Investigating the Impacts Caused by Construction Delivery Inefficiencies

Transport for London

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Executive Summary

Introduction

The primary objective of this project is to quantify the resultant cost caused when vehicles fail to make a delivery on arrival at construction sites. This could be due to inadequate planning, Delivery Management Systems (DMS) and/or Vehicle Holding Areas (VHAs). The key aims of the project are to:

- Determine the environmental, safety and infrastructural impacts of not being able to access sites;
- Provide a cost estimate for the extent these impacts have across London;
- Compare and contrast the efficiencies of sites with and without VHAs; and
- Compare and contrast the efficiencies of sites for each phase of construction

In addition, this study considers issues caused by inefficient deliveries at construction sites and the potential actions that can be taken forward to improve the performance of deliveries.

Methodology

As part of this study, a manual data collection exercise was carried out at 7 sites within Greater London; this was supported by electronic data which was received from 12 additional construction sites.

Data for a total of 19 construction sites was collected across a range of locations, sizes and construction stages.

An impact analysis of each site's vehicle management was undertaken; this determined the economic and environmental effects of vehicle delays and diversions at individual locations as well as allowing comparisons between the sites.

In total, the data covered 40,000 vehicle trips across the 19 sites with time periods varying from a few days to over 12 months, depending on data availability.

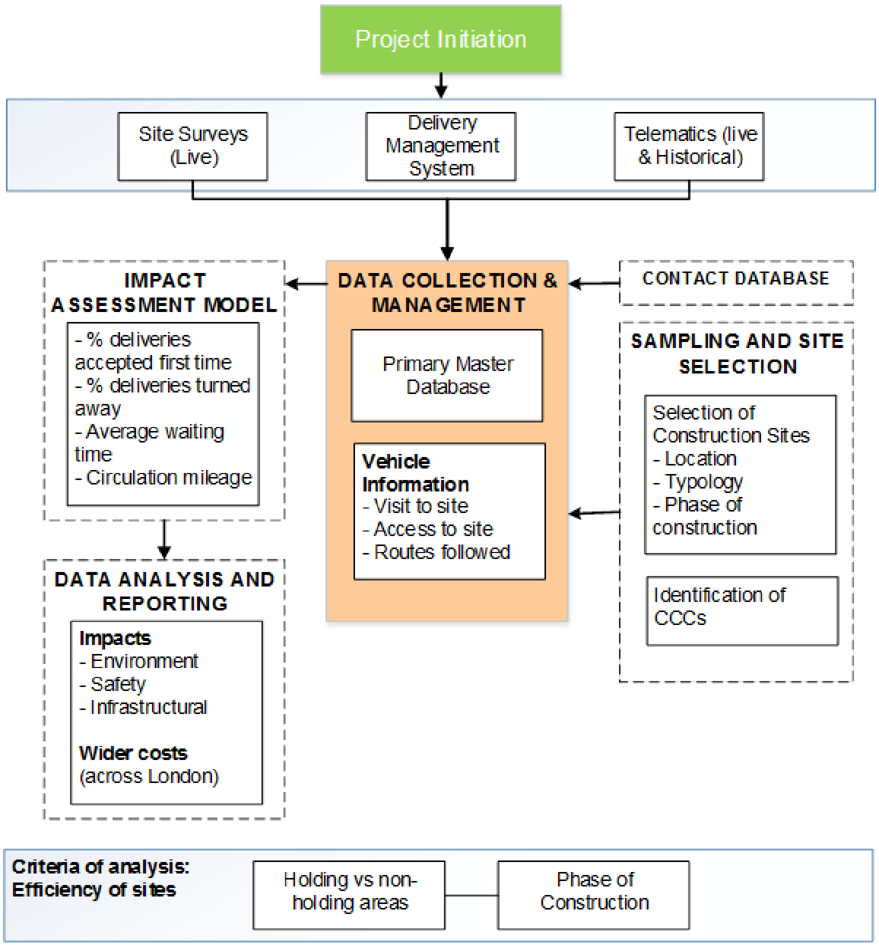


Figure E1: Project Methodology

The overall project methodology from project initiation to data analysis and reporting is presented in **Chapter 2, Figure 2.1.**

Data was collected through a range of DMS as well as 'on-the-ground' manual data collection and survey work.

To gather industry views regarding construction deliveries, consultation was conducted with a number of stakeholders regarding construction deliveries. Consultation comprised using a number of methods such as an online survey, face-to-face interviews and telephone interviews. The results from the consultation are presented in **Chapter 5.**

Key Findings

The key findings are derived from a combination of the outcomes of the primary data collection, stakeholder consultation and the analysis and impact modelling. Some of the findings are site specific whereas others are based on trends identified in the data or witnessed at multiple sites.

Site Management

In some cases, significant variance was witnessed between scheduled vehicle arrival time and actual arrival time at site. This did not lead to the vehicle being turned away (if late) or having to wait (if early). Some sites also used their DMS as a log of vehicles due that day, rather than paying particular attention to the exact time specified. Instead it was more fluid and dynamic, with close interaction between the vehicle holding area and the site entrance controlling entry in a way that reflected requirements.

Vehicles with no booking were witnessed either being turned away (failed delivery) or having to call the site to make an emergency booking and then waiting to gain entry. The stipulation to turn vehicles away varied from site to site and was dependent upon the site's ability to accommodate the vehicle (at some point) and hold the vehicle safely off site until such time that access could be granted.

Delivery Management System

In some cases the DMS appears to be used to schedule a significant proportion of, but not all vehicle trips. It also appears there is some speculative booking of slots to cover all eventualities. This raises possible questions around the level of supply chain forward planning occurring and if more could be done.

There appears to be significant variation between different DMS, their capabilities and use by stakeholders, ranging from basic vehicle scheduling with little monitoring and enforcement, to full vehicle movement planning with a series of metrics/KPIs and remedial actions for non-compliance. Variations across a wide spectrum of elements including:

- Terminology e.g. Delivery Management System (DMS), Vehicle Booking System (VBS),
- Scope and functionality
- Data requirements and capture
- Use at the site/gate and subsequent feedback in to the DMS
- Setting metrics/KPIs
- Monitoring
- Reporting
- Remedial actions

VHAs / Vehicle Flow Management

Different types of VHAs were identified:

- Within the construction site itself
- Adjacent or nearby to the construction site both on and off street locations
- Remote from the construction site on or near the main delivery route (including unofficial VHAs such as service stations)
- Consolidation centres – could also be considered as a form of holding area, although it is not their principal function

Stakeholders who participated in this study highlighted the importance of a vehicle holding area for managing vehicles at sites. Stakeholders also pointed out that without a holding area the construction site(s) might find it difficult to operate effectively with vehicle arrivals and departures. They also help to mitigate against a number of negative impacts such as: traffic congestion, roadworks, on-site incidents i.e. equipment breakdown, vehicle collision, weather and driver illness.

Operator Engagement

'Bunching' of deliveries occurred (i.e. 0700hrs or 1000hrs), throughout the day as drivers often would start shifts at similar times leading to peaks in the number of delivery vehicles accessing each site. Varying levels of awareness existed amongst Local Planning Authorities (LPA), developers, planning specialists, contractors and logistics operators regarding booking deliveries via a DMS and then subsequently adhering to what they had booked or understanding what the compliance requirements were - *i.e. being turned away if they are not on time or booked in etc. Some drivers also commented on the difficulty of using online DMS entry forms.*

KPIs/ Benchmarking

On-site data collection showed that a lot of stakeholders were using DMS, but not really undertaking much in the way of setting metrics/KPIs, monitoring, reporting, remedial actions etc.

Analysis and Impact modelling

The analysis highlighted the ability to mitigate the environmental impacts of site delays through the use of newer vehicles, which have reduced emissions. Analyses of vehicle types indicate that there is a reliance on rigid vehicles for the majority of deliveries and collections including muck-away. This may be for a combination of vehicle availability or access reasons. However the business case for using articulated vehicles where possible has the potential to reduce the number of deliveries and in turn reduce congestion, emissions and road damage per tonne of payload.

There are some factors that can be quantified and some that rely on too many assumptions to make valid conclusions. The variables are as follows;

- Planning – There is a definite need to do more training and planning perhaps by using CLPs. A significant proportion of delivery failures across a number of sites were related to either driver training or vehicle equipment issues. Across the 9 observed sites, unsuccessful deliveries represented 5.7% of vehicle arrivals, which were running at approximately 17/day or 4,080 based on a standard working year.
- Environmental impact – The observed delivery inefficiencies are having a direct effect on the environment. The analysis calculates that an additional 68.88 tonnes of CO_2 is incurred based on 287kgs/day. Similarly NOx and particulate matters are needlessly incurred. Figures are given under each site analysis for these.
- Safety impact – No safety incidents were recorded during the trial. However the DfT have a calculator to show the cost of accidents on a per mile basis. So assuming unnecessary miles are incurred due to inefficiencies and vehicles being turned away then there is an additional cost of this.
- Infrastructural impact – Direct costs of extra road wear has been calculated for this study, road structure impacts were estimated to be a total of £822 per annum
- Cost with/out VHA or with/out DMS – It has proved difficult to estimate costs with or without holding areas or DMS. The reason for this is that each site is unique in nature with its own rules and circumstances. Some of the sites incurring the biggest costs had holding areas and systems in place. Had they not had some form of system in place the cost could have been much higher.

Recommendations

The following actions could form a programme of work for consideration. It is possible that some actions are already being developed. It is recommended that the areas requiring further research are conducted first and then this combined learning can feed into the development of a Best Practice guidance document. Following the publication of this, there will be a requirement for training across the construction sector. This should not only include operators and drivers but be extended to pertinent staff in the construction companies and relevant officers in London Boroughs as well. This is illustrated in a flow chart in **Section 8.2.**

A summary of potential actions includes;

Research:

- **KB1:** Consider best practice for management to promote benchmarking and identify gaps between planned and actual performance and encourage performance measurement and applying the PDCA cycle (Plan, Do, Check, Action).
- **KB2**: Investigate the use of Just-in-Time (JIT) and 'pull' logistics. This study would to help to determine commercial logistics practice and also the effect on the environment of different decisions made
- **DMS1**: Investigate options to prevent speculative or contingency bookings on DMS, such as allowing emergency bookings / compliance toolkit.
- **DMS2:** Investigate options to couple vehicle tracking data to DMS data. In other parts of the logistics sector such as retail, vehicle tracking data is used to monitor estimated time of arrival(s) and hence can be matched to resources on site to maximise efficiency.

Best Practice Guidance:

- **ST1:** Planned Measures to include consolidation, use of VHAs and/or DMS.
- **ST2:** Investigate the profiles of vehicles needed throughout the whole project in order to optimise their numbers. This can include opting for vehicles with an increased maximum gross weight.
- **ST3**: Ensure that VHAs are suitably managed and encourage structured programs based on training, consulting and feedback provided to suppliers to improve performance.
- **V1:** Explore opportunities to convert land to VHAs such as encouraging the use of car park areas as temporary holding bay/area.
- **V2:** VHAs seem to be a uniform positive factor in enabling smooth and efficient arrival/departure of vehicles as a result of congestion/delay/regulation whilst also enabling better management of access to site (ensuring compliance, etc.)
- **OE1**: Investigate 'reduce', retime', and 'remode' options for smoothing deliveries throughout the day and pilot retiming on a selection of sites.
- **OE2:** Improve awareness about DMS among the construction supply chain stakeholders.

Training:

- **OE3**: Provide training as required - e.g. for drivers/operators in the use of the DMS forms and consider testing of end users' perceptions and professionalise the industry through a professional qualification. Train relevant staff in construction companies and in London Boroughs.

1. Introduction

1.1 Background

London is a growing city, experiencing an increase in freight traffic which is required to serve its growing economy. The Greater London Authority (GLA) estimates that the city's population will exceed 10 million by 2031. To accommodate this increase, London will need to expand its housing developments and provide employment opportunities through both new developments and regeneration.

Construction activity in London is essential in enabling the provision of buildings and infrastructure (such as Crossrail and the new Tideway 'Super Sewer'). However, the construction industry faces a number of challenges in its attempt to increase operational efficiency, while reducing the risks and environmental impact of deliveries. Given the current road-based nature of many construction logistics operations, there is a need to ensure that these deliveries are carried out in an efficient, safe and environmentally friendly manner. Deliveries should ensure that they build on the Olympic legacy of Transport for London's (TfL) delivery management principles of 'reduce,' 'retime,' and 'remode'. Yet, the importance of rail and water deliveries should not be disregarded.

This is closely linked with Transport for London's (TfL) 'Healthy Streets' programme, which seeks to boost walking, cycling and public transport use in London, as well as creating better places along streets, such as smooth wide pavements, resting places and shades. By minimising and mitigating the impact of construction traffic activities, the sector can help reduce congestion and improve safety, whilst realising benefits from developing more effective and efficient supply chains.

There are opportunities to improve the effectiveness and efficiency of deliveries for construction sites through developing new and existing practices and using supportive technologies. For example, issues arising from failed deliveries to construction sites due to poor planning could be improved by using DMS and / or VHAs.

This project has been set up to investigate and quantify the external costs resulting from the poor management of construction site deliveries and collections, and to highlight the issues and potential improvements. For example, identifying the cost of introducing construction VHAs (London-wide) in transport chains could bring about a step-change in how such plots of land are safeguarded for such use, either temporarily or even permanently in areas where this would be appropriate.

