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HIGHWAYS AGENCY

Smart Motorways Programme

Productivity Research Report - M25 Schemes

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1. Executive Summary

This report was commissioned to investigate the relatively high output rates delivered by the M25 Smart Motorway Schemes and to determine how these have been achieved.

Its purpose is to share best practice, learned through the process, with the wider Highways Agency (HA) community and to determine if lessons can be learned for further performance improvement.

Context:

The M25 scheme is producing more kilometres of Smart Motorway per week than any other scheme. We were able to determine this through the use of real output data that was available, allowing accurate investigation and analysis.

The report shows comparisons between the M25 output (km per week) and those of other projects currently being built or planned. It investigates and describes in detail the outputs achieved by the M25 team and touches on the enabling factors that have supported the relatively high levels of output. Finally, it will make recommendations for the development of a common process 'production train' for development and use across future Smart Motorway Schemes.

Summary of findings:

- The M25 scheme is building faster than other comparable schemes - between 9% and 67% faster on central reservations works, according to our analysis.
- Data, both quantitative and qualitative, suggests that the top level reasons for this higher output are that the Skanska Balfour Beatty Joint Venture (SBBJV) and their suppliers plan for higher outputs – 200 meters of linear output per day – and achieve this by deploying more resources over a longer time window. Importantly they also developed a parallel working strategy, bringing the NRTS testing and commissioning process within the civils programme.
- There are a number of enabling factors within the team that have supported faster output, these include: good working relationships between the design and HA teams and the maintenance organisation; a contractual agreement which encourages higher performance together with the experience of working together, with many of the team having worked together for some 10 years.
- There are however, other project teams close to achieving the M25 outputs, suggesting that outputs are replicable across other schemes regardless of the maturity of the partnership or the team's experience of working together.

- Approach is a key factor – if other schemes planned to work in more locations, using more resources with increased working hours, they would also deliver faster.

- Analysis and review suggests that a common, more efficient approach to delivering Smart Motorway projects is achievable. Following our research, we propose a methodology entitled ‘Production Train’ that is designed to establish a quicker construction programme over shorter worksites, thereby improving the road user experience. This is as yet untested but we propose a series of trial projects to test this hypothesis.

Summary of recommendations:

- Use the M25 schemes as the current benchmark for all other similar schemes.

- Establish a system for collecting real output data for use when planning other schemes but also to further improve the construction process. When combined with improvement work studies, the ambition should be to plan using the highest average output rates.

- Transfer learning using the current hub system and/or its SMP replacement.

- Extend the range of benchmarking measures to include: safety, cost, quality, customer/stakeholder satisfaction and environmental impact.

- Use the CDF framework to create the right conditions and motivations to adopt, challenge and improve the Production Train approach.

- Standardise and seek to improve through Value Engineering, the design and construction methodology.

- The HA to develop a standard methodology and set of production output rates to be used for all future schemes (ie. adopt the intelligent client approach).

- Produce a handbook for Smart Motorways, outlining best practice and methods.

- Maintain project teams to improve the economies of learning.

- Create a more detailed analysis of verge works.

- Hold discussions with key suppliers on outputs and the potential for improvements in performance through process improvement.

- Establish KPIs as a standard process on all SMP motorways and support this with downtime data collection, analysis and problem solving as standard.

- Complete this research with a revisit to measure the output on Section 5B, which at the time of writing was well underway, this will also include slip form data to determine the efficacy of the 'Volumetrics' concrete process.
- Review ongoing downtime data on the cut and fill activity to identify improvements and show what is possible.
- Carry out work studies on all critical path activities and develop the best method for constructing Smart Motorway Projects.

It's our view that the time is right to challenge the current way of thinking about highways construction as the industry is receptive to innovative ways of working, the client is in the process of change with a view to working differently in future and the new CDF contract can act as an enabler to improve working relationships. In order to deliver the full potential of Smart Motorways Construction, we need motivated people and organisations, standard designs, methods and a spirit of innovation.

2. The Authors

Andrew Moore, Director at Rubicon Wigzell, has been researching the subject of production outputs and efficiencies in construction for the past 15 years. Andrew has been working with the M25 delivery teams since February 2013, in support of the HA Lean Deployment Programme. He has helped the team to deploy collaborative planning on the design process and in some construction activities and, as a result, he has a good understanding of the project and a good relationship with the team. Due to the relatively high outputs delivered by the team he was asked to carry out research to investigate how these were achieved. The results of this research will be used to further develop the thinking and performance of Smart Motorways and other Major Projects.

Phil Ellis of Mace has been working in the HA's Delivery Hub for 3 years as Head of the Planning Function. Part of his work has focused on demystifying and optimising the development & construction processes of HA Major Projects (incl. Smart Motorways). He is also the Programme Manager for the Contingency Schemes and as such has been able to ensure priority and focus has been given to optimising the construction processes of specific schemes, as well as developing a standardised approach that can be utilised as best practice across the Smart Motorway Programme. He has been able to advocate and reinforce desired working behaviours and practices (including 24 hour working over 6 days, multiple daily shifts, minimising traffic management and disruption to the travelling public).

3. The Research Method

To ensure an accurate and balanced assessment, we employed the following research methodology:

- a comparison of overall output rates between the M25 scheme and other schemes to determine whether the scheme is delivering faster.
- interviews with key M25 staff to understand the methodology deployed and the detail of how the project team manage the process.
- analysis of output data across M25 critical path activities to determine the systems capability and average outputs for planning purposes.
- a review of working patterns, hours/shifts worked and resources deployed.
- work studies on two number critical path activities, both to understand the process and to identify further areas for improvement.
- lessons learned workshops across the following areas:
  - Design
  - Construction
  - The scheme overall
  - Comparing outputs with 2 other schemes

Through this process a great deal of information was produced, the most relevant of which can be seen in the appendices to this report. All other information is available upon request.

Note: whilst this report was commissioned to review the outputs achieved by the M25 scheme overall, in terms of improvement recommendations, we have focused primarily on the central reservation works. This was mainly due to the fact that this area lends itself to a production line methodology. However we are working to identify similar improvement opportunities for the verge works e.g. the M25 team aligned the NRTS testing and commission process to the civils construction work.

There are also a number of Value Engineering opportunities being investigated that may benefit the schemes overall.

4. The M25 Schemes - A Brief Overview

The M25 is one of Europe's busiest motorways, handling around 200,000 vehicles every day, with key arterial routes serving Central London, the Home Counties and the A282 Dartford Crossing.

The Connect Plus Consortium - comprising Balfour Beatty, Skanska, Atkins and Egis Road Operation UK - has a 30 year Design, Build, Operate and Maintenance (DBFO) contract to manage and improve the capital's orbital motorway network on behalf of the Highways Agency (HA).

The M25 DBFO also includes the delivery of major improvement projects, such as the widening from three lanes to four between junctions 16-23 (Section 1), junctions 27-30 (Section 4) and refurbishing the Hatfield Tunnel (Section 6) to meet European standards. Collectively, these improvements works are referred to as the Initial Upgraded Sections (IUS) and were subcontracted to the main contractor Skanska Balfour Beatty.

Following the success of the IUS, the Skanska Balfour Beatty Joint Venture (SBBJV) is now responsible for the delivery of the Later Upgraded Sections (LUS) comprising:

Section 2 J5 to J7 – converting the existing hard shoulder into a permanent running lane including central reservation works, delivered as one section between November 2012 to April 2014 (20km or 1.25km per month).

Section 5 J23 to J27, delivered as two sections – converting the existing hard shoulder into a permanent running lane. Section 5a was delivered January 2013 to January 2014 (15km) and Section 5b from January 2014 to December 2014 (11km) with an output rate of 1.08km per month.

Project Planning Strategy:

The project team planned to achieve circa 200m of linear output per day over a 6-day working week. Allowing for emerging constraints and construction issues they hoped to achieve an average of 1km of linear output per week.

Note: linear output does not equal total motorway but includes the central reservation and two verges.

Below is a list of the key components that make up a Smart Motorway with quantities based on the Section 5a & b.

- Bulk Excavation: 200,000m^3
- Gantries – super span: 13 (number)
- Gantries – single span: 5 (number)
- ADS gantries/MS4's: 44 (number)
- A number of HADECS speed enforcement camera sites
- Wavetronics traffic monitoring sites: 50 (number)
- CCTV infrared night vision: 40 (number) and CCTV normal: 28 (number)
- LED temporary traffic management signs: 68 (number)
- Concrete barrier in central reserve: 24km
- Emergency refuge areas with telephones: 13 (number)
- Slot drain: 35km
- Pavement concrete: 20,000m^3
- Surfacing: 46,000t
- Duct crossings: 78 (number)
- Comms & lighting ducting: 30km

5. Comparing Performance - M25 & Other Schemes

Whilst it is clear that no project can be exactly the same, the Smart Motorway Projects are similar enough in scope to be able to make reasonable comparisons between them, in particular with regard to delivery durations.

To measure true 'like for like' performance, it is necessary to make comparisons across the range of key performance measures to ensure a balanced view (for example we may deliver quickly but suffer from quality issues). Typical key performance areas include: Safety, Quality, Cost, Delivery, Sustainability and Customer Satisfaction.

This report however, has been commissioned to look at production output only in order to identify and investigate the factors contributing to accelerated production. Our recommendations going forward would be to make a comparison across the other performance areas to give a more complete and balanced scoring mechanism.

Delivery performance comparisons will be determined using the formula below, which simply measures the number of kilometres of Smart Motorway built per week (measured across the whole project as an average, starting when the Traffic Management (TM) temporary safety barrier starts to go on and when it completely comes off).

This is measured as follows:

$$\frac{\textbf{Length of motorway under construction (km)}}{\textbf{Time to build in weeks}} = \textbf{km per week}$$

Comparing the M25 output performance with other similar schemes:

Smart Motorway Projects in their simplest form, can be described as Central Reservation Works and Verge Works. As not all schemes will do both under one project instruction, we have split these out and then offered an overall measure where appropriate. Similarly, as the schemes do not all have data covering the whole scheme, comparisons are made on the central reservation works only (highlighted in yellow).

Table 1: Comparison of M25 output with other schemes

Scheme	Length (KM)	Central Res (KM per week)	Verge (KM per week)	Overall (KM per week)	Contact
M25 – Sec 5a	15	0.85	0.65	0.4	Liam Maguire
M25 – Sec 5b	11	0.73	0.52	0.3	Liam Maguire
Scheme A	9.54	0.21	No info – prog not agreed	No info – prog not agreed	
Scheme B	30.1	0.72	0.55	0.39	
Scheme C	18.5	n/a[1]	0.23	n/a	
Scheme D	7.9+2.3	0.43[2]	Not in this project scope	Not in this project scope	

Note: Information supplied by the project teams. Nr of weeks measured from the installation of Temporary Safety Barrier to its removal – these milestones were chosen to measure planned construction time only and remove any added time due to mobilisation and or delays handing over.
[1]Could go faster but constrained by Ministerial Commitment & The Other Project.
[2] This scheme is split into 2 phases – shown here is the typical Central Res works activity which is similar to those being constructed across the other schemes – differences in design, scope and construction of each scheme is covered later in the report.

On the basis of central reservation data, the table shows that the M25 schemes have delivered more output per week than other similar schemes. It should also be noted that Scheme B (an accelerated delivery scheme) has similar outputs to the M25. This perhaps demonstrates that, while qualitative research suggests that the M25 team's experience in working together has been an enabling factor in designing an approach for accelerated delivery, the approach can be replicated with similar results across other schemes, regardless of the team's experience.

What are the benefits of achieving shorter construction durations?

It is worth noting at this stage what the benefits of shorter construction durations are for the HA, the travelling public as well as for the contractor and suppliers. These include:

- better value for money: every 1% reduction in time on site equals a 1% reduction in the cost of prelim items linked to time, for example variable costs such as: traffic management, site accommodation, plant and equipment and project management staff.[1]
- improved efficiency: capital assets are utilised for longer periods of time which can result in improved profit margins for the contractor and their suppliers, for example temporary barrier, excavators and lorries etc.
- lower overall project costs through less inflationary pressures on shorter programmes.
- improved journey time reliability: the travelling public spends less time encountering speed restrictions through traffic management
- improved public perception: during their time travelling through traffic management, the public sees more activity in more locations and for longer periods of time – which is a good thing.

[1] *note: a rule of thumb is that prelims amount to 35-40% of total construction costs, however not all of these are variable costs fixed to time, some are sunk or fixed costs and, regardless of the speed of construction, will remain the same e.g. initial cost to erect the compound.*

6. Production Thinking

History shows us that relatively high outputs are achievable if the conditions are right. The Empire State Building was built in just 54 weeks and the conditions that led to this were that resources were freely available, the building design lent itself to a production line philosophy and the project team were motivated by a demanding and immovable end date. Importantly, the team also shared in the success of a quick delivery.

Similarly, the M1 J10-18 Luton to Crick section - constructed back in 1955 and requiring 55 miles of new motorway, 132 new bridges and 92 culverts - was built in just 19 months. The conditions that led to this were the deployment of many resources, standardisation of design, production line thinking and activity at multiple work fronts over the whole length of the project at the same time. As with the Empire State Building, the project team were motivated by a highly demanding programme, an immovable end date and a share in the success of a quick delivery.

We use the formula below to describe the key aspects of production thinking in construction and also to help us calculate the theoretical durations of projects. The formula can be used to describe how project durations are affected by changes in the various components that make up the project delivery process including:

- the quantity of work to be carried out on site (offsite production reduces the duration)
- the number of available resources (deployed at multiple worksites)
- the capability of those resources (their output performance and efficiency)
- available time (hours, shifts and days worked up to the maximum 24/7 working)
- contingency (including local constraints, safety and environmental precautions)

$$\frac{\text{quantity or volume of work carried out on site}}{\text{quantity of resources deployed} \times \text{performance of resources} \times \text{hours, shifts \& days worked} + \text{contingency \%}} = \text{duration}$$

The following two examples show the way in which changes in each of the key components can have a positive effect on durations.

$$\frac{\text{10,000 linear meters of road box excavation}}{\text{1 gang} \times \text{200m per 8 hr} \times \text{8 hrs x 5 days} + \text{10\%}} = \text{55 Days or 11 weeks}$$

$$\frac{\text{10,000 linear meters of road box excavation}}{\text{2 gangs} \times \dfrac{\text{200m}}{\text{per 8 hrs}} \times \dfrac{\text{8 hrs x}}{\text{2 shifts x 7 days}} + \text{10\%}} = \text{13.75 Days or 2 weeks}$$

The above formula can be used to calculate the duration of critical path activities on Smart Motorway Projects and if we begin to factor in performance improvement (not changed in the above example), then we will start to see significant improvements, not only in output, but also in the efficiency of resources and ultimately project costs.

The output of 200m of linear output per day referred to here is an average performance over the duration of the M25 scheme. However there were occasions when the output far exceeded this figure. On one occasion a gang achieved more than double this, at 420m of linear output in one shift.

This idea of ‘core systems capability’ (i.e. what is the maximum output possible if we can create the right conditions) leads us into Lean thinking territory and the theory of constraints. We will touch on this later in the report.

Faster construction relies on the deployment of more resources, operating at higher performance, working in more locations over longer periods of time. In order to achieve this and sustain it, we need to consider the following:

- Management of the constraints which affect production, including haulage, material deliveries, access points, design etc.
- Standardising our approach including design and methods.
- Maintaining teams and building on the experience of delivering Smart Motorway Projects – this is a programme management strategy.
- Balancing the output rates across critical path activities and protecting the critical path.
- Learning to solve problems quickly and as a more integrated team.
- Changing the nature of competing relationships through the deployment of better contracts.
- Changing our working patterns to allow for working in multiple shifts over 7 days a week.
- The client taking a more pragmatic approach to sharing risk.

7. The M25 Schemes (Section 2, 5a & 5b) – Production Outputs and Lessons Learned

In December 2013 we held a 'lessons learned' workshop on the M25 to discuss the key elements/ingredients that supported the programme delivery. Below is a brief synopsis of what was discussed at the workshop, more detail can be seen in the full Lessons Learned Report in Appendix A.

- The team are experienced at this work and some have worked together for almost 10 years – the economies of learning were high.
- The type of contract and incentives created the right climate for performance improvement (M25 is a DBFO contract – Design, Build, Finance and Operate).
- The team used real output rates for their planning based on their own previous experience and established a daily target and rhythm of 200 linear metres.
- The team deployed multiple resources working over multiple shifts (including some nights) and worked weekends as standard.
- The team agreed a concurrent working strategy with the National Roads Telecommunications Services (NRTS) which enabled them to pull cables, test and commission in parallel with the main civils work.
- They had a good access strategy and control of works (openings every 300-500m in Varioguard and an effective workspace booking system).
- The KPI process, which measured daily output across critical path activities, was closely monitored and controlled.
- There were strong relationships within the wider project team, i.e. designers, consultants and the HA project team, which reduced 'transaction costs'.
- There was a distinct culture of problem solving where the team would pull together to solve problems and not fall apart when problems arose.

