LEAN PROCESS BENCHMARKING ACTIVITIES AND LEARNING

REPORT JULY 2022

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EXECUTIVE SUMMARY

This report has eight sections but covers three subjects, each related to productivity improvement.

1. In section three we carry out a direct benchmark comparison of the delivery model between a lean exemplar non-profit construction client and National Highways. The performance of the exemplar organisation is extraordinary and could not possibly have happened by chance. We begin to explore the key differences and point towards what could realistically be achieved in the future.

2. In chapters four and five we discuss how to measure productivity using reliability metrics as surrogates. Together with a case study of learning from a live project. We conclude that until we can grasp and apply the wider systemic changes discussed in chapter three, simple solutions are at least or more effective than heavy investment in technology.

3. In chapter eight the issue of utility diversions as a source of delay and waste is examined in depth. We calculate that a minimum of £2bil pa is wasted due to widespread failure to effectively manage this complex process. We highlight areas of best practice for consideration.

ACKNOWLEDGMENTS

We wish to thank key contributors to this report. The work would not have been possible without the support of the National Highways Lean Team, in particular Stephen Williams and Martin Bolt.

Thanks also go to Paul Ebbs at SMP Alliance, Alan Mossman of the Change Business and Andrew Moore of Rubicon Wigzell. Special thanks also to Peter Crossland and Paul Santer from the Civil Engineering Contractors Association for their help with the utilities study.

Thanks also to the staff and suppliers of Balfour Beatty and Costain Group for their willingness to contribute and proactive help.

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DEFINITIONS/ABBREVIATIONS

Lean construction – An approach to the design, construction and maintenance of the built environment based on a FLOW production system.

Last Planner TM – A production control system that seeks to improve the reliability of workflows.

Collaborative Planning – Another name for Last Planner

SPC – Statistical Process Control

ISO18404 – The Global Standard for Lean and Six Sigma

Six Sigma – an improvement methodology based on the reduction of variation

Value added work – work that happens correctly and changes something in form function or shape in line with customer requirements.

Support Activity – activity that must be done in order to allow value added activity but nothing really changes

Waste – Any activity that is not Value adding or Support

Target Value Design – a collaborative approach where an integrated team of designers and constructors design to a target cost

Big Room – a place where different project delivery stakeholders are physically co-located

A3 thinking - A lean means of communication using A3 sized single page reporting

Integrated Project Delivery IPD – an organisational structure that includes all key delivery partners working to a single profit pot under the same contract

Direct Observation – A techniques for capturing improvement opportunities

1. LEAN PROCESS BENCHMARKING

1.1 INTRODUCTION AND CONTEXT

Lean process benchmarking is simply performance measurement viewed through the lens of lean thinking. Classically we could form a lean benchmark by calculating a ratio of value-added activity to waste in a given process or task.

What is a value-added activity?

Value from a lean perspective relies on delivering what is important to the end user of the product or service. Traditionally this can be expressed in terms of cost, quality and delivery, but other metrics have become increasingly important such as zero carbon and circular economy performance.

In the context of Lean Thinking process improvement, an activity directly adds value if – Something changes in shape, form or function in line with what the customer wants. So for example if tarmac is being placed or compacted and the work is correct, value would directly take place. Measuring, ordering and transporting the material would be regarded as a necessary waste that cannot be avoided but should be minimised. Anything else that happens in the process that does not meet these criteria is avoidable process waste. It is not unusual to find that less than 20% of elapsed time is spent carrying out directly value adding activity.

For example, if it is known that the process time to fit a window is 2hrs for 1 person, and there are 3 persons working full time on this task for 7hrs work time per day and a 5-day week. We might expect to calculate a total capacity of 3 persons Xs 5 days Xs 7hrs = 105hrs per week. Therefore, working optimally, we should be able to fit 52 windows per week. If only 26 are fitted, we could express a value to waste ratio of about .5 or 50%.

Within the above equation would exist necessary waste of measuring, marking, transporting materials etc. In fact a 50% value to waste ratio would be pretty good in construction!

Whilst this simple methodology can be highly effective in appropriate circumstances, and provide valuable and realistic targets for improvement, most construction projects are complicated by the "peculiarities" of the construction sector. These peculiarities need to be considered when trying to apply lean thinking. One cannot simply uplift car manufacturing techniques and expect success in the construction sector, the approach must be tailored. Specifically, some of the key differences between the construction sector and manufacturing we need to take into account are:-

Fixed position manufacturing

- The resources of people, machines and materials move across the product, rather than the product moving across the resources. Shipbuilding is probably the closest manufacturing gets to construction in this regard.

Rooted in place

- Whilst elements can be fabricated offsite, ultimately the building or structure will be in a fixed immovable location. This means that a variety of local conditions must be considered.

One-of-a-kind production

- Construction is more like new product introduction than actual manufacturing. The majority remains bespoke, requiring new or adjusted designs and specialist suppliers procured on a project-by-project basis

Temporary organisations

- Due to unstable demand and bespoke projects, construction work is carried out by temporary organisations.

It is assumed here that the term "benchmark" means a derived performance metric for a construction project based on comparison of similar projects. Usual metrics will relate to cost, time, quality, health & safety, and environmental impact. Lifecycle cost will also be a key consideration.

The ability to benchmark accurately and "compare apples with apples" may be difficult but very useful to industry, facilitating improvement targets and enabling better planning of capital spend. Some very good results have been realised in the last decade in the new build hospital programme in California USA using Target Value Design. This methodology relies heavily on the availability of benchmark cost data.

There is a great deal of research surrounding labour productivity, which is taken to be the biggest identifiable cost variable, however most of this appears insufficient to advise what needs to be done. This is because it does not progress to root causes but rather focuses on symptoms such as "Lack of materials, lack of planning, lack of supervision, lack of skills, lack of information" to name a few. From a lean construction viewpoint, we can summarise most of these problems as "the waste of making do" where it is attempted to start tasks before they are ready to start. In addition, it is tacitly accepted that these problems exist as an integral part of our industry, and it is the construction managers' job to deal with them.

Rather than making do, changes to the organisational systems that caused these problems in the first place is the required focus.

Here we are concerned, not with the efficacy of the benchmark process itself, but rather with the key causes of variance to project targets whether they be based on a benchmark or not. Lean construction techniques have been researched and applied in practice over the last thirty years or so and a body of knowledge has been built during this time by the Lean Construction Institute in the USA and the International Group for Lean Construction. Both organisations have focussed on researching and implementing techniques that result in superior project performance when compared to "usual" practice.

It is known that projects with a high lean intensity are three times more likely to finish ahead of programme and twice as likely to complete within or below budget. (LCI USA)

High Lean Intensity is defined as using the following techniques.

- Co-Location Big Room
- Target Value Design
- Prefab/Modularisation
- Full-Team On-Boarding
- BIM
- A3 Thinking
- Last Planner System

Initially the Lean expertise from University of Dundee was asked to consider the question:-

"Given that benchmarks of performance could be obtained, what would / could cause variance to these from a Lean Construction Perspective?"

From a process perspective the answer is simple & straightforward. The graphic below shows a simple process model that considers how continuously aligning and improving the process inputs of labour, materials, information, and methods will result in measurable improvement in cost, quality, and delivery.

The Plan, Do, Check, Act (PDCA) Cycle

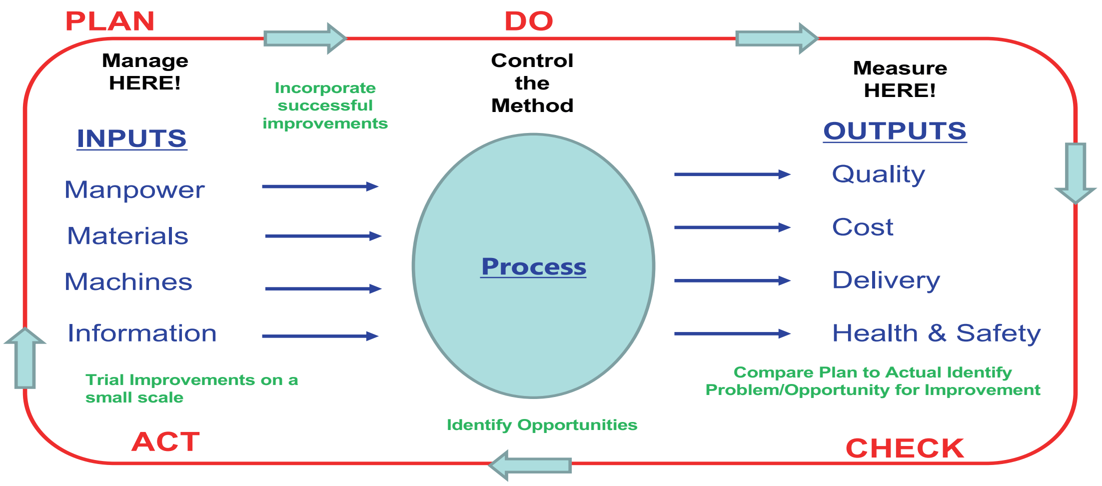


Figure 1 Simple Model for Continuous Improvement

The extent to which these process inputs are effectively managed will in effect provide the resultant measured performance.

However, in construction we must consider wider systemic issues if real improvement is desired. Some of the key systemic factors affecting project performance (benchmarks) from a lean perspective include: -

- **Lack of a clear client brief.** Failure to properly define and articulate the client brief has shown to link directly with out-turn cost and programme performance. A "Project Definition Rating Index" tool exists, back by research from the Construction Industry Institute in the USA, that shows a clear correlation between the extent to which a project is properly defined and successful outcomes. Poor scope definition is recognised as one of the leading causes of project failure, resulting in cost and schedule overruns, and long-term operational issues. As a result, front end planning is one of the most important processes in the construction and operation of a capital asset. The PDRI methodology is proven to reduce risk in capital project delivery by promoting rigorous scope definition and a collaborative review process during front end planning. LCI USA also has a project validation tool that performs a similar function.

- **Early engagement**. 76% of the best performing projects engage key stakeholders in design and construction during the conceptualisation stage, whilst 42% of "typical" projects don't engage stakeholders till the design development stage or later.

- **Procurement and contracts** – Linked with the predecessor, the people with the greatest ability and knowledge to affect project outcomes are usually procured too late in the process to leverage this value. A significant proportion of construction activity surrounds the design and construction of bespoke, one-of-a-kind projects where there are more unknowns than knowns in the early stages. In order to engage early and access the best knowledge it is not possible to procure on lowest price as the resultant price will be meaningless at best and at worst will encourage a culture of claims. When faced with this dilemma, the only approach that makes sense is to procure based on capability, holding that it must follow that the most capable (productive) suppliers will produce the best time, cost, quality results in any given situation, as they are focused on the avoidance of process waste in all its forms. There appears to be a lack of a suitable procurement model based on capability and not cost. We have however, to be discussed later, uncovered a significant opportunity in this regard.

- **Finance and Insurance –** If capital funders of projects are banks, then suboptimal conditions will likely be imposed by these financial institutions with regard to procurement. For example, they will likely require examination of consultants individual professional Indemnity insurances. In contrast, a lean approach would utilise Project PI insurance, negating the need at all for individual consultant insurance, as this has shown to help prevent over-engineering. This is common practice in Belgium and has been piloted successfully in the UK.

- **The Stock Market or current government purse.** The stock markets' focus is on the quarterly dividend, demanding short term performance, this results in pressure to reduce capital spend in favour of whole life cost, adversely affecting long term performance. Short term political pressure acts in the same way.

In summary, lean construction techniques such as value stream mapping, last planner, visual management etc can be highly effective in improving project performance. However, bolting them on to a broken system (poor brief, poor procurement etc) will only yield superficial results. Root causes of waste based in "projects as systems" must be fully examined and methods devised to encourage wholesale change via innovative forms of procurement based on capability and early engagement of stakeholders, working to a clearly defined client brief.

2. SUMMARY OF UNIVERSITY OF DUNDEE AND LEAN CONSTRUCT'S ACTIVITIES FOR LIVING LAB

The original intent of the Lean Benchmarking element of the project (Project 3) was to carry out deep dive process investigations on projects that displayed exceptional performance evidenced by outlying data points identified by projects one and two. However, these data did not materialise and so we sought to engage directly with ALBs to establish how best to add value to the project.

Early in the project we also sought direct involvement with the demonstrators, but we were unsuccessful in achieving this.

We have had excellent engagement with National Highways internal lean team and also the new Smart Motorway Programme Alliance leadership team including Tier one suppliers.

We can report progress and learning in three areas: -

- A direct benchmark comparison of the delivery model between a lean exemplar non-profit construction client and National Highways

- A study of productivity that includes: -
    - The links between predictability and productivity
    - the barriers and practicalities of data capture
    - links between the use of data, understanding variation and capability
    - results from direct observation of works on a live scheme
- The likely cost impact of poor management of utility diversions during infrastructure works, together with examples of best practice and recommendations for improvement

3. COMPARISON OF LEAN EXEMPLAR PROJECT DELIVERY TO NATIONAL HIGHWAYS

3.1 ABOUT THE LEAN EXEMPLAR ORGANISATION

In our opinion as a Lean construction training and facilitation consultancy with 20 years experience, Sutter Health's delivery track record offers an exemplary project delivery performance that other organisations might benchmark against and aspire to emulate. Sutter Health: -

- Are Not-for-profit
- Employ 50,000 people
- 5000 Doctors
- 30 hospitals
- 5,000 beds
- 30,000 births per year
- 50 ER / Urgent care centres
- $500Mil pa on new assets and renovations
- Based in California and only California
- Builds and operates bespoke high value assets

Following major earthquakes in the region in the early 1990's Sutter were compelled to rebuild hospitals to a new building code that must be earthquake resistant. A major infrastructure build programme was required but there were severe budget limitations, and it was viewed impossible to achieve the required outcomes working in the traditional fashion. Through several iterations, Sutter led the development of revised design and construction processes to enable significantly reduced capital costs, given no loss of function and ability to achieve programmes on time. Key changes were made to contractual arrangements with the supply chain and the management of procurement and design.

3.1.1 THE BENCHMARK DATA

Between 2007 to 2019, Sutter delivered 24 projects for $4.7 Billion. Overall, 5% under budget, with a success rate of 92% on time (or better) and on budget (or better) with no scope compromises. This compares with a construction sector average performance in the USA of only 30% of projects that meet or exceed their cost and programme goals.

It is highly unlikely, if not impossible, that Sutter could achieve this level of performance over this sustained period by chance. Therefore, it was taken that a fundamentally different delivery model has been applied.

In the UK we have KPIs for cost predictability and time predictability. In 2018 these were 66% and 59% respectively for individual KPIs but it is not known what percentage of projects were both on time, and on cost. In addition, the data are ratings of perception rather than hard measures.

- Data were collected from the National Highways commercial intelligence team and looking at 23 recently completed projects: -
    - 83% were on time or better (defined as the road opened for traffic as planned)
    - 38% were on cost or better
    - 35% were both on time and cost or better

Note that whilst on the face of it this doesn't look great. It is likely better than average UK project delivery performance which will be comparable to the USA recorded figure of 30%

Major Projects - Earned Value Management for Schemes in Construction

Grey means completed blue wip		% of overall programme spend		Red means loss amber means close to overspend	Millions		Schedule perf index			

Reporting period: March 2019

Scheme Name	rogramm	% of programme EV performed	% of programme EV, forecast at year-end	Cost Performance Construction Phase CPI	Variance (£m)	Trend	Schedule Performance Delivery Plan DFT SPI	Variance (£m)	Trend	Narrative
EY = OPEN FOR TRAFFIC										
A1 Coalhouse to Metro Centre	YNE	1.2%	1.3%	0.93	-3.884	→	1.00	-2.303	→	Open for traffic on Delivery Plan date
A556 Knutsford to Bowden	NW	3.2%	6.4%	0.93	-10.094	→	1.00	0.000	→	Open for traffic on Delivery Plan date
M1 J39-42 SM	YNE	2.6%	-0.3%	1.01	0.664	→	1.00	0.000	→	Open for traffic on Delivery Plan date
A1 Leeming to Barton	YNE	6.8%	11.7%	0.92	-26.375	→	0.86	-39.770	→	Open for traffic 3 months after Delivery Plan date
Manchester Smart Motorways	NW	7.3%	8.0%	0.97	-8.608	→	0.74	-41.794	→	Open for traffic 10 months after Delivery Plan date
A160 / A180 Immingham	YNE	1.5%	2.7%	0.89	-8.053	→	1.00	0.000	→	Open for traffic on Delivery Plan date
A453 Widening	Mids	3.4%	1.3%	1.01	2.040	→	1.06	7.422	→	Open for traffic 2 months before Delivery Plan date
A45 Tollbar	Mids	1.7%	1.3%	1.06	3.929	→	1.00	0.000	→	Open for traffic on Delivery Plan date
M1 J19 Improvement	Mids	3.7%	4.2%	1.08	11.320	→	1.00	0.000	→	Open for traffic on Delivery Plan date
A5-M1 Link	Mids	2.9%	6.4%	1.07	8.556	→	1.05	5.332	→	Open for traffic 1 month before Delivery Plan date
A14 Kettering	East	0.9%	0.5%	1.00	-0.052	→	1.10	3.292	→	Open for traffic 2 months before Delivery Plan date
A21 Tonbridge-Pembury	South	2.1%	3.6%	0.99	-1.291	→	0.76	-8.579	→	Open for traffic 6 months after Delivery Plan date
M25 J30 / A13	South	1.6%	3.0%	0.87	-9.746	→	1.27	13.766	→	Open for traffic 6 months before Delivery Plan date
M1 J19-16 SM	SMP	2.0%	6.0%	1.55	30.176	→	1.00	0.000	→	Open for traffic on Delivery Plan date
M6 J10a-13	SMP	2.3%	-0.2%	1.02	1.452	→	0.98	-2.303	→	Open for traffic 2 months after Delivery Plan date
M1 J28-31 SM	SMP	4.2%	2.4%	0.91	-17.974	→	1.00	0.000	→	Open for traffic on Delivery Plan date
M1 J32-35a SM ALR	SMP	2.1%	3.0%	1.00	0.167	→	1.00	0.000	→	Open for traffic on Delivery Plan date
M6 J16-19 ALR	SMP	5.1%	12.0%	0.88	-30.433	↗	1.00	0.000	↑	Open for traffic on Delivery Plan date
M5 J4a-6 ALR	SMP	2.5%	6.2%	0.99	-0.700	→	1.18	7.418	→	Open for traffic 4 months before Delivery Plan date
M1 J19-16 ALR	SMP	2.7%	9.1%	0.86	-18.119	→	1.00	0.000	→	Open for traffic on Delivery Plan date
M3 J2-4a	SMP	5.9%	11.4%	0.93	-19.792	→	1.00	0.000	→	Open for traffic on Delivery Plan date
A14 Cambridge-Huntingdon	CIP	0.0%	0.0%	1.02	20.828	↘	1.15	117.748	→	
M1 J23a-25	SMP	0.0%	0.0%	0.98	-1.797	→	1.00	0.000	→	Open for traffic on Delivery Plan date
M4 J3-12	SMP	0.0%	0.0%	1.00	0.011	↑	1.00	-0.186	↑	
A19 / A1058 Coast Road	YNE	0.0%	0.0%	0.76	-14.123	↘	1.00	0.000	↑	Open for traffic on Delivery Plan date
M20 J10a	South	0.0%	0.0%	0.96	-1.342	→	0.79	-8.202	↗	Yet to open for traffic after March 2019 due date
M6 J13-15	SMP	0.0%	0.0%	0.98	-1.215	↑	1.46	15.756	↗	
M1 J13-16	SMP	0.0%	0.0%	1.00	0.011	↑	1.00	-0.186	↑	
M6 J2-4	SMP	0.0%	0.0%	0.95	-5.140	→	0.93	-6.975	↓	
M20 J3-5	SMP	0.0%	0.0%	0.99	-0.357	↑	0.89	-4.394	↗	
M23 J8-10	SMP	0.0%	0.0%	0.97	-1.541	↑	0.77	-15.438	↗	
M49 Avonmouth	SW	0.0%	0.0%	0.90	-1.607	↘	2.32	8.084	↘	
M27 J4-11	SMP	0.0%	0.0%	0.00	0.000		0.00	0.000		
M62 J10-12	SMP	0.0%	0.0%	0.00	0.000		#N/A	49.894		

Figure 2 Benchmark data

4. UNDERSTANDING DIFFERING DELIVERY MODELS

Working closely with the National Highways (NH) internal Lean Team we set out to understand the key characteristics of both Sutter and NH project delivery models. We compared four: -

- The NH historic model which has produced the 35% benchmark
- The Regional Delivery Partnership (RDP North) delivery model (Benchmark unknown)
- The new Smart Motorway Programme Alliance model (Benchmark unknown)
- Sutter Health model that produced the 92% benchmark

National Highways have already applied great effort to review and revise their delivery models and further integrate the supply chain in line with currently known best practice. However, it is too early to gauge how RDP (North) is performing compared to the historic model, as no measurable/ comparable benchmark was available for this study. Similarly, the new Smart Motorway Programme Alliance has gone further still in terms of closely integrating the supply chain, but the Alliance is in its infancy, so no benchmark data are yet available.

4.1 THE FOUR DELIVERY MODELS

The graphics below show the broad structure of each of the delivery models compared.

4.1.1 HISTORIC MODEL

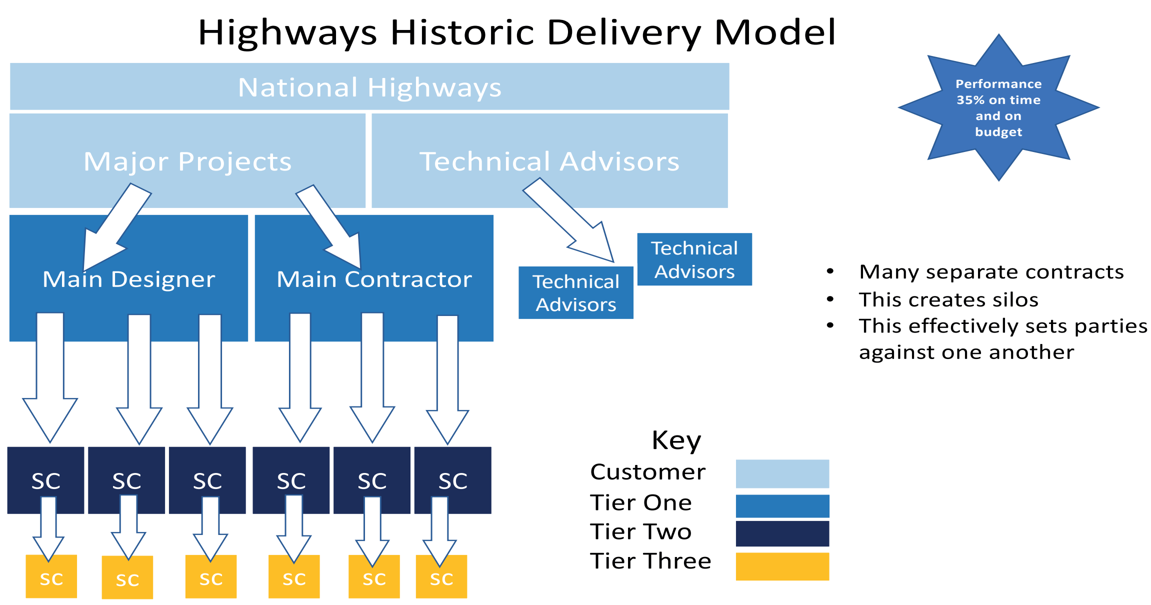


Figure 3 Historic Model

In this Historic Model, each arrow represents a separate contractual arrangement. This is typical of a significant proportion of all construction activity in the UK.