The construction of buildings and infrastructure is the 'final act' in a complex procedure involving substantial design and planning. This is also the period which most impact occurs and can range from weeks to years - incorporate the same principles with respect to the delivery of materials and removal of waste.

It is important to be fully aware of the procurement process that engages the services and materials movements, to understand why construction at a worksite is efficiently organised or not.

1.1.1 Procurement Process of Services and Materials

The procurement process for obtaining services and materials begins once the planning permission for a 'development' has been received and prior to the works programme starting. The type of procurement method adopted depends on the size of the primary contractor and whether there is a reliance on subcontractors. This structure will influence the organisational process and responsibility for managing the supply chain.

Other aspects that affect how efficiently the supply chain functions and how the movement of vehicles are managed are as follows:

- Commitment to sustainable works;
- The extent of information technology used;
- Attitudes to managing deliveries/collections;
- Location of site;

- Ability to incorporate vehicle holding areas or materials consolidation systems;
- Contingency management;
- Construction method and;
- The type of project.

These aspects work together in a complex manner which typically involves a combination of arrangements.

The buying of services and materials can be structured in a number of ways, primarily through:

Frameworks suppliers

These suppliers are contracted to supply a wide range of materials, services or plants. The construction contractor would place large orders with the company which would be drawn down as the project progresses. Deliveries and collections could be made by own account vehicles or third party logistics operators.

Individual suppliers

These companies will provide specific materials, services or plant and orders could be for a single project with or without a draw-down arrangement put in place, or made on an ad-hoc basis.

Where a drawdown facility is available, a third-party supplier should be used to direct deliveries - for example, landscape paving could be delivered in manageable quantities at the site using a contracted general builders' merchant.

Depending on the type of supplier/ delivery / collection type, the transport could be made using own account vehicles or by a third-party logistics operators.

Subcontractors

Subcontractors could be contracted on a 'supply and build' basis or provide a trade or service. Where supply is required, the subcontractor would be responsible for ordering their own materials and organising the transport using either their own account vehicles or a third-party logistics operator. Subcontractors may use specific framework suppliers for materials and equipment, in which case the delivery/collection transport would be organised between these parties.

For materials or equipment provided by the primary contractor, delivery and collection is often arranged by them in coordination with the subcontractor. It is therefore possible to use programmes such as the Construction Logistics and Community Safety (CLOCS) Scheme and the Fleet Operator Recognition Scheme (FORS) to drive up standards. This can be achieved throughout the procurement chain by ensuring these (or similar) programmes are mandated in the procurement process, encouraging and ensuring best practice around issues such as safety, air quality and route planning.

1.1.2 Organising vehicle visits to worksites

When arranging a delivery and collection the site manager / subcontractor will contact a supplier to place the order / request a drawdown and set a date for transport to visit the site. It is good practice to have delivery and collection protocols in place as part of the procurement process – this will improve the efficiency of vehicle visits. These protocols would typically set out the process to follow and what vehicle safety equipment is required. Additional requirements may specify the routes taken to the site, site access times, membership of operator recognition schemes, driver training and site inductions.

The larger the project, the greater the opportunity to include 'gold' standard requirements - major infrastructure projects typically aim to improve construction logistics standards. Other types of development might not include these high standards due to the cost implications that have to been borne by the project.

Once the order and transport has been arranged, the delivery / collection will be confirmed by the logistics operator and project transport manager, a day or two before it takes place. This ensures that aspects such as handling and storage requirements and access slot times are clarified.

Assuming there is no discrepancy in the arrangements, the vehicle visit should take place as planned. Even where all the procedures are followed there are external factors that can alter the planned vehicle visit arrangements. These include technical problems on site, traffic congestion *en route*, or a vehicle failing its requirements inspection at the site gate.

1.2 Scale of the issue

Analysis of the FORS database revealed that around 10,000 vehicles registered in London are associated with the construction sector and over 1,000 vehicles are in the waste sector. These sectors account for around 25% of all lorries registered within the South East and Metropolitan Traffic Commission areas.[1] Assuming these 11,000 vehicles cost £350 per day and work for 240 days a year this equates to an approximate industry cost of £924m. When vehicles that service the sector from outside London are also taken into account, it is expected that this cost increases to an excess of £1bn per year.

The level of inefficiency in managing the transport operations is not clear, but if it is assumed that 3% of vehicle visits to site fail first time, and the recommendations in this report were to reduce these failures from 3% to 2% (a 33% overall reduction). This would save the London construction sector £9.54m a year. Such potential is considered in the analysis and impact modelling chapter of this report.

1.3 Aims of the project

The key aims of this project are:

- To determine the environmental, safety and infrastructural impacts of vehicles that do not gain site access
- To provide a cost estimate on the extent of these impacts on a whole of London basis;
- To compare and contrast the efficiencies of sites with and without VHAs; and
- To compare and contrast the efficiencies of sites across different phases of construction.

The methodology and approach used in this project for these aims is presented in **Chapter 2.**

1.4 Urban Areas

Construction projects involve numerous activities that require a wide range of materials the handled and transported. The logistics operations are carried out to ensure that construction waste and materials are removed from and brought to site(s) at the correct time; quantity and quality is challenging and requires good management practises. Therefore, the critical goal for construction projects is maintaining the timely flow of construction materials along the supply chains present in the construction process.

Construction projects located in larger urban areas, such as London, must organise their overall supply chains as well as effectively managing the delivery of materials at a local level. The lack of on-site space for storing construction materials has led the industry to increase its use of Just-in-Time (JIT) deliveries. JIT deliveries can have associated risks, so to be effective the transport operation must be well considered and properly managed. JIT can lead to higher levels of delivery transport activity, this is partly due to keeping the cost of working capital in the supply chain in check and partly due to lack of space on site. The use of a nearby consolidation centre can help to maximise the productivity of the trunk haul and minimise the risk of a "stock-out" situation by having additional stock in the local vicinity if needed, balancing the need to reduce stock and minimise transport requirements

One of the main challenges during a construction project is construction logistics, including the reception, storage disposal and use of a range of construction materials. Construction projects also involve a number of Local Planning Authorities (LPAs), developers, planning specialists, contractors

[1] Traffic Commission (2016) Annual Report, pp 49

and logistics operators which present complex management challenges, as delays can build up and have significant effects on the overall project programme.

To avoid a reliance on JIT deliveries from a supplier and hence mitigate against the risk of delays which will have an impact on a construction site. On-site storage locations should be considered and sufficient time allowed for deliveries. However, in densely populated urban areas, this approach is not necessarily feasible due to a lack of suitable storage locations available on-site.

The construction industry has developed its own version of JIT, yet problems still exist due to the inevitable uncertainty within the construction industry compared with the manufacturing sector.

The following factors could impact the delivery of a project:

- Design changes;
- Weather conditions;
- Site conditions;
- Road congestion or disruption
- Concerns over theft of raw material and planning conditions;
- Economic conditions,

Any of the above issues could negatively impact the effectiveness and efficiency of the delivery of construction materials. Planned measures to mitigate these issues are discussed more fully in the Literature Review (**Chapter 3)**; although, some appropriate responses to these risks have been summarised below as follows:

- Know the network or suppliers, and select those located close to the construction sites to avoid late deliveries.
- Maintaining a safety stock level of certain raw materials is an important balancing process and important to avoid retiming of the project due to an inability to secure extra deliveries promptly. Insufficient stock levels can cause expensive on-site staff or equipment to be idle and therefore unproductive and this could lead to project delays in certain scenarios. Promote the standardisation of tasks
- Opt for reactive scheduling strategy during the construction project, to have a higher degree of flexibility for retiming deliveries.
- The use of a consolidation centre for deliveries located at a location near the construction site(s).

For large construction projects, especially in large urban areas where land space is scarce, a clear and successful supply chain strategy is likely to need more planning in comparison to smaller construction sites and sites in non-urban areas. New system-based tools may provide the information needed to understand the construction supply chain and adopt the best decision. A number of these are assessed in **Chapter 4.**

1.5 Benefits of Achieving More Efficient Construction Deliveries

There are a number of potential benefits for stakeholders, to achieve higher levels of efficiency in construction logistics, through best practices, use of DMS and performance measurement systems. These benefits include:

- Higher community acceptance of construction projects: Coordination between construction developers and LPAs could result in more efficient construction logistics and better understanding of unnoticed issues inflicted on the community. This open approach could result in higher acceptance amongst local groups, especially in residential areas where successive construction projects feel permanent rather than temporary to them.

- Planning-related use of DMS data: Achieving more efficient construction deliveries means that reliable DMS historic data is available and could be shared. This provides valuable information can be used for various planning works within the boroughs, and would have beneficial outcomes addressing current and future construction logistics issues. It also provides inputs for the design and development of new infrastructure, such as parking areas, pavement design, current road conditions, etc.

- Reduced congestion and accurate road traffic estimation: Freight operators' commitment in following delivery schedules and sharing delivery plans and routes used to construction sites will help local authorities to estimate traffic by time band and measure sources of construction traffic. In addition to atmospheric emissions, construction delivery vehicles also contribute to noise and vibration nuisance. Therefore any reduction in construction traffic would potentially contribute to providing benefits in these areas.
- Protect vulnerable road users: Reliable DMS data could be made available to LPA to identify roads and junctions prone to accidents as well as areas frequently used by vulnerable road users. This information will allow local authorities to define and modify existing strategic access routes for construction traffic (e.g. during certain hours of the day in residential or sensitive areas near schools). Also, fewer vehicle journeys and lower levels of vehicle circulation could result in reducing the number of accidents.

Higher potential benefits could be observed at economic, social and environmental levels such as increased safety, improved air quality, reduction of CO_2 emissions and improved health and wellbeing.

The practical realisation of these benefits, have been assessed through both stakeholder consultation and modelling in **Chapter 6.** Key findings from the study are illustrated in **Chapter 7,** recommendations for realising these benefits are explained in **Chapter 8,** along with a series of actions for achieving this aim.

1.6 Report Structure

This report has been structured as follows:

Chapter 1 – Introduction

Chapter 2 – Approach and methodology

Chapter 3 – Literature review

Chapter 4 – Construction site data suppliers

Chapter 5 – Consultation

Chapter 6 – Analysis and impact modelling

Chapter 7 – Findings

Chapter 8 – Recommendations

2. Approach and Methodology

2.1 Methodology Overview

The overall project methodology from initiation to data analysis and reporting is presented in **Figure 2.1**. As part of the initiation process, it was important to engage with transport operators, site managers and technology providers in order to design the data collection and analysis elements.

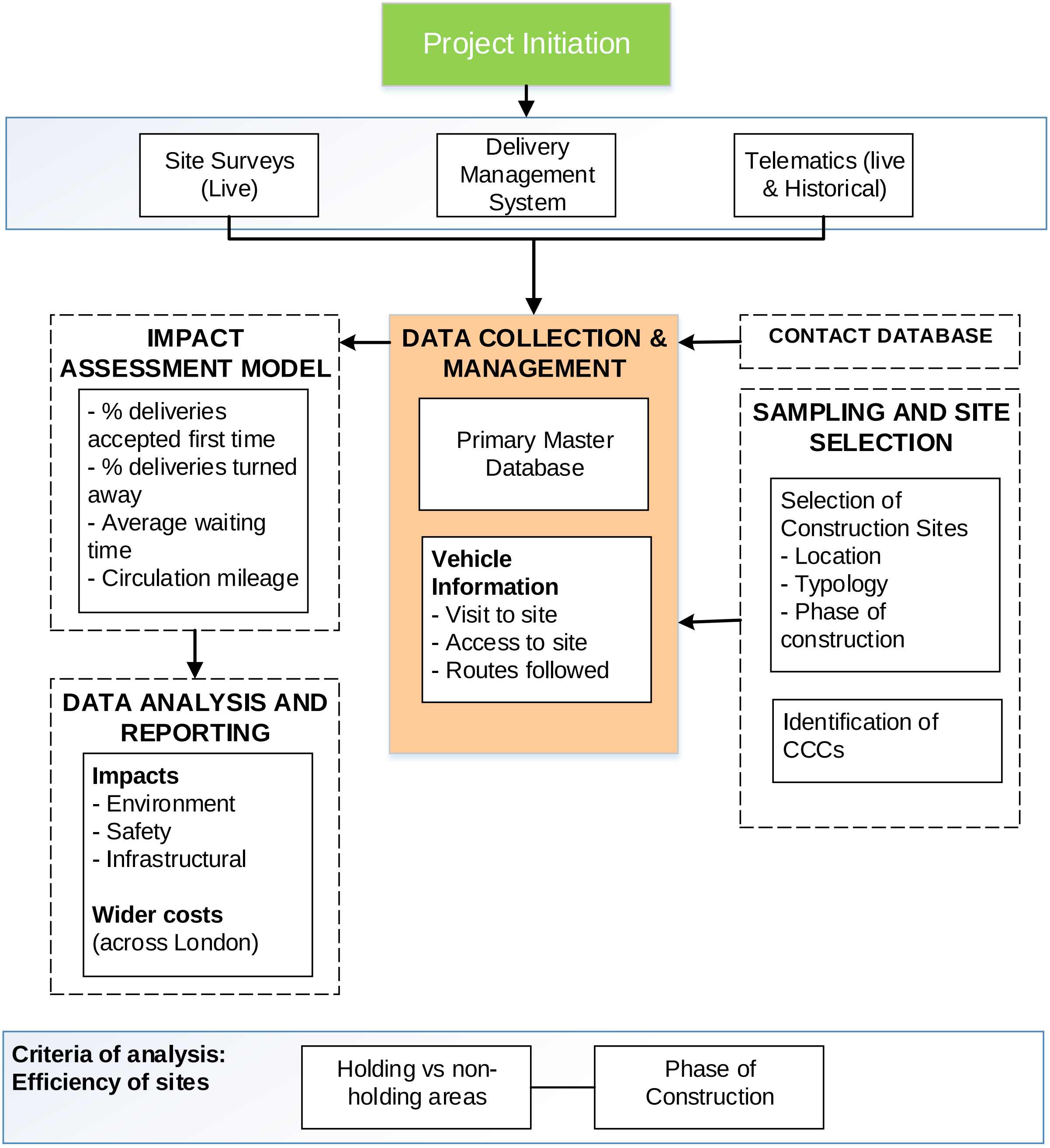


Figure 2.1: Methodology Flow Chart

2.1.1 Vehicle and Industry Types

In order to understand how sites handle a variety of consignments, it is important to appreciate the types of vehicle arriving and likely activities associated with each. The following is a list of vehicle types (see **Figure 2.2** for a selection of images) observed during this study:

