunities / risk registers of previous projects and compares them to those opportunities / risk registers that were actually developed, leading to the establishment of an opportunities / risk register for a new project based on the new scheme features.
6. Ten Key Recommendations

6.1 Project Learning

At the project level, initial activity should focus on streamlining and building on existing processes. The lean teams have some well-defined continuous improvement processes, which are linked to the lean tracker. The efficiency registers also offer another mechanism for reporting of improvements, as well as the knowledge bank. It would help to streamline these processes to reduce repetition and demands on employees to report in various places on a project by project basis. Hence, **Key Recommendation 1 is to streamline the number of repositories and standardize the approach to learning and knowledge capture.** Specific suggestions are as follows:

- Reflect on the naming conventions for the filing of lessons learned, continuous improvement and efficiency initiatives. A standardised structure to underpin efforts will help to identify patterns and facilitate access to these patterns by others.
- The lean tracker, knowledge base, efficiency registers and other knowledge repositories are doing similar things. Hence, it is possible to streamline repositories and their linkages so there is a central point of contact with a reduction in administration for those reporting.

The auditing structure for lessons learned could also be re-thought. Formally, there are records and lessons learned reports associated with a PCF product. However, the quality and utility of this is variable, and the format makes it difficult to see how these may be used in the future. In addition, organizations or JVs within the supply chain, sometimes create their own systems to develop lessons learned, but these are usually private/internal systems. It would be helpful for the whole supply chain and broader knowledge management mission to reflect on the PCF products associated with lessons learned within the major projects domain. For those outside of major projects domain, further reflection on broader governance frameworks, such as gateway reviews, stage gate assessment reviews, and the operations lifecycle, is required to ensure that lessons learned are captured and prompted at appropriate points. **Key**
Recommendation 2 is to modify governance frameworks to include a structured, systems-based approach to learning lessons, which builds on innovative forms of knowledge capture. Specific suggestions for reflection on the PCF include:

- PCF products early in the project cycle that relate to previous learning (i.e. nudge teams to look back at previous learning during the early parts of different project phases)
- The structure, timing and frequency of project audits, considering the inclusion of project story book approaches, micro narratives, oral narratives and visual forms, which could be linked to PCF products.

There is also the incentive structures to include time for reflection, learning and a culture that promotes the spirit of inquiry. It is clear that this task extends beyond the boundaries of HE, and is influenced by organisational performance systems and professional memberships. However, there are initiatives that HE can undertake. Key Recommendation 3 is to incentivise and raise the profile of learning and knowledge as a strategic capability for industry. Specific suggestions include:

- Promote the importance of learning and knowledge in achieving efficiency targets (this could be undertaken through a formal strategy – see later recommendation).
- Instigate projects to better showcase and understand the value of lessons learned and knowledge management initiatives.
- Encourage collaborative knowledge sharing across a project team. This may require reflection on how performance measures, contracts and HR practises incentivise the production of learning and knowledge throughout the supply chain.
- Client leading by example and giving staff time, incentives and workload allowances for innovation, learning and knowledge sharing.

6.2 Knowledge Feedback to Existing/Ongoing Projects

Moving from learning within a project to transfer across other ongoing projects is no easy challenge. Recommendations in this category, therefore, focus on how structures and communication of learning gained on a project can be improved. Clearly, there will be more scope to do this with projects that are linked (e.g. SMP) or within an overall programme of work.

Organising the structure of learning and knowledge management within overall programmes and routes to market will be important to understanding knowledge transfer between relevant projects. Hence, Key Recommendation 4 is to form knowledge champions within existing routes to market. These champions should have access to multi-disciplinary teams and CoP to facilitate their work, leading to better communication of learning. Following on from this, Key Recommendation 5 is to increase visibility and transparency of learning that is taking place. Specific suggestions for this include:

- Build on the consolidation of CI initiatives, streamlined repositories, and standard naming conventions to develop open systems for the supply chain and industry.
- Encourage proactive feedforward communication activities through alerts, CoP, narratives. This may involve redesign of processes to prompt project teams at the outset of developing an opportunities / risk assessment to interrogate existing knowledge.

To bring recommendations 4 and 5 together in a strategic approach, Key Recommendation 6 is to develop a strategy, which is linked to long term goals such as learning legacies and the strategic imperatives. This strategy should help to establish the context and top
level support for learning and knowledge sharing, as well as to give a high level purpose and structure to more micro-level initiatives, single projects and programmes. Examples of legacy learning sites include Crossrail (https://learninglegacy.crossrail.co.uk/) and the 2012 Olympics (https://webarchive.nationalarchives.gov.uk/20180426101359/http://learninglegacy.independent.gov.uk/)

6.3 Knowledge Feedforward to Future Projects

Finally, there is the challenge of knowledge transfer to future projects. The difficulty here is that knowledge can become lost in time and space. Hence, recommendations for this category need to be more radical, more strategic and more extensive in their scope. The first two recommendations in this category are concerned with processes and IT. **Key Recommendation 7 is to analyse patterns and synthesize the knowledge base to create an ontology which can provide a platform for innovation.** This will require, firstly, central or aggregated analysis of lessons learned, continuous improvement initiatives, knowledge assets, as well as any standardised naming conventions for learning, to enable categories of knowledge to emerge. This will allow for the identification of an underlying structure of the knowledge base. This, in turn, can be used to create a dynamic digital approach to retrieval of narratives, learning and relevant knowledge. Such a digital system could then be used as a basis for a more sophisticated risk planning approach. Therefore, **Key Recommendation 8 is to use the knowledge base to feedforward into the opportunity and risk planning of new projects.**

The final two recommendations are concerned with people, teams and culture. Since much of the knowledge in complex engineering projects is tacit, socialisation processes and consistency of teams is importance. Hence, **Key Recommendation 9 is to strive for consistency of successful teams across projects.** Where this is not possible (the authors understand that this is not always achievable, for a variety of reasons), mentoring and CoP may make it possible to transfer knowledge through socialisation across project teams. Finally, **key recommendation 10 is to empower and connect CoPs and working groups.** This will require tolerance and space for reflective practice across the supply chain, a longer-term investment in people and learning, building of the web of relationships, as well as the expertise and leaders that CoP need to function. At a more strategic level, some reflection may also be required regarding the boundaries, interrelationships, extent of formalisation, and resources available to CoP.