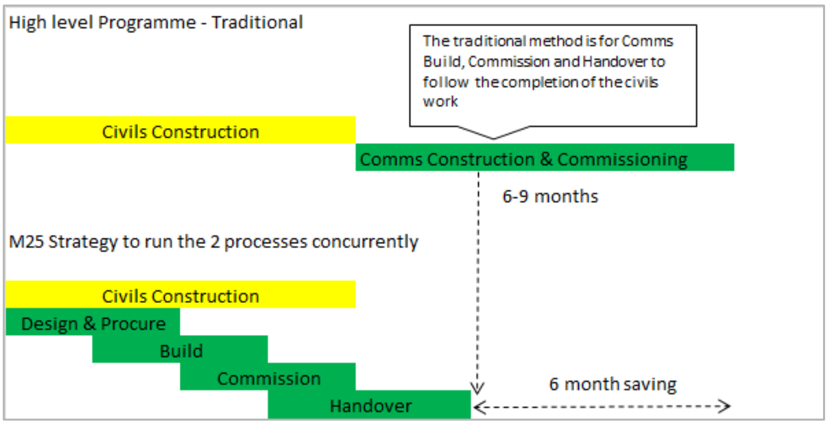
Outputs achieved on the M25 schemes

The M25 team delivered improved programme output through two key areas:

- Programme level strategy
- Detailed Planning Strategy

Programme Level Strategy: At the outset, project teams will determine their programme strategy. For example what direction do we build in, do we start in the verge or central reservation, do we build in multiple locations and to what degree can we overlap critical activities. The M25 team achieved a significant saving of circa 6 months on their programme by overlapping the NRTS testing and commissioning works with that of the civils programme. They believed that they were 'delivering a technology scheme and that the civils work was an enabler to deliver this'. This is a fundamental shift in thinking and as a result allows the team to rethink the overall process.

The diagram below demonstrates the savings that can be made in time by overlapping the technology and civils works in the verge. Here we can see that the team saved approximately 6 months on their programme. However there is much more to this process than simply overlapping activities as the team need to be cognisant of starting their works in the verge first. This can lead to various constraints in terms of design and possible delays in starting the project as well as some environmental considerations.



Detailed Planning Strategy: Earlier we identified the planning strategy deployed by the M25 team as 200m of linear output per day over a 6-day working week. Below is a summary of the actual output rates achieved covering most of the critical path activities.

The source of this information is the project KPI's which were updated daily with actual output and in many cases described the number of shifts worked and quantity of resources deployed (an example of one of these can be seen in Appendix C).

The Average Daily Outputs are averaged out across both sections of the M25, in many cases they were similar on both schemes (which may indicate that the subcontractor performance is not the sole reason for higher overall outputs). The outputs include the use of multiple resources and multiple shifts and includes for non-productive days, for example due to weather, breakdown or general disruption. The table also includes the highest output achieved in a single day per activity, the last column gives extra detail where available.

Using averages in this way does not give a totally accurate representation, as it does not reflect the reality and the output variation involved in the daily delivery process. However, because of the amount of variation in the typical construction process, it is not possible to plan using historical data unless we use averages as a starting point. Project teams tend to manage the variation through buffer, delinked activities and a flexible workforce able to accelerate or decelerate as required. Whilst this is not ideal, nor Lean, it does allow the project teams to plan with some degree of certainty.

Note: The critical activities identified below do not include for any mobilisation works and start at the point the TM is put out. For example, prep work for hard shoulder running, lighting decommissioning and some surveys may be carried out before the TM starts.

Table 2: Central Reservation Works – Daily Outputs on Critical Activities

Critical Activity - Central Res Works	Average Daily Output	Highest Daily Output Achieved	Shift Patterns Where Known	Days Worked Per Week	Notes where additional information was availble
Install TM	This was not covered in the KPI's but an improvement in this area is to install the TM down both carriageways at the same time which then releases the next work activity significantly earlier i.e. 2-3 weeks saving depending on the length of TM				
Lighting Removal	22	42	?	6	
Barrier Removal	732.59	1600	?	6	
Topsoil Strip	277.37	600	?	6	
Road Box + slot drain box	195	584	day	6	2 gangs on day shift (max output for one gang = 420 Linear metres (Lm) in 1 day) (avg output for gang 1 = 205.80 Lm and gang 2 162.60 Lm)
Capping	179.65	555	?	6	
Slot Drain Prep	196	557	day	7	mainly 1 gang deployed but did double up on just 3 of the 168 days (avg output is the same)
Slot Drain Chambers	3.62	10	?	6	
Slot Drain Pour	170	265	night and day	5-7	often 2 shifts worked and with one gang per shift (3 gangs working at several points across night and day and on both sides of the carriageway) - max output for one gang = 250 metres - average per gang nights = 88.62 Lm - Average per gang day shift = 127.28 Lm. PJ Davis (Slot drain supplier) believes the improved output on section 5a was due to the fact that they paved over manholes and then dug out rather than working around existing ones. This saved approximately 1 hour per manhole in lost production
NFD (Narrow Filter Drain)	153	340	day	6	
CSB Plinth	154.64	560	?	6	
CSB	244	610	night & day	6	often 2 shifts worked and in some cases an extra gang were deployed (2 gangs on night shifts) max output for one gang = 293 metres - average per gang per shift = 167 Lm
Wet Lean Concrete Road Base	232.66	585	?	7	
Pavement Quality Concrete	248	93-672	day shift	6	Day shifts only - between 1-5 gangs deployed - max output for one gang = 465 - average per gang 211 Lm per day on main works or 62Lm on piecemeal works
Surface Course (Blacktop) sec 2 only	852.93	2000	night & day	5	often 2 shifts worked and with one gang per shift - max output for one gang = 2000 metres - average per gang nights = 644 Lm - Average per gang day shift = 1212

Table 3: Verge Works - Daily Outputs on Critical Activities

Critical Activity - Central Res Works	Average Daily Output	Highest Daily Output Achieved	Shift Patterns Where Known	Days Worked Per Week	Notes where additional information was availble
Interruptor	?	?	?	?	
Install TM	?	?	?	?	
Decommission	?	?	?	?	
Top soil strip	?	?	?	?	
Stage 1 cut	167.22	40-451	?	?	
Comms ducting	173	520	day shift	6	Mainly day shifts - only one night shift in the whole period - between 1 & 3 gangs but mainly one gang - max output for one gang = 520Lm - Avg per gang per shift= 173 Lm
Stage 1 fill	169.92	696		?	
Cross Ducts	1.43	1-2	?	?	
Ducting	155.33	382	?	?	
Slot Drain	156	446	night & day	6	Mainly 2 gangs working night and day shifts alternating across Clock Wise and Anti Clock Wise carriageways - Average output per gang = 108Lm Max output in one shift = 250
Comms cable	?	?	?	?	
Gantry piling	1	1	?	?	
Slab Replacements	1.86	7.5	?	?	

Note: not all the above are measured in Linear Metres i.e. cut and fill is measured in M3 and cross carriageway ducts are per item.

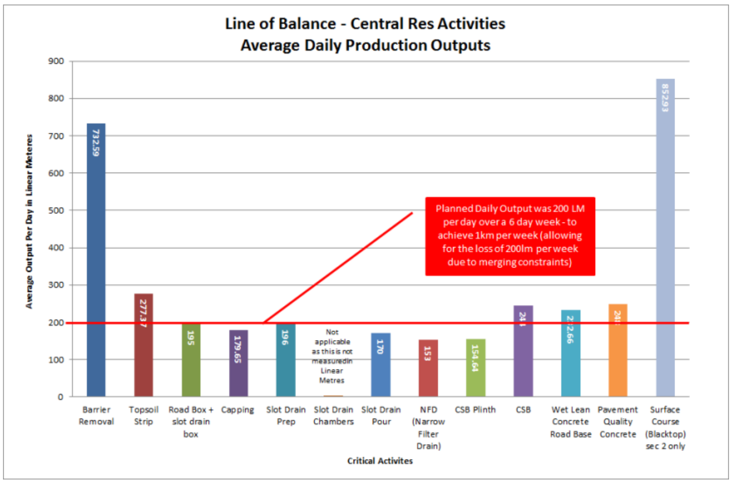
Results

The information displayed in the tables above show the daily average outputs achieved across multiple activities on the critical path in both the verge and the central reservation works. Using these outputs the M25 team were able to achieve an overall output of km per week of:

0.85km per week in the central reservation

0.65km per week in the verge

The central reservation data clearly shows that the team were delivering close to the planned output of 200 linear meters per day (and in some cases more than this).



The chart here, shows that of the 13 critical activities measured, 6 achieved around 200m of linear output, 2 were well above this, 4 were slightly below the mark and 1 is not applicable as it is not measured in linear metres.

Whilst this chart shows that activities are slightly imbalanced (not considering the first and last activity – blacktop is only relevant to Section 2 and only in some cases), it must be appreciated that in construction terms this is a reasonably balanced plan, with little variation in the core activities (albeit these are averages and need to viewed as such). In this example, allowing the first activity to achieve high output does not cause issues with overall production as this will not delay the process. The last activity may cause delay as it will require a large batch of road to achieve its optimum output. This can lead to road users being frustrated by large swathes of motorway free of any visible work activity.

The chart demonstrates that a planned output of around 200m of linear output per day is achievable on the central reservation works for individual activities. However, for this to work effectively, the imbalances in outputs need to be controlled. For example, the CSB plinth team (154m/day) could quickly delay the CSB works (244m/day) unless:

- there is sufficient time buffer between them, for example each activity is a week apart
- the CSB plinth team works more shifts per day or more days per week
- the CSB team work fewer shifts per day or fewer days per week
- the management team are able to flex the resources, i.e. pull in more CSB plinth resource when needed
- the CSB plinth team are protected from downtime and the slip form process is improved

The whole process can only go as fast as the slowest activity, so in this example we should focus our attention on speeding up the CSB plinth and protecting this super critical activity. We will cover the findings from our Slip Form work study in the next section.

The M25 management team were able to flex their resources and the number of hours and days worked to accommodate the ebb and flow of output that is common to construction. This allowed them to maintain a relatively stable flow of construction activity. They also had good management systems in place that were joined up (see an example of this in the M25 planning process map in Appendix D) which included:

- using the KPI's as early indicators of potential delay
- weekly planning and coordination meetings with all suppliers
- collaborative planning
- workspace allocation
- a novel bus tour every Monday morning to review progress as a team

Whilst a similar approach was adopted on the verge works, the balance of the work activity is less relevant as it's a less linear/linked process and more akin to individual worksites (mini projects). However, these are still linked and in many cases must work in a sequential manner.

The key factors in achieving high overall output in the verge are:

- working in multiple locations with multiple resources over multiple shifts and days
- ensuring that there are sufficient access and egress points to facilitate the above working method
- ensuring that there is flow (balanced line) between linked activities
- using the same techniques described for the central reservation works in order to flex the output capability of individual and critical activities, i.e. increase resource, work more shifts and more days etc.
- and, importantly, running the testing and commissioning of the technology in parallel with the main civils works (there is a case study available on the HA Knowledge Management Site to show how this was achieved).

8. There is room for Improvement.

There are two focus areas for improvement at play here:

1. Strategic Improvement: Increase resources and the working window to optimise the daily output and do more work with more resource
2. Incremental Improvement: Improve the process or reduce downtime to optimise output - do more work with the same resource

The reality is there is room for both these improvement strategies, the first one is a strategic decision and can deliver immediate benefits as long as constraints are managed. The second is an ongoing and incremental improvement process.

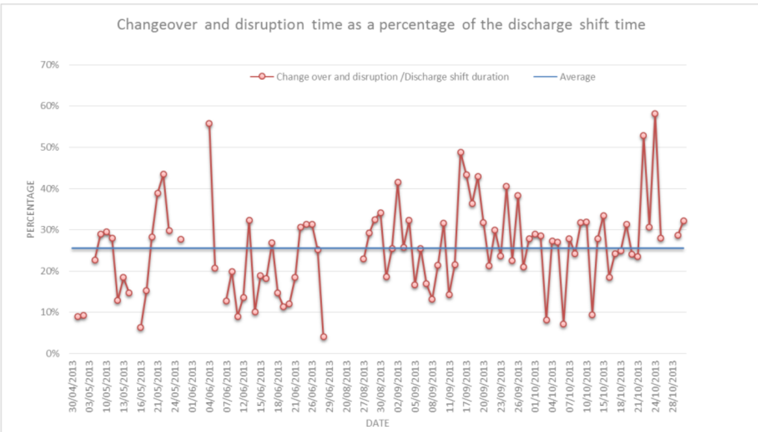
The tables in the previous section focused on average output rates, however they also demonstrated that much higher output is achievable when the conditions are right. We describe this as the ‘core systems capability’ which is effectively determining what the system is capable of, if the right conditions can be created.

Core system capability is an important factor in identifying opportunity for improvement. Take, for example, the CSB team who averaged 167m of linear output per gang per day, with one gang achieving 293m in one day, which is 75% more than average. As the construction process is subject to relative instability, the chances of achieving this high output every day are limited. However with such a large opportunity, every incremental step towards this higher output would have significant benefits on the programme and, ultimately, the cost of construction projects.

Bear in mind that a minute lost on a critical path activity is a minute lost to the entire project. From this perspective, it should be the goal of the project team to continuously improve the process to raise the mean average by focusing on the constraints that limit the production output, in particular those that are within their control.

Slip Form Process

We carried out a very detailed work study on the slip form process with thousands of pieces of data. This was mainly a desktop study of downtime data, which the P.J.Davidson Company collect each day.

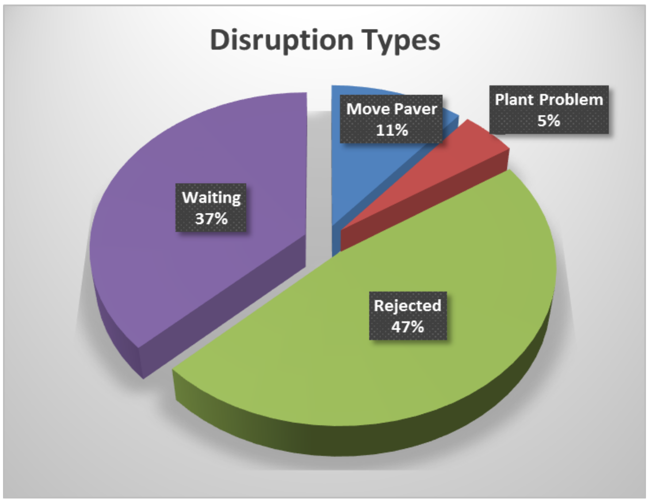


From our experience, this is some of the best quality data we have seen and were happy to use this for our analysis (it was also convenient as there was no planned work activity on site).

Mobilisation / Downtime / Changeover Time

The study showed that on average, the slip form machine is subject to approximately 26% of inactivity during the optimum working window, which is the first concrete discharge to the last. The study also showed that the average time for the first concrete discharge is 2.33hrs after the shift started. Therefore we can see a significant amount of idle time due to issues with the delivery and quality of materials. The table shows this and also demonstrates the huge amount of variation that exists in the process – on good days there could be as little as 4% downtime, on bad days it could be as much as 58%). We included the changeover from one concrete wagon to the next as downtime, as we felt that there is room for improvement in this area due to the amount of variation.

We also analysed the reasons for downtime, seen here, which shows the main issues are concrete quality (too wet, too dry or too much air) and waiting for concrete. The detail of this study can be seen in Appendix F. Without going into too much detail, we can report that the P.J. Davidson and SBBJV team are actively dealing with these constraints and this is mainly through the innovative use of a concrete delivery process called 'Volumetrics'.



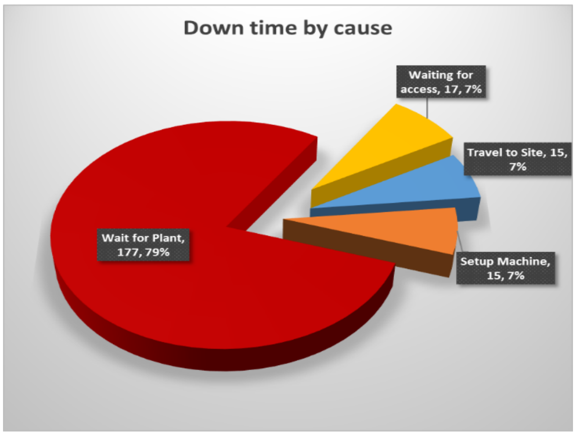
Volumetrics is a dry mix delivery system. It allows for fewer changeovers of the concrete wagons as it holds up to 11m^3 (as opposed to 6m^3) and it allows the team to be more in control of the concrete quality. We hope to report on the benefits of this system over the coming few months as the data becomes available on Section 5b.

Cut and Fill Process

The next workstudy we undertook was in the verge and involved the cut and fill activity. Unlike the slip-form process, we had little data but we could access the site to review the work in progress. This involved direct observation over two days and the installation of a data collection process and ongoing analysis over the past couple of months. This was designed to give a more accurate representation of the performance of the process – the full report can be seen in Appendix E.