- **Tippers** – typically used for single consignments moving muck away or aggregate in. Loading requires site bucket type mechanical handling equipment. Depending on size of bucket (1 to 2 tonnes) vehicles can be loaded in 10 to 20 minutes. Inbound loads can be tipped quicker.
- **Tippers with crane/grab** as above, but with hoist mounted on the chassis, are self-contained and drivers can load / unload without having on-site machines assisting.
- **Flatbeds** - typically used for movement of construction materials, steel girders, panels or concrete sections. These vehicles need on-site handling equipment, typically tower cranes. Depending on size and type of load these can take up to an hour to unload / load.
- **Flatbeds with crane/grab -** typical builder's merchant vehicle, these are self-contained and depending on site rules may allow lorry drivers to unload / load vehicle. It may take 20 to 30 minutes to unload / load vehicle.
- **Curtainsiders** – similar in application to flatbeds, plus pallet deliveries of any type of materials. These vehicles may be unload / load by fork truck or equivalent and typically take around 2 minutes to handle a pallet off/on the vehicle.
- **Curtainsiders with 'mounted forklift trucks'** as above, but offer the option of self-unloading. There are a number of well-known construction supply companies using lorry mounted forklifts which allow the truck drivers to operate independently of any on-site operatives.
- **Cement mixers or cement pumps for site mix** – 'concrete pours' are typically time sensitive activities that can be staff and weather dependent. Typically, concrete mixer trucks with rotating cylindrical barrels need prompt attention for unloading. A proportion of the premix market has transferred to dry mix silos where product is produced on-site and pumped to the required location by a cement pump vehicle. These pumps may remain on site for longer periods depending on the volume needed.
- **Skip Vehicles** – these vehicles vary in size depending on the volume of the skips they move. The vehicles are loaded and unloaded by the lorry driver and dwell times typically vary from 5 to 10 minutes.
- **Sweepers –** these trucks offer a service and hence may be used at various points of the day depending on need. They may clean a site at the end of the day.
- **Refuse Collection Vehicles** – these vehicles typically may be on site for around 5 minutes emptying on-site receptacles.

A number of examples of the vehicles mentioned are shown in **Figure 2.2** below.

Vehicle Type	Image of vehicle
Curtainsider with 'mounted forklift trucks'	
Concrete Mixer	
Rigid Tipper	
Articulated Flatbed	

Figure 2.2: Vehicle types examples

2.1.2 Euro standard profile

Lorry movements account for a significant portion of NOx emissions within the UK and it is imperative that when cleaner, greener and more sustainable technology is available it is implemented by relevant stakeholders in order to reduce the environmental impact of road freight and lorry movements. Lorries numbered 483,400[2] vehicles in 2015 and can make up a quarter of all traffic on the strategic road network, equating to 152 billion tonne-kilometres of goods moved (in 2015)[3]. In 2015 the amount of goods lifted totalled 1,647 million tonnes[4] and the vehicle kilometres travelled equaled 18.3 billion[5].

While emissions regulations date back to 1970, the first EU-wide standard – known as Euro I – was introduced in 1992. Since then, a series of Euro emissions standards have passed leading to the current Euro VI, introduced in September 2014. The regulations – which are designed to become more stringent over time – define acceptable limits for exhaust emissions of new light duty vehicles sold in EU and EEA (European Economic Area) member states.

Using the DfT lorry registration statistics[6] and the Euro standards introduction date[7] we can estimate the number of lorries operating at each Euro standard for 2016 as shown in the table below.

Table 2. 1. Lorry Euro Standard proportions

Engine	Introduction date	No. of lorries (000's)	% of all UK registered lorries
Euro I	1992	8.0	1.6%
Euro II	1996	18.3	3.7%
Euro III	2000	55.8	11.3%
Euro IIII	2005	70.6	14.3%
Euro V	2008	188.7	38.2%
Euro VI	2014	131.1	26.6%

The table clearly shows that well over half of UK registered vehicles now meet the higher standards of Euro V and VI, meaning such lorries are emitting lower levels of harmful exhaust emissions. However, as well as direct exhaust emissions, it is important to note the contribution of non-exhaust traffic related emissions. These include sources such as any vehicle brakes, tyres, and clutches, and road surface wear; they accumulate in the environment as deposited material and become re-suspended due to traffic induced turbulence. Their relative contributions to non-exhaust traffic related emissions range between 16-55% (brake wear), 5-30% (tyre wear) and 28-59% (road dust resuspension). It is estimated that exhaust and non-exhaust sources contribute almost equally to total traffic-related PM_{10} emissions. However, as exhaust emissions control become stricter, relative contributions of non-exhaust sources to traffic related emissions will increasingly become more significant[8].

2.2 Data collection methods

Data collection was conducted using the following methods:

- Operator interviews
- Manual data collection
- Remote data collection

[2] Domestic Road Freight Statistical release, DfT, 2016
[3] DfT Domestic road freight activity statistics, table RFS0104, DfT, 2015
[4] DfT Domestic road freight activity statistics, table RFS01, DfT, 2015
[5] DfT Domestic road freight activity statistics, table RFS0109, DfT, 2015
[6] DfT licensing statistics, table VEH511
[7] Euro 1 to Euro 6 – find out your vehicles emission standard, RAC, 2017
[8] Martini, G. & Grigoratos, T., 2014. Non-exhaust traffic related emissions. Brake and tyre wear PM, Luxembourg: European Commission.

2.2.1 Operator interviews

Stage 1 – Initial Survey

A group of 100 participants selected logistics operators making deliveries in and around London were invited to participate in an online survey throughout January 2017. The online survey asked logistics operators to respond on a scale of 1 (poor) to 5 (excellent) on the following topics:

- Accessibility to construction sites when making deliveries;
- Ease of internal manoeuvres on construction sites;
- Delivery turn-around time;
- The organisation and ease of receiving a timed booking slot prior to delivery;
- The average provision of VHAs at construction sites;
- The average length of waiting time to access site; and
- Delivery success rates.

Additionally, logistics operators were asked whether they ever get turned away from construction sites for any reason and, if they do, to further explain the reasons for being turned away. Logistics operators were also asked if they were willing to participate in a follow-up survey.

Ten logistics operators responded to the survey (results are presented in **Section 5.2**) with a further six indicating they were willing to participate in a follow-up survey.

Stage 2 – Follow-up Survey

The responses from the initial survey were collated and a set of four additional topics were identified for further investigation. In place of an online survey, a telephone interview approach was used to generate responses to the following four questions:

1. Based on your experience what are the main reasons behind construction delivery inefficiencies?
2. How do you usually arrange your deliveries (i.e. by DMS)?
3. Are there any sites in London that are noticeably less efficient at receiving deliveries?
4. Waiting times to access sites while on a delivery are perceived to be relatively high by some logistics operators. Do you believe there is a reason for this?

A number of the logistics operators who participated in the initial survey were unable to participate in the follow-up survey. The survey invitation was then opened to a randomly selected group of operators calling into the FORS helpline throughout March 2017. These were collated and keyword analysis was conducted to identify underlying patterns and themes. The results are contained in **Chapter 5.**

2.2.2 Manual data collection

A number of construction sites were contacted to participate in on-site manual data collection. Construction site managers were provided with a study invitation and relevant data collection briefing materials prior to any data collection agreements being made. In total, over 40 sites and companies were invited to participate for this study.

Manual data collection was carried out at seven primary sites and two secondary sites[9]. The data collection comprised of the site(s) delivery activity observations and short 'driver surveys'. The driver surveys were conducted when vehicle activity at the site(s) was minimal. Only drivers who were willing to participate were approached. The driver surveys captured the following information:

- Vehicle registration number
- Vehicle type
- Body type
- Industry type
- Arrival time to gate/bay (when applicable)

[9] Primary sites are sites where data collection occurred over 5-day period and secondary sites are sites where data collection occurred over a 1-day period, based on stakeholder advice and applies to two sites only.

- Departure time from gate/bay (when applicable)
- Arrival time at site
- Departure time from site
- FORS accreditation status

Additional information regarding the vehicle holding area was collected where relevant. The data was collected through observations by the data collection team stationed at construction delivery gates and recorded into site specific data observation tables.

- Use of SATNAV technology in routing to site;
- Use of consolidation centres in general delivery trends;
- Whether extra distance or time costs were incurred in this delivery; and
- Frequency of failed deliveries over the last month.

Data collection occurred over a five day period at all primary sites and over a one day period at the secondary sites. Data collection began at 0800hrs and finished typically at 1600hrs (depending on site activity, opening hours, and activity restrictions/allowances).

At all the primary sites it was confirmed by the construction/ site managers that on average no less than 90% of deliveries were captured across this minimum 8 hour observation period, meaning the results are representative.

2.2.3 Remote data collection

DMS Data

Additional construction sites and companies were invited to provide historical DMS data to supplement manual data collection from sites. These DMS records were comprised of a variety of data types and included (in some but not all cases):

- Number of deliveries per hour or day;
- Delivery vehicle type;
- Delivery origin and destination;
- Scheduled delivery time;
- Other various datasets related to emissions, timetabling, delivery success, etc.

In total 12 sites provided DMS data for the purposes of the study. This data, alongside that collected manually was used for impact analysis and modelling in subsequent stages of the study. The remote data had a range of variables for use in the analysis, but in general the manual data provided more information. The combination of manual and remote data collection meant that data was obtained for a total of 19 construction sites across of a range of locations and construction types.

Telematics Data

A number of randomly selected logistics operators were invited through telephone interview to share telematics data with AECOM for further analysis. In total, 18 operators were invited however only one operator agreed to share data for the purposes of the study.

3. Literature Review

3.1 Introduction

In this chapter of the report, we present key findings from a range of documents reviewed relating to the construction sector, logistics and materials management.

3.2 UK Construction Industry

The UK construction industry is a key sectors contributing to 17% of the UK's Gross Value Added (GVA). In 2014 the UK construction industry contributed £16.9billion GVA, according to the Office for National Statistics (ONS)[10].

Overall, contract value for the construction industry in February 2017 reached £6.4 billion based on a three month rolling average, according to Barbour ABI[11].

In February 2017, 18% of UK construction contracts (by value) were awarded in the South East. London had the second highest proportion of contract activity by value in February 2017 accounting for 15%. Infrastructure had the highest proportion of contracts accounting for 37% of the total value of projects awarded.

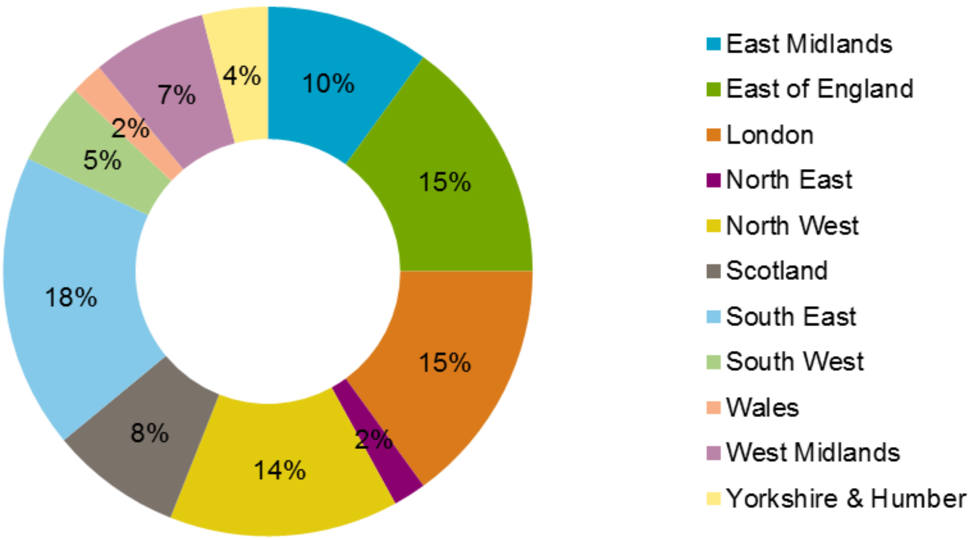


Figure 3.1: Location of Contracts awarded

According to the latest release of the Office of National Statistics (ONS) regarding construction output, during March 2017 the sector grew for the fifth consecutive period on a quarter by quarter basis. Construction output can be broken down by different types of work categorised into new work and repair and maintenance as shown in **Figure 3.2**.