From a lean perspective, this model has the effect of setting the parties against each other. No doubt the intention of all concerned at the outset is to collaborate, but when something goes wrong this can quickly fall apart. For example, consider a new build hospital. Contractor "A" experiences a delay that was caused by a mistake made by contractor "B". Contractor "A" then lodges a claim with the main contractor who in turn seeks to recover the expense from "B". When we introduce more complex design issues into this mix it becomes difficult at best to fully collaborate.

4.1.2 RDP (NORTH)

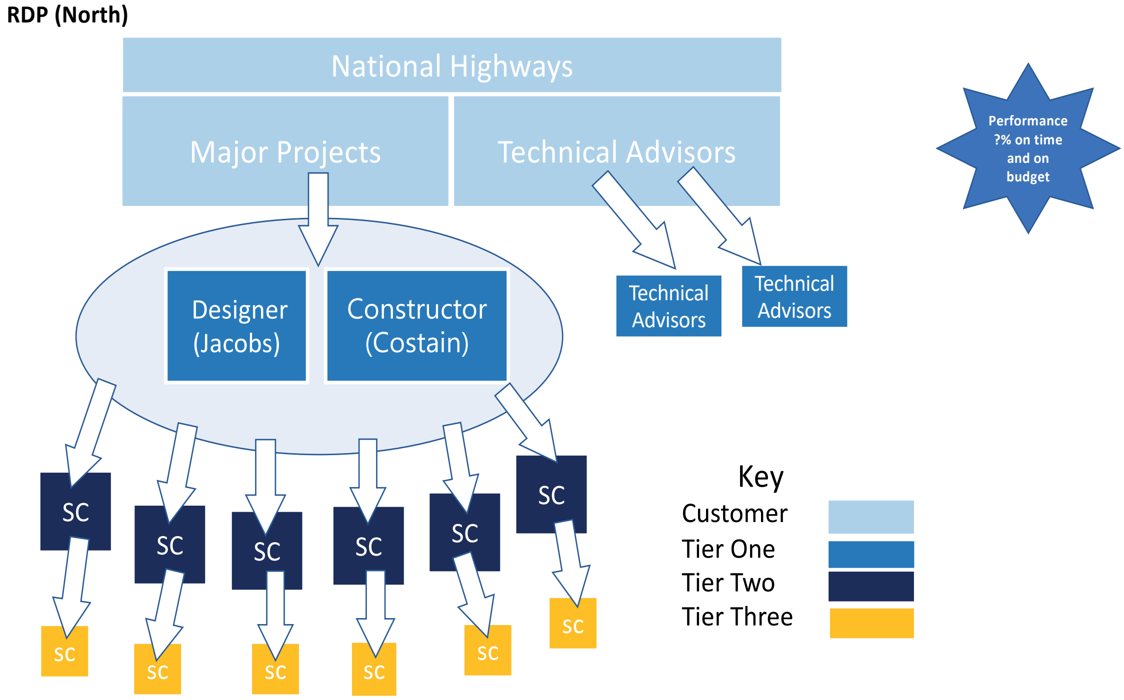


Figure 4 RDP North

In this model Designer & Constructor have been integrated into a single agreement. At this time data are not yet available to enable a comparison of performance.

4.1.3 SMP ALLIANCE

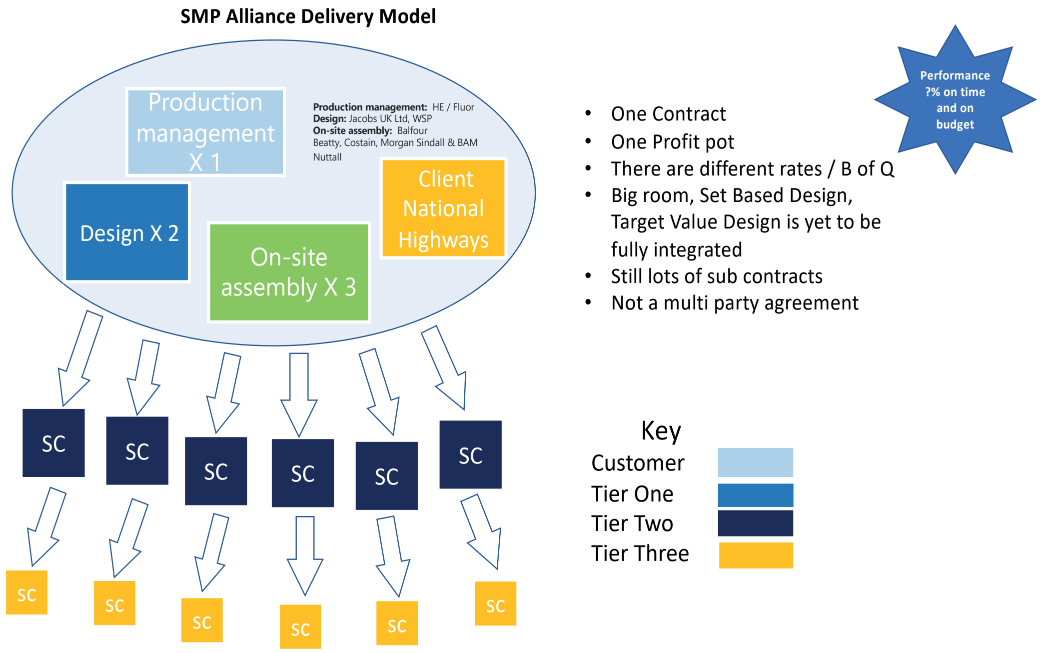


Figure 5 SMP Alliance

The SMP Alliance further integrates the team as shown in Fig 5 above. Other Key Lean Techniques are being actively deployed. It is too early to compare performance of this model as it is still in its infancy.

It may be interesting to note however, that the main parties that do the work, the sub-contractors, remain outside the multi-party agreement.

4.1.4 SUTTER HEALTH

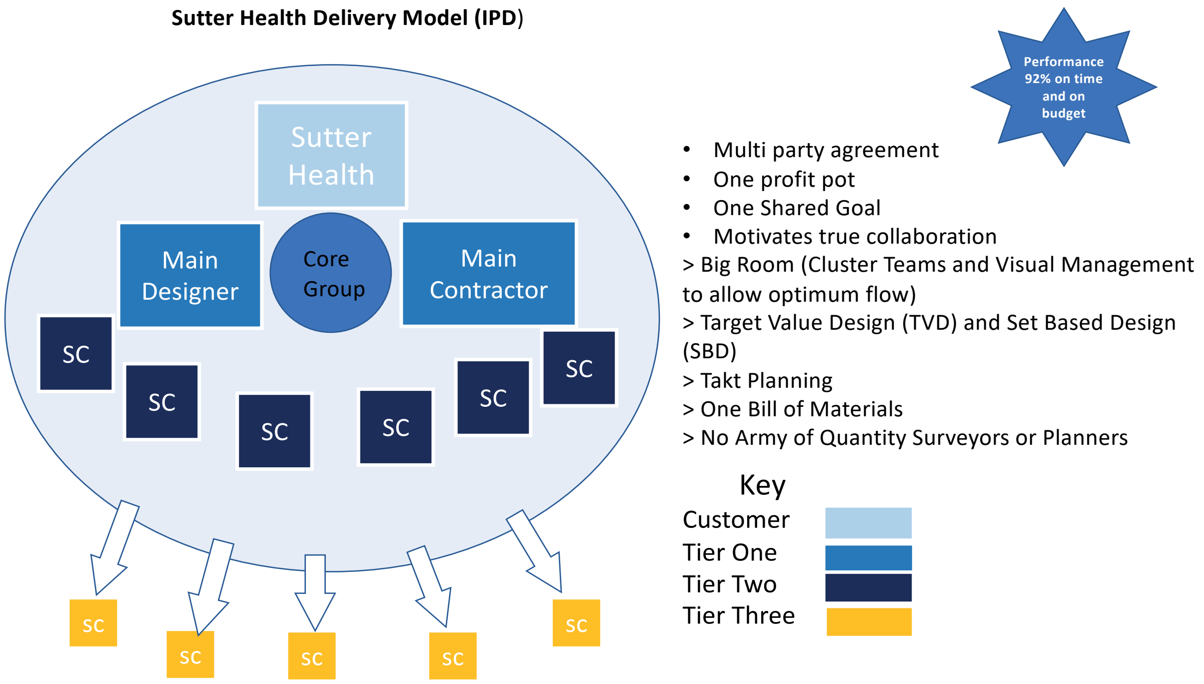


Figure 6 Sutter Health

In the Sutter model depicted in fig.6, Many of the core lean tools are fully deployed.

To repeat some of our introductory text. ***"It is known that projects with a high lean intensity are three times more likely to finish ahead of programme and twice as likely to complete within or below budget. (LCI USA) High Lean Intensity is defined as using the following techniques."***

- Co-Location Big Room
- Target Value Design
- Prefab/Modularisation
- Full-Team On-Boarding
- BIM
- A3 Thinking
- Last Planner System

It can also be observed that a significant shift has taken place in that the Tier Two suppliers are now fully integrated into the multi-party agreement. It may well be the case that this factor is a key enabler of close collaboration. To compare with the example scenario given under the historic model consider that contractor "A" experiences a delay that was caused by a mistake made by contractor "B". In the Integrated form of agreement there is a single at-risk profit pot. This starts off with each contractor agreeing to a % of the total pot according to their work package. If the total pot grows or shrinks during the life of the project, all are affected equally. This encourages the behaviour of "what can we do to help?" rather than endless claims.

4.2 KEY DIFFERENCES

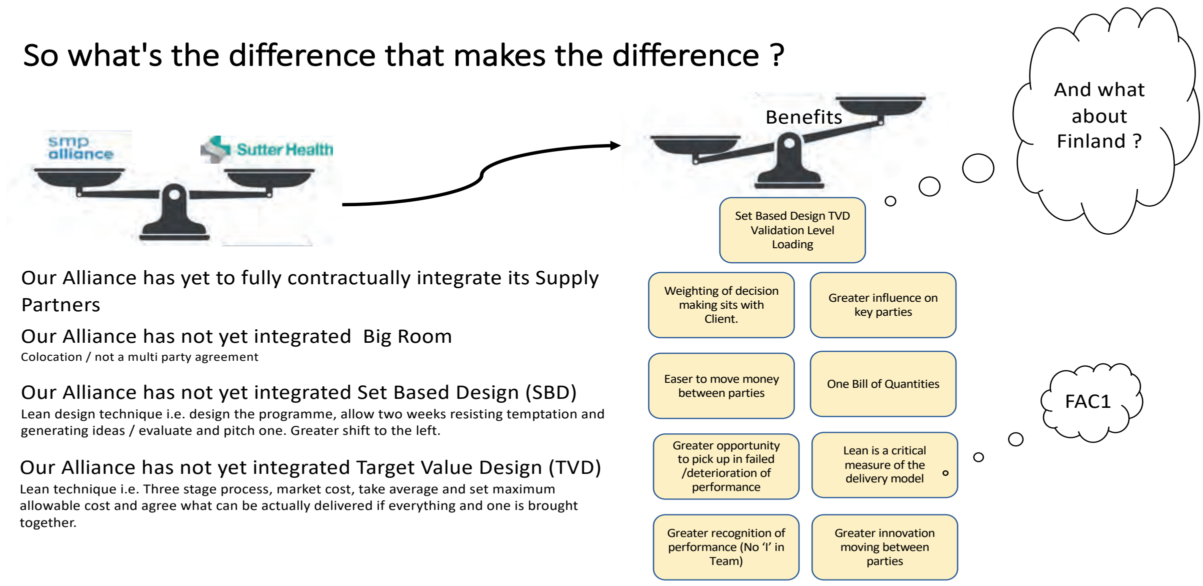
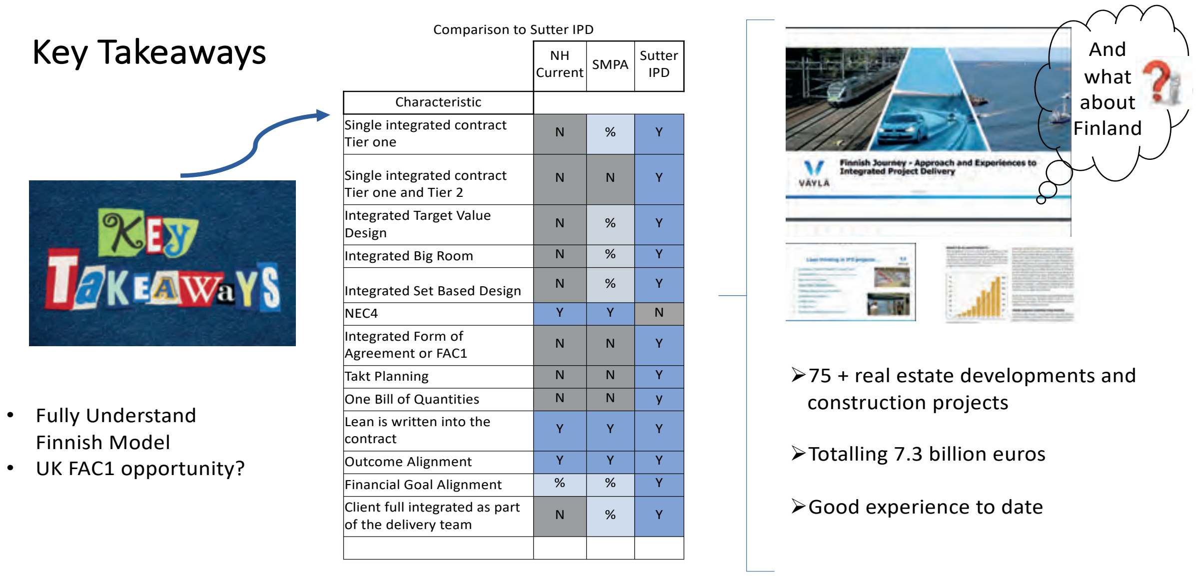


Figure 7 Differences

In Fig 4.4 above we considered the SMP Alliance model against the Sutter benchmark model and some of the key characteristics are compared. It was viewed that opportunity exists within the current Alliance to move closer to the exemplar model. In fig 8 below this is broken down further to include a comparison of characteristics with the more historic model.



Comparison to Sutter IPD

Characteristic	NH Current	SMPA	Sutter IPD
Single integrated contract Tier one	N	%	Y
Single integrated contract Tier one and Tier 2	N	N	Y
Integrated Target Value Design	N	%	Y
Integrated Big Room	N	%	Y
Integrated Set Based Design	N	%	Y
NEC4	Y	Y	N
Integrated Form of Agreement or FAC1	N	N	Y
Takt Planning	N	N	Y
One Bill of Quantities	N	N	y
Lean is written into the contract	Y	Y	Y
Outcome Alignment	Y	Y	Y
Financial Goal Alignment	%	%	Y
Client full integrated as part of the delivery team	N	%	Y

Figure 8 Comparison of characteristics

We found several differences, but we think the predominant causes of success are linked with the method of engagement of the supply chain, client leadership and the resultant contract structure. These lead to a much more effective way of dealing with some of the peculiarities of construction noted in the introduction. In particular, temporary organisations are far more effectively formed in the Sutter model as well as dealing with one-of-a-kind projects.

4.3 OTHER CONSIDERATIONS

We are aware that in the Sutter delivery model there is a definite "left shift" in terms of early investment and engagement with the supply chain, fully utilising techniques such as **Target Value Design** which literally assemble a team of contractors and designers to work together at the start to design a project that will meet the required goals and needs with no loss of function yet come in at significantly reduced cost.

In addition, Sutter senior management are deeply involved as part of the delivery team themselves.

4.3.1 OTHER INTERNATIONAL APPLICATIONS

We are aware that the original Sutter Integrated Project Delivery (IPD) model was taken up in Australia and is used in Canada but then adopted with enthusiasm by Finland, who have delivered €7.3 Billion of projects using IPD. We have not yet been unable to obtain comparable benchmark data but the reported experiences to date have been very positive. We also discovered that these contractual mechanisms have been successfully used in Finland by the Public Sector when delivering infrastructure projects. The procurement route was challenged under EU law, but the challenge was overturned by the EU Commission. Despite Brexit, this should provide comfort that it is at least possible to apply this in the UK public sector.

4.3.2 FAC1

According to The Association of Consultant Architects and Kings College London: -

FAC-1 is a versatile standard form framework alliance contract which :

- enables a client and its team to obtain better results from a framework
- helps to integrate a team into an alliance
- helps to obtain improved value through building information modelling
- works in conjunction with any project contract form in any sector and in any jurisdiction.

An interesting case study is reported in Local Authority Roads maintenance using this bolt on form. Surrey CC, say they have saved 15% cost, significantly improved quality and are receiving unprecedented letters of praise from the public since their adoption of the FAC1 alliance contract due to improved supplier integration & collaboration.

Please see https://www.youtube.com/watch?v=1abKafPJI30

Our understanding is that FAC1 can be "bolted on" to any of the existing common contract forms to enable closer supplier integration that would take our delivery models further toward the exemplar discussed.

4.4 CONCLUSION AND NEXT STEPS

We have identified an extraordinary performance gap, statistically impossible to have occurred by chance, in the delivery of high value, complex, bespoke projects that has been sustained in the long term. We have begun the journey of understanding explicitly what caused this success, but more work is needed before a stepwise action plan can be derived whether this be the Finnish model, FAC1, Sutter, or a fusion of all three.

Given the extraordinary results reported here, we recommend that further work to enable the production of this stepwise plan is commissioned.

5. LEAN PRODUCTIVITY STUDY

5.1 PROBLEMS WITH MEASURING PRODUCTIVITY

Accurately measuring productivity in construction is difficult at best due to the number of variables that need consideration. Consider measuring drainage on a motorway project. To properly calculate productivity, we need to know the input resources used and the output achieved. This sounds simple until one introduces the "construction peculiarities" discussed above. "Rooted in Place" will lead to the variable of access, which will in turn dictate machines and methods able to be used. Then we could consider the variables of size of pipe, depth laid, ground rock or soil, whether the work was carried out on a live network and so on. We have found in practice that once data are stratified to the point where "apples equal apples" there are often unfortunately not enough data left to carry out any meaningful analysis.

5.1.1.1 A LEAN CONSTRUCTION APPROACH TO MEASURING PRODUCTIVITY

If it is so difficult to measure productivity in construction, then what is to be done?

Similar to the value vs waste concept discussed in the introduction, the speed at which differing gangs work is nowhere near as important as being able to go to work at all. The reality of current construction operations is that effort spent in the avoidance of delays and disruptions to the work will usually return more any other form of productivity improvement. In other words, due to the "peculiarities of construction" discussed earlier, workflows are inherently unstable. Introducing measures to improve the reliability of workflow is likely the most effective means of productivity improvement currently available.

In 2000 a thesis entitled "The Lastplanner system of Production Control" (Ballard 2000) was published. This built on earlier work in the field of Lean Construction and based efforts on improving the reliability of workflows. This is consistent with a lean approach as most frequently we find that it is not the difference in output between two gangs that is as important as getting any output at all. In other words, failure to properly make tasks ready to do results in a reliability industry average of around 50%.

Ballard found that when reliability improved from 50% to 75%, this resulted in a productivity improvement of 30%. In a later study (Ballard et al 2007) the hypothesis that Productivity and Planned Percent Complete (PPC/reliability) are positively correlated was also found valid. A regression equation between productivity and PPC was derived as

Prod= 0.693+0.818*PPC

Also, that one unit or % increase in PPC (reliability) causes a 0.818 unit of productivity increase as shown in fig. 9 below.

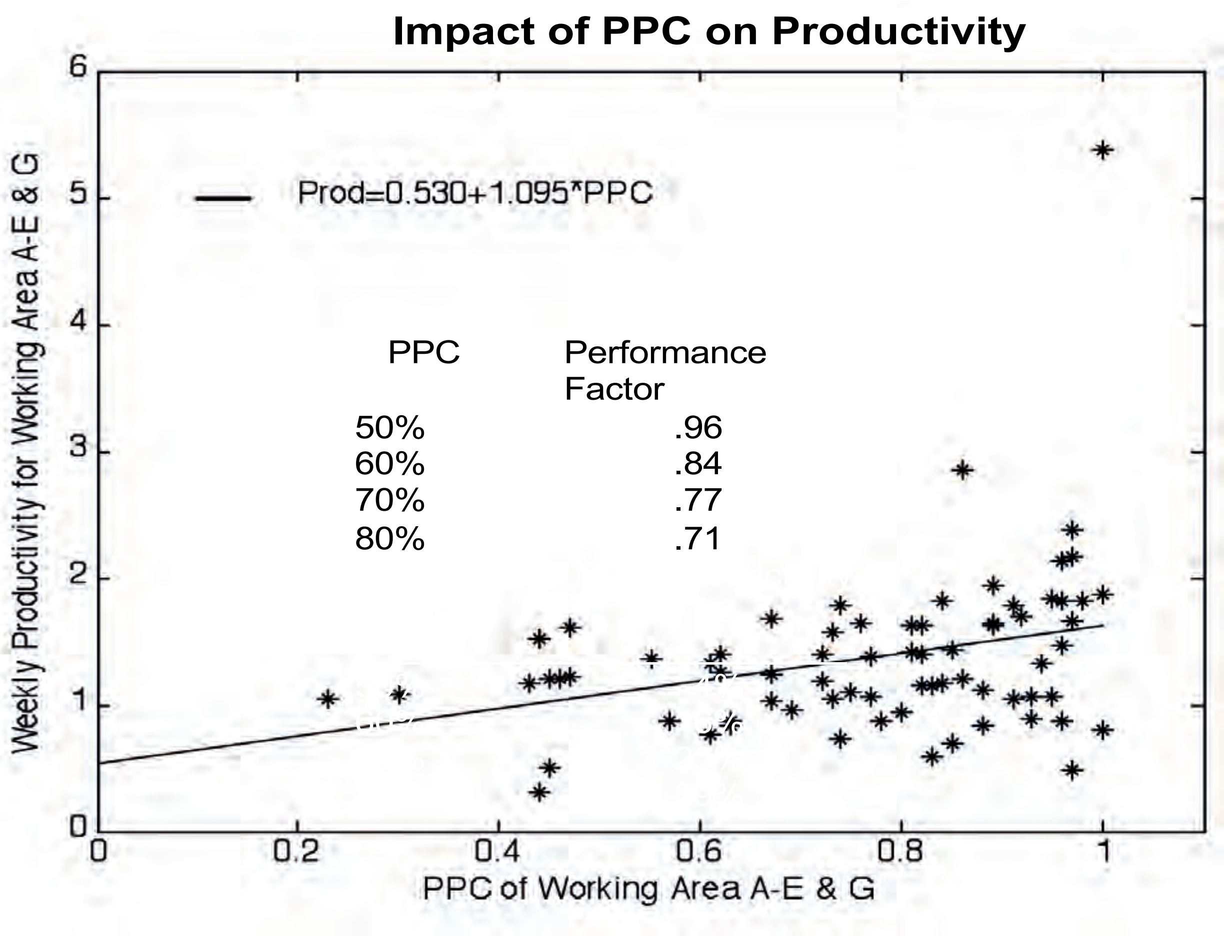


Figure 9 Reliability vs Productivity

In the same paper it was evidenced that, whilst delivering at a reliability figure of about 50%, 96% of planned, budgeted labour hours were used. This effectively backs up the hypothesis that our industry unknowingly plans for a 50% reliability success rate.

Ballard et al 2007: -

"Note also that the analysis was done on PPC measured no more than one week ahead of task execution. Another area of opportunity for productivity improvement, also needing study and analysis, is extending that window of predictability".

Radosavljevic & Horner (2007) hold that forecasting more than 10 days in advance is impossible due to inherent system instability.

However, it would seem to make sense to attempt to extend the "reliability window" further than one week if possible.