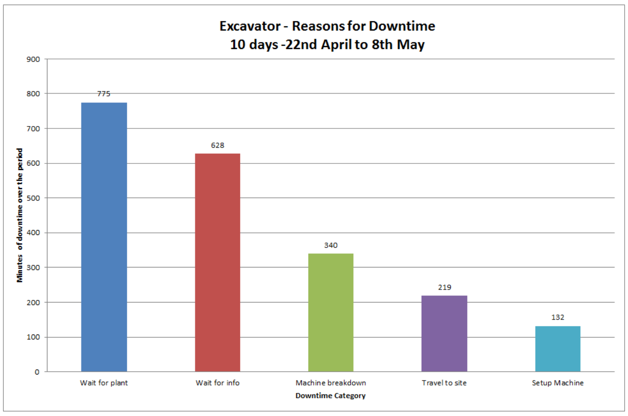
To focus the work study we identified that the excavator is the main value element of the process. In other words, if the excavator is actively engaged in moving muck (picking up or dropping it), then the process is achieving its primary value-adding function.

The initial observation showed that the excavator suffered approximately 39% of planned and unplanned downtime due to waiting for plant, access, travel to site and setting up the machine, of which the main contributor to down time was waiting for plant (wagons).



Waiting for wagons can be split into two areas:

1. Waiting for a wagon to arrive at site (18% of the time)
2. Waiting for the changeover of lorries during the wagon fill cycle (13% of the time)



It was observed that on average a wagon will spend less than 7 minutes actively being loaded with muck, 5 minutes reversing into position from the site entrance and another 3 minutes exiting the site. This totals a 15 minutes cycle time per wagon, from the time it enters the site until it leaves. Further analysis has shown that the process can also suffer downtime from a ‘lack of information’ and ‘machine breakdown’ as shown above.

Understanding the process and, in particular, the constraints which prevent the process from operating, can help the project team deal with each of the constraints individually.

For example, the team has committed to:

- review the optimum number of support wagons to reduce the waiting time of the excavator
- review the changeover process to reduce the amount of lost time between one lorry being filled and the next one moving into position to be filled.
- reduce the time lost due to waiting for information through more detailed look-ahead planning
- review the daily/weekly maintenance regime on the excavator to prevent breakdown.

This improvement work will continue over the coming months after which time we anticipate being able to report positively on the improvements it has brought.

In summary

We can deliver project improvement quickly in terms of time and cost by simply increasing the resource and working over longer periods of time (where this is possible, as we need to consider environmental restrictions). We can also improve the efficiency of the process by using simple work study techniques and problem solving. The solution is not one or the other, but to adopt both on Smart Motorway Projects going forward.

9. Production Train Methodology

During the writing of this report and in the course of various collaborative workshops, we became aware of an emerging process which we feel could be successfully applied as a standard approach for the delivery of Smart Motorway Projects going forward.

NB. this approach is a principle that has been developed by others during the writing of this report, this principle is independent of the M25 DBFO team strategy and seeks to achieve similar outputs but over shorter TM arrangements.

This approach, currently termed 'Production Train', seeks to deliver the same outputs proven by the M25 team but over a shorter traffic management geography. The benefits of this would primarily be for the road user, as it would mean less traffic management (TM) to drive through. However, it could potentially benefit the contractor, client and suppliers as well, as there would be less capital equipment tied up (temporary safety barrier) and less restriction due to network availability, i.e. the limits placed on the amount of carriageway under TM at any point in time.

The Production Train idea is currently limited to central reservation works but work is underway to apply this thinking to verge works.

Overview

The Production Train method has two broad benefits:

- optimisation of the construction of the central reservation works of a Smart Motorway Scheme by <u>reducing the current construction timescale</u>
- improvement of the TM strategy to:
  - reduce the <u>length</u> of TM out on the network at any time whilst constructing the central reservation works
  - reduce the <u>timescale</u> that TM is required on the network with the road released back to the road user as soon as possible.

Central Reservation Works – Typical Activities

Below is a list of the typical activities required to complete central reservation works. These activities have been divided into three categories:

- Critical Path Activities
- Non-Critical Path Activities
- Additional Scope Activities

Critical Path Activities

These activities include Advanced Works & Main Works:

Advanced Works

1. CCTV, SPECS, vehicle recovery – 1mth

Main Works

1. Install traffic management C/Res
2. Site clearance (barrier, columns and bases)
3. Excavation - bulk dig fill to earthworks profile
4. Carrier drainage*
5. Sub-base and capping
6. Drainage V – channel: slip form (or slot drain)
7. Road base layers (blacktop or concrete dependant on width)
8. RCB /TWRCB: slip form
9. Blacktop finishes
10. Remove traffic management Varioguard and narrow lanes
11. Handover into maintenance

*the central reservation will not have carrier drain along the entire length (possibly 15%-50%)

Non-Critical Path Activities

There are a number of activities that are required as part of the central reservation works, but that can be carried out without impacting the critical path. Within the Production Train approach, whilst the TM is operational, time should be scheduled to complete these works:

1. Blisters
2. Cross carriageway ducts
3. Locate existing stats
4. Drainage chambers and connections

Additional Scope Activities

Depending on the particular requirements or design of the scheme, there could be a number of additional activities within the central reservation works. These activities may or may not be on the critical path and, as such, appropriate programming of these activities will be required to understand the impact on the duration of the scheme:

1. Hard-shoulder strengthening (critical path activity)
2. Lighting removal (not critical path)
3. New lighting provision (carriageway – not critical path)
4. Structural repairs to existing structures (under/over bridges – piers, abutments, edge beam protection) (possibly not critical)
5. New, replacement or modified structures (bridges, junctions) (criticality project specific)

Methodology Principles: The Train Approach (Central Reservation Only)

Below are some of the key principles to be considered when applying Production Train thinking:

Productivity
- Each critical path activity has to produce a minimum output of 200 linear metres per day - regardless of volume, for example depth of dig.
- Achieving this balanced output will be done through increasing or decreasing the resources and shifts worked per day
- Improvement focus will likely be on slowest activities, for example excavation and drainage

Programming
- In terms of programme planning, each critical path activity will have a 'start-to-start' relationship with a 1-week lag between activities.
- A 1-week lag in activities gives each critical path activity a clear working site of 1200m (200m of linear output per day x 6 days per week = 1200)
- All activities start in the same location – at one end of the scheme – and progress to the opposite/far end of the scheme. In essence, each activity follows the direction of the previous activity.

Working Practices
- The site will operate full production for 6 working days in a 7 working day week
- The 7th day is likely to be used to:
    - prep for the following week
    - carry out any remedial work required
    - catch-up on any lost productivity within the week
- Access & egress points at 300/400m spacings (we need consider methods to close openings and/or safer working practices, i.e. work across opening only at night)

Productivity Rates and Scheme Duration

As outlined above, by targeting a productivity rate of 200m of linear output per day for each critical path activity, the durations of main works can be calculated for any scheme length.

If the scheme duration formula below is applied, the duration of any scheme can be calculated.

- Calculate productivity per critical path activity, per gang, per day (See table 2 – daily output rates)
- Scheme duration formula = ((Scheme Length/(200x6) + (10x1))
- Scheme duration v scheme Length – see table below

Scheme Duration Formula and Table showing Examples of Scheme Durations

For the Main Works, using the formula below, we can calculate the theoretical durations of schemes using the Production Train outputs - dependent on their length. Using this will help us to establish a set of target measures for schemes going forward which are using the Production Train approach.

$$\frac{\text{(Scheme Length)}}{(200_{DP}\,x6_{d})} + (10_{CP}x1_{WL}) = \text{Scheme Duration}$$

Key:

CP: No. of critical activities

WL: 1 week lag between critical path activities

d: days worked per week

DP: Daily productivity (…of 200m per day)

Scheme Length (km)	Scheme Duration (weeks)	Scheme Length (km)	Scheme Duration (weeks)
8	16.67	20	26.67
10	18.33	22	28.33
12	20.00	24	30.00
14	21.67	26	31.67
16	23.33	28	33.33
18	25.00	30	35.00

Main Works: Scheme Durations

Removal of TM – Direction of Travel

Based on the methodology outlined above, all activities start at one end of the scheme, in the same location and follow each other (i.e. one 'carriage in the train' follows the other). This allows for the final completion of each section of the works progressively from one end of the scheme to the other.

As the works complete, for example progressively from left to right, the traffic management would be removed from the left end of the scheme and added to the right end of the scheme as work starts further down 'the track'.

Using this method and being able to remove traffic management as work completes, prior to the completion of the overall scheme can reduce the overall traffic management on the network by up to 65%.

Note: a graphical representation for this can be seen in Appendix G

Example Programme: Overview & TM Durations for a 23km Scheme

- Advanced Works – 4wks (under night time temporary TM)

- Overall main programme for 23km scheme length = 28wks

TM Layout (for Main Works)

The traffic management is laid out in shorter lengths (for example 6km) and, as the scheme progresses, additional lengths are laid out further along the scheme:

Using 6km as an example:

1. Layout TM in 6km lengths
2. Depending on the precise location (chainage) along the scheme, each 1.2km section along the scheme has a maximum TM Duration of between 12 to 17wks

TM Removal (for Main Works)

Depending on the scheduling of the non-critical path activities, traffic management could be removed frequently, in short lengths, to minimise the impact to road users:

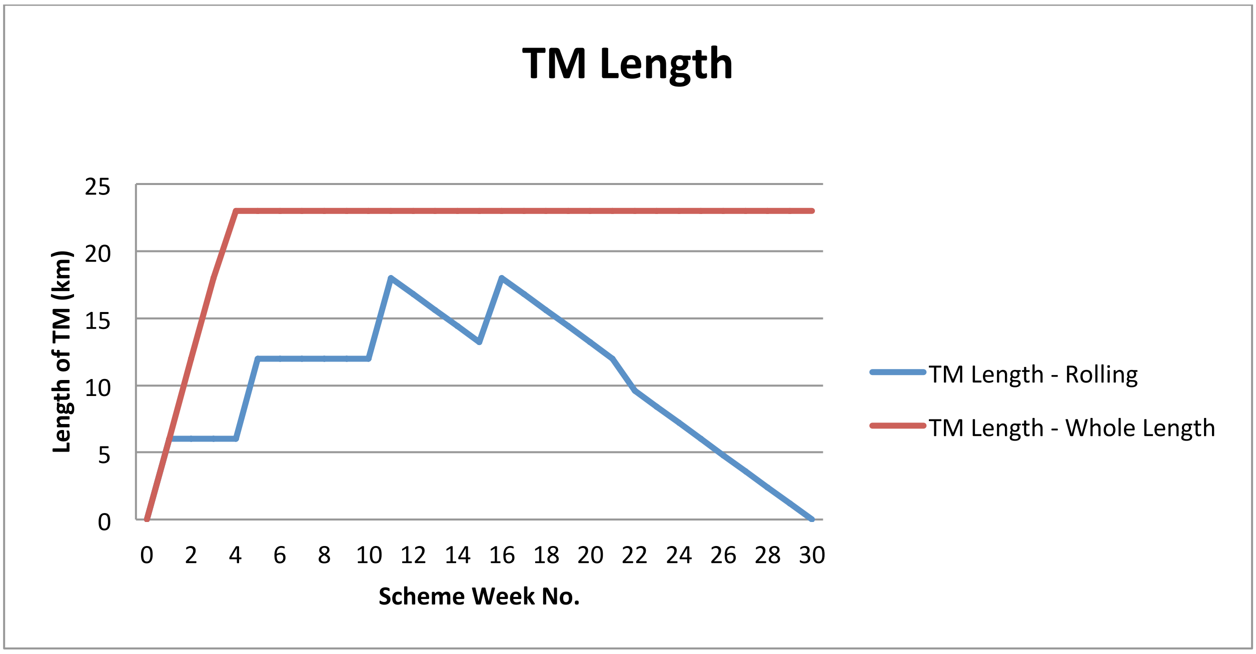
1. Option 1:TM removed in <u>6km lengths</u> to give a TM Duration of 16wks per section
2. Option 2: TM is removed in <u>1.2km lengths</u> to give a variable TM duration of 11 to 17 weeks.

TM Duration - by Chainage

The table below shows, by particular location (chainage), when TM is laid out and removed (by week).

Chainage	TM On (week no.)	TM Off (week no.)	TM Duration (weeks)
0-1200	1	12	12
1200-2400	1	13	13
2400-3600	1	14	14
3600-4800	1	15	15
4800-6000	1	16	16
6000-7200	5	17	13
7200-8400	5	18	14
8400-9600	5	19	15
9600-10800	5	20	16
10800-12000	5	21	17
12000-13200	11	22	12
13200-14400	11	23	13
14400-15600	11	24	14
15600-16800	11	25	15
16800-18000	11	26	16
18000-19200	16	27	12
19200-20400	16	28	13
20400-21600	16	29	14
21600-23000	16	30	15

The chart below shows the length of traffic management for each week of the scheme (i.e. from week 0 to week 30). It can easily be seen that the length of traffic management using a 'rolling' strategy is substantially less than the method of laying out traffic management over the whole length of the scheme, for the entire duration of the scheme. By combining the construction efficiency of utilising the 'Train Methodology' and 'Rolling TM', traffic management can be reduced by up to 65%.



Trial and Error: Whilst the above production strategy works in principle, there is still a lot of work to put this into practice, which will no doubt result in trial and some error. Indeed the finished article or best method, may in fact be different in many ways than the strategy described above. However in order to innovate, we need to be allowed to make mistakes (safely). To paraphrase Thomas Edison 'in inventing the lighbulb I discovered a thousand ways how not to make a lightbulb.

Some areas to consider and or mitigate:

- Availability of TM resource required to make multiple visits to take off and put on TM in smaller quantities
- Road user behaviour may be affected by driving through TM that is less constant i.e. changes more often

10. Proof of Concept - Application to Other Schemes

M5 J4a to 6 - M25

During the period this report was being compiled, we were asked to use the information we had gathered so-far to compare the outputs of a planned scheme (M5 J4a-6) with the outputs achieved by the M25 team. The aim was to identify potential areas for programme improvement. This was the first opportunity to test the concept of being able to apply outputs achieved on one scheme to another scheme of similar, but not identical, scope.

We approached this in the following way:

- hold a design and methodology review workshop to compare the schemes at a high level
- hold a collaborative planning workshop to compare the programmes and strategy
- make recommendations

Comparing Scope and Design:

A summary report from this workshop can be seen in Appendix B but, in brief, the main differences between the two schemes were the drainage system:

Key design, scope and logistics differences between both schemes	
M5	**M25**
30 blisters in 17km (25m long & 1.5m wide)	50 blisters in 14 km (22m long & 0.6m wide)
Includes Lighting	Includes Lighting
Designed with V channel drainage	Designed with slot drain
Use concrete foundations under the RCB in places	No concrete foundations
Attenuated drainage	In line attenuated drainage
Complete new carrier drain reqd	**Not reqd as using slot drain & kept some existing drainage**
Temp lighting not required	Temp lighting required
No muck shift at night	Muck shift carried out at night

All agreed that the requirement for a different type of drainage system on the M5 scheme would have some effect on the programme duration.

Comparing Programmes across the two schemes

We held a collaborative planning workshop with the aim of reviewing the M5 programme to determine if improvements could be made using some of the lessons learned from the M25 projects. This workshop was held at the M25 offices and included the M5 project team, members of the Hub planning team and the M25 project team (including P.J. Davidson, slip-form supplier)

A lot of the detail discussed on the day demonstrated that the M5 project was subject to various constraints. However, it also demonstrated that there was an improvement opportunity of between 4-5 weeks through the adoption of some of the practices used on the M25. In brief these were:

- an increase the number of resources/work gangs in the traffic management
- an increase the number of access points to facilitate the movement of site traffic

M1 J16-19 – M25

More recently we held another collaborative planning workshop with the M1 J16-19 team and the M25 team to carry out a similar exercise. The output from this workshop, is being compiled into a time location chart, which will be reviewed and released on completion. There were several areas of improvement that emerged on the day, demonstrating the benefits that can be gained through bringing different project teams together to share their collective experiences. The identified areas for improvement included:

- the reuse of as many MS3 sites as possible to mount MS4's (69 site available)
- carrying out surveys prior to the project starting especially in the early section to avoid any potential delay in design later
- putting zoneguard out in parallel (potentially saving 4 weeks on programme)
- to challenge the current works info restriction of access points every 1.5 km
- the removal of TM in stages to speed up the demob process
- the use of existing cross carriageway ducts
- the use of mobile laser scanning in order to improve the survey information
- reviewing and seeking to reduce, where possible, the number of cross carriageway pipes in the design
- to construct the plinth base in concrete

Summary

Whilst the above exercise was limited by the timing of the workshops, which in this case were too late to make any significant changes, it did prove that there was opportunity to be had on both schemes by adopting some of the ideas from the M25. To capitalise on this process going forward and to gain useful benefit from lessons learned, this knowledge sharing process across schemes needs to be formalised and implemented.

11. Summary of Findings

This report was commissioned to investigate the reasons why the M25 team seem to be able to produce more kilometres of Smart Motorway per week than any other scheme. Our initial finding was to show, through a comparison of the M25 with 4 other schemes, that this was an accurate observation and that in fact the M25 output is, in the case of some schemes, significantly higher.

Having shown that the M25 is producing more quickly, we then analysed the reasons why. Some of this analysis was quantitative, based on actual output data, and some was qualitative, based on people's opinions gathered during 'lessons learned' workshops. Whilst the use of data is clearly important to prove a concept, we shouldn't underestimate the value of qualitative data, especially in the construction environment where wisdom must sometimes prevail over sparse facts.