In comparison with the same period in 2016, construction output grew by 2.4% in March 2017.

[10] https://www.ons.gov.uk/
[11] http://www.barbour-abi.com/wp-content/uploads/2017/03/EconomicConstructionMarketReviewMarch2017Free.pdf

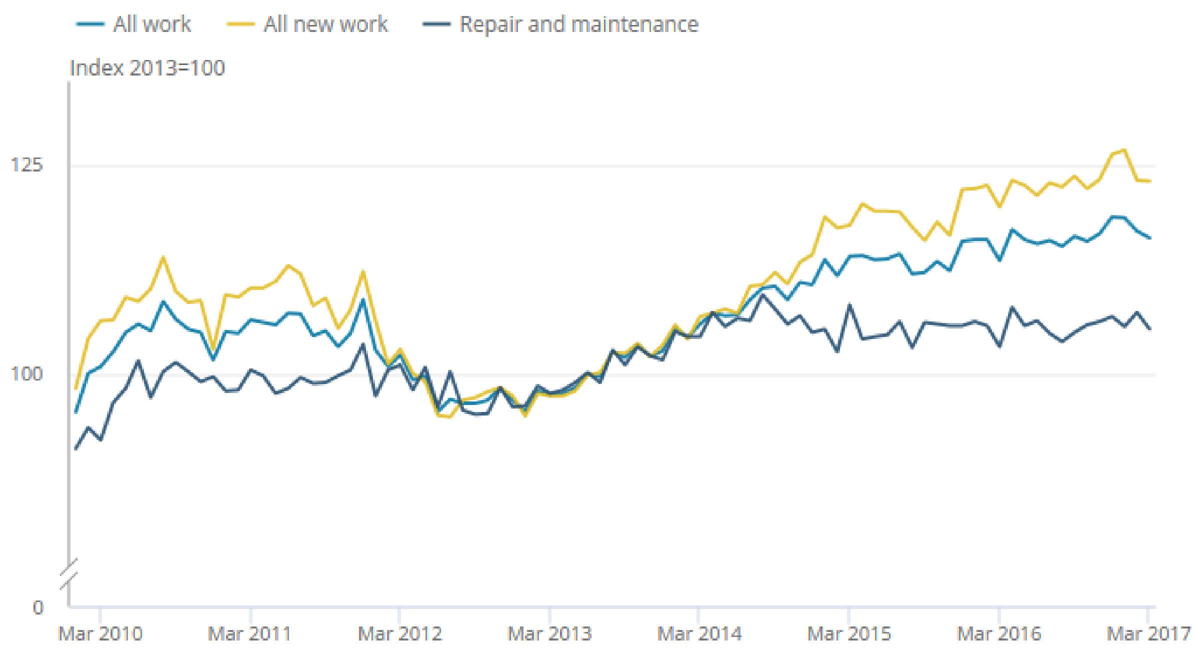


Figure 3.2 Components of all work – Chained volume measure, seasonally adjusted – ONS 2017

Figure 3.2 shows a slight decline in all new work in February 2017; this is explained by the decrease in new housing and infrastructure in the same period. Through to mid-2014, new work, and repair and maintenance followed a similar pattern but since reaching a level peak in August 2014, repair and maintenance has slowly contracted.

The London Office Crane Survey[12] for office development suggests that the combination of schemes currently under construction and those scheduled to start will deliver 38 million sq ft over the next five years. The amount of space under construction that is already let is high and raising, as firms are opting to secure space early.

The construction industry is very competitive and complex, and there is an increasing need to optimise the flow of materials throughout the construction supply chain to achieve high quality projects.

There has been extended research around the application of Supply Chain Management (SCM) techniques in construction and some main differences between the manufacturing industry and the construction industry have been identified by a number of studies[13]. Despite these studies, disparities, efforts are being taken to apply SCM good practice to the construction industry:

- The construction product or the built object is usually meant for a single client.
- The construction supply chain is converging and directs all materials to the construction site where the object is assembled; while in a traditional manufacturing supply chain, multiple products are manufactured and distributed to many customers.
- There is little repetition in the construction product.
- Temporary and repeated project organisation.
- A typical make-to-order supply chain with every project creating a new product or prototype.

Different stakeholders are involved in the construction supply chain such LPA, developers, planning specialists, contractors and logistics operators and many complex relationships and interfaces are needed to achieve the construction project, **Figure 3.3** illustrates this.

[12] https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/real-estate/deloitte-uk-crane-surve-summer16.pdf
[13] Supply Chain Improvement in Construction Industry, Papadopoulos et al, 2016, Universal Journal of Management.

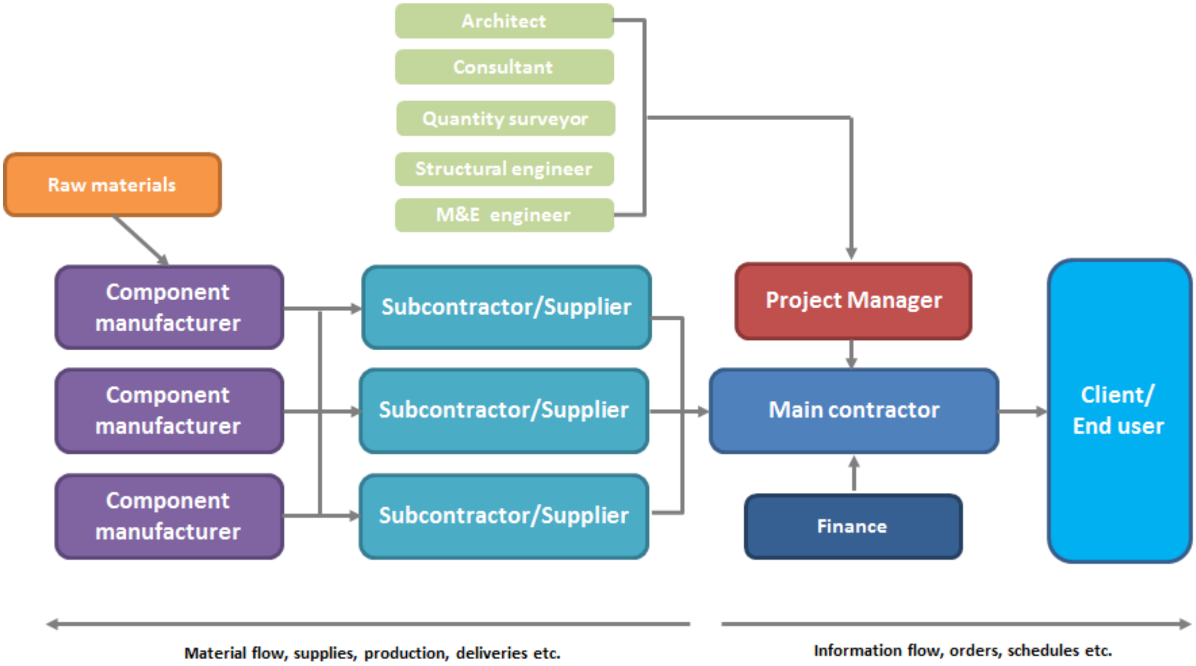


Figure 3.3: Flow of Materials

The construction industry has a large supply chain, almost all of which is sourced within the UK. According to an economic analysis carried out for the Department for Business, Energy & Industrial Strategy[14], it is estimated that for every £1 spent in construction at least 90% stays in the UK. The sector is characterised by high levels of fragmentation.

A report for the Construction Industrial Strategy[15], showed that for a 'typical' large building project, that is in the £20 - £25 million range, the main contractor could be managing up to 70 subcontracts of which a large proportion are small – £50,000 or less.

The UK construction industry is not performing to its full potential and the main problems facing construction[16] can be summarised into the following:

- Construction is a highly fragmented industry, with over 99% of businesses comprising SMEs
- Adversarial relationships due to the existence of various stakeholders/interfaces and a potential for conflict and additional costs at each interface
- Project uniqueness with a bespoke organisation with each new project
- Separation of the design and production process and the consequent difficulties that can arise during construction.

The study identified a number of key factors to successful delivery of a construction project. These include:

- Equitable financial arrangements and certainty of payment;
- Early contractor engagement and continuing involvement of the supply chain in design development; strong relationships and collaboration with suppliers and capability for effective site management, including the ability to respond to change flexibly.
- An efficient sharing of information between all stakeholders is key to reducing errors and delays and as a result achieving effective and efficient productivity[17].

[14] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210060/bis-13-958-uk-construction-an-economic-analysis-of-sector.pdf
[15] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/252026/bis-13-1168-supply-chain-analysis-into-the-construction-industry-report-for-the-construction-industrial-strategy.pdf
[16] Construction Supply Chain Management, Edited by Stephen Pryke, 2009
[17] Effective Applications of E-Commerce Technologies in Construction Supply Chain: Current Practice and Future Improvement, Zou et al., 2006, ITcon Vol.11

3.3 Logistics techniques

Different logistics methods are being used by construction companies around the world. Some of the techniques are presented below:

3.3.1 Construction Consolidation Centres (CCC)

CCC are used to supply and distribute materials to different construction projects. This approach offers safe and efficient supply to sites by contributing to better certainty, less movements to site and safe storage materials. CCCs are considered as an optimal solution for busy urban areas.

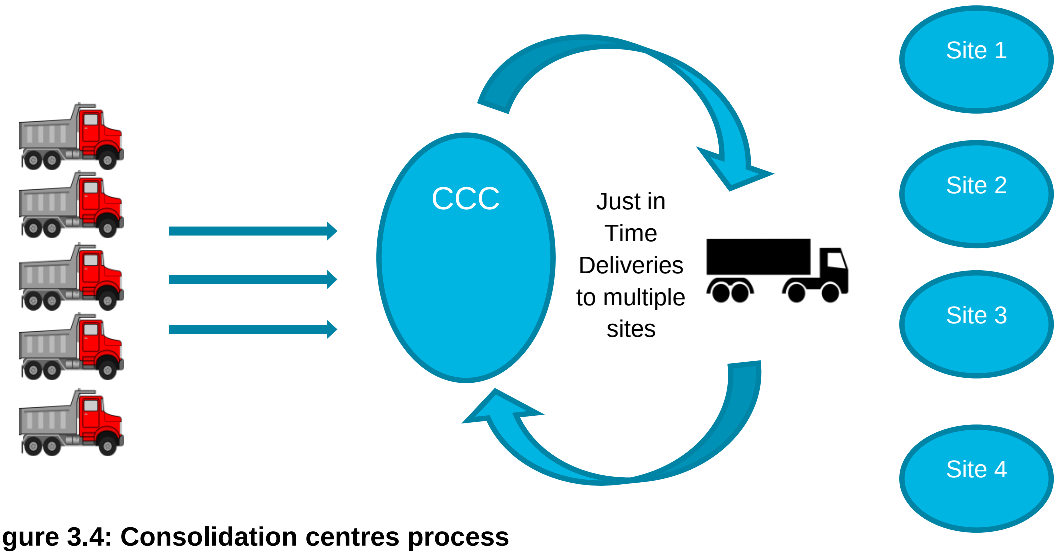


Figure 3.4: Consolidation centres process

3.3.2 Just-in-time Delivery

The JIT delivery technique involves receiving materials from suppliers when they are required, rather than storing materials on site for long periods. This technique offers the benefit of reducing the storage space needed on site, reducing the risk of damage or theft of materials and reducing waste. This can even result in reducing the risk of safety incidents.

Conversely, JIT delivery comes with the risk of running out of stock if the correct procedures are not in place and therefore require a higher level of planning. Moreover, this approach leads to high flows of delivery traffic, as typically the quantity of materials being brought to site are smaller than if being held in an onsite storage point.

3.3.3 Demand Smoothing

Demand smoothing is defined as the technique of smoothing peaks and troughs in a construction project programme to avoid periods of understaffing leading to overtime and/or idle periods with staff underutilisation, this is usually achieved by moving some activities.

3.3.4 Onsite Market Places

Onsite market places are temporary storage space for consumable materials and small tools. This approach offers the advantage of locating all the required materials at one location, avoiding the need for different small on site material storage areas, this results in reduced safety incident risk.

3.3.5 Preassembled and Offsite Fabrication

Offsite fabrication refers to structures built at a different location than the location of use. Research work undertaken by Cambridge and Oxford Brookes Universities in 2013[18], showed that this technique can minimise waste and reduce costs while achieving a high quality project.

3.4 Materials management in the construction supply chain

The management of materials on construction sites is the key to efficient project delivery. Material management requires appropriate tools and techniques to make sure that materials are delivered on time, at the right place.

Kasim[19] discussed in his research work the following material management processes:

3.4.1 Planning

Materials planning process covers setting up and maintaining the records of each material used to determine target inventory levels and delivery frequency. This will help optimise the flows of materials on site and avoid different problems. Stukhart[20] stated that good materials planning would provide guides to the subsequent activities on site and as a result will impact the project plan. Planning also covers access and routing of materials within the site.

3.4.2 Procurement

Procurement covers a wide range of activities including purchasing of materials, equipment, labour and services. The aim of this stage is to provide quality materials in time and place and at an agreed budget. Procurement is also known as the process of organising the purchasing of materials and issuing delivery schedules to suppliers and following-up, to make sure that suppliers deliver on time.

A well organised procurement process would prevent wastage problems due to over-ordering, and therefore over-payment for materials. A control strategy is required during the procurement process to achieve the targeted objectives.