Coincidentally National Highways have been attempting to do just this in recent years with a metric called "Lookahead Execution Index" (LEI)

This metric calculates reliability at monthly intervals based on programme information submitted by Tier 1 contractors. The calculation is as follows:

$$\text{LEI} = \frac{\text{Total number of actual planned starts + Total number of actual planned finishes}}{\text{Total number of forecast starts + Total number of forecast finishes}}$$

Note that this is a purely a measure of reliability – did the work happen as planned. If work took place that was not in the plan it would not count toward success using this metric.

Based on prior research, we might assume that if the industry average reliability metric when measured weekly is about 50%, then extending the time window to a month would naturally yield a lower figure.

LEI project reliability data were made available to us for analysis. We chose Statistical Process Control (SPC) as our preferred method of analysis, and this is discussed below. Monthly data were available for fourteen projects over an approximate two-year period. Our chosen analysis method ideally requires a minimum of twenty data points (or in this case monthly LEI figures) we reduced the project sample from 14 to eight projects that contained at least 20 months of LEI reporting.

The results showed that

- **The best projects average performance was 51% and the expected normal range of variation was between 10% and 92%**
- **The poorest projects average performance was 27% and the expected normal range of variation was between 3% and 50%**
- **The average performance of all 8 projects was 44% and the expected range of variation was between 26% and 60%.**

The expected range of variation is calculated from the data itself based on the level of variation present and can be regarded as a measure of delivery system **capability.** The formula used for the upper and lower limits were as follows. UCL = $\bar{X} + 2.66\,\bar{R}$ and LCL = $\bar{X} - 2.66\,\bar{R}$ where Xbar is the grand average of the data and Rbar is the average range.

Whilst these results may appear to paint a poor picture of performance, we do not consider it is poor compared to the norm in industry, but that it is most likely "just normal" or probably better given the consistent efforts to improve that are actively supported by National Highways.

Several outlying data points were identified and further project information surrounding these was obtained and reviewed. Unfortunately, the data collected at site level and available to National Highways was insufficient to provide any further learning on these outlying data points. This of itself is a key learning outcome of this study, specifically being able to ***use measures of variation to highlight outlying data points.*** Outliers maybe good or bad but both ***equally*** provide opportunity for learning and therefore improvement.

5.1.2 WHY COULD THESE PERFORMANCE FIGURES BE BETTER THAN THE INDUSTRY AVERAGE?

We know that the average reliability metric for tasks completing on time in construction is 54%. However, this is measured to the day and the committed timeframe is one week ahead. We also know that all plans are forecasts, all forecasts are wrong and that the longer the forecast, the wronger it gets. Experience has shown that to plan ahead in real detail longer than six weeks is often a waste of effort, as in that time frame so many things will change.

So if planning to a one week timeframe yields an average of 54% reliability, planning to a one month timeframe would yield a lower figure. The LEI time window is one month, so the average recorded figure of 44% is highly likely to be better than comparable projects, although we do not have data to prove this currently.

It is very important NOT to take these statistics out of context, and to understand the underpinning theories of variation by which they are calculated.

Several outlying data points were identified and further project information surrounding these was obtained and reviewed. Unfortunately, the data collected at site level and made available to National Highways was insufficient to provide any further learning on these outlying data points. This is of itself a key learning outcome of this study, specifically being able to ***use measures of variation to highlight outlying data points.*** Outliers maybe good or bad but both ***equally*** provide opportunity for learning that in this case was missed.

5.2 UNDERSTANDING VARIATION AND USE OF DATA

It was found by the quality gurus Shewart, Deming and Juran in the first half of the 20th century that management were generally not very good at recognising signals from performance data. They taught about two types of variation, common cause, and special cause. Common cause variation is essentially just noise, it is random data. Special cause variation however signals that something odd has happened that is thought to be outside the usual capability of the system.

Deming stated that management frequently made two mistakes that caused economic loss.

Mistake 1. Treating a common cause data point as though it were special.

Mistake 2. Failure to notice a real special cause.

About Mistake 1.

Management often feels compelled to act when reviewing data, no matter what it says. If we don't act on data we aren't doing our job, right? However, If the data are naturally random and only common causes of variation are present, then any action taken based on a single data point is likely to make things worse, not better.

About Mistake 2.

At what point should action be taken? How far away from target is bad? Failure to be able to identify statistically significant data points may lead to a missed learning opportunity at best, or serious financial or other loss at worst.

Statistical Process Control (SPC) was invented to allow management to distinguish between these two types of variation more easily. It is broadly based on three sigma limits. The chance of a data point falling outside the limits by accident is <1%.

5.1.2 WHAT HAS THIS GOT TO DO WITH BENCHMARKING AND IMPROVEMENT?

Consider the SPC chart below which shows performance data from project "a"

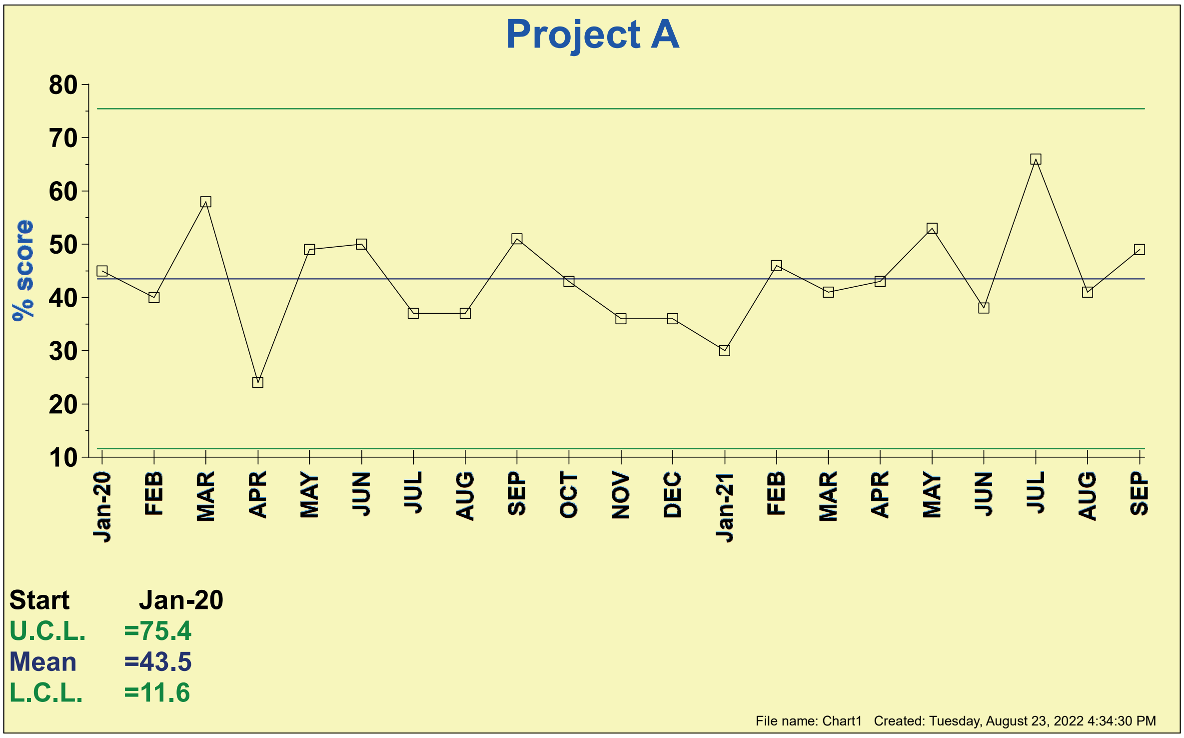


Figure 10 SPC Chart Project "a"

In April performance drops to 24%. Management act on this horribly low figure. They launch an investigation on how this could have happened and see who is to blame. After this it goes up to a respectable 49% in May and holds at 50% in June. Obviously, the action had the desired effect. In July it falls away again to 37%. Someone must have taken their eye off the ball............

In reality this chart contains only random variation and so there are no "bad" or "good" months. The level of variation is just ***normal*** for this project. Reacting to any individual data point is futile and may make things worse. If improvement is sought then actions must be taken that could affect all months, in other words systemic changes are needed, not local interventions.

Now consider the SPC Chart from Project "b" in fig 11 below.

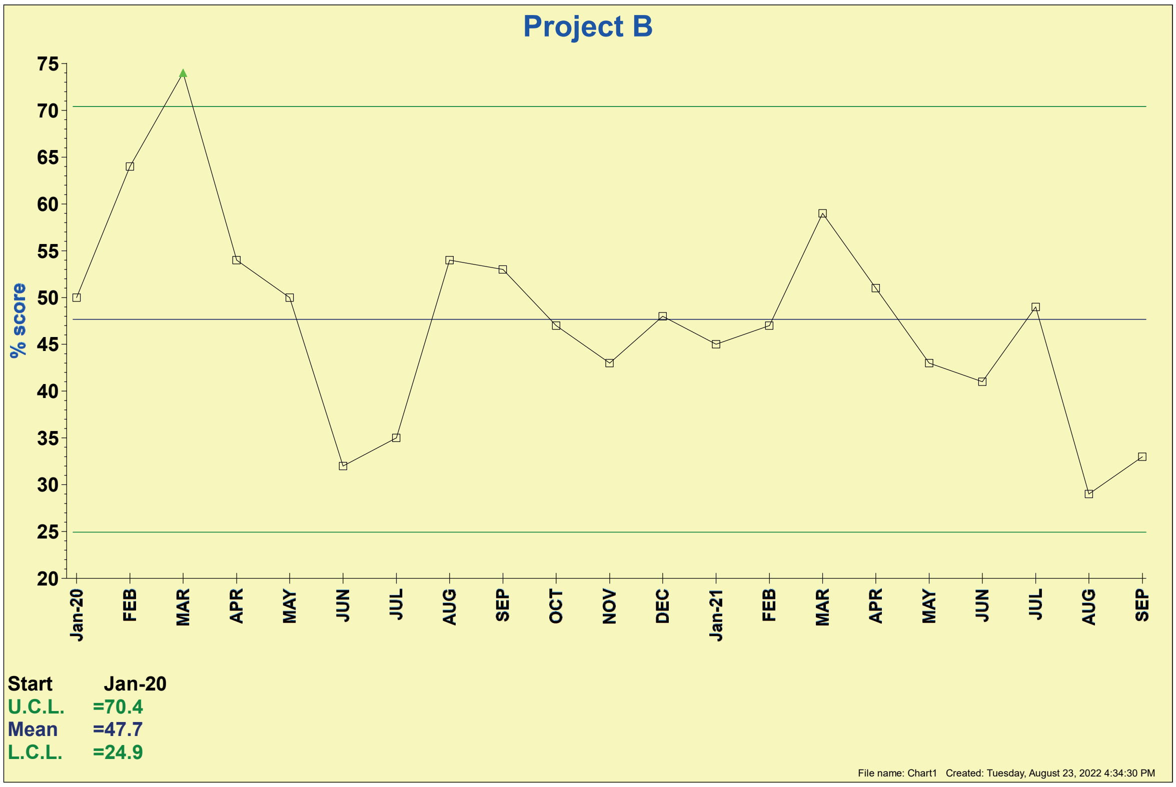


Figure 11 SPC Chart Project "b"

There is an outlying data point. In March performance was 82% and this point lies outwith the upper control limit, signalling a special cause of variation. The chances of this happening by chance are close to impossible, something different happened in March. Several possibilities exist, maybe the data are wrong, but whatever the case it is imperative that management understand clearly what happened. In this instance the project outperformed and exceeded normal capability in March and we must understand why this occurred so that if indeed a different approach was taken on site that resulted in the high performance, actions could be taken to repeat this in the future.

5.2.2 THE USE OF ARBITRARY TARGETS & MEASURES

Figure 12 below shows project performance and outliers (bad) have been highlighted in red or amber.

Cost Performance Index	Variance (£m)
0.93	-3.884
0.93	-10.094
1.01	0.664
0.92	-26.375
0.97	-8.608
0.89	-8.053
1.01	2.040
1.06	3.929
1.08	11.320
1.07	8.556
1.00	-0.052
0.99	-1.291
0.87	-9.746
1.55	30.176
1.02	1.452
0.91	-17.974
1.00	0.167
0.88	-30.433
0.99	-0.700
0.86	-18.119
0.93	-19.792
1.02	20.828
0.98	-1.797
1.00	0.011
0.76	-14.123
0.96	-1.342

Figure 12 Cost Data

This arbitrary approach to interpreting performance is usual practice and widely used. A goal is picked based on a number that seems reasonable. If things fall short, then we take action.

If we analyse these data (which show cost performance) through the lens of understanding variation a different story emerges.

In this data set there is only one data point that is statistically exceptional. One project outperformed all the others in terms of cost with a metric of 1.55 but is not highlighted.

The rest of the data, statistically speaking can be regarded as “just normal performance”. If improvement is sought it is important to understand what caused the exeption.

5.3 UNDERSTANDING VARIATION SUMMARY

Understanding variation is essential when looking at data sets and deciding where to take action. We can use this simple method to assist in efforts to continuously improve. The data can be used to calculate an overall metric of capability which will equal a range of variation based on past performance. If a data point, then falls outside this range (special) then this warrants close investigation. In the real example above, it is the case that management are making the usual two mistakes. Treating common causes as though they were special and failure to notice when something truly exceptional occurred. In this case the project that outperformed is not noted in the table and therefore it is assumed that no investigation took place into why they were able to significantly outperform the usual system capability and so valuable learning is lost. This may present significant value going forward when measuring LEI data, and other performance metrics, that are reported monthly and it would be possible to know relatively quickly if something odd had happened, both in a positive or negative way.

6. CASE STUDY - PRODUCTIVITY STUDY ON A LIVE PROJECT

One of the key barriers to productivity improvement in the construction sector is a lack of appropriate data. This has unfortunately been confirmed again during the Living Lab project. Considering for example the method discussed above to identify extraordinary performance, good or bad, using LEI data. Whilst this is a step forward, unless detailed data are available to explain why this happened, it will still be difficult to move forwards. We are aware that other members of the Living Lab analytical team have suffered similar frustration regarding a lack of data.

Given this background we sought to engage with a Tier One contractor on a live project to try to understand the issues and opportunities in greater detail.

6.1.1 THE STUDY PROJECT

Project “X” is a motorway improvement scheme of approximately £200mil value. The work was carried out on a live network.

The main contractor uses relatively sophisticated techniques for planning the works and measuring productivity. These consist of electronic site diaries, handheld apps that capture delays and detailed planned vs actual volumes of work completed.

We were given access to these data along with the bill of quantities for the project.

6.1.2 SHORT TERM PLANNING AND MEASUREMENT

The software that was used for short term planning is of particular interest as it is similar in principle to the way the last planner system captures data. However, it was not the same. The software used was Aphex.

https://www.aphex.co/

It is possible to configure the software in different ways but on this project the software measures the quantity of work achieved per day / quantity of work planned per day. The planning timeframe was one week in advance. This was quantified as appropriate to the work in focus in either linear or square meterage, number of manholes etc. E.G., if 200 m2 were planned and 160m2 was achieved the performance score would be 80%.

In addition, the system as set up would also measure a score in excess of 100% if more work than planned was actually completed.

A lot of effort had obviously gone in to setting the system up and it appeared very advanced when compared to many other sites we have seen over the last twenty years.

The planning team did report some issues with the automated features of the software. For example, if not up to date corrected input is given, then the software assumes the original programme data are correct and enters that in the short term plan.

This is somewhat different to the Last Planner method of measuring Planned Percent Complete (PPC).

In the example above the same output would have been recorded as 0% PPC as Last Planner measures in a binary fashion, simple asking, “did we do what we said we would?” This is because it seeks overall workflow reliability across trades or tasks in a project. So, whilst we may have achieved 80% of the planned volume, we assume we need 100% for the next task to begin in order to maintain flow.

Given these differences we chose to calculate performance using both methods.

6.1.3 ABOUT THE CAPTURED DATA

Approximately fourteen weeks of production data were analysed together with the recorded delays. This consisted of 1489 tasks recorded as “true” in the output spreadsheet. It is important to note that the period in focus was between November and March and unsurprisingly the biggest recorded cause of delay was adverse weather. (We would like the opportunity to redo this analysis using summer months as a comparison).

6.2 ANALYSIS OF PRODUCTION DATA

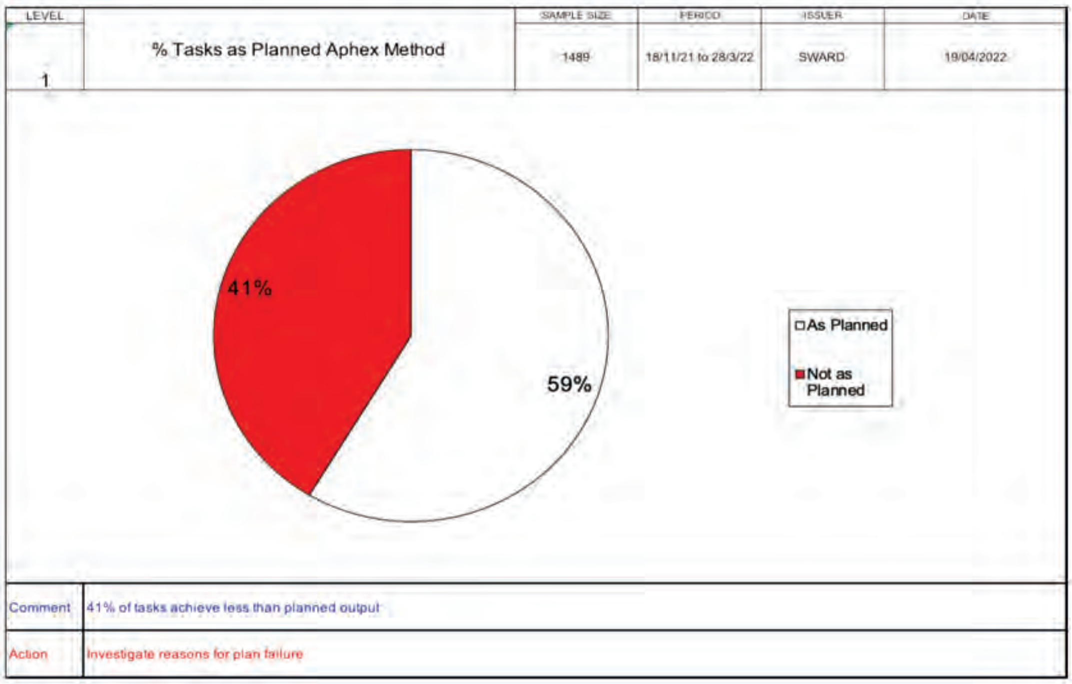


Figure 13 % Tasks on Time using Aphex Method

In Figure 13 above it can be viewed that 59% of the volume of planned work was completed as planned in the period. This takes the average of all tasks, including those that exceeded 100%.

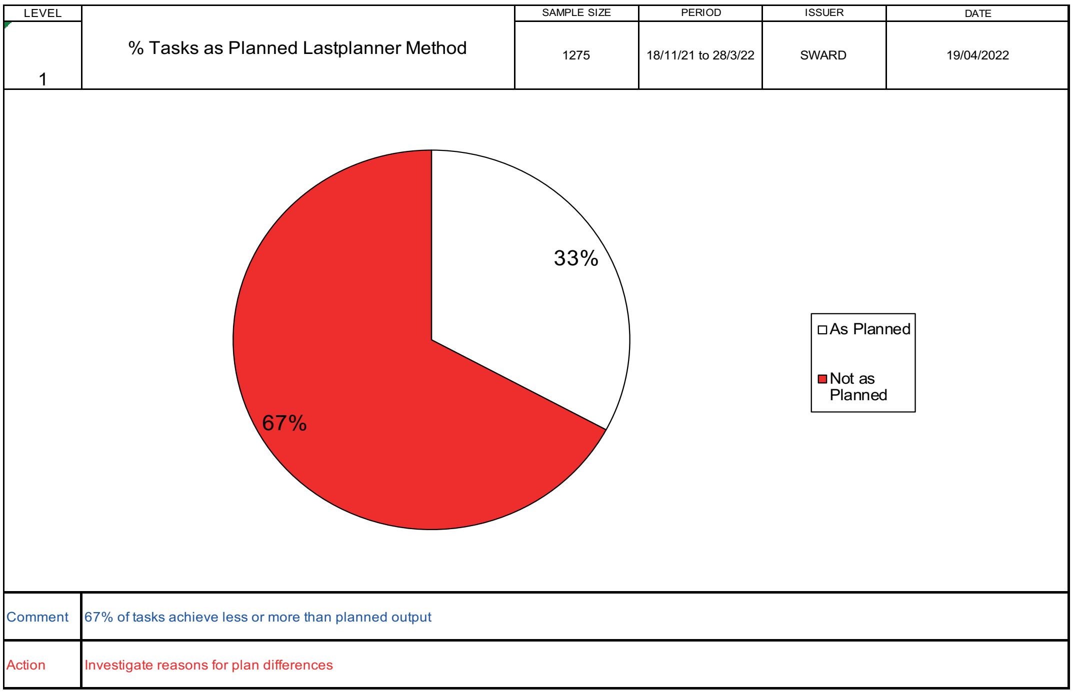
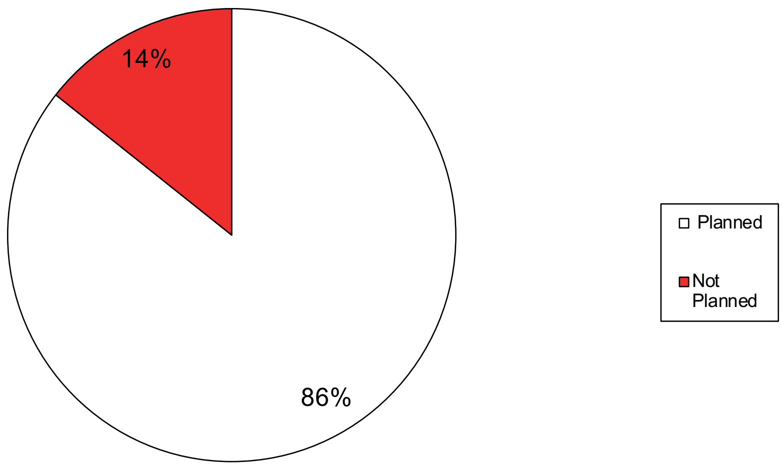


Figure 14 Tasks as planned using LastPlanner Method

In fig. 14 above the same data set is analysed according to Last Planner principles as widely used in Lean Construction. This means in practice that any task getting over 100% would be recorded as a success and any task less than 100% as a failure. This might seem harsh, but the main concern is with reliability as previously discussed. The same data set measured this way yielded a PPC rate of 33% in the period in focus.

LEVEL		SAMPLE SIZE	PERIOD	ISSUER	DATE
1	% Tasks carried out but not Planned	1489	18/11/21 to 28/3/22	SWARD	19/04/2022

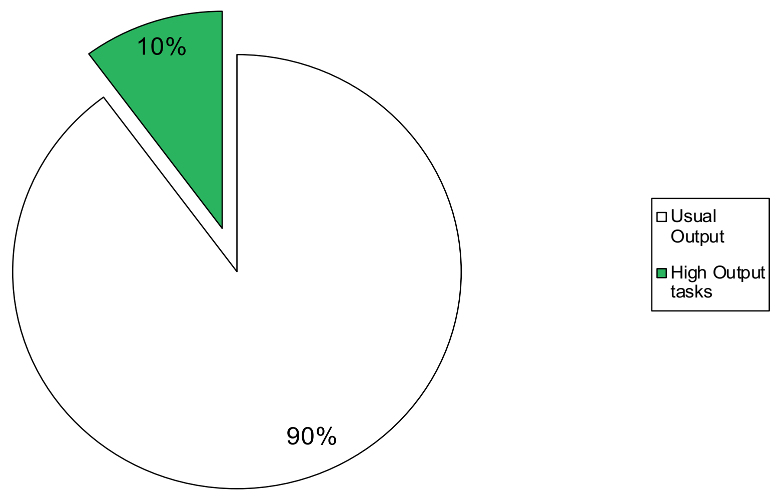


Comment	14% of carried out are not in plan
Action	Investigate reasons for not planned

Figure 15 Tasks not Planned

We noticed that some of tasks were carried out that were not pre-planned. This was recorded as 14% of the sample. It is likely that these were tasks undertaken to utilise the resources on site after experiencing a delay of some kind.