7. Systems Change and Priorities

As shown in Figures 1 and 2, HE’s knowledge infrastructure consists of links between processes, repositories, people and multiple CoP. There are clear examples of islands of excellence in relation to learning and knowledge. In particular, the ongoing efforts within CIP to capture learning across complex projects, and the continuous improvement structures established by the lean community, have clearly gathered momentum. The former has established good impetus across the supply chain, and the latter has focused minds within HE. Through the work presented in this report, it is also possible to see the many and competing system wide barriers and inhibitors of effective learning and knowledge management.

Figure 6 provides a summary of the key recommendations (KR). They are articulated across a spectrum of longer term/high intensity investments and shorter-term, lower hanging fruit. The KR have been classified as either primarily technical, process, people or financial. We should make clear that for simplicity, the KR have been classified under just one term, but
in fact some of the KRs (e.g. KR7, KR8 and KR9) will require considerable redesign of processes and a change in people’s attitudes.

![Figure 6: Summary of Key Recommendations](image)

**Figure 6: Summary of Key Recommendations**

We agree with Williams (2008), who asserts that “learning in complex systems needs a more sophisticated approach than simply writing down lessons” (Williams, 2008, p253). Hence, overall coherency, purpose and structure, along with reflection on the overall knowledge system, is needed. Table 2 identifies the different ‘systems levers’ that can be considered to bring about change with the KRs from Figure 6 included. In addition, they have been linked to the aforementioned vision of better learning in projects articulated in Section 5 and more specifically in Figure 3: feedback to ongoing projects, and feedforward to future projects.

A key part of enabling change through these systems levers is the creation a new learning and knowledge management strategy to legitimise the approach. This should also link to the strategic imperatives of HE, the systems levers highlighted in Table 2, and the future requirements of the efficiency programme. The capabilities for each element of the vision are envisaged as building blocks, leading to greater capability to establish foundations for the longer term recommendations. A foundational activity to establishing this capability building will be the development of a strategy, which is informed by this report and other relevant work threads and endorsed at leadership level.
Table 2: Summary of recommendations to achieve vision across different system levers

8. Concluding Remarks, Overall Reflections and Future Work

8.1 The commercial and tendering context of knowledge sharing

The issues flowing from a competitive commercial environment are well established in the academic literature and industry discourse. This poses particular problems for knowledge sharing, since competitive tendering activity can 'encourage' the organisations to become protective of their acquired knowledge and competence. Hence, it is important that the right business context is established by project sponsors and clients to encourage the right behaviours. If done well, it is possible that organisations from across the supply chain can work well during projects even when teams are drawn from organisations who otherwise can be in competition. This, typically, relies on longer term thinking and frameworks, along with more collaborative mechanisms to support relationship development. CoP and informal networks help to overcome some of the potential for knowledge sharing across organisational boundaries, but the final vision is reflected in KR 9, where successful teams can sustain memories and learning, but also contribute to ongoing stores of knowledge for others to exploit.

8.2 The storybook approach: challenges and next steps

The storybook approach, as outlined in this report, holds much promise but does present some challenges. First, there will initially be a need for a recognised resource to act as a focal point for collection and collation of knowledge, and to ensure that it is managed in a structured
manner, there will be a resource implication. Hence, specific roles related to knowledge management will need to be created and justified. Creating a cataloguing and categorisation logic for the creation of knowledge ontology specific to the domain of civil engineering or HE will be a significant undertaking and will require further fundamental research. However, we envisage that long term, with an established ontology and I.T. infrastructure, knowledge can be managed in a more autonomous way.

8.3 Knowledge Management, Systems Change and Human Centric Approaches

The ten Key Recommendations set out in this report, and systems structure for their implementation (i.e. Table 2), should provide a starting point for the establishment of a strategy. As a network operator and steward, this project has considered the higher level imperative to make serious efforts towards the creation of a learning legacy. It has also considered the role of knowledge and learning in creating efficiency savings and capacity for scaling up even small innovations across projects. We believe that the findings give insight into the knowledge infrastructure that underpins project learning, and contributes to HE’s understanding of the dynamics of interactions between different system elements.

Returning to the title of our report, we consider that engineering work is of a complex nature, requiring human problem solving, collaboration and ingenuity. Hence, knowledge management endeavours should keep this at the forefront of any systems change. CoP, as well as narratives, storybook and storytelling devices will be important in communicating and transferring the type of tacit forms of knowledge that are critical in this domain. Hence, the configuration of human-centric elements with the ‘harder’ knowledge infrastructure, such as processes and technology, will be important in order to capture and transfer knowledge effectively. Further work could seek to identify how the governance approaches that exist in different directorates and areas of HE organise the human, process, technology interface.

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10. References