A typical purchasing procedure is presented below:

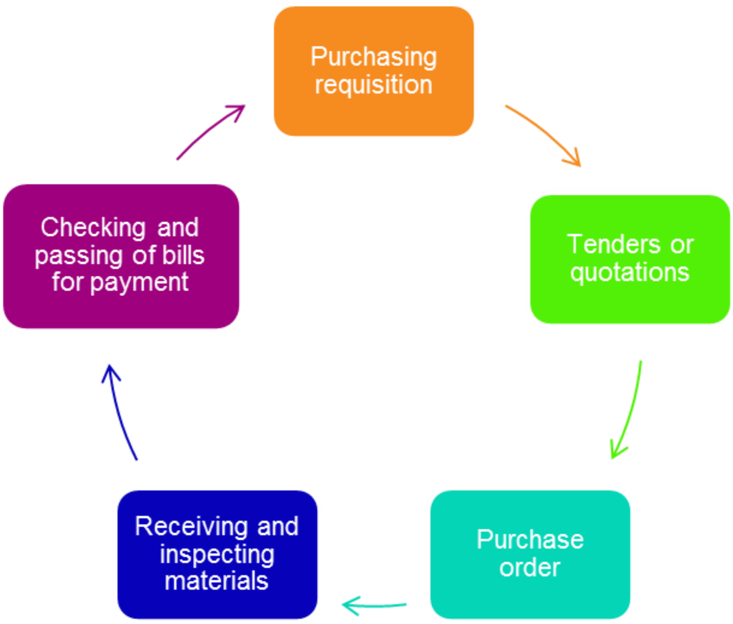


Figure 3.5: Purchasing procedure

[18] Offsite Housing Review – February 2013, Construction Industry Council
[19] Improving Materials management on Construction projects, Kasim, 2008
[20] Construction Materials Management, Stukhart, 1995

3.4.3 Logistics

The logistics concept in construction projects aims at improving coordination and communication between the project participants during all construction phases. The logistics process for effective materials management includes optimum forecasting of materials movement[21] and planning of access and routing of material within the construction site.

3.4.4 Handling of materials

Handling is defined as the effective movement of materials using the right method to provide the right amount of the right material, at the right place, time, sequence, position, condition, and cost. The selection of the material handling equipment is an important function as it can enhance the production process, provide effective utilisation of manpower, increase production and improve system flexibility.

One reason for failed deliveries on site is inadequate loading or unloading equipment. Damaged materials during handling is also a recurring issue, therefore safe handling with suitable equipment will reduce the proportion of waste.

3.4.5 Waste management

Construction activities can generate large and diverse quantities of waste compared to other industries. Materials that are not used are an significant part of waste in construction projects. Waste is defined as any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered necessary in the production of a building. Efficient onsite material storage would prevent waste, loss and any damage of materials which would affect operations. Storage capacity is not always available on-site, therefore requirement of storing space should be taken into consideration at the initial stage of the construction process.

3.5 Monitoring and performance measurement systems

In construction logistics, there is a need to implement performance measurement systems from which relevant performance information can be analysed and further actions can be taken to achieve incremental improvements in efficiency.

Research work around performance measurement provides guidelines for managers in implementing performance measurement systems. Usually, the difficulties reside, first, in defining the metrics and second in using the information provided by them to correct the course of actions.

The UK working groups on Key Performance Indicators[22] (KPIs) have introduced seven KPI groups in order to achieve a good performance, namely: Time, Cost, Quality, Client Satisfaction, Change Orders, Business Performance; and Health and Safety. Each group includes a list of indicators that can be categorised into Headline, Operational and Diagnostic indicators.

- Headline Indicators provide a measure of the overall, state of health of a firm. Examples of these are Time for Construction, Cost for Construction, Profitability, and Reportable Accidents.

- Operational Indicators bear on specific aspects of a firm's activities and should enable management to identify and focus on areas for improvement. Examples of these are Time to rectify Defects, Quality Issues, Return on Value Added, etc.

- Diagnostic Indicators provide information on why certain changes may have occurred in the headline or operational indicators and are useful in analysing areas for improvement in more detail. Examples of these are Outstanding Money, Ratio of Value Added, Change Orders, etc.

The possible lack of visibility of flow of materials from suppliers to construction sites may become an impediment to achieve higher levels of delivery efficiency. Transparency of materials along the supply chain, especially in complex projects or the need for short-term storage, is essential. The existence of

[21] An intelligent materials routing system on complex sites, Mahdjoubi and Yang, 2001, Logistics Information Management
[22] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/16323/file16441.pdf

Radio Frequency Identification (RFID) technology allows developers on construction sites to easily achieve these levels of transparency based on shipment tracking.

Enhancing security and reducing loss of materials, tools and other resources may result in a reduction of unnecessary material movements and deliveries to the construction site. This is particularly important if there are constraints on VHAs in the construction site.

The use and integration of Building Information Modelling (BIM) software and Geographic Information Systems (GIS) for visualising the construction supply chain management are being used more frequently. This facilitates a better connection of the stakeholders (LAP, developers, planning specialists, contractors and logistics operators) and the processes or tasks they are involved in, as well as the visualisation and measurement of all related transport costs for the flow of materials from warehouses to construction sites is a reality.

3.6 Urban Deliveries Best Practice Review

3.6.1 Urban Deliveries Best Practice Review Introduction

Inefficiencies in distribution can be exhibited in different ways such as delays, low load factors, empty running, high number of deliveries made to individual premises within a given time period and long dwell times at loading and unloading points. This has a number of impacts on road congestion, air quality, noise and safety.

According to a study conducted by the European Commission on urban freight transport[23], the reasons behind construction deliveries inefficiencies are mainly related to the fragmented nature of the industry and the project-based nature of the activity. The study suggests that improving logistics in construction has the potential saving around 10-30% of the project costs. A number of existing measures and practices that impact of urban freight transport were reviewed as part of the study and these were classified into the following categories:

3.6.2 Regulatory measures

Regulatory measures include rules and restrictions such as:

- Vehicle weight and size restriction,
- Low Emission Zones (LEZ) and Ultra Low Emission Zones (ULEZ);
- Time-based restrictions on access for freight vehicles.

These kinds of measures are often easy to implement for local authorities and have a high degree of acceptability among stakeholders. However they do require an enforcement system to prevent infractions.

A summary of the regulatory measures that contribute to more efficient and sustainable urban deliveries are provided in the **Table 3.1**. Most measures are considered to have a positive economic and environmental impact even with the cost of implementation and enforcement.

3.6.3 Market-based measures

Market-based measures include fiscal measures such as taxes and tolls. Market prices have a direct impact on the freight industry's behaviour as operators have to respond to changes in their operational costs to remain competitive. Congestion charging is a good example of a market-based measure introduced to avoid unnecessary journeys into urban areas and therefore reduce road congestion and improve air quality.

Another example is the provision of subsidies such as exempting low and zero emission vehicles from congestion charges or allowing vehicles operating from urban consolidation centres to use priority lanes and enjoy wider time windows.

[23] https://ec.europa.eu/transport/sites/transport/files/themes/urban/studies/doc/2012-04-urban-freight-transport.pdf

3.6.4 Land-use planning measures

Local authorities should adopt an holistic approach to land use planning that takes into account the demand for freight transport generated by new developments as well as the needs of the freight industry.

In the UK, a number of consolidation centres have been developed to serve concentrations of retail activity because they create critical masses of traffic and therefore beneficial from consolidate loads. Relocation of freight traffic generators to non-urban locations is also considered as 'best practice'. Land use planning policies should contribute to the development of appropriate parking spaces for freight vehicles in urban areas as well as off-street loading/unloading bays for new developments.

Land-use planning measures could be very powerful in the medium to long-term in supporting sustainable and efficient urban distribution.

3.6.5 Infrastructure

Infrastructure measures are usually integrated into land-use planning measures. Road freight transport remains the most important mode for last mile deliveries and collections in urban areas due to its inherent flexibility. Local authorities should ensure that freight vehicles are able to park legally on the street in order to make deliveries and collections.

The key infrastructure measure at a local level is likely to be the development of a network of designated on-street loading and unloading bays. For construction materials inland waterways and rail as methods of transportation can be very effective for over medium to long distances to urban logistics zones, for subsequent last mile delivery by road.

The development of a network of on-street loading and unloading bays for freight should provide significant economic benefits in terms of lower delivery operational costs and reduced congestion costs.

3.6.6 New vehicles technology

New technology measures contribute to reduce environmental and economic impact of urban deliveries. These include electric, hybrid electric / –plug in, hydrogen and natural gas. Despite some disadvantages and barriers to these technologies such as:

- Greater capital investment,
- Weight of batteries, limited
- Charging technology

New vehicle technologies are considered as a promising alternative to significantly reduce emissions, noise and improve air quality for last mile deliveries.

3.6.7 Management and other measures.

This includes key concepts such as the consolidation of supply through urban consolidation centres and consolidation of demand through collaborative orders. These can be used to increase the average load factors and reduce the number of trips.

A summary of the main management measures that could contribute to more sustainable urban delivery are provided in the **Table 3.1** overleaf.

Table 3.1 Summary of measures

Summary of measures				
Regulatory measures	**Market-based measures**	**Land use planning measures**	**Infrastructure measures**	**Management & other measures**
Extending time windows	Congestion charging	New developments with off-street loading/unloading facilities	Network of on-street designated loading & unloading bays	Developing Urban Logistics Plans
Avoid vehicle weight and size restrictions over extensive areas	Mobility Credits	Safeguarding of rail connected & water connected sites for future use	Development of rail and/or waterborne connected logistics zones	Indirect subsidies to support urban consolidation centres
Harmonisation of regulations (regional and national level)	Subsidies	Requiring large-scale distribution sites to be rail & water connected		Planning permission requirements for CCCs for major construction sites
LEZ to encourage fleet renewal	Operator charging	Deployment of on-street camera / sensor equipment	Installation of enrolment, payment and monitoring technology	Lorry routing & signing strategies
Retiming delivery	Industry efficiency	Utilise existing area(s) on worksite	Site-based acoustic policy and protection	Facilitating night-time deliveries

The measures above illustrate the vision of the European Commission's 2011 Transport White Paper[24]. The white paper aims to make freight deliveries more efficient both economically and environmentally through recommendations that have been categorised as follows:

- **Efficient Deliveries**: Use pricing mechanism such as the internalisation of external costs into the price of freight transport in urban areas and beyond. Prices charged to freight operators should reflect the social and economic costs imposed by the vehicles. Therefore vehicles movement should be electronically monitored.
- **Greater use of low emission vehicles:** This would have a significant impact on improving air quality and reducing noise levels. Funding the European industry to develop alternative fuel, vehicle and infrastructure technology for low emission is key recommendation.
- **Intelligent Transport Systems (ITS)**: Promoting the development of ITS to increase the efficiency of freight deliveries.
- **Night deliveries**: This includes inclusion of low noise equipment in manufacturing standards for freight vehicles and associated loading and unloading equipment. Research around benefits and costs of introducing standards so that quieter freight vehicles and equipment are made available without additional capital investment is key recommendation.
- **Intermodal transfer facilities and other infrastructure**: Development of intermodal freight interchanges and associated warehouses to promote rail/waterborne transport over medium and long distances and efficient road transport for the last mile distribution. Development of re-fuelling infrastructure for low emission vehicles is also key recommendation.
- **Developing and disseminating good practice:** Bring the information together into a guidance document and then share it across the sector.

[24] https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

3.7 Summary

The construction industry is heavily regulated and faces a variety of challenges. For logistics operators, as materials are in high demand a key challenge is ensuring that there are efficient material deliveries to construction sites. We have enlisted existing best practices and measures that may increase the efficiency of freight deliveries, and logistics techniques that help with the visualisation of the entire construction supply chain management. The ability to track and quantify transportation environmental and economic impacts is key element in providing recommendations for efficient freight deliveries.

4. Construction Sites Data Suppliers

4.1 Introduction

The use of DMS has grown considerably in recent years and it is now viewed as essential tools to address an increasingly complex and regulated construction environment.

There are a range of software systems used by the construction sector for delivery management including their vehicle booking and monitoring system.

The majority of DMS are provided by established construction logistics companies and are largely shaped by the sites they have been deployed on. Therefore, procurement of DMS is often associated with decisions being made around the selection of a logistics operator.

The majority of DMS provide the same core booking functionality, with some variance around ability to provide access via handheld devices.

Fulcrum from Wilson James

Fulcrum

Fulcrum is an end-to-end material delivery system used at Wilson James Consolidation Centres that improves operational efficiencies across construction projects. Fulcrum prevents deliveries to construction sites from those freight operators that do not meet minimum standard for the site against FORS. The aim is the reduction of delays of material delivering in the construction site due to inadequate praxis.

At the same time, when Fulcrum identifies a freight operator which is not accredited against the FORS Standard, the delivery is planned to be directly diverted and storage to Wilson James Consolidation Centre to be finally delivered by an accredited operator. Therefore, delivery risks are reduced, and inadequate or rejected deliveries at construction sites are avoided.

Roadtech

ROADTECH
Innovate. Integrate. Secure.

Roadrunner is another DMS that indicates vehicle routes from its origin to destination. This fleet management software provides the user with a complete platform solution to trace and visualise vehicles using a real-time web-map.