LEVEL		SAMPLE SIZE	PERIOD	ISSUER	DATE
1	% Tasks exceeding 120% planned productivity	1489	18/11/21 to 28/3/22	SWARD	19/04/2022



Comment	10% of tasks outperformed (> 120% planned output)
Action	Investigate reasons higher than expected output

Figure 16 High output tasks

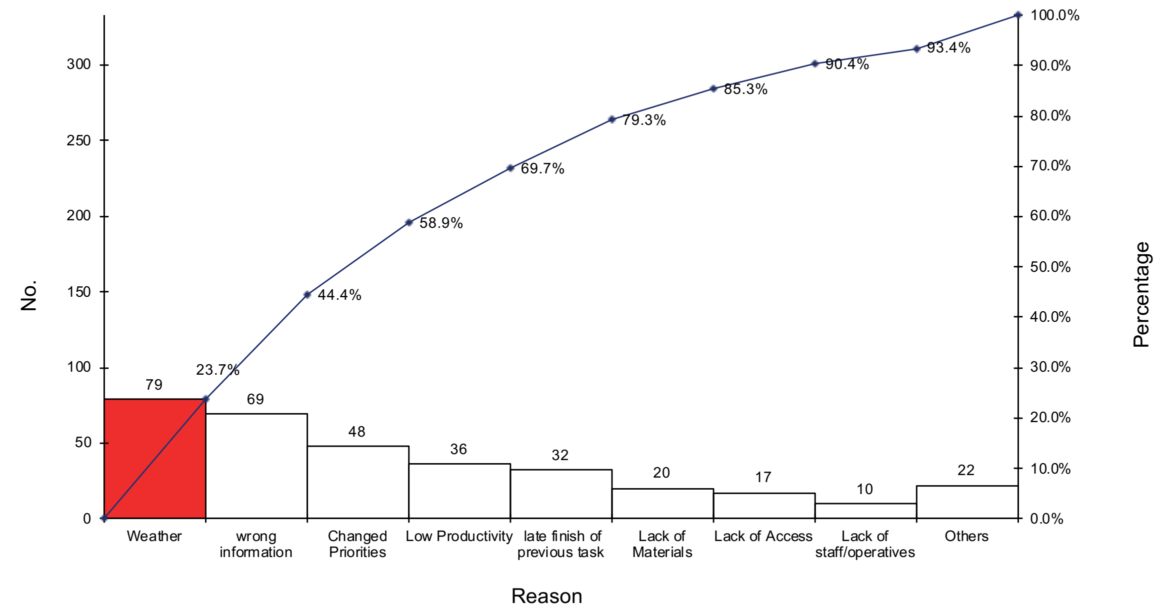
It is just as important to recognise successes as it is problems and so we recorded the percentage of the sample that exceeded 120% of planned output. A list of these tasks was fed back to the site team for exploration.

6.3 DELAY DATA

Following our discussion on basic lean planning principles the view is that is it usually more important to spend effort avoiding delays and disruptions than to focus on individual task speed or productivity. It would be useless to proceed at pace but then be delayed at the end. In a recent case study from China, a 57-storey high rise building was claimed to be completed in 19 days due to offsite manufacturing techniques. However, it was delayed for 1 year during construction due to issues surrounding planning regulations. In fact, the 19 days were worked continuously so if 3 Xs 8hr shift then it is 57 days. This is still very impressive and a great achievement if not for the oversight that caused the 1-year delay.

The Delay data recorded in the Aphex software were analysed by frequency of occurrence as shown in fig. 17 below. Discussion took place concerning some of the pre-ordained categories for the delays which were reported as "imposed". For example is "low productivity" a cause or an effect?

LEVEL	Frequency of reasons for plan failure	SAMPLE SIZE	PERIOD	ISSUER	DATE
2		333	18/11/21 to 9/2/22	SW	27/03/2022

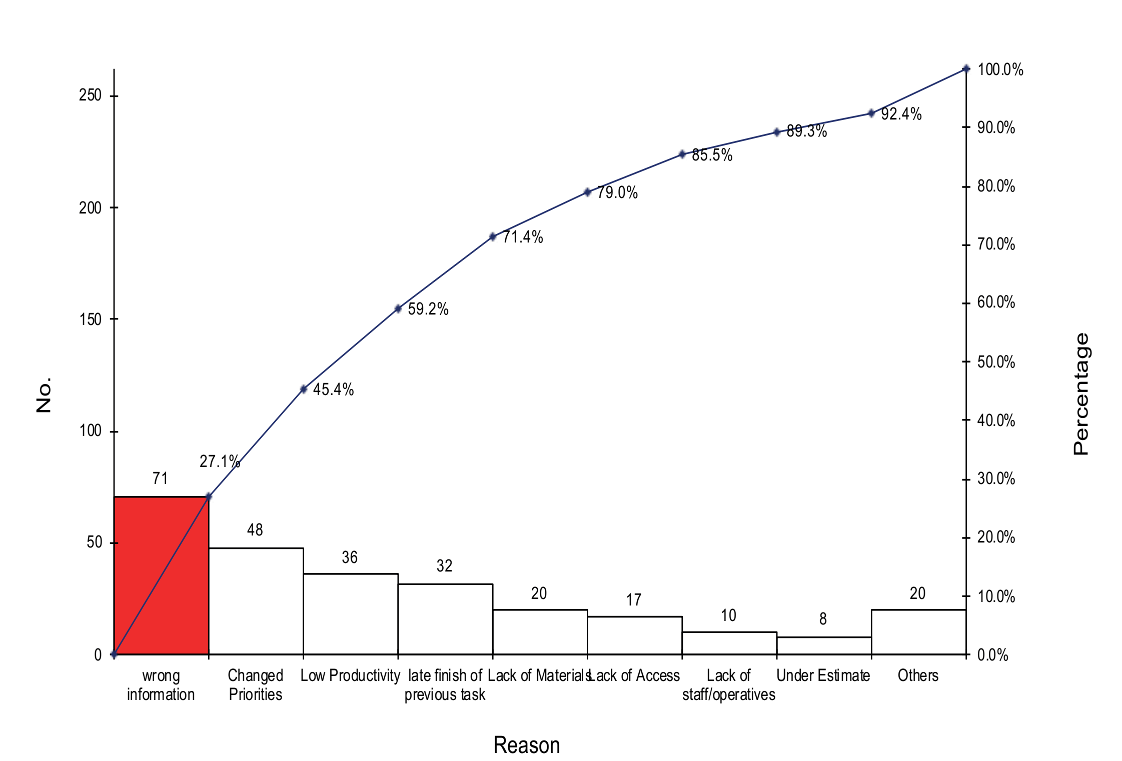


Comment	21% of delays due to wrong info
Action	investigate reasons for wrong info

Figure 17 Reasons for Delay

It can be seen in fig. 17 above that the biggest cause of delay in the period was weather. This may be reasonably expected for the time of year and is not controllable by the site team. In these circumstances the logical next step is to look at the next biggest cause of delay, in this case “wrong information”. In fig 18 below that same data are presented but with the “weather” category removed.

LEVEL	Frequency of reasons for plan failure (not incl. weather)	SAMPLE SIZE	PERIOD	ISSUER	DATE
2		262	18/11/21 to 9/2/22	SW	27/03/2022



Comment	27% of plan failutres due to wrong information
Action	investigate causes of wrong information

Figure 18 Reasons for delay - no weather

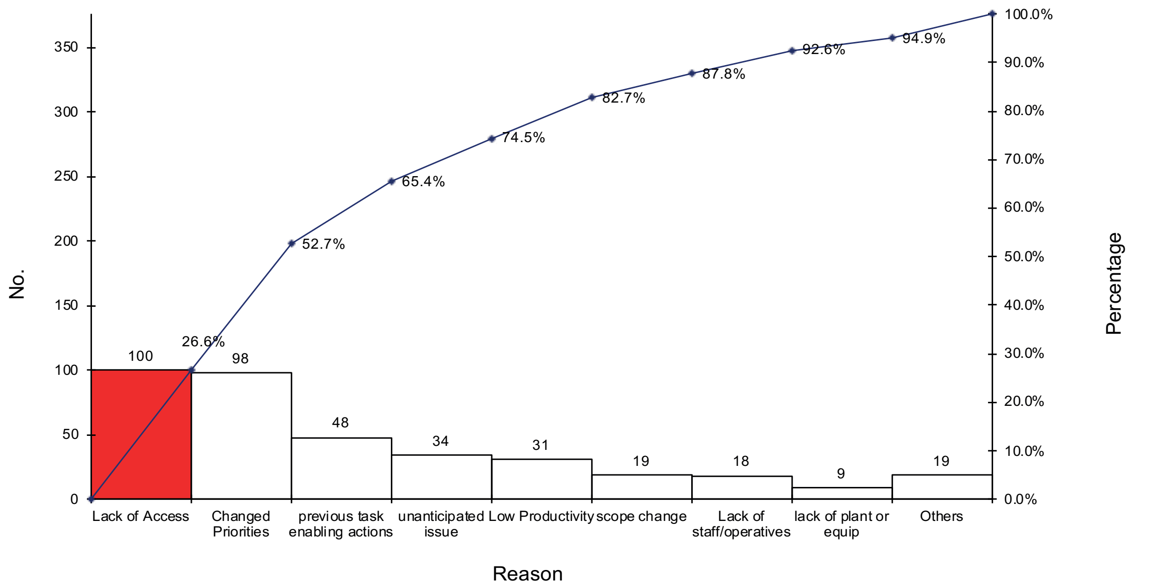
6.3.1 REVIEW OF DATA WITH SITE TEAM

After conducting the analysis above we held a review workshop with the project management team.

The response to the delay data was “that is not correct”. When asked why it was not correct, they reported that a particular subcontractor had input incorrect data, presumably to obscure the real reasons for the delays. When asked what the real reasons were the response was that this was unknown.

The analysis was repeated with a more recent data set as shown below in fig.19. Upon review the team agreed the data “felt about right”. However, It was still unclear what was causing many of the problems.

LEVEL	Frequency of reasons for plan failure (not incl. weather)	SAMPLE SIZE	PERIOD	ISSUER	DATE
2		376	20/1/22 to 24/3/22	SW	19/04/2022

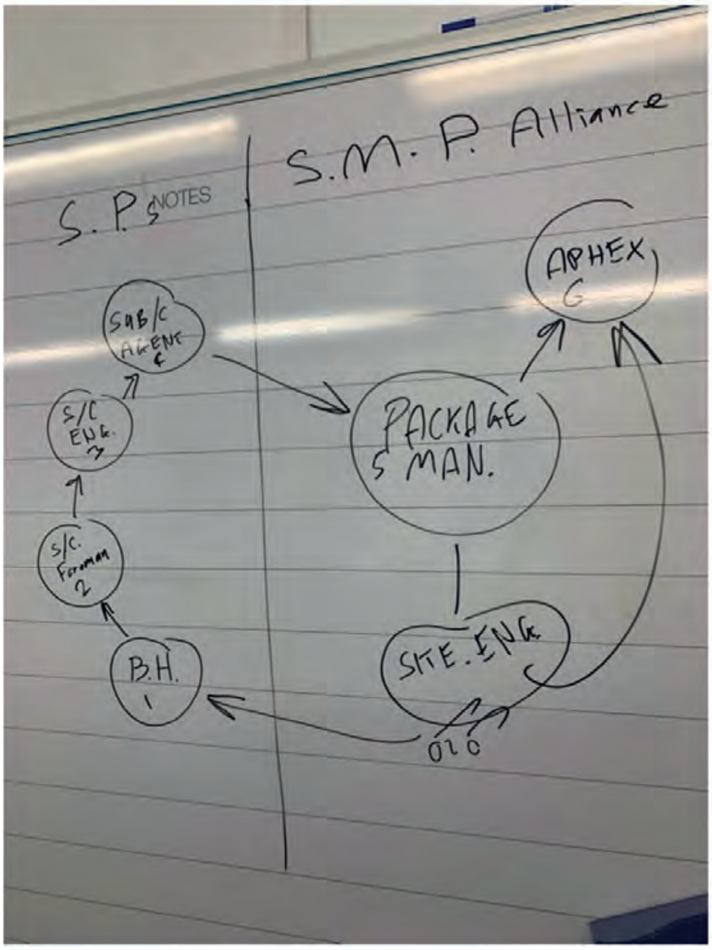


Comment	27% of plan failures due to no access
Action	investigate reasons for no access

Figure 19 Updated reasons for delay

6.3.2 DATA ENTRY AT SITE LEVEL

The management team expressed some concerns in terms of how the data were collected in the first place, which could possibly lead to inaccuracies. We captured the path that the data capture took and this is shown in figure 20 below.



Currently taking 6 steps to get productivity data from Black hat onto Aphex.

Figure 20 the route data capture takes

6.4 ANALYSIS OF BILL OF QUANTITIES

The Bill of quantities for the works was made available to us. In our analysis of this, we are not really concerned with individual costs or rates, but rather with identification of "cost significant items" that can be used to provide focus for efforts to improve productivity. This technique is well documented in ***More for Less- a contractor's guide to improving productivity*** (Horner & Duff 2001)

Our summary analysis is:-

- Of the Direct Works elements there were 5576 lines listed with costs.
- Of these:-
    - 18% of the number of items (1001) accounted for 81% of the cost.
    - 4% of the number of items (232) accounted for 52% of the cost
    - 1% of the number of items (63) accounted for 30% of the cost

6.5 DIRECT OBSERVATION

Following the analysis of data and discussions with the site management team, it was decided to carry out a period of intense direct observation of the current works, which consisted mostly of drainage activities during the period.

One of the most useful of all Lean techniques is direct observation. ***"Go see for yourself",*** whilst perhaps the most basic of lean tools can often be the most effective. Work is viewed through the lens of lean thinking looking to identify opportunity to improve the flow of value-added activities and remove as many wasteful activities as possible.

The writer has trained many construction professionals in this technique, and it is common for seasoned professionals with over 30 years construction experience to be able to identify opportunities for improvement previously unnoticed by other means.

In this case specialist resource was employed, a post grad construction professional who had obtained both MCIOB (chartered institute of building member) but also certified to Lean Leader level (Black Belt) under ISO18404. (The international standard for Lean & Six Sigma)

Nine days direct observation of the works took place interspersed with frequent management reviews with senior project leadership.

The observer engaged directly with the workforce to establish causes of waste & frustration at site level, together with opportunities to improve. Over 30 pages of comments and ideas were collected. These were worked up into a practical improvement plan which consisted of 32-line items, each one costed in terms of the direct loss (and opportunity) associated with labour as well as additional preliminary costs associated with the delay caused by the problem.

6.5.1 SAVINGS CALCULATED

The savings calculated were estimated based on observed number of occurrences and the assumption that with no intervention the same frequency would continue for the life of the project or one further year. The sums were agreed directly with the project leadership as being reasonably calculated. However, it was noted that in some cases the activities would not continue for a year but only 3 or 6 months. The original data report possible savings that range between £353K and £19mil if all the identified work activities would proceed the same manner for an entire year.

The theoretical grand total identified was more than £30mil but a conservative estimate of actual achievable savings was agreed as approximately £2.2mil. The top five activities required to release the savings included:

- re-design to reduce the number of manholes, which expert opinion thought excessive
- revised H&S procedures (viewed possible with direct collaboration from H&S professionals and operatives)
- improved external and internal site logistical planning to avoid waiting for materials
- location of bucket changes
- the access gate process

These items represented the bulk of the potential savings.

We are aware that the site management acted immediately on many of the identified issues once these were clarified. It will be possible to properly calculate the actual immediate savings achieved in time but suffice to say that the return on investment of resource will repay many times over, in this case, more than 100:1.

6.6 DISCUSSION AND CONCLUSIONS ON CASE STUDY

The Tier one contractor in the case study is in the top twenty by size in the UK. They have invested heavily in both the competency of their staff and in the latest technology. In certain areas they arguably lead the field. The staff we engaged with appeared extremely professionally competent and very willing to engage in productivity improvement. Given this background, why did the predictability appear so low, and it was so easy to find savings with a trained eye?

To begin to answer these questions we must look back to section 2 and the Sutter Health study. Considering our over twenty years of effort in the application of Lean Construction in the UK we conclude that whilst worthwhile gains can be made using intervention, technology, and software these appear ephemeral and wholesale transformation is needed. Bolting on tools like Last Planner System / Collaborative Planning to a system that is fundamentally broken will only ever yield superficial results. We can see from analysis of the delay data, how the current contractual practices discouraged true collaboration, even if the intent was there at the outset to fully collaborate.

So whilst investment in technology and digital solutions are of course to be encouraged, we should place at least as much emphasis on low tech approaches such as the Mk1 human eyeball's ability to find productivity improvements, when properly trained, as these can provide immediate benefit, are easy to do and very cheap in comparison to development of new technology.

6.6.1 SHORT TERM ACTIONS FROM CASE STUDY

It is easy to assume that when our sub-contact labour force has "done this many times before", and we also employ the latest digital productivity and planning tools, that the work must be taking place in an optimal fashion. However, the reality we find time and time again is that this is most often not so. It is perhaps not wise to assume that learning is taking place at the coal face because of our continued efforts to improve productivity.

Most projects have several key phases. Our case study project had three or four.

It would be useful to pre-programme direct observation activities, conducted by suitably trained construction professionals (Not Lean Manufacturing Consultants), to synchronise with the beginning of key construction programme phases. If this effort also considered the "cost significant item" approach discussed in 4.4, then a project-by-project productivity improvement plan could be derived in principle as a standard approach. Whilst the longer-term efforts should focus on systemic change as identified in section 2, this will yield immediate benefit.

In addition, the delay codes recorded need to be re-visited to better capture meaningful data.

7. OTHER OPPORTUNITIES FOR LEAN

The key characteristic that defines a lean approach is to focus on and optimise project FLOW rather than any individual project resource or asset. Over recent years despite applying aspects of lean to many projects, such as collaborative planning, the levels of work in process appear to have gone up rather than down. Preliminary costs on projects whilst the network is live can account for as much as 40% of project value. **A focus on speed of delivery may well yield more cost savings than concerns over any individual task's productivity performance**.

It is known that reducing work in process by 50% can yield a lead time reduction of around 30%. (Ward & McElwee 2007) If these techniques could be successfully applied to infrastructure projects significant saving could be achieved with no new technology. In fact, in order to do this it is often necessary to ***reduce*** the productivity of some individual tasks to benefit the project as a whole.

8. UTILITY DIVERSION STUDY (EXECUTIVE SUMMARY ONLY)

By Callum Yeowell MCIOB

We sought to understand utility diversions best practice within the construction industry, including any utilised performance measures. The full report attempts this by reviewing existing knowledge, including a literature review, case studies, and by undertaking a questionnaire survey to obtain current opinions persons in industry who deal with diversions on a daily basis.

Utilising questionnaire responses and the understanding obtained from the review of existing knowledge a calculation was derived using appropriate assumptions for the cost of utility diversions delays per year within the UK. The range identified was £1.35 - £2.03 Billion. These figures are based on extra preliminary costs incurred because of delays. It is likely the real figure is much higher if the full associated costs could be calculated but this is not practically possible.

It was quickly evident during the literature review that legislation around statutory authorities' performance on utility diversions was deemed weak in reprimanding poor performance, but also potentially acts as a de-motivator for statutory authorities to perform well on utility diversions. The questionnaire responses supported this. It is thought that a review and improvement of the legislation would provide a benefit to diversionary works and enable appropriate action to be taken on failings. A statutory role was identified in Scotland of the Scottish Road Works Commissioner and stated to be of great benefit. This was backed by industry opinion. A similar role within England for utility providers would likely be of benefit to industry.

Findings were present surrounding collaborative approaches being more effective than traditional approaches with regards to the parties involved in utility diversions that enter contract. It is noted that statutory authorities are not required to enter contract due to acting under their statutory powers, due to this it is recommended to obtain voluntary entry into practices such as code of conducts as Bristol City Council has implemented.

Early engagement, planning and collaboration are reviewed at length within several case studies and literature. The questionnaire findings support the existing knowledge review findings. It is found to be of great importance to achieving good utility diversion performance both from the common opinion of this and findings presented within case studies.

Utilisation of modern technology including digitisation in all elements of utility diversions is shown to provide benefits via the case studies reviewed. Good examples identified include technological surveys (such as electronic tracing and ground penetrating radar), cloud-based systems, AI forecasting, automated design and augmented reality. It is advised to appropriately invest in technologies found to provide benefit. The literature supports the investment in planning to return a tenfold return in the delivery.

Missing information or inaccuracy of Utility records are found to be an industry wide issue. They are evidently the cause of several delays within projects due to delaying planned utility diversions or causing for further diversions of which the process is required to start much later in the process.

Recommended best practice methods are summarised as follows:

- Operate a collaborative approach such as alliances/codes of conduct rather than traditional contractual approach. However, legislation change would be beneficial to allow consequences for poor performance and ensure motivation is present as it could be seen that the current legislation is a de-motivator.

- Operate a "Single source of information" to avoid late information whereby information is shared and worked on under a central database rather than individual control & issuance.

- Early engagement with a focus on strong coordination and obtaining the necessary competent input to reduces redesign and associated delays, in turn also reducing variation in anticipated costs.

- Use of Technology.

- Implementing a role, ideally with statutory powers, but if not, generally, that will capture performance data and keep a register of utility diversions. Should the role be able to be implemented with statutory powers then the role should include the necessary utilisation of such powers to implement fines where required.

- Appropriate investment in utility record investigation balancing risk and cost expended. Including the sensible and collaboratively agreed placement of risk within contracts.

- Implement an early landowner engagement process ahead of the full typical legal process operated within the utility diversion process itself.

Utility diversions are a complicated process within any project and require many steps and processes with the involvement of numerous parties. It is difficult to clearly identify an exact best practice methodology for the overall process that this report reviews. It is clear the issues and suggested improvement areas are well known and have been discussed within the industry for a long time, the industry appears to be moving in the right direction but there is not an immediate fix and it requires several large associated elements to change to enable significant progress. We believe that investment in improving performance in this area would yield a very high return.

9. APPENDIX ONE- SUMMARY OF DIRECT OBSERVATIONS

- XXX gang had to change working direction and therefore pull in area and welfare now at wrong end.

- XXX gang c. 20m away from an area that wasn't ready for them (Gabion baskets or similar for embankment)

- XXX gang had traffic building up into their work area due to close proximity of previous gang.

- YY gang was c.20m away from tarmac that hadn't been cut out by Tier 1. In downtime where empty wagons are available this could be carted away by gang. Could agree a reduced adhoc fee per wagon as Sub/C 1 are paying their gang to be stood anyway?

- Lack of survey or accuracy of surveys causing design difficulty.

- Large amount of manholes on this scheme apparently compared to previous schemes.