The analysis identified that faster delivery was achieved by the M25 team because they planned for 200m of linear output per day and - through the use of various techniques, experience, systems and relationships - delivered against this ambition.

This raised a question around the applicability of this learning to other schemes, as it is not always practical to compare on a 'like for like' basis, and as other project teams may not have the same enabling factors which helped the M25 team to deliver their planned output.

Whilst there is merit in this question, in practice the success of the M25 team was not so much in the content of their work but in their approach to it; if other schemes adopted a similar approach of working in more locations, using more resource and working longer hours they too would deliver more quickly. Indeed, when we compared the M25 with other projects it became apparent that there are other project teams who are already close to achieving the M25 outputs. This suggests that the outputs are replicable across other schemes, regardless of their maturity and experience.

As a result of the various discussions with the M25 team and the lessons learned over a number of workshops, we can show that a different and more efficient approach to delivering Smart Motorways is theoretically achievable. To this end, we have proposed a methodology entitled 'Production Train', which is currently untested but is based on factual data. We now collectively need a prevailing wind and a great deal of enthusiasm to deliver, learn and improve on this methodology.

The time is right to challenge the current way of thinking about highways construction as the industry is receptive to innovative ways of working, the client is in the process of change with a view to working differently in the future and the new CDF contract can act as an enabler to improve working relationships. In order to deliver the full potential of Smart Motorways Construction, we need motivated people and organisations, standard designs, methods and a spirit of improvement.

12. Recommendations:

- Use the M25 schemes as the current benchmark for all other similar schemes.
- Transfer the learning using the current hub system and/or its SMP replacement.
- Extend the range of measures for benchmarking beyond delivery and output to include:
  - Safety
  - Cost
  - Quality
  - Customer / Stakeholder Satisfaction
  - Environmental impact
- Use the CDF framework to create the right conditions and motivations to adopt, challenge and improve the Production Train approach.
- Standardise elements of the product and seek to improve the design and the construction methodology, for example slot drain versus V channel.
- The HA to develop a standard methodology and set of production output rates to be used for all future schemes (the ‘intelligent client’ approach).
- Produce a handbook for Smart Motorways, outlining best practice and methods.
- Maintain project teams to improve the economies of learning – a programme approach to building multiple projects will help to facilitate this.
- Create a more detailed analysis of verge works – where there are more variations in work activity, unlinked activities etc.
- Discuss outputs with key suppliers and the potential for improvements in performance through process improvement.
- Establish KPI’s as a standard process on all SMP motorways and support this with downtime data collection, analysis and problem solving as standard.
- Carry out another detailed analysis of the slip form data on Section 5B to determine the efficacy of the ‘Volumetrics’ concrete process.
- Review ongoing downtime data on the cut and fill activity to identify improvements and show what is possible.

Appendix A – Output from ‘lessons learned’ workshop: ‘how are the M25 team able to build quicker than other similar schemes’

Output from M25/AD Lessons Learned Meeting (initial draft doc)

Held on: 05th Dec 2013 at M25 Project Offices	**Produced by:** A. Moore

Attendees: David Blackburn, Kieran McGibbon, John McGinty, Jerry Clarke, David Hall, Paul Tomlinson, David Riley, Alan Brockhouse, Phil Ellis, Suzanne Moore, ? Atkins, ? SBBJV

Purpose of the meeting: The M25 schemes have been brought to construction and are being constructed faster than all other ALR schemes. The purpose of this workshop is to explore how the team are achieving this and to share lessons learned with people who are currently involved in establishing a new Smart Motorway Programme worth around £3.5bn.

Performance Statements (to be developed further with key metrics)

The m25 team have constructed the equivalent of 8nr £150 million projects in 5 years (each one taking a yr inc technology and commissioning)

They are currently constructing an average of over 2KM of ALR per month

They are currently constructing an average of 1km per week of hardened central reserve inc CSB drainage and structures work

Navigation:

Linking lessons learned to future strategy

Opening Statement: The success of the m25 team in delivering projects quickly and efficiently is attributed to multiple factors inc structural, contractual, cultural, innovative and systems led. Below is just a highlight of some of the key lessons learned on the m25 project, contact details have been provided so other interested parties can contact the relevant people in the m25 team for more information if required.

#	Area	(Stage of Project) that the improvement is made or setup	Lessons Learned Opportunity	Contact name and details
1	Relationship	setup and contract	The team had mutual benefits in mind and have worked together for many years across a whole programme of work - this has enhanced the working relationship	John Worsfold, Kieran McGibbon, Suzanne Moore
2	Team work and culture of continuous improvement	start, middle and end	There was a commitment from all key parties to improve (year 1 verge = 22 wks. for every 2 verges by yr 3 this was 15 weeks for the same)	Kieran McGibbon, Jerry Clarke & Jim McNicholas
3	Team work and culture of continuous improvement	start, middle and end	There is a tangible culture of striving for continuous improvement across the whole project team and the team are happy to challenge the process and adopt new ideas	statement
4	Team work and culture of continuous improvement	start, middle and end	The team had a real 'Cando' attitude and have engaged in innovative thinking to overcome problems but also an eye on lifecycle cost savings and have developed a healthy efficiency register - some examples: the team have 200% CCTV coverage to reduce unplanned maintenance also cctv can be accessed remotely to reboot rather than requiring physical maintenance, smooth face retaining walls, non painted sheets piles etc.	John McGinty and Peter Johns
5	Customer/supplier relationship	setup and programme strategy	It helps that the maintainer and construction team (connect + and SBBJV) are from the same organisations - enhancing collaborative working up and down the value stream	statement
6	Concurrent working and programme	project setup	The team saved a significant amount of time on the programme by completing the Comms build, test and commission within the main construction works. - the team worked to earliest possible start times and not latest starts	John McGinty

Appendix A continued…

7	Concurrent working and programme strategy	setup and programme strategy	Linked to the above, the m25 team and NRTS worked closely together which resulted in the NRTS Comms team regularly working nights to facilitate the process and working days in parallel with the main civils activity (NRTS are reimbursed approx £30,000 for an 18 month saving on programme)	John McGinty
8	Logistics	construction phase	We aimed to get the compound as close to the works as possible to ensure we lose less time on the mobilisation and demobilisation of key construction staff inc satellite compounds	Jerry Clarke
9	Contractor/Designer relationship	setup and programme strategy	From day 1 we struck up a good relationship between the construction team and the design team, as a result the two teams were able to work in relatively close harmony i.e. changes to sequence were adopted by the design team without contractual implications - designers were incentivised to improve as they shared some of the savings from finishing early.	Suzanne Moore, Kieren McGibbon Calvin Blacker
10	Contract	contract phase	The contract (DBFO) for the project ensured there is one point of contact and one point of responsibility for delivering the project but also putting the onus for performance on the construction team - a fixed price lump sum contract meant that any problems were the teams problems and they were incentivised to fix them	Kieran McGibbon
11	Contract	contract phase	Linked to the above, a 50:50 commercial relationship between contractor and HA ensures fairness and encourages performance on all sides - this encouraged all parties to challenge the programme and constraints	Kieran McGibbon
12	Strategy	setup and programme strategy	The project programme had a technology focus and incorporated all technology and NRTS inc commissioning within the period - the programme was not dominated by the civils works	John McGinty
13	Concurrent working and programme strategy	setup and programme strategy	Verge First Non Contraflow on the LUS section- Verge works were constructed first and run concurrently on both sides of the carriageway (space dependent but needs challenging)	Jerry Clarke
14	Concurrent working and programme strategy, systems and logistics	construction phase	We needed to change our thinking to achieve the above i.e. no contraflow - we had the same space but in 2 locations (long and thin) and we could only work with one activity at a time. Work space booking was essential.	Jerry Clarke
15	Concurrent working and programme strategy, systems and logistics	construction phase	We had an advanced phase to strengthen the hard shoulder to facilitate the above (this is a temporary measure and only applicable sec 2 where due to env constrainst it was not possible to go into the verge first)	Jerry Clarke & Jim McNicholas
16	Systems and production control	construction phase	The team have developed a high level of production control to facilitate the above	Jerry Clarke & Jim McNicholas
17	longer working hours	construction phase	the team and supplier adopted periods of working 24 hours and in some cases 7 days per week on targeted critical path activities or essential works to support critical path activities	Jerry Clarke & Jim McNicholas & Kieran McGibbon
18	Programme and real output rates	planning	The team used output rates derived from work studies carried out on the first project - this allowed them to challenge the programme duration and also make the case with the supply chain as the output rates were measured accurately	Jerry Clarke & Jim McNicholas & Kieran McGibbon
19	Strategy and Culture	construction phase	The team would challenge the programme every 3 months (a programme strategy meeting) - to re-align the works and identify opportunities to work more quickly	Jerry Clarke & Jim McNicholas
20	Work scope	start, middle and end	The team challenged some of the content/scope of work - some examples inc access footpaths across the scheme, these were reduced, wavetronix used instead of MIDAS loops - see efficiency register for more	John McGinty
21	Logistics, Working hours and Productivity	construction phase	The team achieved an average of 500m of slip Central Res Barrier per day (the wall only)	Jerry Clarke & Jim McNicholas
22	Traffic Management	setup and programme strategy	Longer the TM the quicker the build? There was one work site every kilometre with an access point every 300-400 metres - this was enhanced by close coordination and central planning of access points	Jerry Clarke & Jim McNicholas
23	Traffic Management	setup and programme strategy	Challenge the Benefits to Cost Ratio (BCR) model at the outset (Kieran to elaborate)	Kieran McGibbon
24	Concurrent working	setup and programme strategy	Much of the design was delivered in parallel with the construction works allowing the project to start earlier than planned (6 months) - this required some planned in-efficiency but had a greater improvement opportunity overall	Suzanne Moore and/or Kieren McGibbon & Calvin Blacker
25	Programme improvement	setup and programme strategy	Linked to the above - there was a real sense of urgency to start the current schemes early to maintain the team from the previous project (linking the current schemes with the end of the previous scheme) **this is about to come to an end as the team is disbanded**	Kieran McGibbon
26	Programmes and not projects	setup and programme strategy	Linked to the above - treating multiple projects as programmes of work ensures many of the above improvements can be realised - this is a key component of the lessons learned on the M25	John Mcginty and Kieran McGibbon
27	Programme improvement	setup and programme strategy	The commercial process ran concurrently - design, costing and HA commercial. Also this was delivered through joint teams from SBBJV and HA and CP	Kieran McGibbon
28	Relationship	setup and programme strategy	Commercial team priced more on the concept design - increased risk but quicker process the teams were more familiar with the risks due to working on the previous project	Kieran McGibbon
29	strategy	setup and programme strategy	The responsibility for technology was maintained within the construction team and there was representation at board level - supporting technology resource was brought in on a when needed basis	John McGinty

Appendix B - Output from 'lessons learned' workshop – comparing M25 scheme and M5 Scheme

M25 / M5 RCB Knowledge Share - Workshop Notes

Workshop Date: 28-01-14 Location: HA Hub, Birmingham
Organisations Represented: Highways Agency, Skanska-Balfour Beatty JV, Carillion, Mott McDonalds, Mace, Rubicon Wigzell

Purpose& Objectives: To share best practice and understand the process and methods deployed on the M25 ALR project that enabled the team to achieve a relatively quick construction programme on the RCB works. This will take into account the differences in the two projects inc scope, design and programme strategy.

Outcome: Learn lessons from M25 project team and apply to M5 and all other ALR schemes if applicable

Format:
Agree objectives and define the two construction sequences for the M25 & M5
M25 present their strategy and discuss in detail – Q&A
Present M5 design details and discuss key differences
Present M5 construction methodology and output rates and compare to M25
Knowing what we know – carry out a more detailed review of the M5 programme

Some comparative data presented on the day:
M25
Example 1: 14km in 18wks (780m per wk or 3.11km per mth)
Example 2: 8.5km in 9wks (940m per week or 3.78km per mth)
Example 3: 8km in 9wks (890m per wk or 3.56km per mth)
M5 J4a-6
10.1 km in 20wks (510m per week or 2.02 km per mth).

What if the above M25 outputs could be applied to the M5 scheme (the improvement goal):
1. Using the M25's slowest production rate (Example 1), the M25 are producing 54% more in the same time and would complete the works in 13wks instead of 20wks.
2. Using the M25's fastest rate (Example 2), the M25 are producing 87% more in the same time and would complete the works in 11wks instead of 20wks.

Facilitators notes:
Members from the two teams presented their schemes including, design, scope and methods deployed. We then had a healthy debate around the similarities and differences in design, construction & programme strategy i.e. number of work sites, resources deployed and hours worked – below are the key findings.

Key design, scope and logistics differences between both schemes

M5	M25
30 blisters in 17km (25m long & 1.5m wide)	50 blisters in 14 km (22m long & 0.6m wide)
Includes Lighting	Includes Lighting
Designed with V channel drainage	Designed with slot drain
Use concrete foundations under the RCB in places	No concrete foundations
Attenuated drainage	In line attenuated drainage
Complete new carrier drain reqd	Not reqd as using slot drain & kept some existing dr
Temp lighting not required	Temp lighting required
No much shift at night	Much shift carried out at night

Summary: There are some differences with the M5 design and logistics that may affect the overall duration when compared to the M25 i.e. v channel drainage, not shifting muck at night and use of concrete foundations (need for attenuation not inc as this is not yet programmed) However there are also differences with the M25 with more blisters, more concrete to break out and requirements for temp lighting. This is useful but there is more to do:

Next Steps: Compare the Gantt chart & time location of both schemes in detail to establish:

- Detailed sequencing (how activities are linked together, i.e. the degree of 'start to finish' activities which actually could be overlapped).
- Detailed working practices (which activities are actually being carried out at night, how much work is actually being carried out on day 6)
- Establish the list of constraints inhibiting production (... tip opening times, location of batching plants, NDD design constraints...).
- Review the contract T&Cs (...it was said that the current MM Contract does not 'encourage' speed of delivery).