The system is capable of showing each vehicle or delivery site, while real time information can be automatically retrieved and integrated. Therefore, the user can draw conclusions on a set of vehicle/site standard key performance indicators (KPIs). At the same time, users can define their own KPIs. Through Application Programme Interface (API), information can be further analysed using other software.

PODFather

PODFather Ltd provides internet based system solutions to businesses operating in logistics, construction, and various field service sectors. The mobile and internet based back office system allows operators to record details of the vehicles arriving at site via the PODFather Application.

PODFather removes the problems associated with paper based systems, as information is recorded digitally on the users' handheld device, enabling data to be updated easily and regularly. Data is stored on the central database in real time, but if a mobile signal cannot be obtained, the 'electronic forms' are stored into the App until reception is regained and the completed forms transmitted to the PODFather system.

Datascope

Datascope has developed the 'Delivery Scheduler' which is designed to provide a flexible system for web based booking of deliveries to site and for scheduling crane and hoist requirements of each delivery. In addition, it provides reports to the management team in respect of the delivery schedules and hoist/crane utilisation. Furthermore, Datascope also offer to customise the user interface to suit a projects specific requirement.

The Delivery Scheduler has is used by numerous organisations including Balfour Beatty, Mace, Vinci, Sir Robert McAlpine, Kier, Skanska, Galliford Try, Costain, Interserve, ISG, Morgan Sindall, Miller Construction and many others.

TomTom Telematics

Webfleet is a navigation and mapping solution which provides vehicle tracking, navigation, two-way communications, job scheduling and report-logging capabilities to organizations. TomTom solutions are based on the use of real time data in managing traffic, e.g. construction sites, etc. The average speed on vehicles is reported and updated every five minutes.

TomTom relies on GPS real time data that updates or validates changes to the network every 24 hours. A traffic management tool is available for users to update changes to the network, such as road works. In addition TomTom have a data sharing agreement with roadworks.org, who provide them with updates about the road works that they are undertaking in an accurate and consistent format.

4.2 Summary

Within the timescales of this study, it was not possible to find sufficient suitable telematics data for analysis. Without accurate use of DMS as well as the wide variety of data available both in terms of parameters recorded and format of data available, telematics data would have been helpful but still remained of limited use in being able to provide accurate comparisons of plan (in the DMS) versus actual (via telematics) information.

However, effectively linking such systems with DMS could provide benefits such as trend analysis and practical management of vehicles. Such information would be able to provide information about a site's performance in real time and identify where delays are occurring, for example: at the gate, in the holding area or *en-route* to site. Consequently it could also identify driver/operator responses to delays, for example choosing to wait, circle the site or divert elsewhere/back to depot. This data would also allow the impact of delays to be accurately evaluated in terms of distance travelled; time spent idling and vehicle time on site. In turn emissions, delay costs and infrastructure damage can be more accurately assessed.

5. Consultation

5.1 Introduction

This chapter of the report details the consultation undertook with a range of stakeholders with an interest in the construction industry. Consultation was undertaken using a number of methods including an online survey, face-to-face interviews and telephone interviews to gather stakeholders' thoughts on issues regarding construction deliveries.

5.2 Online Survey

An online survey was undertaken in order to understand the opinions of logistics operators delivering to construction sites within London and the potential inefficiencies of completing deliveries. Logistics operators were questioned as to what aspects of the site(s) they felt were well or poorly managed. This survey sought to understand the root cause of inefficiencies found delivering to construction sites.

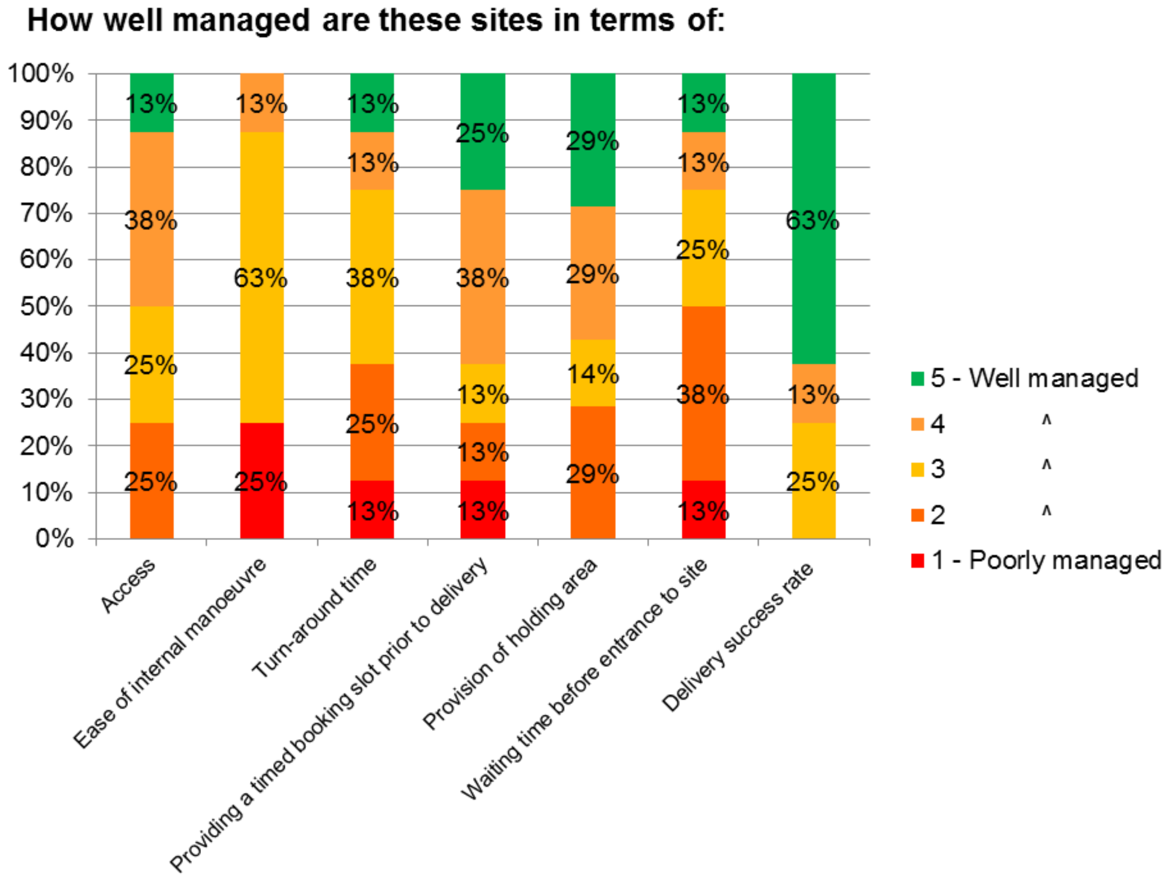


Figure 5.1: **How well managed are these sites**

Logistics operators were asked to rank how well certain aspects of the construction sites to which they deliver are managed. They were asked to rank the aspect from one (considered to be poorly managed) to five (considered to be well managed).

- 13% of respondents thought that turnaround time was poor and providing a timed booking slot was completely lacking.
- 50% thought that waiting times before entrance to the sites were poorly managed.

A quarter of respondents said they had experienced difficulty manoeuvring vehicles onsite. This could be caused by a number of reasons, such as, a constrained site or other deliveries onsite causing manoeuvring difficulties.

50% of respondents stated that they had been turned away from sites. Respondents indicated that there were a number of reasons for this such as: the site not being ready and/or too many vehicles in front suggesting the holding area was full or missing the assigned time slots.

When questioned as to what typically happens when a driver arrives at the site:

- 38% stated they would be asked to wait onsite until a space became available
- 25% state they are accepted immediately.

This suggests that for sites where logistics operators have been turned away, there is a need to implement a holding area where they can wait (subject to space available). If they are being turned away, despite a holding area already in place, it would suggest a need to extend the holding area or to better manage the booking slots from the DMS.

- 25% of respondents state that booking delivery slots are currently well managed at their sites.
- 29% of respondents gave provisions of VHAs a ranking of 5 (well managed).

This represents an inconsistency within the construction industry in adopting best practice with regards to logistics planning, which can ultimately reduce inefficiencies. Respondents suggested that despite these inefficiencies the delivery success rate is well managed with 67% ranking 5 (well managed).

There is potential for a greater saving in inefficiencies for logistics operators rather than for construction sites themselves. This saving is experienced through less time spent at sites, which can be utilised on other deliveries.

Better utilisation of time is essential within the construction logistics industry Further data is required from logistics operators with regards to inefficiencies. 37% of respondents currently use telematics which has the potential to support further data analysis. The systems that are used include Fleetmatics, Fleet Tracking and RAC Telematics.

This survey has highlighted that there is a considerable variation between sites which perform well and those that are well managed, compared with sites that need further improvement.

This suggests a need for a consistent approach across the industry that developers can use to set the standard in delivery management. Establishing a minimum requirement for construction sites to contain certain features, for example, to have in place a loading bay where possible and a DMS, could be the key to improving the efficiency across the construction and logistics industry.

5.3 Logistics operators' interviews

Logistics operators who completed the online survey in January 2017 were invited to answer an additional four questions on the telephone. These questions are as follows:

- 1) Do you deliver to sites which utilise a DMS? Can you name a few?
- 1b) If so, do you have to wait on site? What is the reason for the wait?
- 2) Do you deliver to sites operating without DMS?
- 2b) If so, do you experience long waiting times?

A total of 8 logistics operators responded to the additional questions.

The responses received are illustrated in **sub-section 5.3.1:**

5.3.1 Logistics operator responses

Logistics operators often complete multi-drop deliveries to a number of varying sites which may or may not use a DMS. Often for route planning, costing and efficiency purposes, logistics operators will deliver to a number of sites rather than completing one delivery and then returning to the depot.

1: Do you deliver to sites which operate a DMS?

Please can you provide the names of the some of the sites you deliver to that operate a DMS?

All respondents stated that they deliver to some sites which operate a DMS. Some of the key sites mentioned include those operated by:

- Balfour Beatty
- Carillion Construction
- Crossrail
- Kier Construction
- Skanska
- Thames Tideway Tunnel
- Westfield

This confirms that many of the largest and most significant construction sites within London use a DMS as part of their logistical/delivery planning measures.

1b: If so, do you have to wait on site? What is the reason for the wait?

Respondents were then asked whether they had to wait on sites which operated a delivery management system.

However 50% stated that due to the delivery management system they did not experience any waiting times. This suggests that the system was being efficiently utilised. As a result this reduced the amount of time spent on site. This provides additional benefits such as reduced turned away deliveries, less congestion on site for other deliveries and reduced levels of waiting times to complete deliveries. This potentially results in less idling time for the trucks, therefore potentially improving the air quality.

On the other hand, 50% stated that despite having a DMS in place they still faced waiting times on site. The waiting times ranged from 20 minutes to five hours. When probed as to why they were still facing such waiting times, it often came down to the day-to-day conditions on site. Reasons included:

- Delays onsite e.g. waiting for a crane to become available
- Companies delivering at the wrong times therefore making it busy for those with prearranged time slots
- Site managers being uncontactable
- Waiting in queues to deliver, and no spaces on site and therefore being sent away to wait to be called when the site was ready for their delivery.

2: Do you deliver to sites operating without DMS?

All respondents stated that they deliver to some sites which do not operate a DMS. Small construction sites do not tend to use DMS as they are able to process deliveries at a faster pace compared to larger sites (however this varies depending on the type of load). Some smaller sites do have a DMS in place however delays are still experienced although they are not long delays than those which could be experienced at a larger site.

For sites without a DMS in place, respondents stated that they would contact the site beforehand to put an indicative time in place for when they would complete their delivery.

On the other hand, one respondent stated that the delivery would be scheduled into the deliveries they complete for the day and therefore would turn up to on-site when it suited them. This has the potential to become an issue if the site operates on a first come first serve basis when a delivery may be attempted during a busy period. Sites operating on a first come first serve (FCFS) basis when a delivery may be attempted during a busy period. Sites operating on a FCFS basis potentially lend themselves to delays should several deliveries arrive at the same time, such as in the morning when the site(s) opens, typically at 0800hrs.

2b: If so, do you experience long waiting times?

The majority of sites without a DMS in place tend to be smaller construction sites. Most respondents that we with whom we engaged agreed that they experience some waiting time however it varied in its severity. Waiting times ranged from 10 minutes to 2 hours suggesting that sites without a DMS are particularly inconsistent about when the delivery could be completed. The reason for this has been put down to congestion on site due to other deliveries being made. Respondents stated that their drivers often get turned away from sites and are forced to park in car parks until a loading bay becomes available.

5.4 Stakeholders Consultation with the construction sector

AECOM and PBA were invited by TfL and the Chartered Institute of Logistics and Transport (CILT) to attend the Construction Logistics Improvement Group (CLIG) working group and the CILT construction supply chain forum (respectively) in order to present the project and provide an update on its progress. These meetings were attended by representatives from project team

- CLIG meeting (28th November 2016) – Geoff Clarke, AECOM
- CLIG working group (3rd March 2017 and 29th March 2017) – Paul Wilkes, AECOM
- CILT construction forum (8th March 2017) – Tim Hapgood, PBA

5.4.1 Construction Logistics Improvement Group (CLIG)

The project outline was presented, asking for buy-in to the next steps. The concept of improving delivery efficiencies was well received leading to a number of questions regarding the impacts of construction vehicles on the local road network. Discussions thereafter suggested a need to make recommendations towards further studies into efficient logistics (e.g. just in time deliveries rather than storing supplies on site) which could potentially have a positive impact on the local road network.