- Negative reaction from team from use of aggregate skips. From observations and discussions it appears:
    - They cannot take a full wagon load
    - Ducks cannot completely empty skips of stone so never fully emptying
    - Require chains to move as most often cannot be easily dragged.
    - Wagon going round filling skips up by grabber which is very slow for the gang waiting, holds traffic up etc. too.
    - Look tidy...
- Concrete seems to be an issue, previous schemes have had their own mixing plant to have it more readily available?
- Generally gangs are proactive in "down time" on required jobs that can be done whilst waiting but this could be further improved as there are still a few tasks being undertaken whilst key tasks such as trenching, pipe laying etc. etc. could be being undertaken:
    - Holes for MFD pipe
    - Set down areas
    - Prepping of chains
    - Bucket Moving etc.
- H&S
    - Key note: H&S deemed two way split (not necessarily 50/50)
        - General ignorant non-compliance due to no care or understanding of risk
        - Genuinely difficult to undertake the task with the H&S provisions in place.
    - General observation: H&S reps seem to arrive, request measures that can cause works to be difficult or impossible and the operatives do not discuss any alternative methods.
    - General observation: H&S reps have different opinions and approaches on what's ok. Causes for operative behaviour to just do what's said on the spot then continue as normal once they leave again until the next visit. This was observed with:
        - Manholes
        - Drag box gaps
        - Use/Purpose of WAGs
    - Thought: Tier one need a standards book to align internally their H&S approach.
    - Thought: Tier one H&S reps to identify where a H&S process may not be being followed due to difficulty and proactively engage operatives to try and agree a better approach.
- One gang I was with didn't know about the new concrete spec (above bottom ring) to roadside only so was still concreting all round.

10. APPENDIX TWO: MANAGEMENT OF UTILITY DIVERSIONS AND THEIR IMPACT ON INFRASTRUCTURE PROJECT PERFORMANCE

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LIST OF ABBREVIATIONS

ACE	Association of Consultancy and Engineering
AFR	Accident Frequency Rate
AI	Artificial Intelligence
ALB	Arms Length Body
BIM	Building Information Modelling
BT	British Telecomms
CAD	Computer Aided Design
C3/C4	Sections of appendix C
CI	Continuous Improvement
CoP	Code of Practice 1992
DCO	Development Consent Order
DfT	Department for Transport
HAUC	The Highways Authority & Utilities Committee
H&S	Health & Safety
ICG	Infrastructure Client Group
ISO	Internation Organisation for Standardisation
JCT	Joint Contract Tribunal
JV	Joint Venture
KPI	Key Performance Indicator
LADs	Liquidated & Ascertained Damages
LPS	Last Planner System
NBS	National Building Specification
NJUG	National Joint Utilities Group
NRSWA	New Roads & Streetworks Act
OO	Overseeing Organisation

PP	Pull Planning
PPC	Planned Percentage Complete
PS	OO's Project Sponsor
REM	Rapid Engineering Model
SoS	Secretary of State
SMP	Smart Motorways Programme
SRWC	Scottish Road Works Commissioner
SU	Statutory Undertaker
TfL	Transport for London
TMA	Traffic Management Act
UK	United Kingdom
UKRI	United Kingdom and Republic of Ireland

ACKNOWLEDGEMENTS

We would like to express our gratitude to those persons whose assistance and cooperation made this research possible. Firstly, to the Transport Infrastructure Efficiency Strategy (TIES) Living Laboratory for commissioning the research. Secondly, to all of those who undertook the questionnaire, with particular thanks to the Civil Engineering Construction Association (CECA) for its distributions amongst both its member's and peer groups. Thirdly, to the contribution of, and data provided by, National Highways.

EXECUTIVE SUMMARY

This work seeks to understand utility diversions best practice within the transport infrastructure industry, including any utilised performance measures. The report achieves this by reviewing existing knowledge, a combination of academic literature review, case studies, and undertaking a questionnaire to obtain current opinions on the findings from the review of the existing knowledge.

Utilising questionnaire responses and the understanding obtained from the review of existing knowledge a calculation was derived, utilising appropriate assumptions for the cost of utility diversion delays per year within the UK. The range identified was £1.35 - £2.03 Billion. It is likely the real figure is much higher if the full associated costs could be calculated.

It was quickly evident during the literature review that legislation around statutory authorities' performance on utility diversions was deemed weak in reprimanding poor performance, but also potentially acts as a de-motivator for statutory authorities to perform well on utility diversions. The questionnaire responses supported this. It is deemed that a review and improvement of the legislation would provide a benefit to diversions and enable appropriate action to take on failings. A statutory role was identified in Scotland, the Scottish Road Works Commissioner, and stated to be of great benefit, this was backed by industry opinion, a similar role within England for utility providers would likely be of benefit to the industry.

Findings were present around collaborative approaches being more effective than traditional approaches, with regards to the parties involved in utility diversions that enter contract. It is noted that statutory authorities are not required to enter contract due to acting under their statutory powers, due to this it is recommended to obtain voluntary entry into practices, such as a code of conduct, as Bristol City Council has implemented.

Early engagement, planning and collaboration are reviewed at length within several case studies and literature. The questionnaire findings support the existing knowledge review findings. It is found to be of great importance to achieving good utility diversion performance, both from the common respondent opinions and findings presented within case studies.

The case studies reviewed shows the utilisation of modern technology, including digitisation in all elements of utility diversions, provides benefits. Particular good examples identified included; technological surveys (such as electronic tracing and ground penetrating radar), cloud-based systems, AI forecasting, automated design and augmented reality. It is advised to appropriately invest in technologies found to provide benefit. The literature supports the investment in planning, referring to a return a tenfold return of investment in the delivery output.

Missing information within, or inaccuracy of, Utility records is found to be an industry wide issue. They are evidently the cause of several delays within projects. This is due to delaying planned utility diversions or causing for further unplanned diversions of which the process is required to start much later in the process.

The limitations of this research are summarised as follows;

- Each diversion is different in nature and scope,
- The sharing of recently commissioned or underway research has been limited,
- No information on currently utilised KPIs for utility diversions was identified,
- Delays in construction are typically from multiple factors and parties, consequently making the true direct impact of just utility diversions difficult to quantify
- The number of questionnaire responses provided was limited.

It was evaluated that whilst the questionnaire responses were limited the response was still representative and of good quality.

Recommended best practice methods are summarised as follows:

- Operate a collaborative approach such as alliances/codes of conduct rather than traditional contractual approaches. However, legislation change would be beneficial to allow consequences for poor performance and ensure motivation is present as it could be seen that the current legislation is a de-motivator.

- Operate a “Single source of information” to avoid late information whereby information is shared and worked on under a central database rather than individual control & issuance.

- Early engagement with a focus on strong coordination and obtaining the necessary competent input to reduces redesign and associated delays, in turn also reducing variation in anticipated costs.

- Use of Technology.

- Implementing a role, ideally with statutory powers, but if not, generally, that will capture performance data and keep a register of utility diversions. Should the role be able to be implemented with statutory powers then the role should include the necessary utilisation of such powers to implement fines where required.

- Appropriate investment in utility record investigation balancing risk and cost expended. Including the sensible and collaboratively agreed placement of risk within contracts.

- Implement an early landowner engagement process ahead of the full typical legal process operated within the utility diversion process itself.

Utility diversions are a complicated process within any project and require a large number of steps and processes with the involvement of numerous parties. It is difficult to clearly identify an exact best practice methodology for the overall process that this report reviews. It is clear the issues and suggested improvement areas are well known and have been discussed within the industry for a long time, the industry appears to be moving in the right direction but it’s certainly not an immediate fix and requires several large associated elements to change to enable a true transformation.

1. INTRODUCTION

Diverting Utilities is a complex, potentially hazardous, and always expensive activity. The successful management of Utilities on all infrastructure schemes will have a key impact on the project success in terms of safety, time and cost. Failure to manage this well could have catastrophic consequences as it is evidenced from data analysis and literature review that utility diversions often cause delays to projects with costs varying largely from initial predictions.

It is vital that best practice, developed in managing Utility Diversions, is identified and shared amongst client organisations to enable efficient management on present and future schemes.

It is recognised that all Utility companies, as regulated businesses, are facing increased pressure on costs and resources to deliver a satisfactory return to their shareholders. The work they are required to do for diversions is typically both without choice and commercially unprofitable.

This report looks to undertake academic research into best practice methods within the industry, including both current procedures and advisory, and the comparative performance measures of utility diversions. It was noted from the literature review that there is extensive literature available for Health and Safety (H&S) best practices. The brief also eludes to the wider process, from concept through to site, rather than the onsite process. Therefore, the H&S best practice of utility diversions has not been a point of focus or coverage within this report.

1.1. REPORT FOCUS

The aim of this report is to investigate the performance of utility diversions within the construction industry to identify causes, best practice and effective KPI measures.

1.2. REPORT OBJECTIVES

Item	Objective
A	Identify Best Practice Methods for Management of Utility Diversions inc. Process map of key stages.
B	Identify measures of reporting utility diversion performance (both current & advisory).

1.3. RESEARCH OBJECTIVES

Number	Objective
1 (A&B)	Identify typical performance of utility diversions and Capture causes of success and delays.
2 (B)	Calculate the impact of utility diversion performance.
3 (A)	Reviewing the causes of successes and delays with any correlations between actions/approaches and the corresponding success/delay.
4 (A)	Review motivators for statutory authorities/utility providers to enable successful diversions inc. Profitability & enforced KPI's via regulating bodies.
5 (A)	Review processes & procedures of other ALB's Utility Diversion Management, including any current KPI measures.
6 (A&B)	Summarise Findings to create a best practice approach, including associated performance indicators.

2. REVIEW OF EXISTING KNOWLEDGE

A review of existing knowledge was undertaken including reviews of academic research, investigative reports and case studies. This was to ascertain current knowledge, any existing themes and any potential gaps in knowledge with regards to utility diversion best practice.

2.1. DEFINITION AND PURPOSE OF A UTILITY DIVERSION & A STATUTORY AUTHORITY

A utility diversion is defined appropriately by Premier Energy Specialists in Utility Infrastructure (2019); a utility diversion is when utility apparatus needs to be relocated or altered in some way. This is normally done when existing utility infrastructure is constraining the development of a site. There are examples of utility diversions present in numerous infrastructure and housing projects, and it is a common need to divert utilities to facilitate the scheme.

The purpose of a utility diversion is to facilitate new construction where a current utility asset exists. This is to ensure utility assets are not encroached or damaged by third party construction activities. They are to be positioned in a safe place to allow construction to be undertaken, whilst maintaining suitable access and protection to utility assets for the new infrastructures end use.

A statutory utility is a supplier of electricity, water, gas or telecoms which is licensed by the government. This license grants them statutory powers, among which is the right to locate their services in the public highway (Weaver, R. 2019).

2.2. THE NEED FOR IMPROVEMENT

Highways England undertook analysis into utility diversions for recently completed works on the A585, finding 32% of programme delays were attributable to the statutory authorities work. The additional costs of utilities on the A585 added 19% (£1.75 million) to the total project costs. The report also forecasted a potential delay of 10% to the programme on section 4 of the A14 with utility estimates doubling during quote progression stages. This equated to an additional 2% (£28 million) of project costs (Williams, S. et al. 2021). The report states that whilst causes of the delays were identified, accurate calculations of the true effect on time; cost and quality are unknown. The initial findings within this report would suggest that, whilst utility diversions impacts are not easy to quantify exactly/accurately, there is an evident issue which warrants investigative research into methods of improvement.

2.3. DELAY CAUSES

Moore, A. (2021) undertook an analysis into various aspects of utility projects and captured the delay causes, from Highways England case studies, on the A14 and the M4. The causes on the A14 are listed below in order of nr. Occurrences., in ascending order. The delay causes noted on the M4 are largely similar but vary in their number of occurrences.

- Theft
- Quality-issue
- Lack of standard approach
- Insufficient resources
- Environmental compliance
- Damage and rework

- Appointments delayed
- Payment delay to SO
- Legal issues
- Land issues
- Inexperienced resources
- Roles and responsibilities issues
- Issues with working procedures
- Procurement delays
- Safety requirements
- Resource quality/experience
- Contractual issues
- Software/systems
- Design issues
- Late/poor quality information
- Coordination

The variety of delay causes suggests a complicated process with various areas for improvement. It is noted that safety requirements were a common delay factor but, during the literature review, it was noted that numerous documents and best practice is available. Therefore, this research focuses on the wider process, from start to finish, rather than the onsite safety practices.

2.4. CALCULATING THE IMPACTS OF DELAYS

The impacts from delays are assessed as "damages"; this is typically required for when calculating the chargeable cost of any delay for the liable party. These impacts can be categorised into two main groups: direct and indirect. Direct impacts are those easily quantifiable I.e. time, cost of labour/ materials or preliminaries. Indirect impacts are those more difficult to accurately quantify, such as loss of revenue or the effect of longer periods of road congestion. Contractually, these direct impacts are referred to as actual damages and indirect impacts are referred to as liquidated or ascertained damages. Whilst this is typical construction industry knowledge, and stated within contracts, it is succinctly summarised within a journal on the overview of components when calculating a delay claim by William C. Last, Jr. (2016).

Safeer Ali et al. (2017) has undertaken a detailed appraisal of both direct and indirect delays in construction engineering projects. The literature focuses on singular tasks and shows that delay factors are often intertwined with each other. Whilst there is a correlation between efficient practices and poor-quality workspaces or lack of competence etc. The correlation for each aspect is not linear nor directly proportional. The journal refers to direct impact costs being easier to calculate and applies logic to using evidenced figures, although it should be noted that this is for singular activity tasks. Where projects are delayed for multiple causes simultaneously (concurrent delays), or where delays to multiple activities have combined and caused a larger or different impact, this will be harder to quantify.

2.4.1. INDIRECT

The indirect impact from delays to infrastructure projects are deemed numerous with the true knock-on impacts extremely difficult to capture and quantify. This is evidenced in research by Goodwin, P (2005) who investigated the delay costs from utilities streetworks, one of the most obvious indirect costs being traffic congestions, in Bristol. The report, whilst detailed, did not conclude a true cost and refers to different parties, including the Department for Transport (DfT), calculating different figures and further highlighting the complexity. It notes that the DfT, in 2005, deemed that the average cost of a Utility Streetwork Day, regarding the congestion, was £600.

More recent literature, studying the anticipated costs of congestion amongst other various highways impacts, depicts the cost in various forms. A study by Grant Muller et al. (2007) refers to the percentage of trips affected by congestion; as do later publications on behalf of the Association of Consultancy and Engineering (ACE) in 2019.

The calculations and literature on indirect delays from streetworks, with highway downtime or increased congestion, are vast and in depth. Whilst the impact should be noted when considering the delays from utility diversions, it is not the primary aim of this research nor would it add significant value to this research and is therefore not commented or investigated further.

2.4.2. CONCURRENT

A concurrent delay is defined by Dyton, R. et al. (2018) as a situation where a construction project is delayed by two events at the same time, one being an event for which the employer takes responsibility under the contract and the other for which the contractor takes responsibility. It is known that in construction projects are typically delayed for numerous reasons, either simultaneously causing a delay or the combined effect. This is evidenced by concurrent delays being recognised under the commonly used Joint Contract Tribunal (JCT) contract forms. It is acknowledged that delays from utility diversions may not be the only factor causing delays to projects. However, in order to evaluate the potential impact of utility diversion performance, any calculations or examples assume the utility diversions are the only cause of delay and concurrent delays will not be investigated further.

2.4.3. DIRECT

Direct impact as a result of delays can be numerous. The most commonly and primarily referred to impact is the preliminaries. The National Building Specification (NBS) (2022) defines preliminaries as “Preliminaries relate to the cost-significant items required by the method and particular circumstances under which the work is to be carried out, and those costs concerned with the whole of the works rather than just Work Sections. These costs may either be ‘one-off’ fixed costs, such as the cost of bringing to site and erecting site accommodation (and subsequent removal) or time-related, such as the heating, lighting and maintenance cost for that accommodation.”

Acceleration measures, and therefore acceleration costs, can be employed to reduce delays or to bring forward projected completion dates (Long, R. 2020). The article elaborates this and refers to the contractual sense, whereby an instruction is provided to the contractor to bring forward the completion date, for which the contractor can price to achieve this for acceptance/rejection by the client.

For the purpose of this research, it is acknowledged that delays can be mitigated by acceleration. However, given the required acceleration factors will be project specific and the ownership of the delay may vary (and therefore the liable party for acceleration) it is deemed this level of analysis on delay impact would not add value to the research. It is therefore intended that any calculations analysing the cost of utility diversion impacts will use a representative average preliminary figure. It is also acknowledged that not all preliminary cost items are time relevant but, as any exploratory calculations to represent the impact of utility diversions will be generalised, an average cost per week for preliminaries on infrastructure is deemed appropriate.

2.5. STATUTORY AUTHORITIES MOTIVATORS FOR SUCCESS

Judged by an analysis of annual financial reports, the percentage of Water utility company income from diversions is small, at approximately 1% (Severn Trent 21). To date, review of the annual value of works undertaken includes Water – 11 providers annual reports/accounts reviewed, of which 4 had income from diversions listed on the accounts. As a percentage of turnover these were all <1%, with the highest being Severn Trent at 0.998% and the lowest ,Wessex Water, at 0.58%. The National Grid, with £5.2 Billion turnover, had 0.94% coming from diversions.

In addition, the New Roads and Streetworks Act 1991 requires Utility companies to discount their profits by 18% when undertaking these works. As it is such a small part of their business, and the fact that profits are driven down, it may be the case that motivation is low on the part of the Statutory Undertakers. However, failure to manage Utility Diversions effectively can lead to extensive and expensive delays to projects. No performance measures were found apart from an obligation to compete.

"There is no performance obligation to the agency/authority beyond completing the diversion." (Anglian Water 2021).

A very thorough research paper, which included a heavy focus around the legislation at the time, referenced numerous other papers, including relations to other countries. It deemed the NRSWA is ineffective at dealing with statutory authority failures because the court process is deemed lengthy and fines are relatively low (Brady, K. Et al 2001). Whilst this is a dated source, it was backed by surveys and court cases. The main applicable failings of the NRSWA relevant to this research are noted below:

- Formal procedures for co-ordination of street works are still not in place nor is there a national register.
- There is no mechanism to ensure that work is completed as rapidly as possible.
- Emergency powers are being abused.

The Highways Authority & Utilities Committee (HAUC) produced an advice note in 2009 on performance management (HAUC 2009) for achieving good performance for works associated with the Traffic Management Act 2004 (TMA). Within this note it advises authorities to create their own relevant performance measures to create motivation around achieving good performance and encouraging continuous improvement.

2.5.1. BRISTOL CODE OF CONDUCT FOR STREET WORKS AND ROAD WORKS

A code of conduct, written by Bristol City Council (Venison, D. et al. 2018) and its key statutory undertakers, provides the principles they all agree too for working together. The authors are stated to be; Bristol City Council, Bristol Water PLC, Wales & West Utilities, Wessex Water Ltd, Western Power Distribution, Streetworks UK and Virgin Media Group. Please note that these parties have all signed this document and this could be deemed as buy-in and acceptance of these principles. Whilst this code of conduct review is not on major infrastructure projects, the points noted below are deemed relevant.

The council holds quarterly collaborative forward planning meetings to review anticipated major schemes over the next 5 years. It's said that the main focus of this is to look at collaboration opportunities to utilise the same spaces and increased forward visibility of coordination issues.

Whilst no detailed prescription is provided on frequency or method, communication is highlighted as essential between all parties throughout the code of conduct.

It requests all "work promotors" to focus on developing and innovating products in order to continuously improve across all aspects of their work.

2.6. TIME OF ENGAGEMENT

Research by the SCAPE framework found that when they engage with clients early in the design process, they are typically able to deliver a 10% increase in efficiency. This refers to the issues of more traditional procurement forms, where the contractor is engaged at a later state and therefore is of less influence due to design progression.

Whilst there is a potential for bias, it should be noted that Utility Specialist contractors and consultants advise that their early involvement helps in ways such as reducing risk, providing programme certainty and achieving best value solutions (D2 Rail website 2022 & Fisher German website 2022).

There is an indication of a correlation between the time of engagement between the Utility provider and the Contractor and the successful delivery of the project. This literature finding will be further investigated in the questionnaire/survey and case study reviews.

2.7. LEAN THINKING, STAFF INVOLVEMENT & LEAN MATURITY IN THE SUPPLY CHAIN

Angelis et al. (2012) analysed 300 operatives via interview and performance review in order to make processes, involving those persons, leaner. It concluded that staff participation was highly beneficial due to staff knowledge of the workings and improved collaboration from the level of involvement. This would suggest interviews with those involved in the process to be a valuable source of information to inform improvement/ best practice rather than being reliant purely on the client's feedback and experience of the utility diversions.

Singh et al. (2010) produced an in-depth study into one construction material production company via comparison, before and after lean thinking was introduced. The findings show lean implementation can prove beneficial, as per the table below:

Aspect	**Percentage Increase (%)**
Lead Time Reduction	83.14
Processing Reduction	12.62
Reduction in work-in-progress inventory	89.47
Reduction in manpower required	30.00
Rise in productivity per operator	42.86

Construction is a risk-averse industry and companies often want to deliver projects in ways that they are confident can meet the client expectations, thus lean change is unlikely without supporting information (Fraser 2013). This suggests lean requires supporting information and a positive attitude to sustain its implementation and, in turn, to sustain the improvements.

Sfakianaki (2015) suggests all stakeholders, at every stage, should commit to lean thinking to enable a change in perception and allow method change/improvement thus increasing efficiency. The paper highlights the importance of a coordinated supply chain in the construction sector. A conference held by London et al. (2000) discussed the importance of changing the traditional supply chain perspective in order to improve the efficiency of the construction industry itself. Segerstedt (2010) supported this with findings clarifying that well managed supply chains contribute to the overall efficiency of a project. Erikkson (2010) states increased cooperation among supply chain actors is an appropriate starting point for further development of the lean concept.

When planning the procurement process, it is important to consider the potential supplier's experience of the process selected as this is vital for any element which requires multiple parties' involvement (Fraser 2013). This is furthered by Zaman et al. (2014), who has undertaken research into the performance of various lean supply chains, which state the entirety of any system implemented needs to be fully understood by all participants, with detailed and collaborative planning, to smooth workflow and reduce waste.

2.8 . LINKS BETWEEN PLANNING AND EFFICIENT DELIVERY

Mawdesley et al. (2010) produced in-depth analysis on what increases project efficiency; the results suggest investments in planning and control have been most beneficial for productivity and investments in safety, motivation and reduction of disruptions. Hinze (2012) evaluated several projects, with varying levels of importance/time allocated to programming prior to construction. The results showed a correlation between increased planning and reduced project durations. These findings suggest a larger investment in the planning/design stage could achieve greater project efficiency. By elucidating the relationship between preconstruction planning and project execution tasks, it can help contractors achieve project performance improvement through effective task-level strategies (Kim et al. 2013).

2.8.1. CONSTRUCTION PLANNING

Thomas et al. (2013) produced a paper on Pull Planning (PP); it describes PP to remove the waste of waiting, redundancy, and over processing. PP's importance builds from the concept of "Pull". This is recognising that each step is an input to the next, which needs to be delivered at the right time, quantity and quality (Hamzeh 2012). Hamzeh (2012) investigates the success and failure of PP and it found that although most companies registered improvement from implementing PP, some had adverse effects from insufficient implementation. Two case studies are analysed, which both introduced PP to improve their resource allocation and the task completion per operative was compared before and after PP, showing resource efficiency was found to have improved.

Warcup et al. (2014) describes the Last Planner System (LPS) as a commitment-based planning system that integrates PP with constraint analysis, weekly work planning and learning based upon analysis of Plan Percent Complete (PPC) and the reasons for variance. Lean Construction Institute (2015) breaks down LPS to the following key elements:

Table 6: Last Planner System Break Down (Lean Construction Institute 2015).