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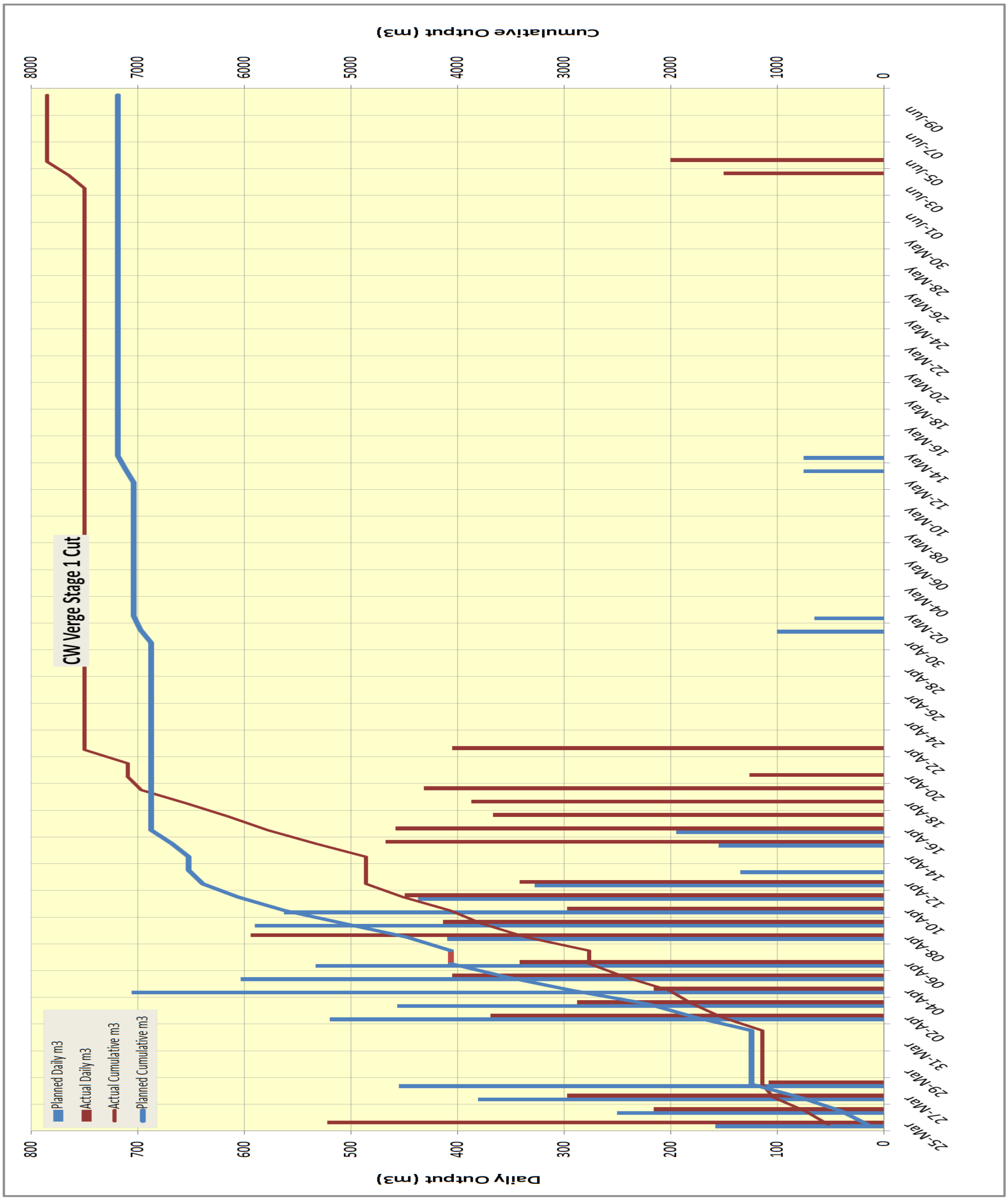
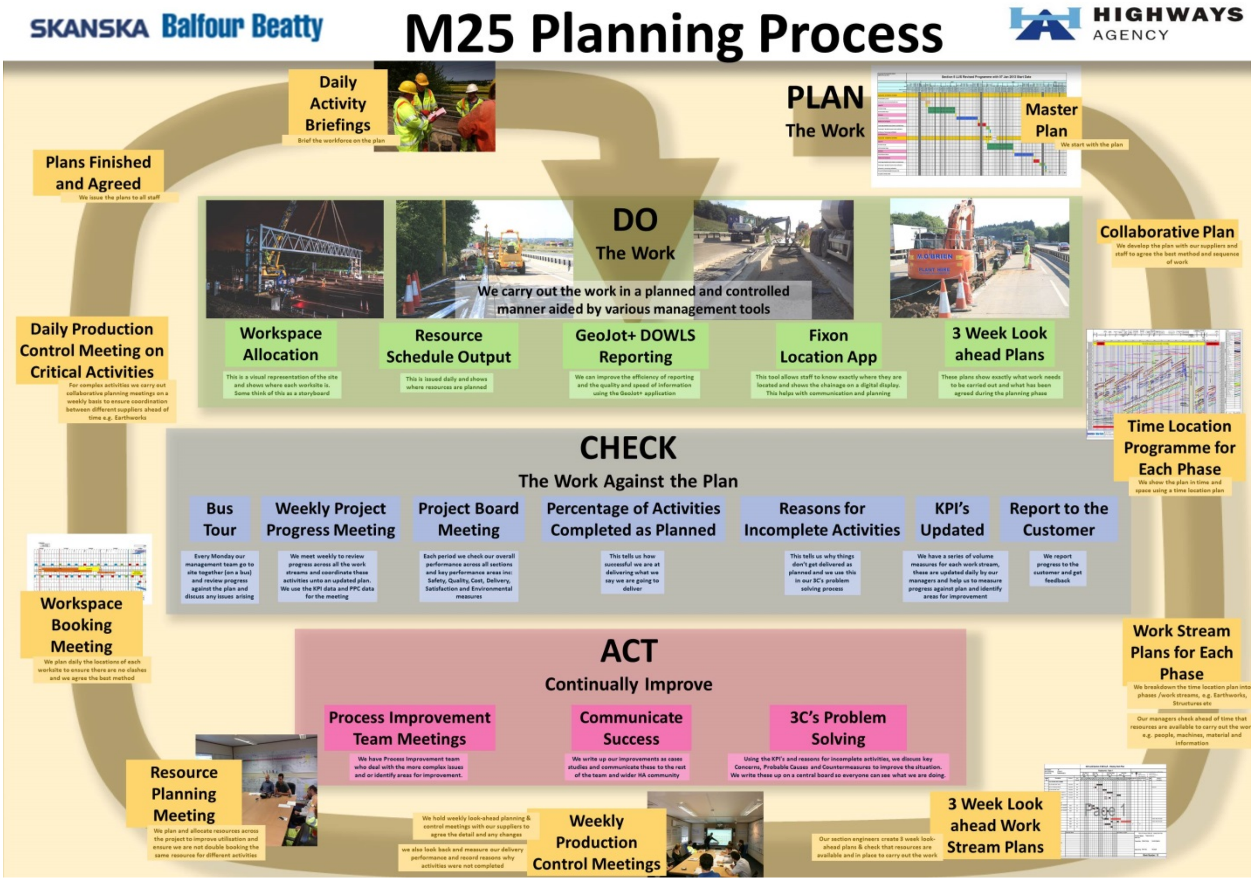
Appendix C - Individual Output Rates for activities used on the M25 scheme

Earthworks - verge	Stage 1 cut	26-Mar	05-Jun	167.22	185.21	m3	day	40-451						
	Comms ducting	11-Apr	04-Sep	155.33 (138.65)	176.77	LM	day	50-382						
	Comms ducting	01-Jul	07-Nov	188	209			40-520	1-3	7	?	day shift	6	Mainly day shifts - only one night shift in the whole period - between 1 & 3 gangs but mainly one gange - max output for one gang = 520LM - Avg per gang per shift= 173 LM
	Stage 1 fill	03-Apr	11-Jun	169.92	238.11	m3	day	40-696	?	?	?		?	
	Cross Ducts	11-Mar	08-May											
	Ducting	11-Apr	04-Sep	155.33 (169.70)	176.77 (185.5)	lm	day	50-382	?					
	Slot Drain	15-Apr	28-Jun	153.96	185.46	LM	Day	50-460	?	?	?		?	
	Slot Drain	19-Aug	19-Dec	156	168	LM	Day	40-446	1-3			night and day	6	Mainly 2 gangs working night and day shifts alternating across Clock Wise and Anti Clock Wise carriageways - Average output per gang = 108LM Max output in one shift = 250
	Comms cable			?	?	?	?	?	?					
	Gantry piling	04-Apr	02-Jul	1	1	nr	day	1	?					
	Slab Replacements	21-May	19-Jul	1.86	3.01	lm	day	1-7.5	?					
Central Reservation	Lighting Removal	02-Jul	05-Jul	22	22	Nr	day	20-42	?					
	Barrier Removal	20-Jul	03-Aug	732.59	793.7	LM	day	500-1600	?					
	Topsoil Strip	23-Jul	14-Aug	277.37	325.24	LM	day	110-600	?					
	Road box	25-Jul	28-Oct	181.92	197.02 (231.26)	LM	day	30-475	?					
	Road Box + slot drain box	14-Jan	26-Apr	208.75	234.84	LM	day	50-584	1-2			day	6	2 gangs on day shift (max output for one gang = 420 Linear metres in 1 day) (avg output for gang 1 = 205.80 Lm and gang 2 162.60 LM)
	Capping	01-Aug	28-Oct	179.65 (212.92)	211.31 (243.3)	LM	day	45-555						
	Slot Drain Prep	16-Aug	28-Aug	217.59	282.53 (315.74)	LM	day	90-725	?					
	Slot Drain Prep	15-Feb	22-May	159.65 (174)	170.01 (187)			40-390	1			day	7	mainly 1 gang deployed but did double up on just 3 of the 168 days (avg output is the same)
	Slot Drain Chambers	13-Sep	22-Nov	3.62	5.7	Nr	day	1-10	?					
	Slot Drain Pour	27-Aug	04-Nov	183.71	186.53	LM	day	67-280	?				7	PJ Davis (Slot drain supplier) believes the improved output on section 5a was due to the fact that they paved over manholes and then dug out rather than working around existing ones. This saved approximately 1 hour per manhole in lost productino
	Slot Drain Pour	19-Aug	10-Jan	157.75	169.58	LM	day	13-250	between 1-3			night and day	5-7	often 2 shifts worked and with one gang per shift (3 gangs working at several points across night and day and on both sides of the carriageway) - max output for one gang = 250 metres - average per gang nights = 88.62 LM - Average per gang day shift = 127.28 LM
	NFD	01-Aug	16-Oct	138.97 (158.28)	184.66	LM	day	20-340						
	NFD	07-Aug	09-Dec	167.75	195.25	LM	day		between 1-3			Day	6	
	CSB Plinth	24-Sep	22-Oct	154.64	197.5 (240)	LM	day	90-560						
	CSB	21-Aug	10-Dec	254.57 (340.76)	261.56 (351.24)	LM	day	60-600						
	CSB	22-May	15-Jul	234.52	360.65	LM	day	143-628	between 1-3		?	Night & Day	6	often 2 shifts worked and in some cases an extra gang were deployed (2 gangs on night shifts) max output for one gang = 293 metres - average per gang per shift = 167 LM
	PQ Concrete	03-Sep	03-Dec	255 (300.89)	266.5 (304.91)	LM	day	60-685	?			7		
	Wet Lean Concrete	27-Aug	03-Dec	232.66	251.11	LM	day	35-585	?			7		
	Wet Lean Concrete	18-Apr	06-Jun	248	300	LM	day	93-672	between 1-5			day shift	6	Day shifts only - between 1-5 gangs deployed - max output for one gang = 465 - average per gang 211 LM per day on main works or 62LM on piecemeal works
	PQ concrete			278	346	LM	day	69-1209	between 1-6			day shift	5-7	Mainly day shifts - only one night shift in the whole period - between 1 & 6 gangs - max output for one gang = 460LM - Avg per gang per shift= 164 LM
	Surface Course (Blacktop) sec 2 only	15-May	25-Jul	852.93 (956)	882.34 (994)	LM	day	35-2000	01-Feb			night and day	5	often 2 shifts worked and with one gang per shift - max output for one gang = 2000 metres - average per gang nights = 644 LM - Average per gang day shift = 1212

Appendix C – Example of Project KPIs used on the M25 scheme


CW Verge Stage 1 Cut
Planned Daily m3
Actual Daily m3
Actual Cumulative m3
Planned Cumulative m3
Daily Output (m3)
Cumulative Output (m3)
0
100
200
300
400
500
600
700
800
1000
2000
3000
4000
5000
6000
7000
8000
25-Mar
27-Mar
29-Mar
31-Mar
02-Apr
04-Apr
06-Apr
08-Apr
10-Apr
12-Apr
14-Apr
16-Apr
18-Apr
20-Apr
22-Apr
24-Apr
26-Apr
28-Apr
30-Apr
02-May
04-May
06-May
08-May
10-May
12-May
14-May
16-May
18-May
20-May
22-May
24-May
26-May
28-May
30-May
01-Jun
03-Jun
05-Jun
07-Jun
09-Jun

Appendix D – M25 planning and management process map



Appendix E - Improvement Work Study on the Cut and Fill Activity

LEAN IMPROVEMENT SUMMARY

Objective

- To ensure the 'Cut and Fill' activity is delivered safely, effectively and efficiently in terms of Time, Quality, Costs, and Customer Satisfaction.

How we did it

- We applied a 'day in the life of (DILO)' technique to observe measure and analyse the performance and flow of the process with the aim of identifying key issues and potential improvements.

Transferability / Use on other schemes

- This set of techniques can be applied across all schemes of a similar scope and of any size project.
- Suppliers can learn from the first run study and apply across all schemes

HIGHWAYS AGENCY

M25 Managed Motorway Improvement Works - Junctions 23 to 27 'Cut and Fill' process

Knowledge Transfer Pack (KTP)

Produced by: Wisam Hasan & Andrew Moore (Rubicon Wigzell Ltd)

Please contact the HA deployment office for further information

IMPORTANT!

All Knowledge Transfer Packs received by the HA will be added to the public domain area of Highways Gov, available for download by any interested parties and the general public. Any commercially sensitive or personal identifying information that is necessary for your KTP must be sent to the HA in a separate appendix.

If in doubt about whether a particular piece of information is sensitive, please speak to one of the HA Lean Technical Managers and your company Data Protection Officer.

DETAILED REPORT

1.0 Project Background

The M25 DBFO includes the delivery of major improvement projects, such as the widening from three lanes to four between junctions 16-23 (Section 1), junctions 27-30 (Section 4) and refurbishing the Hatfield Tunnel (Section 6) up to European standards. Collectively, these improvement works are referred to as the Initial Upgraded Sections (IUS) and were subcontracted to main contractor Skanska Balfour Beatty.

Following the success of the IUS, the Skanska Balfour Beatty Joint Venture (SBBJV) is now responsible for the delivery of the Later Upgraded Sections (LUS) comprising:

Section 2: converting the existing hard shoulder into a permanent running lane, M25 junctions 5 to 7.

Section 5: converting the existing hard shoulder into a permanent running lane, M25 junctions 23 to 27.

The M25 is one of Europe's busiest motorways, handling around 200,000 vehicles every day, with key arterial routes serving central London, the Home Counties and the A282 Dartford Crossing.

The Connect Plus Consortium - comprising Balfour Beatty, Skanska, Atkins and Egis Road Operation UK - has a 30 year Design, Build, Operate and Maintenance (DBFO) contract to manage and improve the capital's orbital motorway network on behalf of the Highways Agency.

Roles and Responsibilities

Liam Maguire	*SBB Planning & Productivity Engineer*
Verdun Davies	*SBB Works Manager*
Tom Cooney	*Sub Agent*
Denis Barlow	*SBB Site Manager*
Jim Johnson	*SBB Foreman*
Wisam Hasan	*Rubicon Wigzell, Lean Consultant*
Andrew Moore	*Rubicon Wigzell, Director*

2.0 Understanding the current state

Historically the 'Cut and fill activity' on the M25 improvement project isn't data rich and unlike the 'Slot Drain' activity there were no detailed data collected to help understand the current state.

To get around this, we have spent a full day shift on site observing the 'As-is' process as well as collect downtime data through data collection techniques

3.0 What we did

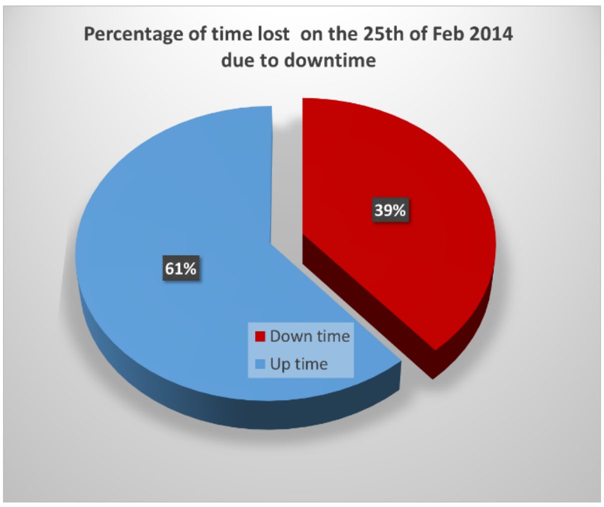
On the 25th of Feb a Rubicon Wigzell consultant accompanied a gang of workers on a full shift to observe and collect the data needed to understand the current state and to be used as a baseline for any improvement initiatives later.

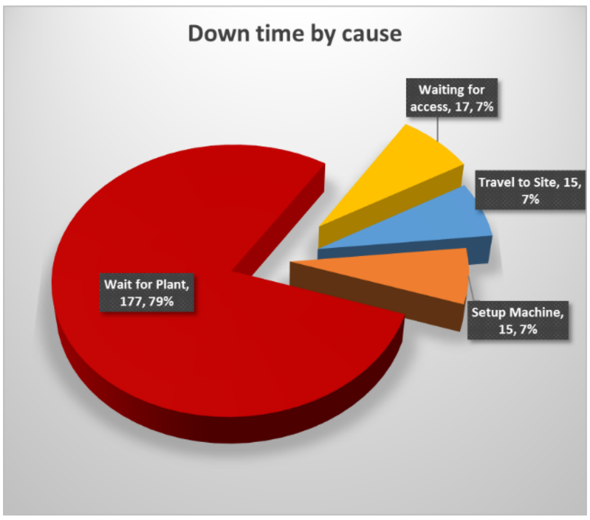
During the shift, data and information were collected on:

- Delay (Down) times and causes
- Times of Wagons activity on site.
- Process flow and site traffic congestion.
- Good practices.