Assumptions were made during the presentation that sites were not utilising the afternoon periods of the day for deliveries when road conditions tended to be quieter. Attendees were able to see the benefit from representing the spread of deliveries across the day in our study in order to test this assumption.

5.4.2 CILT Construction Forum

The progress of the project was presented, along with a call for interested parties to get involved. Some initial scepticism was reported from the forum with regards to how useful the data would prove to be and the timescales for the project. After further discussions it was agreed that this project should be viewed as a positive initiative for the industry and one where the greater the involvement of participants, the greater the value of the project.

Regardless of this, the meeting proved effective with some attendees such as *O'Donovan, Wincanton and CSB Logistics* agreeing to participate in the project. These potential opportunities were pursued following the meeting.

A letter from TfL setting out the scope of the project and the type of data required from stakeholders was sent round to attendees of the forum. This was to provide further information regarding the project and to invite them to participate with some data collection

6. Analysis and Impact Modelling

6.1 Introduction

Data from 19 sites was collected using either manual counts or electronic means. This was consolidated, cleaned and analysed within a single impact assessment tool allowing analysis of individual sites, as well as comparison between them. In total, the data covers forty thousand vehicle trips across the 19 sites with time periods varying from a few days to over 12 months, depending on data availability.

However, whilst this methodology was advantageous in allowing us to look at a variety of sites (in terms of construction stage, size and location), each, particularly those where data was collected electronically, presented it in different formats and more crucially provided different levels of data and across different parameters. As such, a number of assumptions have had to be made across certain parameters in order to provide a comprehensive view. Where possible those assumptions have come from extrapolation of data from those sites where the information has been recorded. **Table 6.1** outlines the parameters and sites, where data was available and where assumptions were made.

A green tick indicates data availability (✓), a red cross indicates an assumption (X) and a yellow dash indicates some data available (-). Further detail regarding assumptions is dealt with within each parameter section.

Site	Vehicle Profile	Delay	Diversion	Delivery Failures	Reasons for Failure	Euro Engine Profile	Emissions Calculations	Collisions	Infrastructure Damage
1	✓	✓	✗	✓	✓	✓	-	✓	-
2	✓	✓	✗	✓	✓	✓	-	✓	-
3	✓	✓	✗	✓	✓	✓	-	✓	-
4	✓	✓	✗	✓	✓	✓	-	✓	-
5	✓	✓	✗	✓	✓	✓	-	✓	-
6	✓	✓	✗	✓	✓	✓	-	✓	-
7	✓	✓	✓	✓	✓	✓	✓	✓	-
8	-	✓	✗	✗	✗	✗	-	✓	✗
9	-	✓	✗	✗	✗	✗	-	✓	✗
10	-	✗	✗	✓	✓	✗	✗	✓	✗
11	-	✗	✗	✓	✓	✗	✗	✓	✗
12	-	✗	✗	✓	✓	✗	✗	✓	✗
13	-	✗	✗	✓	✓	✗	✗	✓	✗
14	-	✗	✗	✓	✓	✗	✗	✓	✗
15	-	✗	✗	✓	✓	✗	✗	✓	✗
16	-	✗	✗	✓	✓	✗	✗	✓	✗
17	-	✗	✗	✓	✓	✗	✗	✓	✗
18	-	✗	✗	✓	✓	✗	✗	✓	✗
19	-	✗	✗	✓	✓	✗	✗	✓	✗

Table 6.1: Assumptions Summary

All sites were categorised according to their size, construction phase, location within London and their performance in terms of delays to vehicles. Table **6.4** outlines the ratings for each site (numbers in italics, indicate the use of averages.

Tables 6.2 and **6.3** outline the ranges for size and performance. For the purposes of the analysis, we have based the size of the site on the number of vehicles arriving.

Congestion within the study is measured by two parameters, delay on site, either in terms of a schedule deviation or where such information is unavailable, deviation from the average time spent on site; as well as additional kilometres, either as a result of delivery failure or inability to get on site.

Telematics data was unavailable at this stage for vehicles using the site; therefore, diversion information was not present. In terms of delay however, the assessment measured mean average dwell time and the deviation from such time for each vehicle.

Table 6.2: Site Size

Size	Vehicles per day
Small	0-14
Medium	15-29
Large	30+

Table 6.3: Congestion Performance

Performance	Duration	Deviation
GOOD	Less than 35 mins	Less than 20 mins
AVERAGE	35-50 mins	20-30 mins
BAD	More than 50 mins	More than 30 mins

Table 6.4: Site List

Site No	Location within Greater London	Construction Stage	Digital (D)/Manual (M) Data	Vehicle Dwell Time	Vehicle Delay	Vehicles Per Day	Size	Duration Performance	Delay Performance
1	Central	Bsmnt Excavtn & Piling	M/D	00:29:07	00:18:30	38	Large	GOOD	GOOD
2	Central	Bsmnt Excavtn & Piling	M	00:37:40	00:29:12	74	Large	AVERAGE	AVERAGE
3	Inner	Sub-Structure	M	00:00:00	00:26:55	53	Large	GOOD	AVERAGE
4	Inner	Site Setup & Demolition	M/D	00:23:02	00:07:48	27	Medium	GOOD	GOOD
5	Outer	Not Applicable	M	00:38:38	00:41:59	18	Medium	AVERAGE	BAD
6	Outer	Fit out, Testing & Commissioning	M	00:32:47	00:42:47	11	Small	GOOD	BAD
7	Inner	Site Setup & Demolition	M/D	*00:47:48*	00:24:54	9	Small	GOOD	AVERAGE
8	Outer	Fit out, Testing & Commissioning	M/D	*00:47:48*	*00:29:20*	21	Medium	AVERAGE	AVERAGE
9	Inner	Bsmnt Excavtn & Piling	D	00:53:58	00:36:13	38	Large	BAD	AVERAGE
10	Outer	Site Setup & Demolition	D	-	-	0	Small	NA	NA
11	Inner	Site Setup & Demolition	D	-	-	5	Small	NA	NA
12	Inner	Bsmnt Excavtn & Piling	D	-	-	0	Small	NA	NA
13	Central	Site Setup & Demolition	D	-	-	1	Small	NA	NA
14	Central	Bsmnt Excavtn & Piling	D	-	-	1	Small	NA	NA
15	Central	Site Setup & Demolition	D	-	-	2	Small	NA	NA
16	Central	Site Setup & Demolition	D	-	-	2	Small	NA	NA
17	Inner	Site Setup & Demolition	D	-	-	0	Small	NA	NA
18	Central	Site Setup & Demolition	D	-	-	3	Small	NA	NA
19	Inner	Site Setup & Demolition	D	-	-	2	Small	NA	NA

The performance of sites 10 onwards could not be categorised, as no data was available relating to their overall delay performance. As such, the average of the rest of the population was taken. However, given the relatively low number of deliveries per day, the sites are unlikely to experience high levels of congestion or delay.

Outside of these, the study has managed to obtain data for a balance of sites both in terms of size and performance. However, it is possible that certain badly performing sites did want to engage with the study.

Costs have been calculated for both vehicle delays as well as emissions generated as a result.

6.2 Site analysis

The site analysis process took all available information that related to the 19 sites and the data has been assimilated under a number of headings. In this chapter we show the results in mainly graphic form with a short summary of key points.

A detailed description of each site is provided in **Appendix A**. The first seven locations contain manual data collected at the sites and include supplementary electronic data where available. The remaining sites are based on the electronic data supplied and there are various gaps if the companies do not collect certain elements of information.

As an example sites 10 to 19 are small sites with limited information and as a result they have been summarised together. The remainder of this section explains what is covered under each sub-heading.

6.2.1 Background

In this section we detail the stage of construction that the site is at and confirm whether it has a holding area and booking system. Many of the smaller sites did not have a booking system in place. The sites are categorised in size and average number of vehicles handled per day using the parameters outlined in the previous section, e.g. 30 vehicles and above are classed as a large site. The study has also recorded information from sites in three geographical areas; central, inner and outer London. The location is recorded into one of these categories but for confidentiality reasons site names have been omitted from this report.

6.2.2 Vehicle profile

The site surveys have enabled a vehicle “body type” profile to be compiled. This profile relates closely to the stage of construction so, for example, during the two early stages of development site traffic is likely to be dominated by tipper traffic (primarily 4-axle, 32t gross vehicle weight (GVW)) to facilitate muck-away. As can be seen for Site 1, this represents 83% of observed vehicles, but this will change at later stages of development as the construction progresses.

6.2.3 Delivery success/failure rate

The next figure shows the % of unsuccessful deliveries. This data was collected manually at the gate, as many of the electronic data collection systems did not record this data, because the vehicles may not have been booked and hence may be immediately turned away without record. There is also a number of reasons why vehicles are turned away, including using inappropriate or defective vehicles - e.g. not having sideguards or FORS stickers - as well as driver issues such as lack of training or not having suitable Personal Protective Equipment.

Also there were instances of vehicles leaving the queue before entering the site due to concerns about the level of waiting time. At some of the larger sites there was little room for flexibility. There was evidence of a number of emergency bookings being made as vehicles arrived without a booking but were allowed on to site once the necessary paperwork was completed.

In addition there was evidence of excessive block booking of vehicles where a particular logistics operator might have booked 10 vehicles in but only 5 actually arrived that day. There was a range in failure rate with some having no failures. Site 1 for example had 11% of all vehicles arriving being turned away, which was well above the average seen across all sites of around 4 to 5%.

6.2.4 Congestion/arrival profile/delays

The pattern of deliveries for an average day at each site is shown where this data was available. The patterns vary between sites with some illustrated by a wave-like nature of deliveries, with peaks at 0700hrs, 1000hrs and 1300hrs. This typically appears to happen where the same vehicles are making multiple visits to the site during the day.

The majority of the sites in this survey are only open during standard working hours typically 0800hrs until 1700hrs. Construction traffic arrival is particularly high between 0800 and 1000 hours, which coincides with the morning traffic peak and is one of the most congested times of day on the road network. Site access may be restricted even further within the working day due, perhaps, to intensive pedestrian activity at lunchtime, or if near an education establishment at change of lesson/lecture times.

6.2.5 Economic cost

There is a real economic cost of inefficiencies in the delivery system. A significant proportion (89%) of economic costs in terms of delays and diversionary/wasted mileage are borne by the transport operator. These costs are examined below.

In estimating the cost of delays we have taken the average waiting time and the number of vehicles involved in some sort of delay, to calculate total delay time per day. Costs have been calculated based on an assumed daily operating cost of £350 per day and a 10 hour working day with 45 mins - one-hour break, putting costs at £38.88 per hour. This estimate is based on a large rigid vehicle (typically used in construction deliveries) and is a mid-point between smaller vehicles and articulated vehicles. Total costs of delay to operators have been estimated.

Site failures were assumed to involve the vehicle either returning to the depot or moving onto another destination. Distances for these wasted trips were not available for most sites, so an average of 16.27km was used based on data from Site 7 which had comprehensive data available.

In reality, the diversionary distance will be dependent on whether the vehicle needs to return to base or can go on to another delivery/collection point and so diversion distance could be substantially longer or shorter than 16.27km. This figure fits with a 2003 study of construction within London[25] that estimated journey distances to be between 10 and 25 km. Similarly, significantly longer distances would be ruled out as this would likely affect the number of trips the vehicle could make within a day and therefore impact on the revenue generated. Taking these factors into account, coupled with limited data availability, the study assumes this to be a realistic midpoint. Therefore we have estimated that refused deliveries travel an additional 16.27 km.

Costs are again calculated based on a daily operating cost of £350 per day and a 10 hour working day with 45mins - 1 hour break, putting costs as 38.88 per hour.

Measures that lead to improvements could result in significant savings to operators and the wider economy.

6.2.6 Emissions

Emissions have been measured on the basis of the delay information relating to accessing the site. An emissions profile of the vehicles has been created for each site based on the on-site surveys or information provided using the year of vehicle registration. So for example a vehicle registered in 2016 is assumed to have a Euro VI engine. From this an emissions profile can be estimated. Although this method has a small number of anomalies such as the use of personalised private number plates, this is a small proportion and can be included on a pro-rata basis.

[25] http://www.bre.co.uk/pdf/constructiontraffic.pdf

Without significant information on diversion, idling is the key factor in determining excess fuel consumption as a result of congestion and delay on site and its economic costs. The amount of idling taking place was assumed to be 50% of the total amount of delay time based on the fact that the latest vehicles have stop/start technology that helps prevent accidental idling and these vehicles account for around 50% of those visiting the sites. A typical truck burns around 2 litres of diesel per hour when idling and around 0.63 litres per hour for a van.

CO_2 emissions are calculated on the basis of 2.64 kg of CO_2e per litre of diesel burnt[26].

Local emissions are calculated based on emissions standards and therefore real world emissions may vary. Emissions for lorries are calculated per KWh and a figure of 11.92 KWh per litre of diesel is used in conversion. Emissions for vans and other light vehicles are based on the distance driven, therefore a figure of six litres per 100km is used in conversion.

Total delay time at the site was calculated enabling an estimate to be made of the potential waste in fuel due to delay. The fuel used for wasted trips due to vehicles being refused entry can then be added to show the daily net “unnecessary” localised emissions for the site.

6.2.7 Collisions

No collisions or near misses were recorded during the measurement period. As such no conclusions on this factor can be reached. However it is likely that the introduction of various initiatives such as FORS, CLOCS and WRRR have had a positive impact on reducing the level of incidents.