Element	**Description**
Master Scheduling	Setting milestones, identification of lead items
Phase Pull Planning	Specify handoffs; identify operational conflicts
Make Work Ready Planning	Look ahead planning to ensure that work is made ready for installation; re-planning as necessary
Weekly Work Planning	Planning the work to be completed per week
Learning	Measuring PPC, analysing reasons for failure, developing and implementing lessons learned

AlSehaimi et al. (2014) compared a project implementing LPS to one that didn't; it found the project implementing LPS achieved a higher PPC overall. The paper states the critical success factors for LPS implementation are top management support, commitment to promises, involvement of all stakeholders with sufficient communication and coordination. The paper also describes barriers to the full potential of LPS, including varying attitudes of subcontractors and stakeholders. This is supported by Cho et al. (2011) which states implementing LPS is found to have a correlation with improved project efficiency.

The importance of effective planning has been in utility diversion literature for many years, an example being Highway Authorities & Utilities Committee (HAUC) (1992) Advice Note no. 2009/05 - Performance Management Process for Works in the Highway. It is therefore anticipated that effective planning measures are already implemented within highway projects and utility diversions. These will be sought after for review within this research.

2.9. INFORMATION TECHNOLOGY

Successful implementation of Building Information Modelling (BIM), with respect to lean procedures, will reflect new business processes and the redefinition of the value systems across a project to become leaner (Dave 2013). Sacks et al. (2010) claims BIM holds the potential to improve workflow and reduce waste by providing both process and product visualisation at the work face.

A cloud-based system was introduced for managing utilities, including diversions, for the Heathrow Expansion. This was introduced to assist with effective management of the numerous diversions affecting over 70 utility companies. The report (Claase, R. 2021) was written by one of the systems instigators and may be biased. However, the benefits noted within align with the aspects deemed necessary for effective management of utility diversions identified within other case studies including; routine & effective communication, better information management/ records and improved decision making I.e. not producing unnecessary deliverables. Whilst detail on the system is limited it, or an equivalent, would be worth investigating further.

Jorgensen et al. (2009) researches the links between design and construction from a lean perspective. The research supports that design and construction need successful integration, conversing back and forth evaluating decision consequences and methods, to successfully implement lean construction. The report concluded that this is greatly improved by the use of collaborative software's and digitisation.

2.10. STATUTORY OFFICER – SCOTTISH ROAD WORKS COMMISSIONER

The report by Barton, J (2016) reviews the role of the Scottish Road Works Commissioner (SRWC) which is a statutory officer appointed by the ministers as legislated in the Transport (Scotland) Act 2005. The report suggests that no equivalent role has been identified within the UK or the rest of the world.

The role is to monitor the carrying out of road works in Scotland for quality, coordination and timeliness to promote compliance with the NRSWA 1991. The responsibilities of the commissioner are to publish an annual report, prepare an annual account and keep a register of all planned and completed road works. This includes powers to impose penalties of up to £50,000 for systematic failures under the NRSWA 1991.

The report summarises that the role is highly successful and appends the surveys undertaken to inform the research. Survey findings showed 78% of respondents were aware of role with only 22% unaware. All respondents agreed with the statement that coordination and delivery remain with the road authorities and undertakers with the SRWC are responsible for monitoring, promoting compliance and encouraging good practice where the commissioner only intervenes if there is a systematic failure.

2.11. STANDARD METHODOLOGY FOR ASSESSING UTILITY WORK REQUIREMENTS

Placement of risk via contract particulars did not arise in most of the literature reviewed. However, a report by Rumney, D. (2010) called "Standard Methodology for Assessing Utilities' Works Requirements refers to an appropriate balance of risk within the procurement approach. In summary, it advises the appropriate assessment of risks and how to tackle them be it invest in further investigations to lower the risks, or to allocate the risk(s) or elements of the risk(s) within the contracts.

One of the common risks is accuracy/inclusion of service information within records and surveys. At the time of the research, BT plans scale mean that 1mm route is 1.25m out on the ground and chambers are much larger than the actual.

3. CASE STUDY REVIEW

3.1. CADENT (A GAS NETWORK PROVIDER)

Cadent, a large gas provider to over 11 million homes across England, undertook a case study review including re-occurring faults, lessons learnt/opportunities and a self-review on all DfT Major Infrastructure Schemes they are involved with. This case study included Lower Thames Crossing (9 areas), HS2 (18 diversions totalling 17Km), Heathrow expansion and various HE schemes including the M42. The research by Rogers, P. et al. (2021) found the below:

Re-occurring issues:

- Coordination discrepancies between various professionals and appropriate sign offs.
- Early design decisions made without their professional input. These require earlier engagement so that the appropriate utility requirements can be captured in the designs early enough and coordination can take place. Multiple examples stated: where designers' intentions could not be followed, and the required adjustments to designs were costly and were later in the process than required.
- Insufficient regular communication due to covid restrictions.

Lessons Learnt & Opportunities:

Both Cadent, and their clients commissioning ground investigations, advised combining requirements and commissioning a joint ground investigation to enhance processes and aid coordination.

- It was their opinion that they often had to guide new client team members through their own processes as well as Cadents processes. Also, where processes are not shared efficiently within JV's, there are suggestions to provide training/mentoring and to have greater processes and competence prominence as well as consistency across multiple projects.
- Regular and structured coordination despite covid-19; they found that the pandemic caused a breakdown to the frequency and structure of their communications, which was perceived to have a consequential effect to performance.

Cadent self-review:

- Even though the topic was not evaluated for its benefits within the literature, it was identified that they don't currently undertake Development Consent Orders (DCO's) for early agreement with the relevant landowners.

- Cadent identified that they do not make money on customer driven diversions. This would suggest it is stated for them to review how to provide motivation for them to drive diversion performance.

It should be noted that within the case study Cadent gave specific results that they deemed to be achieved as a result of early engagement. This included significant lengths of gas mains not being required to be diverted, such as 5km less on the M25 works. In addition, there was the Lower Thames Crossing which had a descope from an originally intended 9 diversions down to 4 diversions, reducing costs from c. £100m to c.£40m. A description of "early engagement" was not provided.

3.2. NATIONAL JOINT UTILITIES GROUP (NJUG)

The NJUG have reviewed a case study (NJUG 2014) involving collaboration between Bristol City Council and four local utility companies; Bristol Water PLC, Wessex Water, Wales & West Utilities and Western Power Distribution. Whilst the research covers typical utility maintenance and repairs, in addition to larger works such as diversions and/or new services, the principles discussed are likely to still be relevant and transferrable to larger diversions within major infrastructure projects. The whole approach is focused around collaborative early engagement, allowing planning of works to coincide and reduce road closure timescales. Whilst timescales, or a definition around "early", is not provided it aligns with wider literature review around efficiencies. The benefits stated within the case study that are deemed relevant to this reports research are as follows:

- 24% decrease in extensions, allowing a better overall coordination of works.
- 50% reduction in associated charges attributable to late completions.
- 120 days of highway occupation reduced (in the annum of the report), therefore minimising disruption to public road users.

3.3. EDINBOROUGH TRAM INQUIRY

Rumney, D. (2018) is a report produced by an engineer with over 40 years' experience; the report investigates the relationship between tramways and utilities apparatus, including its diversions to allow tramway installations. The report is very thorough, with over 80 pages of content, and covers a large number of aspects.

Evaluated within is the contributions needing to be made by the statutory authorities towards diversions that are enforced on them to enable new tramways (or other infrastructure). It refers to points of contention around the requirement for statutory authorities to provide a level of diversion cost estimates for free and around the contribution sums. The report later reviews the statutory undertaker's interest in keeping costs low and diversions as cost effective as possible due to the contributions often meaning they cannot profit from the works.

Potential sources of delay in carrying out divisionary works, which in turn frequently cause delays to the wider project, are evaluated within the report. There are some details specific to Tramway installations or deemed no longer relevant due to their age. Those deemed relevant are referenced below.

3.3.1. UNJUSTIFIED OPTIMISM

This is explained as the anticipated timescales of works being much shorter than the actual required timescales. The examples discussed range from 1990 through to 2013. Whilst the causes of this are not analysed in detail for why the timescales required were longer, I.e., the timescales could have included mistakes etc, there are routine references to initial timescales being without detailed assessment or use of historic knowledge.

3.3.2. UNDISCOVERED APPARATUS

Where investigations are carried out and utility records are reviewed to identify the services in the area, the report states that it was common on the tram infrastructure projects that utilities were discovered which were not identified previously. These were both a mixture of live and redundant services. These live unidentified utilities need to go through the same process as the known diversions and, given the much later commencement of this lengthy process, this is frequently a delay cause. The report does not describe what would be deemed as suitable investigations, or that an improved investigation process would lead to lowering the likelihood of unidentified services, and therefore lowering the likelihood of delay. However, this can be reasonably assumed.

3.3.3. ZONING

Compared to intelligent and well assessed scheduling of works between multiple parties, it is deducted that due to the ways tramways can be constructed in sections, and in no particular direction, this may be an appropriate approach in some circumstances. Whilst it provides this as a consideration, it notes that intelligent scheduling of works between parties, with shared programmes and sufficient collaboration time, is a more logical approach. It should be noted that sufficient time between all parties to properly plan is a reoccurring theme throughout the report and is commonly referred to under several of the other delay causes.

3.3.4 . FAILURE TO COMPLY WITH AGREED TIMES-CALES

As utility companies are undertakers with powers granted by the statute, they have no need to bind themselves by contract as long as they are carrying out works in accordance with their powers. The report details the requirements under the NRSWA and states that "on the face of it" they should be liable for delays but comments that from experience and findings, utility providers will rarely commit to a firm target. They can always claim their legal service requirements (examples given of repairing cable strikes on another site by where the diversion works on the reviewed site are left stood with no progress whilst this repair elsewhere occurs). It then also suggests that the NRSWA calling for "the avoidance of unnecessary delay" causes difficulty to ever suitably justify that the delays were not necessary. This would suggest that the obligations placed on the statutory undertaker for timely completions of works, via legislation or a contractual format, should be reviewed.

3.4. THE CAUSES AND CONTROL OF COST CREEP AND COST ESCALATION

A report by Rumney, D. (2010) named "The Causes and Control of Cost Creep and Cost Escalation" captured the findings of one of several other activity groups, consisting of professionals with considerable experience in the field and supported by the DfT, who were tasked to review the various approaches of operators in the UK for how they protect and divert utility apparatus. Four case studies were reviewed as part of this research covering; Manchester, Croydon, Edinborough & West London. These case studies covered multiple phases of infrastructure from 1998 to 2009 with numerous statutory undertakers involved, suggesting a good sample of both region and statutory undertake.

The report inputs an element of cost variation between C3 estimates and later outturn costs down to inflation. However, it does not note this against all case studies despite most of them having similar time frames from planning and engagement through to work completion.

A few examples within the case studies show hugely expensive proposals by statutory undertakers as a C3 estimate that are then reviewed and a much more cost-effective approach is agreed. Equally, several C3 estimates when reviewed had to significantly increase within these case studies where client/statutory authority requirements were not factored in sufficiently or inaccurate utility records were available.

Report findings that are applicable to wider infrastructure are captured below:

- Inflation, most diversions from planning to completion were over 4 years.
- Several deviances from C3 to later costings were due to engagement of clients/contractors etc. after the estimate was produced.
- Poor network records that were later updated following detailed surveys which caused for some variations from C3 estimates.

3.5. ALLIANCE APPROACH OVER TRADITIONAL CONTRACTUAL RELATIONSHIPS

A report by the Infrastructure Client Group (2015) reviewed forms of alliancing rather than traditional contractual arrangements. The report defines an alliance as "an arrangement where a collaborative and integrated team is brought together from across the extended supply chain. The team shares a set of common goals which meet client requirements and work under common incentives". Alliances covered in the above operate on a gain/pain share, similar to a target cost contract form. Four cases were reviewed covering British Gas, Anglian Water and two Network Rail projects. The summary results indicate large financial and time savings. The report makes reference to the large shift from traditional contracting, with the need for cultural and behavioural changes. It is noted that the agreed overall outcomes are incorporated in a legally binding contract and that the set up and overhead costs associated require the project to be of a certain size to justify the expenditure and ensure the value is realised. It suggests an arbitrary of £35m project value being the cut-off point.

One of the keys referred to the benefit of alliancing is involving the suitable parties early enough whereby their expertise and requirements can be factored in whilst the designs/approach can still be influenced and adjusted. The figures below are extracted from the report:

Traditional Approach

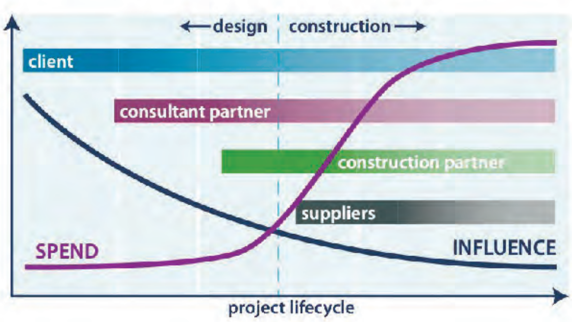
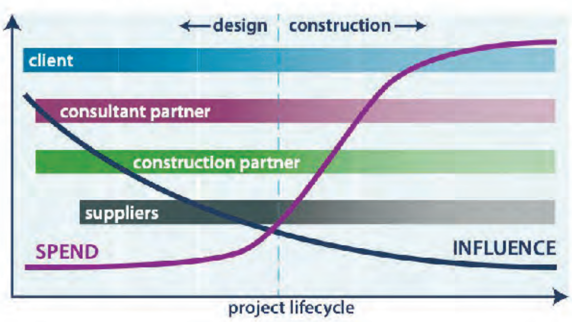


Figure 6
Alliancing Approach



3.6. PROJECT 13

3.6.1. FROM TRANSACTIONS TO ENTERPRISES

Infrastructure Client Group (2017) wrote a report about the need for a new approach to delivering high performing infrastructure. A project named "Project 13" was created to pilot new approaches for delivery on live projects, offer peer review and support to colleagues to implement the ideas within the report and disseminate the findings. The 2015 report by ICG is largely investigative into alliancing with initial case study findings and showing the benefits. This report, only two years later, is intended to drive out collaborative approaches within infrastructure projects.

The main focus within the report is to move away from "cheapest price wins" and "transactional" relationships towards collaborative approaches. It begins by stating the focus should be on outcomes rather than purely cost. It looks to move away from traditional terminology such as "client" to "owner" as it believes it implies a purely transactional relationship, or "contractor" to "supplier".

An early up taker of the Project 13 new approaches, Anglian Water, was reviewed as a case study for its findings from 2005 to 2017. The headline findings are the Accident Frequency Rate (AFR) dropped from 0.4 to 0, cost of investment projects reduced by 30% and carbon embodied in new infrastructure has halved.

The report refers to 5 pillars and principles for a matrix for change and successful delivery. It summarises that the below are key for successful delivery teams:

Five Pillars	Principles
Capable Owner	○ Owner develops Enterprises built on long term business to business (b2b) relationships ○ The Enterprise is set up to deliver: - Clearly articulated customer outcomes - Long term asset performance
Governance	○ Value is defined at outcome level (through baselines, benchmarks or affordability) ○ The Enterprise is rewarded for outcome performance ○ Risk allocation is aligned with capability and where possible jointly owned ○ The commercial arrangements provide the potential for sustainable returns ○ There are clear incentives and opportunities for investment
Integration	○ The Integrator brings together capabilities that deliver effective solutions through production systems ○ The Integrator enables a platform approach to delivery ○ Supply systems are organisationally and commercially aligned with the outcomes to be delivered ○ The Enterprise has a common and committed approach to health, safety and wellbeing
Organisation	○ The integrated Enterprise is aligned with the outcomes to be delivered ○ Supplier capability is engaged early in developing solutions ○ The Enterprise integrates the required capability in high performing, collaborative teams
Digital Transformation	○ The Enterprise digital transformation strategy enables an integrated digital approach to asset management and delivery. ○ The Enterprise effectively integrates engineering and digital technology to deliver intelligent solutions ○ Data and information are recognised and treated as digital assets that enable customer outcomes

An article by Crompton, J. (2022), who is the Strategic Pipeline Alliance Director at Anglian Water, refers to the live implementation of the Project 13 approach in Anglian Waters works and how persistence with focus on the new approach is key. It states that the success factors of Anglian Waters Alliances, which are all of the noted points above, with an additional focus on alignment of goals so that success for one party means the same for another.

3.6.2. HOW CULTURAL AND DIGITAL INITIATIVES ENHANCED INTEGRATED WORKING AND GOVERNANCE ON THE A14

Berg, M (2021) reports on the A14 stating it is the only £Bn+ project in Europe delivered ahead of programme (eight months) and on budget. The scheme targeted efficiencies of £108m but achieved £196m.

Key points identified within the case study:

- 5m+ hours RIDDOR free through observations app
- Digital signage motivating over 14,000 people
- Saved £2m+ and 2 months through standardised deck units for great River Ouse Viaduct
- +50% increase in ability to achieve the plan through AI forecasting?
- Over 50% increase in productivity through Andon App
- Data champions

It's said to have moved data to central cloud-based platforms, having a one "single source of truth". It reinforced the importance of the culture shift routinely, stating people initially feared the use of the data being used to point out and blame for under performance. They had to use a top-down approach to prove this wasn't the case.

Whilst the extent of digital implementation and usage was high, less than one percent of the total budget was allocated to these initiatives. The scheme was c. £1.5bn. A 1% investment of c.£15m contributed towards achieving a return of c. £196m. Whilst other factors would have contributed, and it does not accurately portray what the digitisation investment directly caused, much of the case study refers to how the digitisation was used to enable many other factors. These include; collaboration, improved innovation, AI forecasting to improve accuracy of planned works and increase in productivity.

3.7. THAMESLINK PROGRAMME

3.7.1 . LONDON BRIDGE DIVERSION EXAMPLES

A case study reflecting on undertaken diversions and their impact if they weren't suitably identified and assessed early enough in the project was undertaken on the Thameslink London Bridge project by Weaver, R. (2019). The case study is not overly detailed but recognises some key factors for identifying and planning the service diversions CAD model analysis which was built up from previous sweeps, electronic tracing, ground probing radar and trial holes. The case study also evidenced that from early involvement, and close liaison with each of the statutory providers, the outcome solutions were sensible and appropriate in costs as some of the initial proposals from the providers were large in works and from the outcomes achieved likely unnecessary in scope. It is evident within the study that should sufficient investigative measures not have been employed early enough, and the necessary parties engaged and liaised with sufficiently as well as early enough that the project itself would have faced delays or increases in costs when the services were identified at a later stage and then their diversions needing to be acted upon.

3.7.2 . BERMONDSEY DIVE UNDER – LESSONS LEARNT

Lessons learnt, both for what worked well and areas to be improved upon, are collated within a case study written by Dike, U (2018). The findings that are relevant to the topic being researched are as follows:

What went well:

- Integrated Planning and Relationship Management – the teams routinely engaged planning and coordination meetings to ensure an integrated approach and they also appointed a point of contact to facilitate communication with the other projects.

- Management of third-party relationships – early engagement and maintenance of relationships enabled agreement of requirements and planning of works to take place effectively.

- Integrated working – Network rail and the main contractor shared an office space to enable quick discussions and therefore making shared decisions, mitigating the "back and forth" nature of communications. The report focus on this aspect was the effective and collaborative communication. It also stated that this co-sharing enabled Integrated Master Planning which was found to be effective.

- Change management – a specific focus on change, as in variations to the project, was enabled from the team sharing an office and the high levels of communication. This change management was deemed to deal with change well which, in turn, was stated to be critical for achieving some of the delivery deadlines.

- Value engineering – this point relates to environments allowing innovation; the environment referred to here is one of collaboration and effective communication.

What could be improved:

- Contract content and administration – it was deemed that the content of the contract was insufficient and caused for "grey areas" when determining responsibilities.

- Rework/redesign costs – if the contractor was not engaged early enough and therefore expertise was not employed at the right stage.

3.8. TRANSFORMING INFRASTRUCTURE PERFORMANCE: ROADMAP TO 2030

A report by Infrastructure and Projects Authority (2021) sets out the perceived key points for improving infrastructure on numerous aspects. Within the report there are some case studies that cover; the problem that was aiming to be tackled, the implemented action and what the results of these actions were. Those that are deemed potentially applicable to utility diversions have been referred to below. A common theme throughout is the reliance on digitisation/information technology to obtain improvement.

3.8.1. NATIONAL HIGHWAYS: AUTOMATED DESIGN VIA THE RAPID ENGINEERING MODEL (REM)

Smart Motorways Programme (SMP) conceived around standardised rules and assets to overcome the traditional design approach within construction of a “one off” solution. A platform was created combining a rules-based engine, data analytics and digital product catalogue to automate the designs. It was found to provide a single source of truth, which enabled automated design and integration of estimating, sequencing and costing. It is said it improves the accuracy of construction and cost planning. The case study also notes the application of the same principles by TfL for cable route management and suggests this automated design has potential benefits across other infrastructure delivery too.

3.8.2. HS2: IMPROVING COST MANAGEMENT US-ING 5D BIM

Engineering models for 5D estimating were created to reduce the time taken to calculate quantities and prices. The model automatically updates material quantities, costs and carbon as designs are changed. This resulted in a very large resource reduction from the original amount planned and greatly reduced the time taken to calculate the carbon footprint.

3.8.3. XYZ REALITY: ENGINEERING-GRADE AUGMENTED REALITY WITH HOLOSITE – SUPPORTED BY UKRI

Augmented reality is utilised to improve the inspection process on-site and it is said to eliminate errors before and during installation. It states that construction teams have reduced inspection times by 97%.

3.8.4. LANDSEC – THE FORGE: PIONEERING A PLATFORMS APPROACH FOR MORE PRODUCTIVE AND SUSTAINABLE AUTOMATED BUILDS

Offsite manufacturing with automated onsite construction is combined with multiskilled operatives. The case study project is predicting to achieve a 19.4% reduction in carbon, reduced capital cost and reduced programme durations.

4. DISCUSSION OF EXISTING KNOWLEDGE

4.1. LEGISLATION, AGREEMENTS & MOTIVATION

It is suggested from much of the literature available that there is a natural lack of motivation from statutory authorities to perform well on utility diversions due to the mandatory profit deductions. However, some arguments are present that suggest due to the low profit margins of utility diversions available, that statutory authorities are encouraged to keep diversions as cost effective and as minimal as possible. It may be circumstantial, but it could be argued that this naturally reduces motivation to engage and perform well.

The lack of ability to enter a contract with statutory authorities, as they are obligated by statutory powers rather than contract mechanisms, appears to mean their obligation to perform well is limited. The literature suggests that legal cases for poor performance have been unsuccessful due to the wording of the legislation and the examples of court cases reviewed. The research suggests that the legislation in place lacks formal procedures for the coordination of street works or a national register. It was also noted that there was no mechanism to ensure prompt delivery of the services. These findings have been a common occurrence within the literature, dating back to 2001 up to 2021, suggesting this has been an issue for a continued length of time.

There does, however, appear to be ways organisations or government have tried to increase motivation such as; the Bristol Code of Conduct, the National Joint Utilities Group collaborative approaches or the Alliances approach as detailed by the Infrastructure Client Group. Collaboration is mentioned throughout the literature and the case studies with both theoretical and proven gains. How to effectively implement a collaborative approach was therefore investigated and a “Project Collaboration Toolkit” was identified (Engineering Construction Industry Training Board, 2019). Within this toolkit an International Organisation for Standardisation (ISO) standard was identified which is the ISO44001: Collaborative Business Relationships Standard. All of the case studies reviewed that refer to collaborative approaches over the traditional contract form or reliance on requirements via legislation are stated to have found results. The phrase “integrated delivery” occurs in some of the case studies, to summarise its meaning it can be reviewed as all project members acting off and working with the same information and tools set to deliver a scheme. Case studies that were found to operate with this integrated delivery approach did not flag communication or coordination as an issue and those that did not refer to it flagged coordination and communication as a reoccurring issue across the examples provided. This suggests a correlation that an integrated delivery approach reduces delays and issues from communication or coordination issues.