3.1 Down time

On the 25th Feb observation it was recorded that 39% of the shift time suffered downtime due to waiting for plant, access, travel to site and setting up the machine, of which the main contributor to down time was waiting for plant

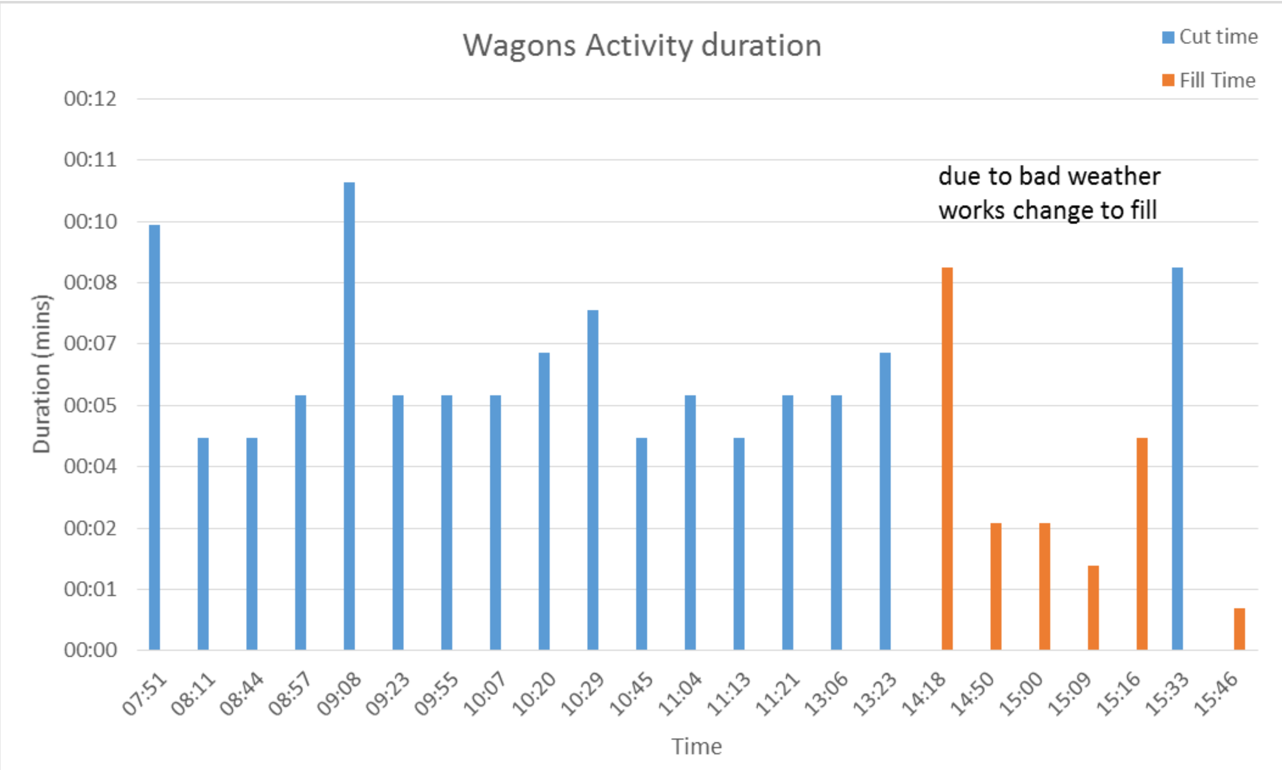




(Wagons).

3.2 Wagons Activity time in and out.

It was observed that on average a wagon will spend less than 7 minutes actively being loaded with muck, this is the value added time as the excavator is engaged in moving soil which is the 'value statement'. Non Value Added Time includes an average of 5 minutes for the wagon to reverse into position from the site entrance and another 3 minutes average for the wagon to exit the site. This totals a **15 minutes cycle time** per wagon from the time it enters the site until it leaves.



3.3 Process flow and site traffic congestion

As in most motorway work sites, site traffic is a major constraint due to lack of sufficient space and close proximity to live traffic. This worksite was no exception, wagons overtaking another wagon had only a few inches of space between them, also traffic outside the site can cause delays when wagons are late to arrive, and when they do, potentially more than one will arrive together where it will cause further delays inside the site.

3.4 Good practices.

Below are some examples of good practice observed during the work study

3.4.1 Work sequence flexibility:

Cut Vs Fill - As a rule of thumb digging (Cut) will take place during day shifts while night shifts do the fill part. This is due to the fact that digging during the night can cause problems, historically "dig" night shifts could result in:

1. Cables cut - potentially due to impaired visibility.

2. and/or Digging more than required which in turn will require another shift to re-fill the extra dug up area. Digging requires trimming the edges of the trench and because of poor visibility this won't be possible.

Despite all of that, if the weather isn't at its best ie raining, the team will be running the risk of the trenches being filled with rain water and this is when the work sequence can be changed from Cut to Fill very quickly as shown in the Wagon activity duration graph.

3.4.2 Site access:

Although it is not the standard, similar motorway projects specify the distance between site access points at 800 - 1000m intervals. At this project the earthworks team coordinate constantly with the traffic management team to optimise the location and the intervals of the site access point to minimise wagons reverse time. Currently the intervals between access points is averaging 350m.

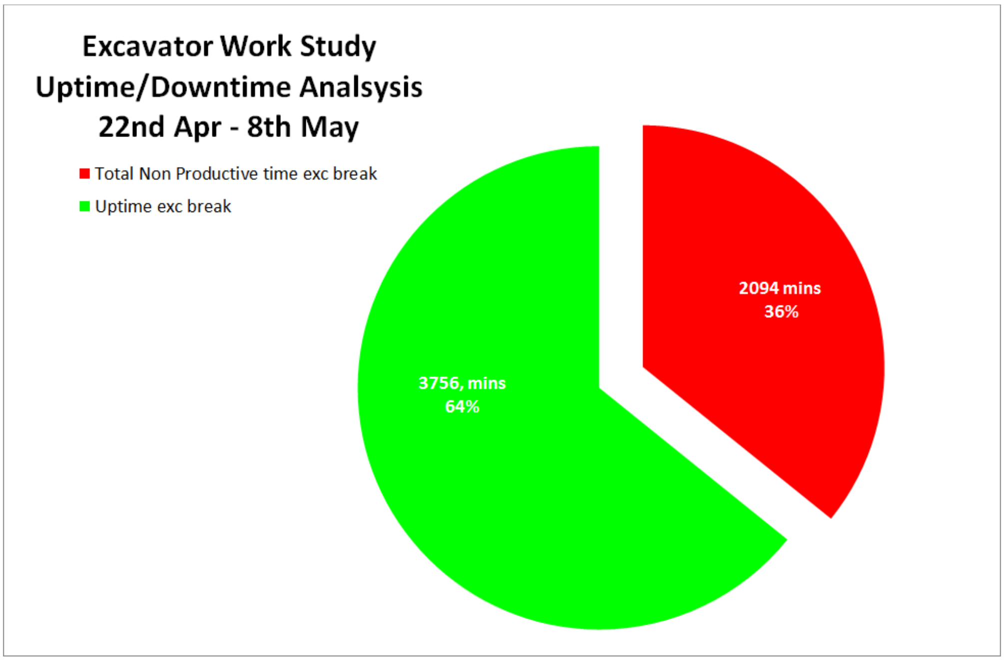
3.4.2 Time management:

The team conduct task briefings at the worksite as opposed to the project office, this helps reduce any transportation and subsequent non value adding time.

Summary:

This case study is built on using one shift worth of data including observations, interviews with field staff and management. Any conclusions from analysing this information can only be improved by collecting and analysing more longitudinal data over a longer period of time. This will highlight and identify further issues to be rectified, albeit already highlighting a potential 39% percent of programme duration improvement.

Update: the table below shows downtime data collected over 2-3 week period and supports the initial figures described above.



Conclusions and action plan (to be agreed with project team):

#	Action	Accountable	Due date
1	Further analyse the process to identify potential data collection points	Andrew Moore	May 2014
2	Set up a data collection plan for an agreed period of time	Tom Cooney	May 2014
3	Investigate and agree potential improvement actions with the team	Tom Cooney	June 2014
4	Update this case study with Improvements and new analysis results	Andrew Moore	July 2014

4.0 Sustaining the improvement (What needs to be done?)

After the initial analysis a meeting with the project team need to take place to identify improvement areas around reducing downtime due to traffic, wagon movements and enhance the utilisation of excavator productive time. This meeting needs to include site staff as they are the people living the process and have the most knowledge on issues and potential improvements.

5.0 Benefits (Before and After Performance)

Potential Benefits at this stage includes higher productivity, shorter construction programme, enhanced perception form the travelling public that progress is being made, and as we improve the traffic movement on site it we will get an improvement in safety.

6.0 Transferability

This process can be transferred not only to SMP projects but also any HA project and in particular those that require cut and fill but also any excavation work such as the road box excavation in the central reservation.

7.0 Issues and Barriers

Failure to collect good data and respond to the findings, a resistance to collect data potentially for fear of being caught out (the drivers or supervisors may feel uncomfortable), there needs to be an incentive to improve on the programme and not just meet the agreed programme.

8.0 Top Learning Points

The process suffers large amounts of waste in the form of downtime due to waiting and change over time due to logistics.

Appendix F – Improvement Work Studies on Slip Form Process

LEAN IMPROVEMENT SUMMARY

Objective

- To ensure the 'Slot Drain' activity is delivered safely, effectively and efficiently in terms of Time, Quality, Costs, and Customer Satisfaction.

How we did it

We analysed historical data recorded by the site staff to understand the current state and draw conclusions and suggested actions to improve the process and further investigate the process

Transferability / Use on other schemes

- This set of techniques can be applied across all schemes of a similar Scope, regardless of size.

M25 Managed Motorway Improvement Works - Junctions 23 to 27 'Slot Drain' process

Knowledge Transfer Pack (KTP)

Produced by: Andrew Moore and Wisam Hasan

Please contact the HA deployment office for further information

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DETAILED REPORT

9.0 Project Background

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Following the success of the IUS, the Skanska Balfour Beatty Joint Venture (SBBJV) is now responsible for the delivery of the Later Upgraded Sections (LUS) comprising:

Section 2: converting the existing hard shoulder into a permanent running lane, M25 junctions 5 to 7.

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The Connect Plus Consortium - comprising Balfour Beatty, Skanska, Atkins and Egis Road Operation UK - has a 30 year Design, Build, Operate and Maintenance (DBFO) contract to manage and improve the capital's orbital motorway network on behalf of the Highways Agency.

Roles and Responsibilities

John Crouch	*PJ Davison*
Alan	*PJ Davison*
Liam Maguire	*SBBJV*
Chris Till	*SBBJV*
Wisam Hasan	*Rubicon Wigzell Lean Consultant*
Andrew Moore	*Rubicon Wigzell Lean Director*

10.0 Understanding the current state

To improve a process we first need to understand the current state process. We can then assess the performance of the current state and apply lean techniques to develop an improved future state.

On construction projects, it can be difficult to gather good data to check for the performance of the current state process. Ideally we would like data over a significant period of time to ensure we have sufficient data points for analysis. We would then support this analysis with onsite observations.

Due to the slot drain activities position on the programmes critical path it was chosen to be the subject of this study, an hour delay on a critical path activity means an hour delay for the whole project, and consequently any improvements realised on this activity will lead to improvements to the whole programme.

In this case, we had excellent data produced by both SBBJV on daily output rates but also P.J. Davidson who complete very detailed daily operator and machine allocation sheets. As P.J. Davidson were not due to carry out construction works during this period, we relied initially on the data only, but will then follow this up with onsite observations when work starts.

11.0 What we did

11.1 What to Analyse

There were two sources of data records that were available; the daily laying statement (Concrete) forms and the daily labour, plant & material allocation forms.

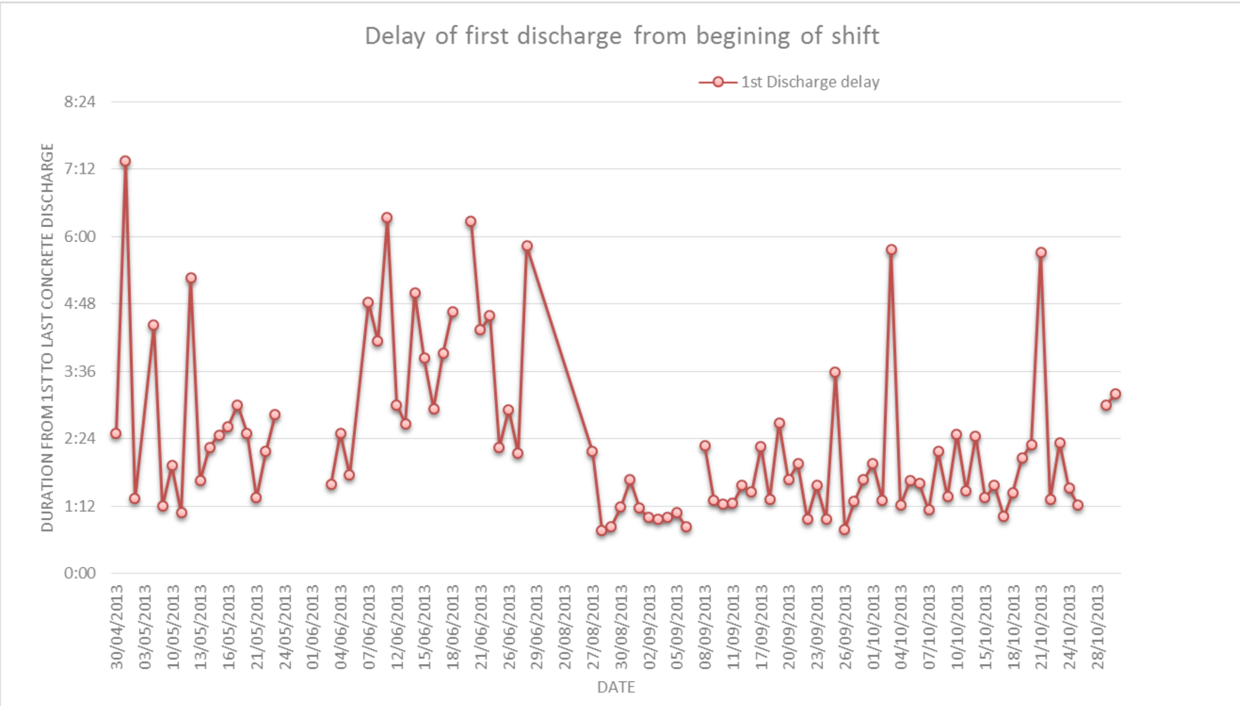
The laying statement had detailed data on individual wagons in and out of the site with exact times and statistics of the concrete deliveries and reasons for delay and/or rejections of concrete after inspections.

Whilst the labour and plant allocation forms had data on the number of staff on site, start and end times of shifts and plant used.

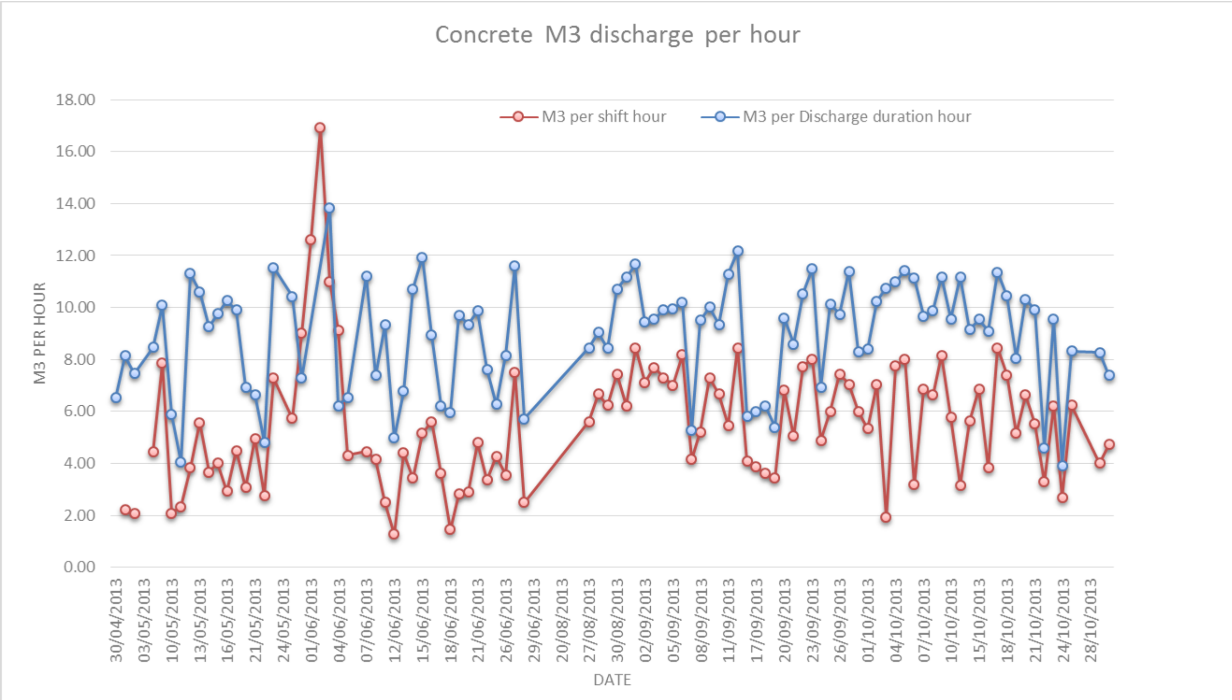
Analysing this data will help us to identify down time, changeover time, the volume of concrete laid and other issues that might arise during the construction process.

11.2 The Analysis

11.2.1 Late start.One of the earliest observations during our analysis was the gap between the shift start and the first concrete discharge, the graph below shows that it can be an average of 2:33 hours per day and anything up to 7 hours delay. The project manager indicated that this was expected giving the circumstances of the geographic location of the worksite.



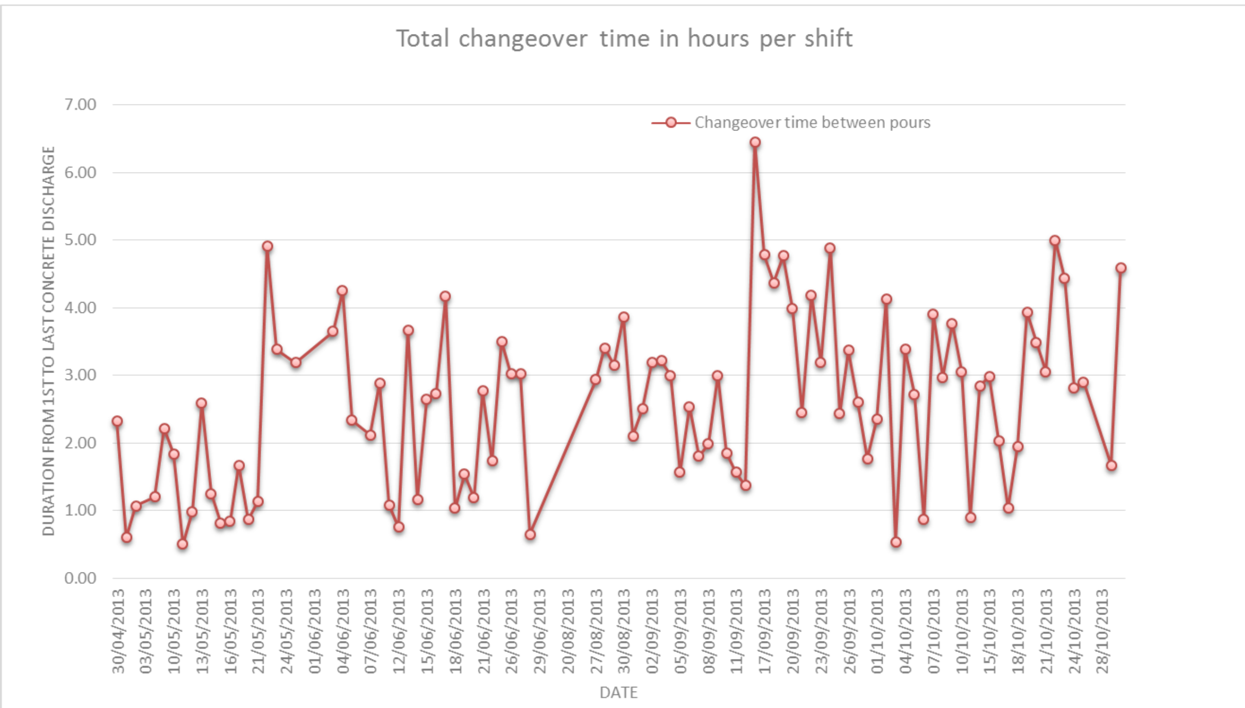
3.2.2 Productivity. Since the first concrete discharge showed an average of approximately 2 hours delay, then this would skew the volume per hour calculation if we measured the time from the start to the end of the shift. Therefore, the graph below shows both volume per hour measured twice. One using the time from the first discharge and ends with the last (8.9 M^3/hour) whilst the second measure is the shift start and end times and shows an understandably low 5.5 M^3/hour.



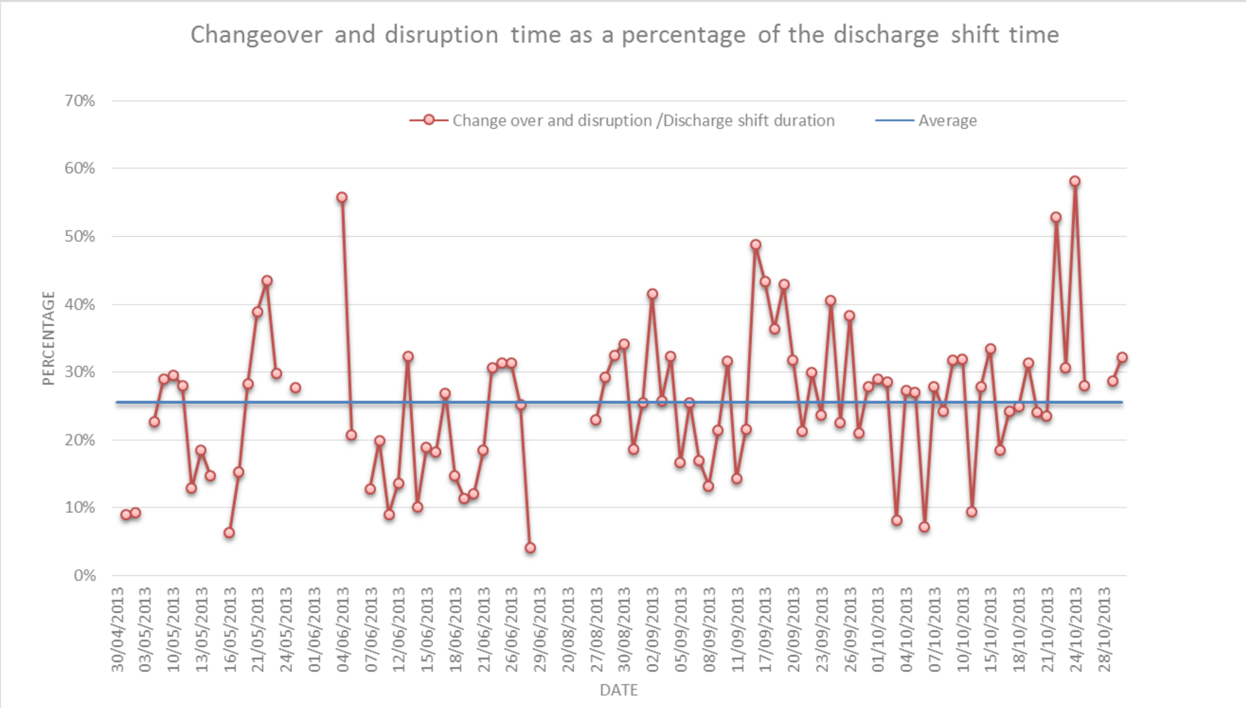
3.2.3 Downtime.

During the shift there will be time when work will be disrupted for many reasons, understanding the duration of disruption and those reasons will help reduce the downtime which in turn improves productivity.

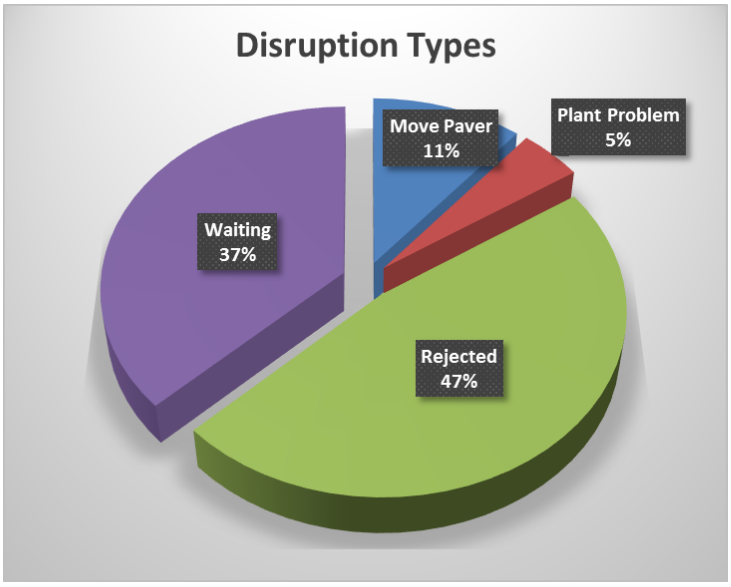
The period of time between a wagon leaving the site and the next one entering is called the changeover time. The graph below shows the changeover time per shift and although it peaks at more than 6 hours per shift the average is 2:40 hours.



Changeover time is not the only downtime observed, there were also disruption times which, when combined with changeover time we can calculate the percentage of Disruptive time and Changeover of the total shift time as shown below. Although the average is only 26% it can peak at close to 60% of the time.



When analysing the reason for delay and disruption times it was found as shown below that almost half of the time was due to the concrete being rejected because of its unsatisfactory levels of air, too wet or too dry. The second highest reason is excessive waiting periods, which can be considered as external factors that we cannot reasonably control, such as traffic jams on the motor way.



3.3 Conclusions and recommendations

- Disruption and down time are non-value added periods which we all should strive to eliminate or reduce when feasible. These periods on this specific project might look within acceptable levels from one point of view yet there is still generous room for improvement.

- The project has already started using a new volumetric concrete method that will reduce the rejection rate by maintaining the quality of concrete delivered to site which should cut the disruption time significantly. Based on the current workload it was suggested that we collect the data again around mid Apr 2014 and compare the performance using the new method with the current data we have.

- Another suggestion would be to conduct a further study on sequencing the works to align plans to move the paver from one side of the carriageway to another as this activity causes significantly long periods of downtime.

Summary:

This business case was produced based on data analysis and interviews with the project team, to reach any improvement conclusions there need to be at least a site observation and collaborative workshop with the project and site teams to run through the findings and investigate any improvements, this is especially important since the project will be using a new volumetric method for installing slot drain.

4.0 Sustaining the improvement (What needs to be done?)

Action plan (to be agreed with project team):

#	Action	Accountable	Due date
1	Meet with project team to agree key issues in the process to observed onsite.	TBA	TBA
2	Set up a data collection plan for an agreed period.	TBA	TBA
3	Report to the project tem with new findings and agree potential improvement actions.	TBA	TBA
4	Update this case study with Improvements and new analysis results	TBA	TBA

5.0 Benefits (Before and After Performance)

Consider focusing on only improving the late start and downtime periods, which equates to north of 5 hours, the room for improvement is very high and can significantly improve the programme delivery cycle time, which in turn will lead to higher productivity.

6.0 Transferability

This process can be transferred not only to SMP projects but also any HA project and in particular those that require cut and fill but also any excavation work such as the road box excavation in the central reservation.

7.0 Issues and Barriers

Although the documentation provided to us by SBBJV was rich in details, yet it lacked the consistency required for statistical significant conclusions.

8.0 Top Learning Points

Although the current time of late start is perceived as acceptable, yet it is significantly high by all standards and should be tackled as a matter of urgency.

SUPPORTING DOCUMENTS – EXAMPLE OF DAILY LABOUR, PLANT & MATERIAL ALOCATION FORM, THE DAILY LAYING STATEMENT FORMS AND RAW DATA ANALYSIS

P.J. DAVIDSON (UK) LTD

01451

DAILY LABOUR, PLANT & MATERIAL ALLOCATION

QA04

Main Contractor	Cross Section	Foreman	Date
M25 SECT B/B	C/RES	Scotty	21/10/13
Site	**Direction**	**Paver**	**Product**
M25 SECT 5	CW	SP 500	TWCSB

DAILY DIARY Set up Paver

M/S 021

R/A 046

Waited 1 Hr 15 mins for concrete almost had to pull off due to concrete going hard in mixer wagon missed access had to go round again

CONCRETE	Ordered	Supplied	COMMENTS
Volume m3		78	
Time of first load	20-45		
Time of last load	6-25		
OPERATION	TWCSB		
Start Chainage	50094		
Finish Chainage	50189		
Start Time	7.00		
Finish Time	8-30		

	No	Hrs	No	Hrs	No	Hrs	No	Hrs	No	Hrs
Vans + 1x4x4	1	12								
Tools										
LABOUR	7+1 Foreman									

DAILY BRIEFING Weather! - Dry at moment

PPE to be worn at all times

Watch for all moving parts on paver tracks auger etc

FIRST AIDER Scotty

NAME	SIGN	Start	Finish	Total
Scotty	[signature]	14.00	8.30	18.5
Peter E.	[signature]	18.30	8.00	13.5
IGAR	[signature]	18.30	8.00	13.5
E PODER	[signature]	18.30	8.00	13.5
MARCEL	[signature]	18.30	8.00	13.5
DONALD	[signature]	18.30	8.30	13.5
[illegible]	[signature]	14.00	8.30	18.5
PAVEL	[signature]	18.30	8.00	13.5

TOOLBOX TALK

NAME	SIGN	Start	Finish	Total

P.J. DAVIDSON (UK) LTD

01403

DAILY LAYING STATEMENT - CONCRETE QA02

Main Contractor	Cross Section	Foreman	Date
S.B.B	CENTER	SCOTTY	23/10/13
Site	**Direction**	**Paver**	**Product**
M25 SECTION 5	CLOCKWISE	SP500	T.W. CSB

LOAD	VEHICLE REG	TICKET NO.	DISCHARGE QTY M3	DISCHARGE TIME ON	DISCHARGE TIME OFF	CUBE REF.	CHAINAGE FROM	CHAINAGE TO	COMMENTS
1	BX56 WWF	295074	6	20.20	21.15		50272	50278	
2	YN06 FZM	295076	6	21.22	21.52		50278	50284	
3	YJ58 BNV	295079	6	21.58	22.30		50284	50291	
4	YJ56 ORC	295082	6	22.37	23.05		50291	50297	
5	YN06 FZU	295085	3	00.00	00.10		50297	50300	ONLY 2m³ USED JUMPED BRIDGE TO
6	YJ58 BNY	295092	6	02.20	02.50		50341	50346	
7	YJ56 ORC	295096	6	02.57	03.25		50346	50352	
8	GN06 UXA	295097	6	03.28	03.40		50352	50359	
9	YJ56 OSG	295099	6	03.43	04.08		50359	50366	
10	PO54 CCX	295101	6	04.15	04.43		50366	50373	
11	YU04 WNB	295102	6	04.50	05.12		50373	50379	
12	YN06 FZM	295105	6	05.18	05.40		50379	50386	
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									

Total Quantity 69 m³

For PJ Davidson SIGNED [signature]

PRINT [illegible]

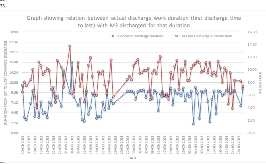
For Client SIGNED

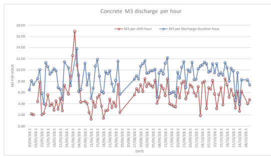
PRINT

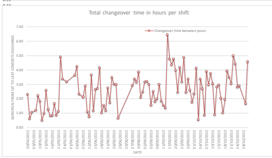
Daily Labour, Plant and Material Allocation