The literature found referred to allocation of risk within procurement, be it more traditional formats or the newer and upcoming collaborative procurement/alliances approach. It suggests the need to appropriately review whether risk elements could be further investigated, ahead of allocation, to ensure they are not being costed for or bought ineffectively. A key example of risk within utility diversions and infrastructure projects is noted to be the identification of unknown utilities present within the ground and the associated poor or inaccurate records of utilities.

Whilst researching motivators for utility diversion performance within major infrastructure projects a statutory officer position, known as the Scottish Road Works commissioner, was identified which covered street works. Whilst the role of the Scottish Road Works Commissioner does not appear to cover utility diversions under major infrastructure projects, the benefits from the role align with some of the perceived highlighted flaws from case studies and literature review whilst obtaining good performance on utility diversions. These include; enhanced compliance with legislation, ability to engage punitive measures that are less onerous than the court system and an-unbiased reporting mechanism which could score the various statutory authorities and cause peer competition.

The case studies and literature reviewed also found that the quality of utility records are often poor, with records rarely being updated when unidentified utilities are discovered. Perhaps a role similar to the SRWC could improve this.

4.2. LINKS BETWEEN EARLY ENGAGEMENT, PLANNING, COLLABORATION & EFFICIENT DELIVERY

Early engagement of the statutory authorities, within major infrastructure projects that require diversions, is referred to numerous times throughout the literature and case studies. There were no negative connotations found around early engagement. Whereas all examples found referred to a positive outcome from early engagement, some instances provided figures such as the SCAPE framework of 10% increase in efficiency when they are engaged early. No definition was identified for "early engagement". NJUG specifically refer to collaborative early engagement and its associated improvements to performance. The case study review by Cadent (gas network provider) found a reoccurring issue of design decisions being made ahead of their involvement and consequently requiring re-design work. Cadent provided examples deemed to be associated via early engagement of large cost savings/avoidances. Further impacts from a lack of early engagement are reviewed with the Tram Enquiry, such as lack of tangibly assessed timescales and intelligently scheduled work.

The research and literature by the Infrastructure Client Group further suggests that collaborative approaches, such as alliancing, allows all parties engaged to have a larger influence much earlier in the project. Thus, suggesting that this achieves both the early engagement aspect but also ensuring the influence is available from those its required of.

Early engagement could be seen to increase cost certainty, also, as the literature review suggests that many initial estimates need to vary highly. This includes not having the necessary requirements factored in by all parties and needing to change greatly when the relevant bodies are introduced to the project. It could be argued that early involvement before initial utility estimates could increase accuracy. It should be noted that deviations in cost estimates could also be a resultant factor of the large timescale diversions can take (case studies showed over 4 years in some instances) in which time inflation would cause cost variation.

Some literature and case studies referred to not only the statutory authorities not being engaged early enough, but also the required landowners of which the utility diversion would affect. A method referred to as beneficial by one Fisher German (utility diversion consultant), and that was deemed by Cadent to have improved their procedures, was an initial engagement method for the landowners ahead of the full legal process. This was referred to as Development Consent Orders.

Several of the case studies link collaboration, early engagement and planning when discussing key elements for good performance. There appears to be synergy between early engagement, planning and collaboration. Early engagement allows earlier and more informed planning with the collaborative approach, then furthering the effectiveness of any planning efforts via aligned goals and stronger team relationships.

Numerous research papers were available on the benefits of investment into planning for achieving efficient delivery. The findings were typically that investing time or money into the planning of work, be it generally or planning software, a return was realised within the delivery of the work across both time and cost reductions. This supplements the case studies and strongly suggests any form of investment into the planning of utility diversions would incur benefits in the delivery stage. A case study example on the A14 widening project of c. £1.5bn invested 1% in digitisation covering collaboration, improved H&S, innovation, AI forecasting to improve accuracy of planned works and increases in productivity and provided a return of c. 13%. The Bristol Code of Conduct, which appears successful from the literature sources that refer to it, states that anticipated major schemes over the next 5 years are reviewed with collaborative forward planning meetings. Given the literature shows an investment in planning returns improvement in delivery efficiency, it would be interesting to see how this investment of time into longer term planning provides a return in delivery.

4.2.1. INFORMATION TECHNOLOGY, DIGITISATION

It should be noted that the majority of the good practice findings or examples provided within case studies, that were found to provide an improvement to the utility diversion performance, included the use of technology/software. The suggested benefits from the technologies and software's also appear to match some of the shortfalls identified in case studies where improvement areas are identified. The examples included; BIM use (including the build-up of the digital data by various technological surveys such as electronic tracing, ground penetrating radar), cloud-based systems, AI forecasting, automated design and augmented reality. The literature review supports the use of BIM to improve efficiencies.

4.2.2. LEAN THINKING, STAFF INVOLVEMENT & LEAN MATURITY IN THE SUPPLY CHAIN

The literature suggests a lean supply chain is important; efficiency at all stages increases the overall lean procedure more than just at an individual stage. A key method identified for managing the effectiveness of the supply chain is awareness and training of the anticipated methods for sharing information. The Bristol code of conduct gets its supply chain to sign up to CI & innovation. Many of the case studies stated about good performance but seldom do they state CI is a requirement and focus.

4.3. UTILITY RECORDS

One of the most commonly reoccurring themes throughout the literature and case studies is the quality of existing underground utility records, both in their detail and accuracy but also the number of services present within the ground that were unknown and therefore not on record. The issue with identifying services once the works commence, where they were not anticipated, is that the full process needed to divert utilities still needs to be undertaken. It is a lengthy process as the research shows and it is naturally commenced much later in the project than if the services were known about and acted on during the design stage.

The literature and case studies refer to examples of undertaking what was deemed as suitable investigations and still identifying services. The London Bridge case specifically refers to the point of where unknown services were identified via investigations and that the project would have been significantly delayed if they hadn't been identified.

The answer of how to completely avoid delays with this aspect of utility diversion works is not clear within the literature or case studies. However, it was certainly evident that suitably thorough investigations, via different methods and appropriate parties' involvement, reduced the likelihood of identifying unknown services, or those known services were in the incorrect position, late in the project. This inaccuracy of service information is also deemed to be a contributor to some of the cost deviations from early utility providers estimates to final costs due to over or underestimating the work required if the services are thought to be in a different location from the truth. It is therefore deemed that if utility records content and accuracy was improved, the accuracy of cost estimates would increase also.

4.4. CALCULATING DELAYS

Calculating delays in detail is a complicated process with numerous factors that cannot always be exactly quantified. This is furthered by construction projects normally having various factors contributing towards any delay, and therefore isolating the cause and effect of individual elements is made further difficult again. It is deemed from the review of existing knowledge that delays from utility diversions can be large and costly. Whilst a detailed review of delays caused would add further knowledge to the impact of poor utility diversion performance, the findings from the case studies are deemed appropriate to justify the potential extent of delays.

5. METHODOLOGY

The research objectives will be achieved through literature review, data analysis of past diversions and a questionnaire.

Research Objectives	Research Method	Data Analysis
Objective 1 Utility Diversion Performance	Literature Review	Review books, Journals, Online Sources etc. Literature will be assessed for representativeness and credibility before being referenced.
	Questionnaire	Structured questions to ascertain professional opinions on Utility Diversion Performance from Live Projects.
Objective 2 Calculating Impact of Diversion Performance	Data Analysis	Delay (time) x (Cost (prelims) + Damages (LADs etc.) Harder to quantify losses like highway downtime etc.
Objective 3 Identifying Success/Delay Causes	Literature Review	Review literature that has relevance to the discovered successes and delays within practice. These must be assessed before being referenced.
	Questionnaire	Structured questions to ascertain professional opinions on Utility Diversion Performance from Live Projects
Objective 4 Statutory Authority's Motivators & KPI's	Literature Review	Review of any available literature on motivating factors, how to motivate and any associate KPIs.
	Questionnaire	Structured questions to ascertain professional opinions on Utility Diversion Performance motivators and any existing or suggested KPI's.
Objective 5 Other ALB Process & KPI's	Literature Review	Review literature identifying the known correlation aspects. Literature will be assessed for representativeness and credibility before being referenced.
	Questionnaire	Structured questions to ascertain key process points and any associated KPIs.
Objective 6 Summarise Suggested best practice approach and performance Indicators	Summarise & Present	Relate literature review findings, case study findings and questionnaire analysis to conclude key elements required for best practice. If possible, provide suggested KPIs to aid the above.

6. ANALYSIS OF RESULTS

6.1. RESPONSE REPRESENTATION

There were 19 respondents to the questionnaire, 18 of which stated they dealt with utility diversions, these consisted of 11 contractors, 3 consultants, 2 clients, 1 statutory authority and 2 others. Of these respondents 60% were from large organisations (organisations with over 250 staff). All twelve regions geographic regions of the UK were represented with an even spread across the regions. The exception was Northern Ireland which only had one respondent. There was an even spread of experience from the respondents about specific undertaker types. i.e. Gas, water, electric, telecoms etc. When asked what stage of the utilities diversion process they were involved in over 68% said design & technical and construction. Over 42% said land & legals and commercial. It is therefore deemed that whilst the number of respondents was not large it is still representative.

6.2. GENERAL FINDINGS

6.2.1. OPINION ON EFFECTIVENESS, MOST INFLUENTIAL PARTY & PERCENTAGE OF DELAYED PROJECTS

When asked how effective their organisation is at managing utility diversions on a scale of 1-10 the overall average score was 5.9 or 59% good, leaving a 41% opportunity for improvement. The rating of which party had the greatest influence on a successful outcome the opinions scored Statutory Authorities the highest, followed by Contractors, Clients and then Consultants. Respondents were asked what percentage of their projects that experienced delays due to utility diversions, this ranged from 5% to 100% with the average being 62% of projects experience delays due to utility diversions.

6.2.2. STRUCTURE OF MANAGEMENT/ APPOINTMENT

When asked how SUs are appointed 67% said by Client, 28% by Contractor and 5% by consultants. The responses for if this is the most effective way to appoint there was no clear answer with a fairly even split between "Yes, No and Not Sure". Looking at management structure for utilities diversions there was a fairly even split between Direct staff with dedicated role, direct staff as part of a wider role and Sub-contractors/consultants. Despite the even split on type of organisational structure 68% said it was the most effective way, with 16% saying no it wasn't and 16% saying not sure. When those that stated "no" were asked why the responses included references to all parties being included in the contract/appointment and that whatever the appointment structure it had to happen early in the process.

6.2.3. KPIS

In terms of performance measurement 33% said they used KPIs to measure performance, 39% said no measurement and 27% were not sure. In response to whether these KPIs help or could help 25% said yes, 33% said partially, 16% said no and 25% were not sure.

6.2.4. EARLY ENGAGEMENT

Early engagement was enquired on within the questionnaire where 72% of responses said the utility provider was engaged too late on their projects. 22% said suitably early or just in time and 5% said too early. 83% felt that the timing of engagement reduced the performance of the utility diversion process. When asked what stage Statutory authorities are engaged there was a fairly even split across four stages of Concept, Developed, Detailed and Construction. This could suggest; that there is dispute amongst professionals of which stage statutory authorities should be engaged, that the point of engagement varies dependant on the requirement or that the stage of which a statutory authority should be engaged is not known within the industry.

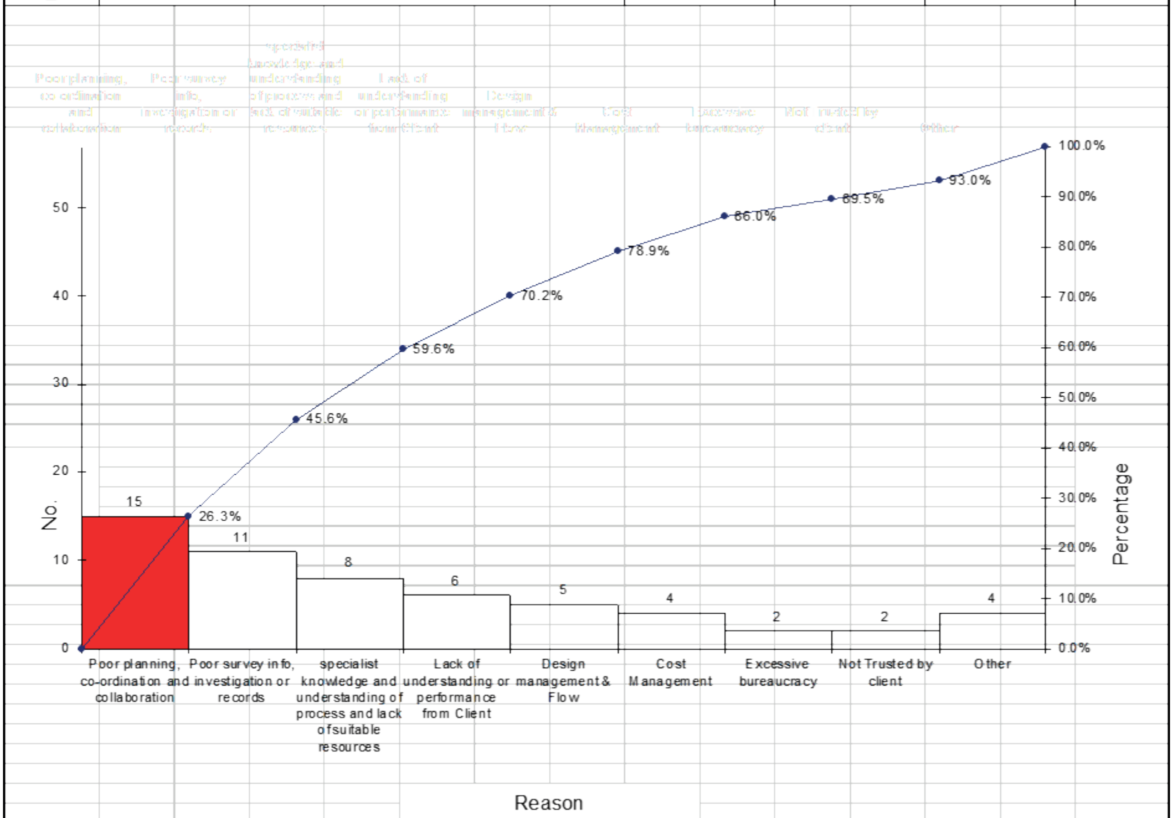
6.2.5. COLLABORATIVE PLANNING

Reviewing the responses showed that 66% said they employed Lean Collaborative planning techniques to manage the diversion process, 32% said they didn't or were not sure. On a scale of 1-10 the level of engagement in the collaborative planning process was scored at 5.2.

6.3. BIGGEST REASONS FOR DELAYS

Respondents were asked to state their 3 top causes of delays, generating 57 responses. The responses were coded into like types and the biggest stated reason for delay was poor planning, co-ordination and collaboration which accounted for 26% of responses. The next two most commonly occurring reasons for delays were poor survey investigations/utility records and specialist knowledge. These three reasons made up for 60% of the reasons for delays. The others are noted in the chart below.

LEVEL	Reasons for Utility Deversion Delays	SAMPLE SIZE	PERIOD	ISSUER	DATE
2		57	N/A	SW	25/04/2022

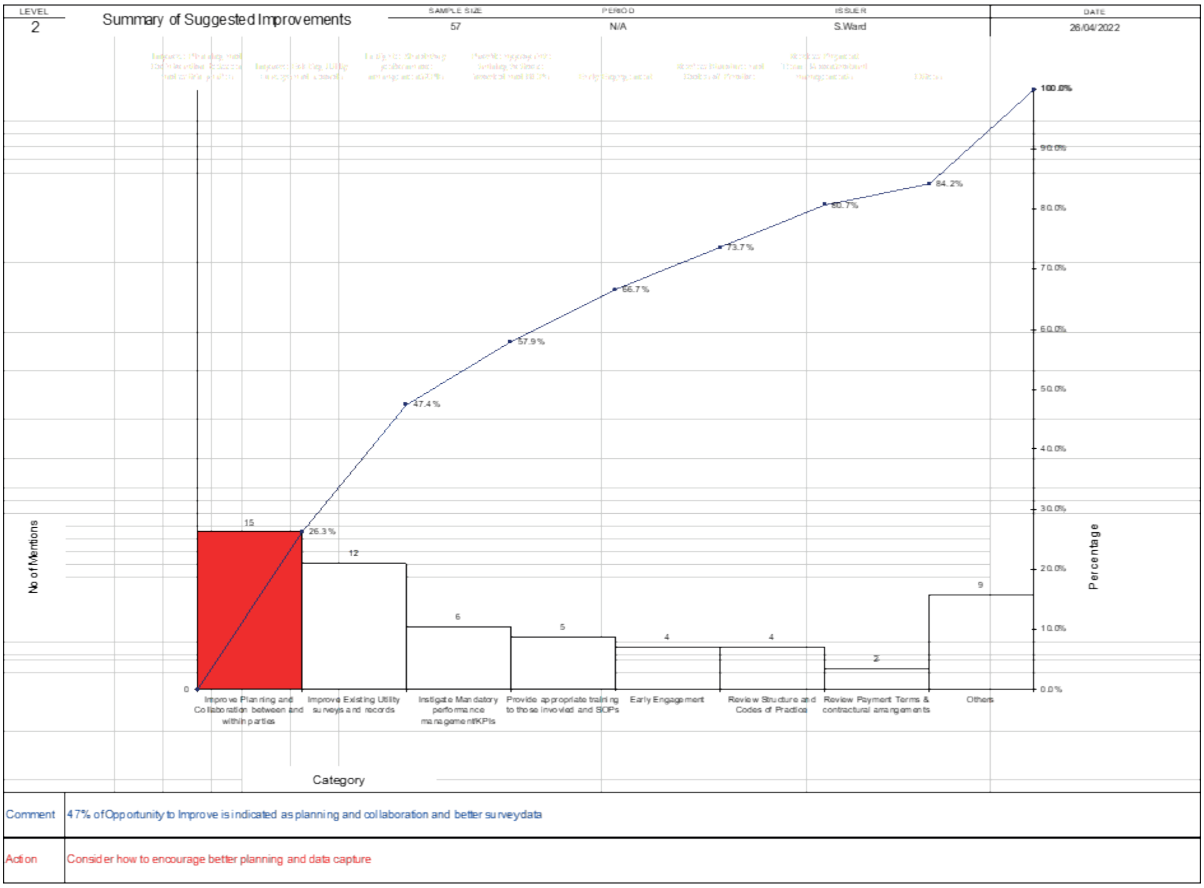


Comment	Poor Planning & Co-ordination is the biggest cause of utility diversion delays
Action	Investigate how the planning and co-ordibation process can be improved

University of Dundee Lean Construct Living Lab national highways

6.4. MOST CITED IMPORTANT FOCUS AREAS FOR IMPROVEMENT

Respondents were asked to state their top three resolutions required to improve performance. 57 resolutions were received and coded into 8 categories. The top two categories accounted for 47% of the stated improvements. These were "Improve Planning and collaboration between and within parties" and "Improve existing utility surveys and data capture".

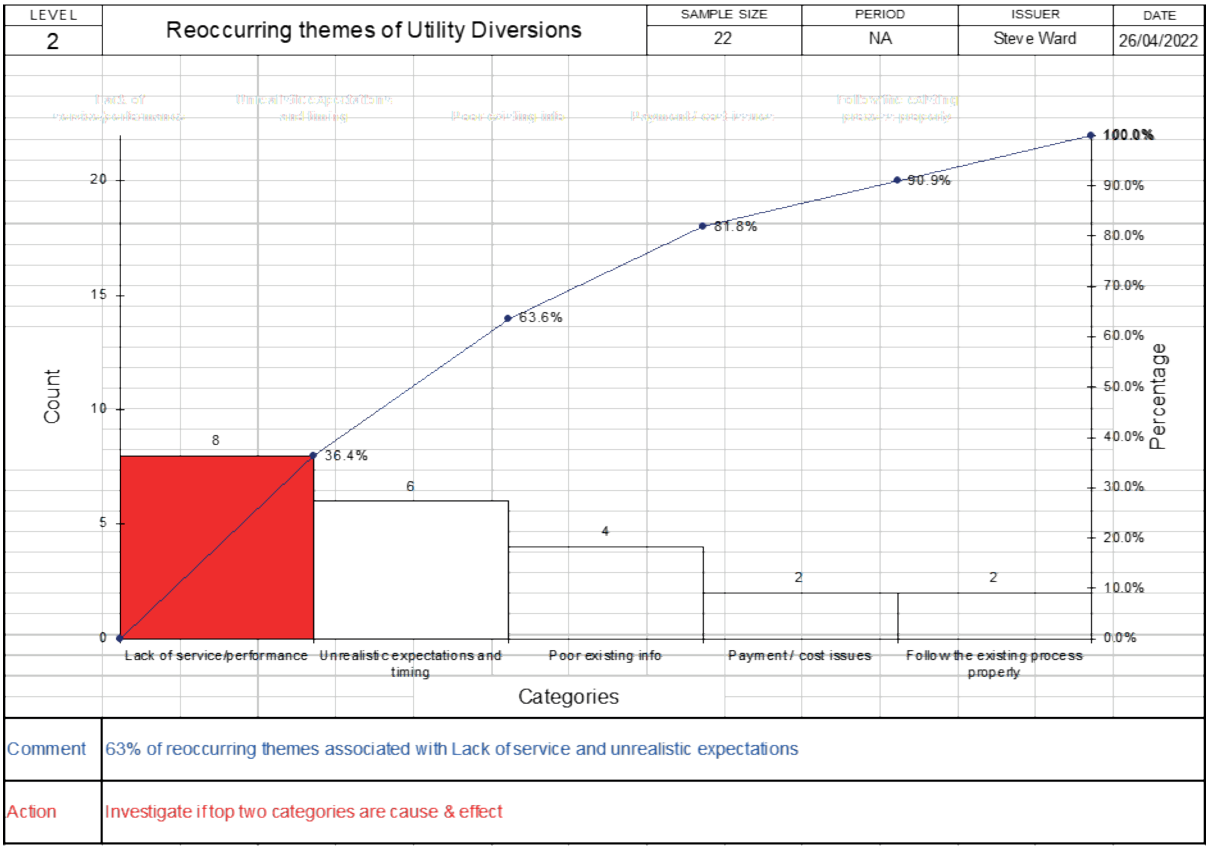


6.5. KEY TO SUCCESSFUL MANAGEMENT OF UTILITY DIVERSIONS

When respondents were asked what they felt was the overall key to successful management of utility diversions the biggest item identified was "Early engagement, planning & collaboration" as shown below.

6.6. REOCCURRING THEMES

When asked “Please state any recurring themes you find apply across utility diversions regardless of service and infrastructure type” 36% of themes surrounded lack of service or performance and 27% stated unrealistic expectations. The second most raised theme was unrealistic expectations. Given a lack of performance and unrealistic expectations accounted for 64% of the reoccurring themes it could be argued that there is a correlation between disagreements on performance and expectations.



6.7. DELAY QUANTIFICATION FROM QUESTIONNAIRE RESPONSES

When asked “If you experience delayed projects due to diversions, how many weeks on average would you say the delay was?” the results were as follows.

Answers ranged from 2 to 30 weeks with an average delay of 8 weeks, one respondent was able to quantify delays on Highways projects with properly quantified data in their capacity as the lead utility specialist as an average 16% of project duration. The average project delay recorded from this questionnaire was 24%.

According to our survey data, on specific individual projects, additional costs due to poor management of utility diversions can be as much as an additional 66% of project value.

We asked respondents “If you have experienced any additional costs associated with utility diversions due to time overrun, disruption, acceleration or logistics issues please provide an example using the fields below.” Not all were able to provide this data, but the table below summarises specific recorded project losses experienced by the respondents.