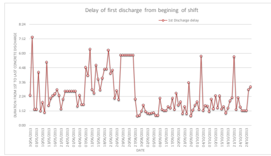
Laying Statement

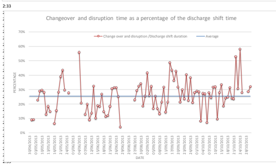
Date	start of shift	finish of shift	nr of operative	total hrs worked	First Concrete Discharge	Last Concrete Discharge	Total M3 discharged	Changeover time between pours	Disruption / waiting	Concrete Discharge duration	M3 per Dis	Change ov	Average	Shift durat	M3 per shi	1st Discharge delay	
30/04/2013	7:00	0:00	8	127.5	9:30	20:50	74	2.32	2.12	11:20	6.53		26%	########		2:30	2:33
01/05/2013	7:00	20:30	8	101.5	14:21	18:02	30	0.60	0.62	3:41	8.14	9%	26%	13:30	2.22	7:21	2:33
02/05/2013	7:00	18:30	7	72.5	8:20	11:33	24	1.07	0.00	3:13	7.46	9%	26%	11:30	2.09	1:20	2:33
03/05/2013	7:00	13:00	6	31	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	6:00		1:20	2:33
08/05/2013	7:00	20:30	8	105	11:25	18:30	60	1.20	1.87	7:05	8.47	23%	26%	13:30	4.44	4:25	2:33
09/05/2013	7:00	20:00	8	101	8:12	18:19	102	2.22	1.55	10:07	10.08	29%	26%	13:00	7.85	1:12	
10/05/2013	7:00	18:00	7	81	8:55	12:50	23	1.83	1.42	3:55	5.87	30%	26%	11:00	2.09	1:55	
11/05/2013	7:00	19:00	7	84	8:05	15:00	28	0.50	2.87	6:55	4.05	28%	26%	12:00	2.33	1:05	
12/05/2013	7:00	18:00	7	77	12:16	15:59	42	0.98	0.43	3:43	11.30	13%	26%	11:00	3.82	5:16	
13/05/2013	7:00	21:00	8	104	8:39	16:00	78	2.58	0.00	7:21	10.61	18%	26%	14:00	5.57	1:39	
14/05/2013	7:00	19:00	8	88	9:15	14:00	44	1.25	0.52	4:45	9.26	15%	26%	12:00	3.67	2:15	
15/05/2013	7:00	19:00	8	75	9:28	14:23	48	0.82	1.25	4:55	9.76		26%	12:00	4.00	2:28	
16/05/2013	7:00	20:00	8	84.5	9:37	13:19	38	0.83	0.00	3:42	10.27	6%	26%	13:00	2.92	2:37	
17/05/2013	6:30	22:30	8	102	9:30	16:46	72	1.67	0.78	7:16	9.91	15%	26%	16:00	4.50	3:00	
20/05/2013	7:00	22:00	8	94.5	9:30	16:08	46	0.87	3.37	6:38	6.93	28%	26%	15:00	3.07	2:30	
21/05/2013	6:30	21:00	8	106.5	7:51	18:40	72	1.13	4.50	10:49	6.66	39%	26%	14:30	4.97	1:21	
22/05/2013	6:30	19:30	8	97	8:40	16:08	36	4.92	0.73	7:28	4.82	43%	26%	13:00	2.77	2:10	
23/05/2013	6:30	20:30	8	105	9:20	18:10	102	3.38	0.78	8:50	11.55	30%	26%	14:00	7.29	2:50	
24/05/2013	6:30	15:00	8	48	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	8:30	#N/A	2:50	
30/05/2013	7:30	19:00	16	188	0:00	6:20	66	3.18	0.00	6:20	10.42	28%	26%	11:30	5.74	2:50	
31/05/2013	7:00	19:00	13	160	6:50	21:40	108	#N/A	0.00	14:50	7.28		26%	12:00	9.00	2:50	
01/06/2013	7:00	19:00	16	189	3:00	18:36	151.5	#N/A	0.00	#N/A	#N/A		26%	12:00	12.63	2:50	
02/06/2013	7:00	19:00	15	180.5	6:26	18:39	203	#N/A	3.08	#N/A	#N/A		26%	12:00	16.92	2:50	
03/06/2013	7:00	19:00	15	181	8:35	18:08	132	3.65	0.00	9:33	13.82		26%	12:00	11.00	1:35	
04/06/2013	7:00	18:30	14	171	9:30	17:04	105	4.25	2.17	16:52	6.23	56%	26%	11:30	9.13	2:30	
05/06/2013	18:30	7:30	7	85	20:15	4:49	56	2.33	0.37	8:33	6.55	21%	26%	12:59	4.31	1:45	
06/06/2013	18:30	7:30	7	85	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	12:59	#N/A	1:45	
07/06/2013	15:00	7:30	7	90.5	19:50	2:24	73.5	2.12	0.00	6:33	11.22	13%	26%	16:29	4.46	4:50	
10/06/2013	17:30	8:00	7	90.5	21:38	5:46	60	2.88	0.00	8:07	7.39	20%	26%	14:29	4.14	4:08	
11/06/2013	17:30	5:30	7	73	23:50	3:04	30	1.08	0.00	3:13	9.33	9%	26%	11:59	2.50	6:20	
12/06/2013	20:30	7:30	7	71	23:30	2:20	14	0.75	0.75	2:49	4.97	14%	26%	10:59	1.27	3:00	
13/06/2013	18:00	9:00	7	96	20:40	6:25	66	3.67	1.18	9:44	6.78	32%	26%	14:59	4.40	2:40	
14/06/2013	17:00	7:00	7	87.5	22:00	2:30	48	1.17	0.25	4:29	10.71	10%	26%	13:59	3.43	5:00	
15/06/2013	17:30	7:30	7	87	21:20	3:23	72	2.65	0.00	6:02	11.93	19%	26%	13:59	5.15	3:50	
16/06/2013	17:30	8:30	7	94	20:26	5:51	84	2.73	0.00	9:24	8.94	18%	26%	14:59	5.61	2:56	
17/06/2013	17:00	8:30	7	95	20:55	5:56	56	4.17	0.00	9:00	6.22	27%	26%	15:29	3.62	3:55	
18/06/2013	17:00	7:30	7	88	21:40	1:12	21	1.03	1.10	3:31	5.97	15%	26%	14:29	1.45	4:40	
19/06/2013	18:00	7:30	7	88	3:20	0:14	38	1.53	0.00	3:55	9.70	11%	26%	13:29	2.82	4:40	
20/06/2013	17:00	5:30	7	66	23:16	3:08	36	1.18	0.33	3:51	9.35	12%	26%	12:29	2.88	6:16	
21/06/2013	17:00	8:00	7	89	21:20	4:39	72	2.77	0.00	7:18	9.86	18%	26%	14:59	4.81	4:20	
24/06/2013	17:00	5:30	7	74	21:35	3:07	42	1.73	2.10	5:31	7.61	31%	26%	12:29	3.36	4:35	
25/06/2013	18:00	9:00	7	94	20:15	6:28	64	3.50	1.20	10:12	6.27	31%	26%	14:59	4.27	2:15	
26/06/2013	18:00	7:30	7	85.5	20:55	2:49	48	3.02	1.22	5:53	8.16	31%	26%	13:29	3.56	2:55	
27/06/2013	18:00	6:00	7	75	20:08	3:54	90	3.02	0.00	7:45	11.61	25%	26%	11:59	7.51	2:08	
28/06/2013	17:30	9:30	7	98	23:20	6:21	40	0.65	0.00	7:00	5.71	4%	26%	15:59	2.50	5:50	
29/06/2013	18:00	7:30	7	85.5	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	13:29	#N/A	5:50	
30/06/2013	9:00	10:30	2	16	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	1:30	#N/A	5:50	
19/08/2013	19:00	4:00	8	87	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	8:59	#N/A	5:50	
20/08/2013	10:00	18:00	8	64	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	8:00	#N/A	5:50	
21/08/2013	18:00	6:00	8	66	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	11:59	#N/A	5:50	
22/08/2013	19:00	3:00	8	77	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	7:59	#N/A	5:50	
27/08/2013	18:00	9:00	8	120	20:10	6:08	84	2.93	0.50	9:57	8.44	23%	26%	14:59	5.61	2:10	
28/08/2013	19:00	8:30	8	101	19:46	5:44	90	3.40	0.55	9:57	9.05	29%	26%	13:29	6.67	0:46	
29/08/2013	19:00	8:30	8	101	19:50	5:49	84	3.15	1.23	9:58	8.43	33%	26%	13:29	6.23	0:50	2:33
30/08/2013	19:00	9:00	8	105	20:11	5:54	104	3.87	0.92	9:42	10.72	34%	26%	13:59	7.44	1:11	2:33
31/08/2013	18:30	9:00	8	104	20:10	4:15	90	2.10	0.60	8:04	11.16	19%	26%	14:29	6.21	1:40	2:33
01/09/2013	19:00	8:30	8	101	20:10	5:57	114	2.50	0.93	9:46	11.67	25%	26%	13:29	8.45	1:10	2:33
02/09/2013	19:00	8:30	8	101	20:00	6:11	96	3.18	2.42	10:10	9.44	42%	26%	13:29	7.12	1:00	2:33
03/09/2013	19:00	7:30	8	101	19:58	6:03	96	3.22	0.00	10:04	9.54	26%	26%	12:29	7.69	0:58	2:33
04/09/2013	19:00	9:00	8	105	20:00	6:18	102	3.00	1.52	10:17	9.92	32%	26%	13:59	7.29	1:00	2:33
05/09/2013	19:00	7:00	8	89	20:05	4:33	84	1.57	0.43	8:27	9.94	17%	26%	11:59	7.01	1:05	2:33
06/09/2013	19:00	7:30	8	100.5	19:50	5:50	102	2.53	0.65	9:59	10.22	26%	26%	12:29	8.17	0:50	2:33
07/09/2013	7:00	20:00	8	105	20:36	6:50	54	1.80	0.40	10:13	5.29	17%	26%	13:00	4.15	0:50	2:33
08/09/2013	19:00	10:00	8	99	21:17	5:30	78	1.98	0.00	8:12	9.51	13%	26%	14:59	5.21	2:17	2:33
09/09/2013	19:00	9:00	8	105	20:18	6:30	102	3.00	0.00	10:11	10.02	21%	26%	13:59	7.29	1:18	2:33
10/09/2013	19:00	8:30	8	101	20:14	5:53	90	1.85	2.42	9:38	9.34	32%	26%	13:29	6.67	1:14	2:33
11/09/2013	19:00	6:00	8	81	20:15	1:35	60	1.57	0.00	5:19	11.29	14%	26%	10:59	5.46	1:15	2:33
12/09/2013	19:00	8:30	8	103	20:34	5:57	114	1.37	1.53	9:22	12.17	22%	26%	13:29	8.45	1:34	2:33
16/09/2013	19:00	9:00	8	105	20:27	6:18	57	6.45	0.38	9:50	5.80	49%	26%	13:59	4.08	1:27	2:33
17/09/2013	19:00	9:00	8	105	21:16	6:17	54	4.78	1.28	9:00	6.00	43%	26%	13:59	3.86	2:16	2:33
18/09/2013	19:00	10:00	7	99	20:19	5:03	54	4.37	1.08	8:43	6.20	36%	26%	14:59	3.60	1:19	2:33
19/09/2013	19:00	9:00	7	93	21:41	6:37	48	4.77	1.23	8:55	5.38	43%	26%	13:59	3.43	2:41	2:33
20/09/2013	18:30	9:30	7	96.5	20:10	6:48	102	3.98	0.77	10:37	9.61	32%	26%	14:59	6.81	1:40	2:33
21/09/2013	18:30	6:00	7	71.5	20:27	3:13	58	2.45	0.00	6:45	8.59	21%	26%	11:29	5.05	1:57	2:33
22/09/2013	19:00	9:00	7	92.5	19:58	6:14	108	4.18	0.00	10:15	10.54	30%	26%	13:59	7.72	0:58	2:33
23/09/2013	18:30	8:00	8	98	20:04	5:28	108	3.18	0.00	9:23	11.51	24%	26%	13:29	8.01	1:34	2:33
24/09/2013	19:00	8:30	8	101	19:58	5:30	66	4.88	0.58	9:31	6.94	41%	26%	13:29	4.89	0:58	2:33
25/09/2013	18:00	9:00	7	95	21:35	6:29	90	2.43	0.95	8:53	10.13	23%	26%	14:59	6.01	3:35	2:33
26/09/2013	19:00	9:00	7	92	19:47	6:29	104	3.37	2.00	10:41	9.73	38%	26%	13:59	7.44	0:47	2:33
27/09/2013	18:30	7:00	7	79	19:47	3:31	88	2.60	0.02	7:43	11.40	21%	26%	12:29	7.05	1:17	2:33
30/09/2013	18:30	7:30	6	76	20:10	5:34	78	1.77	1.85	9:23	8.31	28%	26%	12:59	6.01	1:40	2:33
01/10/2013	18:00	7:30	6	72	19:57	4:33	72	2.35	1.55	8:35	8.39	29%	26%	13:29	5.34	1:57	2:33
02/10/2013	18:30	9:00	7	93	19:48	5:46	102	4.13	0.00	9:57	10.25	29%	26%	14:29	7.04	1:18	2:33
03/10/2013	17:00	5:30	7	73.5	22:46	1:01	24	0.53	0.48	2:14	10.75	8%	26%	12:29	1.92	5:46	2:33
04/10/2013	18:30	10:00	7	100	19:43	6:39	120	3.38	0.85	10:55	10.99	27%	26%	15:29	7.75	1:13	2:33
05/10/2013	18:30	8:00	7	86	20:09	5:37	108	2.72	0.93	9:27	11.43	27%	26%	13:29	8.01	1:39	2:33
06/10/2013	18:30	6:30	7	75.5	20:06	23:31	38	0.87	0.00	3:25	11.12	7%	26%	11:59	3.17	1:36	2:33
07/10/2013	18:30	8:30	7	89.5	19:38	5:35	96	3.90	0.00	9:56	9.66	28%	26%	13:59	6.87	1:08	2:33
08/10/2013	18:30	9:00	7	93	20:40	6:24	96	2.97	0.55	9:43	9.88	24%	26%	14:29	6.63	2:10	2:33
09/10/2013	18:30	8:30	7	89.5	19:52	6:05	114	3.77	0.67	10:12	11.18	32%	26%	13:59	8.15	1:22	2:33
10/10/2013	19:30	8:00	7	81.5	21:59	5:32	72	3.05	0.93	7:32	9.56	32%	26%	12:29	5.77	2:29	2:33
11/10/2013	18:30	4:00	7	58	19:58	22:39	30	0.90	0.00	2:41	11.18	9%	26%	9:29	3.16	1:28	2:33
14/10/2013	19:00	8:00	6	73.5	21:27	5:27	73	2.83	0.78	7:59	9.14	28%	26%	12:59	5.62	2:27	2:33
15/10/2013	18:30	8:30	7	89.5	19:51	5:55	96	2.98	1.70	10:03	9.55	33%	26%	13:59	6.87	1:21	2:33
16/10/2013	18:30	5:30	7	68.5	20:04	0:42	42	2.03	0.00	4:37	9.10	19%	26%	10:59	3.82	1:34	2:33
17/10/2013	19:00	8:30	7	88.5	20:01	6:04	114	1.03	2.23	10:02	11.36	24%	26%	13:29	8.45	1:01	2:33
18/10/2013	18:30	8:30	7	89.5	19:56	5:52	103.5	1.95	1.53	9:55	10.44	25%	26%	13:59	7.40	1:26	2:33
19/10/2013	18:30	8:30	7	89.5	20:33	5:30	72	3.93	0.45	8:56	8.06	31%	26%	13:59	5.15	2:03	2:33
20/10/2013	18:30	9:00	7	93	20:48	6:07	96	3.48	0.00	9:18	10.32	24%	26%	14:29	6.63	2:18	2:33
21/10/2013	14:00	8:30	15	206.5	19:43	6:02	102	3.05	1.30	10:18	9.90	24%	26%	18:29	5.52	5:43	2:33
22/10/2013	18:30	8:30	15	186.5	19:49	5:50	46	5.00	2.38	10:00	4.60	53%	26%	13:59	3.29	1:19	2:33
23/10/2013	18:30	9:00	15	194	20:50	6:16	90	4.43	0.00	9:25	9.56	31%	26%	14:29	6.21	2:20	2:33
24/10/2013	18:30	9:00	15	198	20:01	6:00	39	2.82	5.60	9:58	3.91	58%	26%	14:29	2.69	1:31	2:33
25/10/2013	18:30	8:00	14	171	19:43	5:50	84	2.90	0.87	10:06	8.32	28%	26%	13:29	6.23	1:13	2:33
26/10/2013	14:00	22:00	2	16	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	8:00	#N/A	1:13	2:33
28/10/2013	18:30	9:00	15	190	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		26%	14:29	#N/A	1:13	2:33
29/10/2013	19:00	8:30	15	179	22:00	4:33	54	1.67	2.20	6:32	8.27	29%	26%	13:29	4.00	3:00	2:33
30/10/2013	17:30	10:00	14	192.5	20:42	7:17	78	4.58	0.72	10:34	7.38	32%	26%	16:29	4.73	3:12	2:33





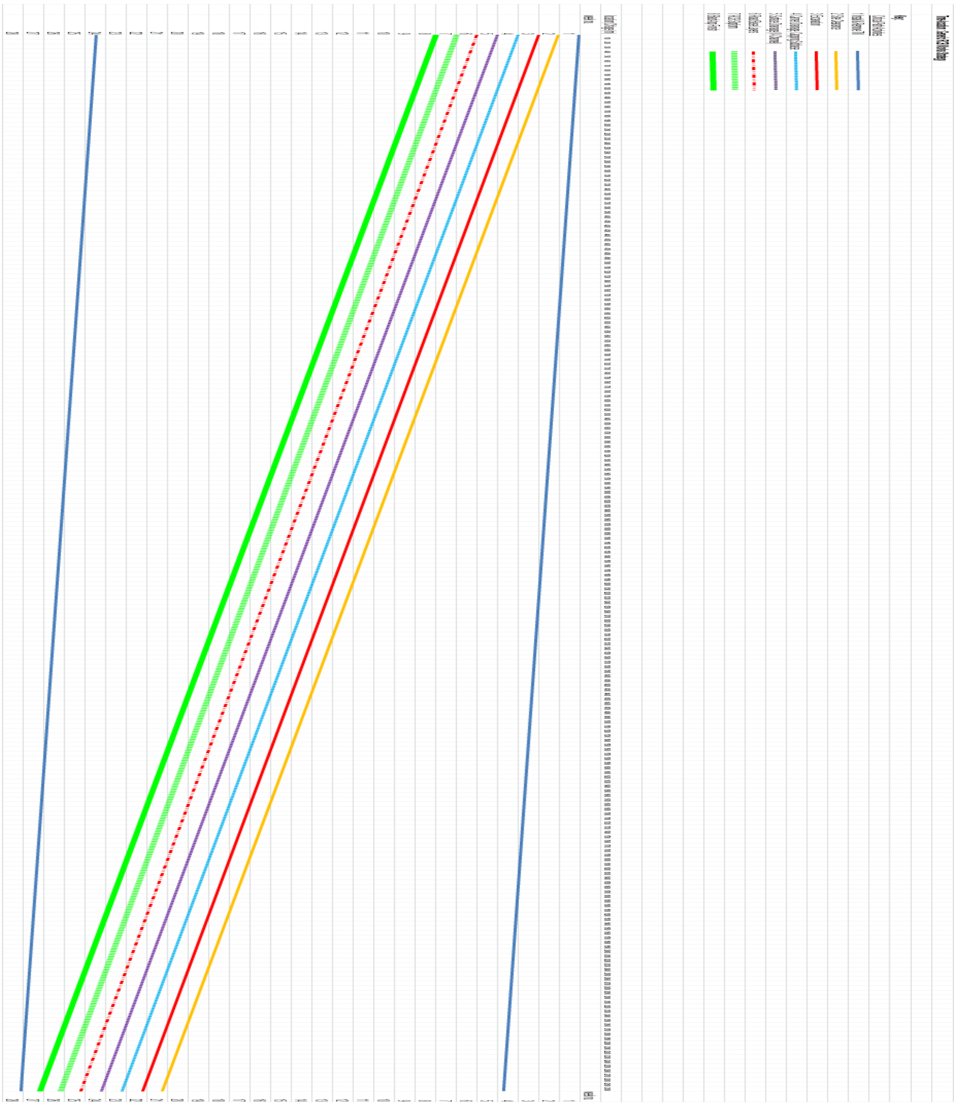






Appendix G – Time location example showing the benefits of the production train approach

Traditional Methodology – Note a detailed excel version is available on request



Production Train Methodology – Note a detailed excel version is available on request