Project duration in weeks	Project Value £s	Delay duration in weeks	Cost of disruption (acceleration or logistics)	Did the project still finish on time?
156	£500mil	30	£100mil	No
47	£7.5mil	15	£1.45mil	No
208	£3mil	52	£2mil	No
30	£25mil	8	£1mil	No
20	£1mil	4	£80k	No
20	£1mil	6	£200k	No

It is difficult to, if not impossible, estimate the overall cost to UK PLC of failure to effectively manage utility diversions but if we assume the following, we might form a reasonable conservative estimate.

- Annual Value of Infrastructure projects = approx. £65billion per annum
- Prelim costs for managing these works will range between 15% and 40%.
- It is reasonable to assume that a delay to a project would result in a roughly equal additional spend on prelim costs or acceleration costs to mitigate the delay.
- The 16% advised by one respondent is a true representation of the delays within highways.
- The 24% average deduced from the questionnaire results is a representative of delays within infrastructure projects that have diversions.

From this research the average number of projects that experience delays due to diversions is 65% and we have a quantified 16% average delay time from highways specifically and a 24% average delay to infrastructure projects generally. If we assume an average prelim cost of 20% the potential losses range could be calculated as:

65% of £65 billion x 20% preliminary costs x 16% additional prelim costs. The same calculation again with the 24% then this provides an indicative range.

This range calculated is therefore £1.35 - £2.03 billion lost per year on the additional prelims alone. It is likely that the real figure is much higher if the full associated costs could be calculated.

6.8. SUMMARY

The stated; main delay causes, biggest area for improvement and the deemed key element for successful management of utility diversions all included Planning & collaboration and existing utility records as the most stated points amongst the respondents.

Most respondents, 73%, said the utility provider was engaged too late with 83% feeling that the timing of engagement reduced the performance of the utility diversion process. The average score of the perceived performance of their collaborative planning efforts was a 5.2 out of 10. Responses refer to agreements including all parties to be of benefit and that they need to be set up early enough to enable suitable engagement.

The general opinion of respondents is that their organisation is not that effective at managing utility diversions given the average performance score was 5.9 out of 10. The biggest influencer for performance was deemed to be the statutory authority and the average percentage of projects deemed to be in delay due to utility diversions was 62%. Only 33% of respondents were certain KPIs were utilised for monitoring performance.

The questionnaire findings enable an approximate cost range of utility diversion caused delays to projects of between £1.35 & £2.03 billion a year.

7. COMBINED DISCUSSION

7.1 . LEGISLATION, AGREEMENTS & MOTIVATION

The literature and case studies routinely refers to legislation being insufficiently worded to enforce good utility diversion performance and that it not only doesn't promote good performance can be argued to demotivate statutory authorities. The literature reviewed has matched this for the last twenty years. One of the responses in the questionnaire supports this. Successful examples are referred to within case studies of collaborative approaches be it a voluntarily signed code of conduct (such as Bristol Code of Conduct) or an alliancing contracting approach between the parties that can enter a contract. The questionnaire responses do not directly suggest these examples but does refer to agreements and that if all were to be included it would be of benefit. Some of the collaborative approaches reviewed referred to the need to pass practices down through the respective parties' supply chains but seldom do they state CI is a requirement and focus.

Allocation of risks within contracts with regards to utility diversions was stated in the literature review to be of importance but was not referred to within the questionnaire responses, this could be either due to the questions asked or that it is not perceived to be an issue or a key success factor by respondents.

7.2. LINKS BETWEEN EARLY ENGAGEMENT, PLANNING, COLLABORATION & EFFICIENT DELIVERY

Early engagement of statutory authorities due to enabling the input of their competence is stated to be of crucial benefit throughout the majority of literature and case studies reviewed. This is supported by the questionnaire results with 73% of respondents feeling that statutory authorities are involved too late and 83% believing that this effected the performance of utility diversions. There appears to be a clear synergy between early engagement and collaborative planning as they are routinely referred to together with positive case studies stating that they effectively got all the necessary parties involved "early" and implemented collaborative planning. The definition of "early" was not clear within literature or case studies, it was therefore investigated within the questionnaire but the responses provided no clear project stage that was described as early.

Planning, both generally and collaboratively, is noted throughout the literature and case studies to be of a huge benefit to performance. The case studies provided examples of investment in collaborative planning of 1% providing a return of 13% in value, this example is supported by the literature general finding of investing in planning returning an improvement in delivery efficiency. The questionnaire results found that poor planning, co-ordination and collaboration was the most commonly stated cause of delays within utility diversions.

7.2.1. INFORMATION TECHNOLOGY INCLUDING DIGITISATION

The use of information technology or digitisation was not referred to within the questionnaire responses by some of the newer case studies reviewed gave examples of it's effectiveness. It should be noted that the discussion of information technology or digitisation in case studies suggests it is still not common practice and many examples reviewed are trials or very new and it is therefore possible the questionnaire respondents have therefore not yet had experience of new technological approaches or software's being utilised.

The suggested benefits from the technologies and software's also appear to match some of the shortfalls identified in case studies or elements identified within the questionnaire response where improvement areas are identified. The examples included; BIM use (including the build-up of the digital data by various technological surveys such as electronic tracing, ground penetrating radar), cloud-based systems, AI forecasting, automated design and augmented reality. The literature review supports the use of BIM to improve efficiencies.

7.3. UTILITY RECORDS

The quality of utility records is stated numerous times throughout the reviewed literature. The case studies reviewed often noted delays from unrecorded services or inaccurate service records, some specific examples of direct cause and effect are included within the case studies. The questionnaire responses found improving existing utility surveys and associated data capture was deemed the second most cited area for improvement. The findings from all sources suggest the quality of utility records to be an industry wide issue.

8. LIMITATIONS OF RESEARCH

Evaluating and understanding research limitations is vital to ascertain their impact on the results and conclusions (Wargo 2015). The limitations of the research are identified below. Whilst these limitations restrict the effectiveness of the research, it is still deemed credible.

- Each diversion is different in extent of work required, number of land owners involved, nature of utility (electric, gas, water, telecommunications, drainage etc. Etc.). Therefore some will naturally will take much longer to do onsite or to pass through the legal procedures.

- Various research efforts have recently been completed, is currently underway or is soon to commence yet the data sharing between research parties has been late or limited.

- Only a third of questionnaire respondants stated KPI's were utilised and none of these KPIs were offered. No KPIs were evident from literature review or case studies.

- Delays caused by utility diversions were an understandable cause for the research commission. However, within construction delays are typically caused by multiple factors and parties causing it to be extremely difficult to justify the effect from any particular cause.

- The number of questionnaire responses was limited and less than desired. However, the responses are deemed representative and of good quality.

- Some aspects identified are complex in nature and would have distracted from the current research focus if investigated further and therefore are covered to a limited extent. See "further research" for aspects advised to research further.

9. CONCLUSION

A brief was provided to Living Labs in August of 2021 to investigate utility diversions to identify best practice methods and identifying measures of reporting utility performance to enable the creation of KPI's. The brief made referral to reviewing how others within the industry operated. This brief was refined in October 2021. The brief was analysed to ascertain how this may be achieved and what relevant information should be obtained, analysed and discussed. This led to the identification of 6 research objectives.

A review of existing knowledge including both academic literature and case studies was employed to ascertain current knowledge within the industry as well as identifying any current perceptions or gaps in knowledge. This process provided the identification of factors deemed to be key for good utility diversion performance and areas that often caused for delays or poor performance. These can be summarised and sectioned into; 1. Legislation, agreements & motivation, 2. Links between early engagement, planning, collaboration & efficient delivery, 3. Information Technology Including Digitisation & 4. Utility Records.

A questionnaire was formed to obtain current industry opinion on the matters identified within the existing knowledge review. The responses of the questionnaire were analysed and summarised. The findings were then compared to the findings of the literature review and were similar in most instances.

The questionnaire findings said; 1. poor planning, coordination and collaboration, 2. Poor survey investigations/utility records and 3. specialist knowledge accounted for 60% of delay reason responses. The literature and case studies identified and reviewed mainly address these 3 aspects also.

Limitations of the research were assessed and stated. The report is concluded by deducing best practice elements identified from the aforementioned literature and questionnaire findings. Advisory KPIs are provided in addition to those that may detract from proper analysis or create unintended consequences.

Further research is recommended where the findings presented areas that were reviewed to a level suitable for the purposes of this research but may provide a benefit of further research into.

9.1. CONCLUSIONS AND RECOMMENDATIONS

9.1.1. BEST PRACTICE

The best practice elements identified can be summarised as follows:

- Operate a collaborative approach such as alliances/codes of conduct rather than traditional contractual approach. However, legislation change would be beneficial to allow consequences for poor performance and ensure motivation is present as it could be seen that the current legislation is a de-motivator.
- Operate a "Single source of information" to avoid late information whereby information is shared and worked on under a central database rather than individual control & issuance.
- Early engagement with a focus on strong coordination and obtaining the necessary competent input to reduces redesign and associated delays, in turn also reducing variation in anticipated costs.
- Use of Technology.
- Implementing a role, ideally with statutory powers, but if not, generally, that will capture performance data and keep a register of utility diversions. Should the role be able to be implemented with statutory powers then the role should include the necessary utilisation of such powers to implement fines where required.
- Appropriate investment in utility record investigation balancing risk and cost expended. Including the sensible and collaboratively agreed placement of risk within contracts.
- Implement an early land owner engagement process ahead of the full typical legal process operated within the utility diversion process itself.
-

9.1.2. KPI'S

No clear KPIs in current use were identified through the literature review, case studies or the questionnaire. No advisory KPIs have been concluded from this current research, at the current stage of research it is advised to implement the suggested practices with KPI implementation to follow.

9.2. CONTRIBUTION TO KNOWLEDGE

This research identifies best practice approaches to the management of utility diversions. It identifies what is deemed to be key for success and the common causes of delays. Suggested KPIs to monitor and improve utility diversion performance are provided.

9.3. FURTHER RESEARCH

The recommended areas to research further are listed below:

- This reports focus is to produce best practice from the positive impacts of how they are currently managed. The next phase of research could be to implement proposed best practice approaches on a pilot project sample list and compare performance.
- The potential of undertaking diversions in zones, referred to in research reviewed as "Zoning" which is essentially determining whether utility diversions could be undertaken in batches rather than as one continuous diversion.
- Use of any Cloud based single sources of information systems in which all project team members have access to a central depository of information, reports etc. Rather than traditional separate servers/file storage that is then issued by email etc.
- Employing alliance contractual approaches where different payment mechanisms and contractual terms are agreed which encourages a collaborative one team approach over the use of traditional contract approaches.
- Investigating methods of both dealing with poor utility records & unknown services but also obtaining suitable records of all services to reduce the likelihood of further unanticipated diversion works during the project.
- Define "Early" when discussing the early engagement of statutory authorities as it does not appear to be properly defined or agreed within literature, case studies. Or questionnaire responses.

9.4. FINAL THOUGHTS

Utility diversions, whilst bespoke in nature, can have general management principles and approaches applied to improve the process and minimise delays. Whilst there are large elements of utility diversions that are within the project teams control it is noted that a large part deemed to influence performance is legislation which is out of the project teams' control.

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APPENDIX B: QUESTIONNAIRE RESPONSE FULL CODING ANALYSIS

		Biggest reasons for delays			
Reason	Code	Reason	Code	reason	Code
Inaccurate records of existing services	1	No programme buy in from SU leading to	4	Not enough contractual 'clout' to fine SUs for delays/	4
Not being trusted by the client e.g. not being appointed OO Agent	2	Indecision with respect to being clear about betterment / deferment of renewal everyone tries to sneak extra in and it is very disruptive and the client does not stand firm	4	Clients wanting to do things themselves rather than letting the utilities contractors get on with it	2
Client proposals are ill-defined and / or do not take account of complex stakeholder interactions and dependencies	3	Clients approach the utility company far too late in the design or construction process	3	Clients do not appreciate the complexity, risks and timescales of utility works	3
lack or missing ground investigation	1	quality of ground investigation and not clear picture of where existing utilities are located	1	flow of information, information duplicated or not shared in once centralised database with access to everyone who is involved	5
Uncertainty of actual location	1	Lack of understanding of the process meaning internal staff can't push process	8	Not wanting to pay fees ahead of start on site	6
Poor planning	4	Unforeseen conditions	1	Lack of process and procedure knowledge	8
Poor co-ordination	4	Quality & timeliness of information	1	Design challenges	5
Large Infrastructure projects	9	Prioritisation of other disciplines - utilities can always be moved mentality	4	Poor record mapping leading to unexpected utilities being encountered during construction	1
Slow progression of Main Contractor Design proposals	5	Lack of skilled resources - coordination, design, PM, construction of stats diversions	8	Unnecessary and overcomplicated requirements from major infrastructure Client	3
Poor trial hole data used to produce designs	1	slow approval period of designs	5	miss understanding of all steps required to get a diversion completed	8
Commercial clarity on costs	6	Availability of resource	8	Dispute between network design requirements against site requirements	5
Adherence to process rather than common sense	7	Ignorance of what's going on outside immediate workofthoseinvolved	8	Unwillingness to take responsibility for boundaries and interfaces between utilities or between roads and utilities	4
Later payment to avoid pre-empting planning permission	6	Wayleave/easement agreements with 3rd party land owners	4	Slow diversion design process, particularly in the water industry.	4
Planning	4	People	8	Resource	8
Byrocracy	7	Council approval	3	SI	9
Strikes	9	Inadequate Planning	4	Uncharted utilities	1
poor planning	4	inaccurate statutory records	1	poor collaboration	4
Unknown existing services	1	Late engagement from Clients	3	Lack of space	9
Utility provider time to quote	6	Unresponsiveness of provider and lack of contact person	4	Client timescales unachievable	4

	Summary Analysis of Codes	
Code	Key Words/Phrases	count
1	Poor survey info, investigation or records	11
2	Not Trusted by client	2
3	Lack of understanding or performance from Client	6
4	Poor planning, co-ordination and collaboration	15
5	Design management & Flow	5
6	Cost Management	4
7	Excessive bureaucracy	2
8	specialist knowledge and understanding of process and lack of suitable resources	8
9	Other	4

		Opportunities to Improve			
Resolutions	Code	Resolutions	code	Resolutions	code
National data base of utility records with high quality (modelled) as built/ GPR/ Trial hole data	1	Early/ engaging conversation with SUs with regular touch points in the process and programme creation to add 'ownership' around the piece	3	Review of NRWSA contractual arrangements	5
Clear framework for OO Agent - National Highways model?	2	More open discussion involving HAUC, clear boundaries set at an early stage. Betterment, cost share and DoR are standard things and to be encouraged not hidden away and avoided. Utilities need to adopt the CoP better - they don't set out their C4s properly	2	Clear timelines for a ramp up of delivery from the planning stage particularly if the utilities opt not to use their framework contractors	4
Engage with utilities as early as possible when considering major schemes and looking at options	3	Provide funding in a timely manner - utility design and consultancy services cost money.	6	Employ a programme planner or somebody with construction experience to create a draft schedule as early as possible	4
Better management of existing utilities. Not BIM - but more focus on GIS. Usually BIM teams on the project have no understanding of GIS	1	Focus on standardising quality of GI and storing this in one place. Continuously improving quality of survey (PAS128, PAS256)	1	Educating Contractors and Subcontractors on how to use geospatial information and properly train staff how to use CAD tools. It is very common that engineers don't know or even don't want to learn CAD tools in bigger spectrum	1
More accurate scans and trial pits, company records are poor	1	Specialist consultant or internal management	2	Re negotiated payment terms	6
Provide training to the site team on how to effectively plan works	4	Ensure that information gathered from pre-constructions utility surveys and intrusive investigation is communicated and shared with the construction team	1	Make it mandatory for staff involved in utility diversions to be familiar with system owner procedures and requirements	7
Managing Utilities as strategic suppliers	2	Upskilling Supply Chain & inhouse capability	7	Commencing Performance Reporting from Utility Co's.	5
Proper planning for utilities, and consideration early in the project	4	Better understanding of utilities risk, and the consequences that utilities may have.	4	Record utilities when encountered and force the utility company to update and improve their records.	1
Only request significant involvement from stats once the major infrastructure designs are sufficiently developed	8	Training and development of a core utilities coordination team.	7	Client and/or MWC should facilitate and make it easy for utilities to undertake their diversions.	4
Full intrusive surveys completed prior to designs starting	1	Utilities companies to have step by step document to educate contractors of what work is required	7	Constuction companies to have a better understanding of timescales required to complete a diversion.	4
Early engagement of statutory undertaker	3	SU to review design restrictions of client prior to start of process	4	SU and client consider options, there is not just one way!	4
Upatelegislationto set interests of consumer as being paramount	5	Sort ownership of conduit and maintenance of right of way	8	Get it right first time and do work no more few entry that once per three years under any section of road. Minimum section length 1 km.	5
Improved planning, recognising that the advanced payment is crucial to start the diversion process. Remove the need to pay an advance payment to obtain the SU contribution	4	Ensure sufficient land is procured for the diversions as part of the CPO/DCO.	8	Apply pressure for SUs to provide C3/C4 estimates in line with the durations suggested in the CoP for service protection/diversion	5
Plan better and understand each other's constraints	4	Be accountable and collaborative	4	Assign adequate competent resource	8
Shorter lead time for approvals	4	Easier access to network	8	Visibility of stakeholders contacts	8
Updated utility plans that are mutually available on a common platform	1	Sufficient time/cost allowance to be afforded for safe excavation work	4	Improved training standards for all those involved with breaking ground not just those on site	7
conduct PAS128 survey early in the process	1	encourage collaboration across utilities	4	invest more in utility detection at QLA	1
Government mandate to map all services	1	Set legal requirements for minimum engagement dates for appointing roles and level of information to be given	5	Roads & Highways specifications to allow for ducts/services	8
Online portal and quicker turnaround	8	Named contact	8	Early engagement	3

	Summary Analysis of Codes	
Code	Key Words/Phrases	count
1	Improve Existing Utility surveys and records	12
2	Review Structure and Codes of Practice	4
3	Early Engagement	4
4	Improve Planning and Collaboration between and within parties	15
5	Instigate Mandatory performance management/KPIs	6
6	Review Payment Terms & contractural arrangements	2
7	Provide appropriate training to those invovled and SOPs	5
8	Other	9

Reason	Reason Code	Count
Lack of service/performance	1	8
Follow the existing process properly	2	2
Unrealistic expectations and timing	3	6
Poor existing info	4	4
Payment / cost issues	5	2

Please state any recurring themes you find apply across utility diversions regardless of service and infrastructure type	Codes
Delays to attendance on site to carry out the work and then similar/longer delays to attendance on site to carry out connections/disconnections	1
Following the process and trust.	2
Insufficient time allowed to design, investigate and construct utility works. Immature designs and / or frequent changes. Arguments / reluctance to fund adequate upfront investigation works and surveys, leaving it to the Principal Contractor to sort out on site. Unrealistic expectations of utilities; we are not the fire brigade, it takes time to secure resources and prioritise works.	3
Existing utilities information - only indicative location	4
Very late works undertaking	1
Timescales for guidance and especially approvals can vary drastically depending on the SU and your relationship with them - its all about who you know.	1
As an Infrastructure Promoter, we are consistently low on their priorities, as they focus on Regulatory compliance & delivery of their own Capital Programmes	1
Poor records and mapping, late consideration of utility issues, low prioritisation given to utilities as most people just assume they can be moved.	4
Major infrastructure clients and MWC are understandingly very keen on getting stats involved at an early stage but rarely provide sufficiently developed designs in good time to allow diversion plans to be developed. Unrealistic expectations on stats by client and or MWC. Lack of coordination of all stats by client or MWC	3
The main works contractor thinks they can instruct the utilities company to come in and complete works at short notice (as they do with normal sub contractors). On the other side the utilities company has no need to rush as the current location of the service would be fine if not for the new construction works. So they are happy to wait months and delay the project.	1
Changes to design. Lack of understanding of the SU restrictions. Lack of appreciation of lead times. Lack of knowledge of the estimation process C3,C4,	3
Lack of interest in pursuing objectives and resolving difficult issues which matter to people outside own organisation	1
Finding the right person to contact can be difficult Utility plans (C2) can be erroneous Central hub mandating the free access to all utility drawings is a must. Repetitive C3 requests can put off the SUs Diversion designs for water mains can take up to 12 months to design. More contractor involvement rather than the SU contractor should be considered.	1&3&4
Client not understanding time scales	3
Long period until access to works is granted	3
If we all worked to HSG47 then we would be in a better place.	2
poor statutory records	4
Longer routes that may be safer are not given priority over direct routes due to the Client not wanting to pay increased costs.	5
Changing regulations. Lack of contact and local representatives to meet and discuss requirements. Poor payment systems and recording of payments being made	1&5

Reason	Reason Code	Count
early Engagement, Planning and Collaboration	1	10
Invest in proper investigation and data capture	2	3
Regulatory changes	3	3
Specialist Knowledge & experience	4	1
Understand and follow the process	5	2

What is key for sucessful management of utility diversions?		
	Reason	reason Code
Early, regular and continued engagement to create an integrated team between SU, Client and Contractor - this breeds engagement, ownership across the board.	early Engagement, Planning and Collaboration	1
If everyone follows the CoP properly it will work. There is a worrying trend at the moment to use the terms non-contestable etc - these do not belong in diversionary works and should be left with the new connections part of the industry. Its a different legal framework. Diversions are not done for customers they are done for Authorities.	Understand and follow the process	5
Approach the utilities early, identify potentially impacted assets and request indicative timescales. Employ a specialist who understands utility works and / or who can produce a draft schedule. Work together, and stop arguing about the price of every nut and bolt because that just slows the whole process down!	early Engagement, Planning and Collaboration	1
Properly undertaken investigation works prior design and construction. Post construction as-built as per PAS256 and centralised database for future mainatainace and construction works.	Invest in proper investigation and data capture	2
Understanding of process by all involved	Understand and follow the process	5
Knowledge and experience of working with utilities is key - building relationships and having a dedicated team which the construction team can go to for advice and guidance also.	Specialist Knowledge & experience	4
Relationship build. Regulatory Scrutiny. Obtaining comparative performance data.	Regulatory changes	3
Early consideration, and common sense approach. Coordination between utility companies needs to be better.	early Engagement, Planning and Collaboration	1
Generally Stats see diversionary works as hassle! It takes their limited resources and gives limited benefits eg renewal of short sections of their infrastructure (which they have to contribute) There should be a way to encourage better collaboration and the MWC/Client should really roll the red carpet out to make it very easy to come in to undertake their diversionary works.	Regulatory changes	3
A good relationship between the utility company and the main works contractor. This relationship needs to be open and clear so that everyone understands the steps required to get the diversion completed on time.	early Engagement, Planning and Collaboration	1
Early engagement and understanding of the two different agendas. Client/Designer should not commit to a delivery without SU input.	early Engagement, Planning and Collaboration	1
Common sense focused on consumer (and taxpayers)	Regulatory changes	3
An integrated team collaboratively working together. Team must include designers, contractors, commercial team, planners, and client	early Engagement, Planning and Collaboration	1
Collaborative approach from all and involve stakeholders and third parties as early as possible to mitigate risk of delays	early Engagement, Planning and Collaboration	1
Collaboration and reduction of red tape	early Engagement and Collaboration	1
100% knowledge of where the assets are.	Invest in proper investigation and data capture	2
collaboration between planner, contractor and survey company	early Engagement, Planning and Collaboration	1
Planning and sufficient trial holes to get correct route / design	Invest in proper investigation and data capture	2
Adequate timescales	early Engagement, Planning and Collaboration	1

LEAN PROCESS BENCHMARKING ACTIVITIES AND LEARNING

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University of Dundee

Lean Construct

Living Lab
Transport Infrastructure Efficiency Strategy

INDUSTRIAL STRATEGY

UK Research and Innovation

national highways