6.2.8 Infrastructure damage

The use of strict weight regulations as well as active enforcement, help contain potential infrastructure damage as a result of lorries though the damage incurred can alter depending on the types of roads the vehicles are using. Lower quality local roads are far more susceptible to damage from frequent use by lorries than high quality trunk roads and motorways due to build characteristics and surface quality.

Clearly if there is inefficiency in the delivery system with for example 4% of vehicles being turned away, these wasted trips are causing unnecessary road wear. Whilst accurate weight information was not available for all vehicles servicing the sites, assumptions have been made based on legal weight limits and the axle configuration of the vehicles identified. All vehicles were assumed to have maximised their gross weight in at least one direction and so this is likely to present a worst case scenario.

The average gross weight (weight of the vehicle, driver and payload) of vehicles accessing the sites was calculated.

In order to understand the level of wear to the pavement, engineers convert the weights of vehicles into an equivalent number of axles all weighing the same – typically around 8 tonnes (t). It should be noted that front steer axles with just two wheels are plated less (e.g. around 7t or 8t) than typical drive axles which usually have four wheels (e.g. around 10t). The calculations take the differences into account and are known as Equivalent Standard Axle Loads or ESALs. Therefore, the more a vehicle weighs, the more ESALs it has and the more damage is done to the road. However, the relationship is not linear but is in fact a ‘power 4’ relationship. At its most basic assuming an average 8t axle, the relationship is defined as:

$$N_{ESAL} = \left(\frac{Load}{8\ tonnes} \right)^4$$

Using the formula above, the number of ESALs is determined by 2 factors, the gross weight of the vehicle and the number of axles. Each vehicle type was assigned a max gross weight based on the legal limit of that particular axle configuration. Empty legs were not accounted for since journey

[26] http://www.northeastfreightpartnership.info/bestpractice/Publications/Performance%20Management/Monitoring%20and%20Understanding%20CO2.pdf

distances were not available. As such each vehicle is assumed to generate the number of ESALs equivalent to its fully laden leg.

ESALs are determined by looking at the ratio of real axle weights to the theoretical 8t standard axle. As such, each lorry had its gross weight spread between a steering axle taking a load of 8t, and the remaining weight spread equally among the residual non-steering axles. Vans had their weight distributed evenly amongst both axles. For example:

- A typical 3 axle rigid has a maximum gross weight of 26t (incurred at least once on access/egress and assuming it's filled to the maximum).
- 3 axles = 1 steering (8t) and 2 non-steering (26-8 = 18t spread over 2 axles). Therefore weight distribution on each axle is 8, 9, 9t.
- Each axle is then processed according to the formula above to work out the number of equivalent axles.

The service ability of the roads is again important in working out the true impact of the traffic however; this data was not available for this project. Nevertheless, it does provide a method of analysing the relative impact on the infrastructure of each site.

In terms of economic costs incurred due to inefficiencies, this is based on the number of wasted kilometres. The total annual cost of infrastructure damage is estimated based on a damage cost of £0.001 per km and the average number of refused deliveries per day grossed up for the year.

6.2.9 Construction Stages

For the purposes of this report the activities at each site have been allocated to the 'construction stage(s)' that best describes the status of the site during the survey. They are as follows:

- **Site setup and demolition** – Includes establishing welfare accommodation, demolishing existing buildings and clearing the site of debris.

- **Basement excavation and piling** – Typically includes removing excavated material from the site and excavating the basement. As the basement is being dug, piling is required to form the basement walls and structural footings of the building.

- **Sub-structure** – Below ground works include foundations and basement walls. Plant installation can also occur.

- **Super-structure** – Above ground works including the structural elements of the building including floors.

- **Cladding** – Cladding includes the external elements of the building including the façade, roof and glazing.

- **Fit-out, testing and commissioning** – This stage includes all mechanical, electrical, and plumbing installation and testing of newly installed systems.

6.3 Site 1

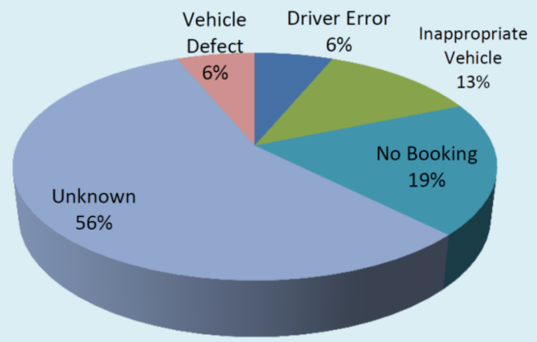
BACKGROUND

Construction stage	Excavations and Pilings
Holding area	YES
Vehicles per day	38
Average delay (Mins)	18:30
Duration performance	GOOD
Delay performance	GOOD

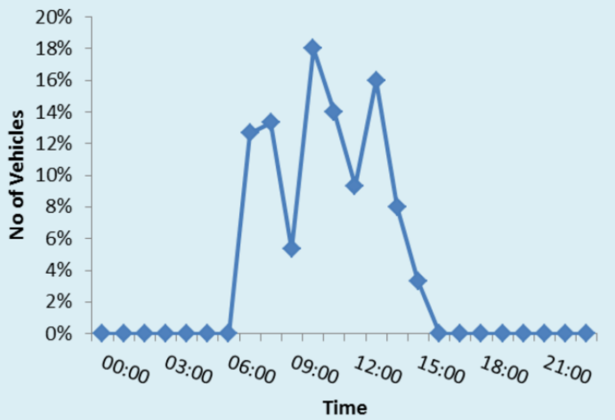
DELIVERY FAILURE and DELAYS

11%

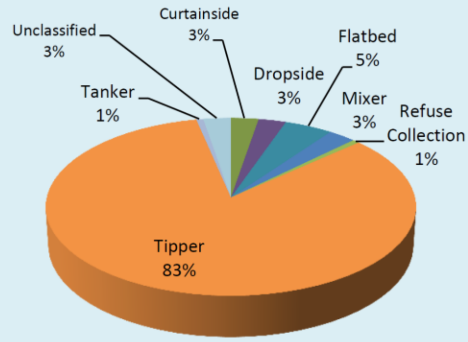
of deliveries were unsuccessful



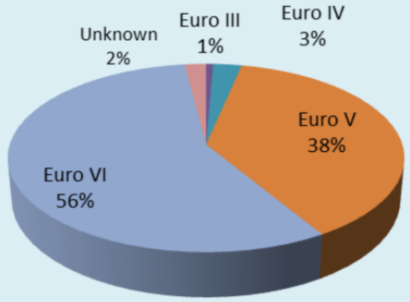
VEHICLE ARRIVAL PROFILE



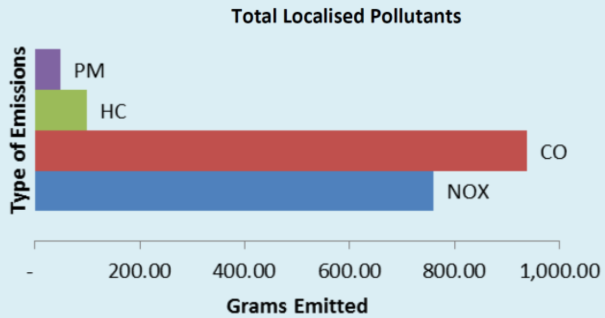
VEHICLE TYPE PROFILE



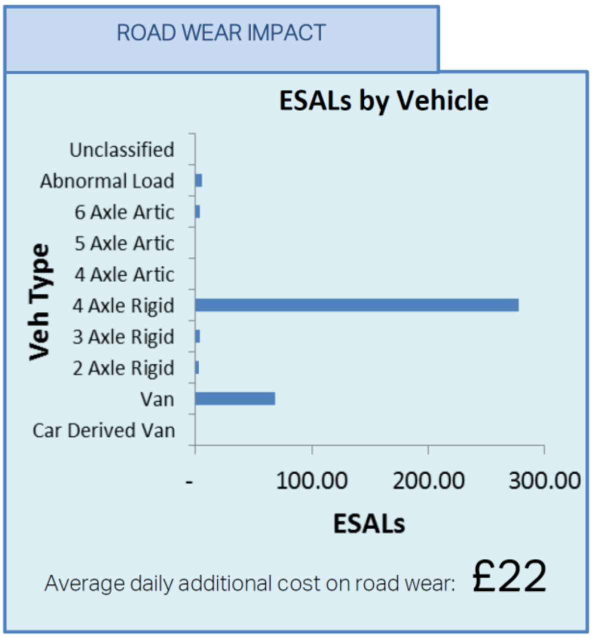
EURO ENGINE STATUS

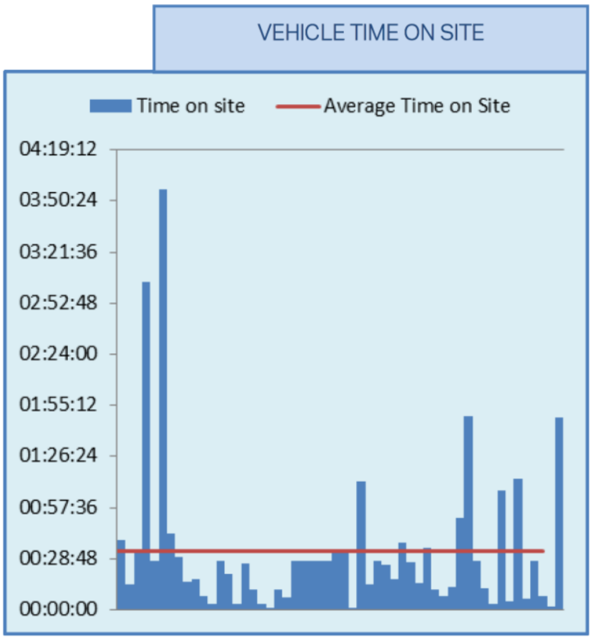


POLLUTION



Daily CO_2 emissions: 39 kg





6.3.1 Summary

This large central London site is currently in the initial stages of excavation and subsequent piling for foundations. The use of the vehicle booking system and VHAs are keeping delays low at the moment, with average delays of 29 minutes. However as the development progresses and requires more complex servicing activities and time sensitive deliveries, it may become more difficult to maintain this level.

Despite strict enforcement of bookings, the management of it may need to be revised as large block bookings are creating waves of vehicles arriving. These are causing delays on the site itself and likely to cause further congestion to the surrounding road network, given the relatively small size of the holding area. Site managers may need to better liaise with operators in order to spread the peaks in vehicle arrivals, which primarily occur in three peaks. This will become more important for the concrete pour where large numbers of vehicles are required to arrive and cannot be held for long periods.

Emissions are being kept low due to a modern fleet with 94% of vehicles being Euro V or Euro VI and low delay times; this may increase if delays increase.

The economic costs in terms of delays and emissions for the site are **£55,441** per annum. A significant proportion (89%) is borne by the operator themselves, such action therefore could result in significant savings to operators and the wider economy.

6.4 Site 2

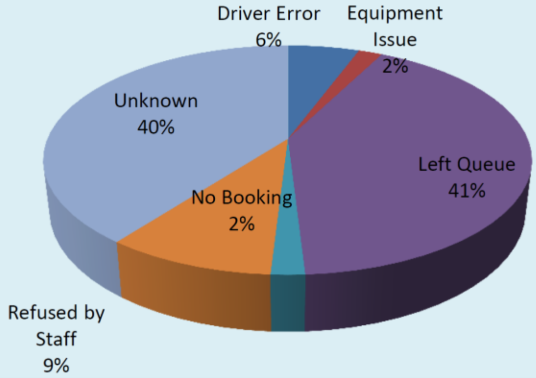
BACKGROUND

Construction stage	Excavations and Pilings
Holding area	YES
Vehicles per day	74
Average delay (Mins)	29:12
Duration performance	AVERAGE
Delay performance	AVERAGE

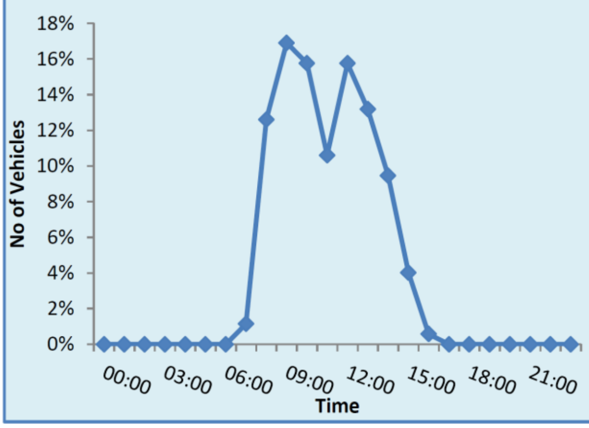
DELIVERY FAILURE and DELAYS

14%

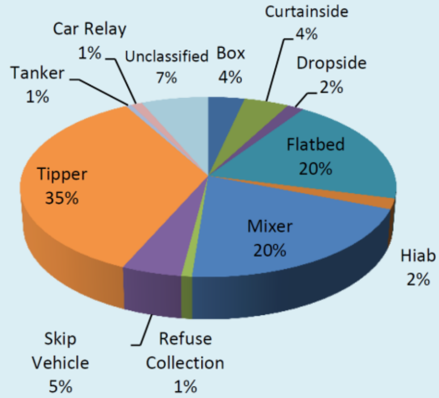
of deliveries were unsuccessful



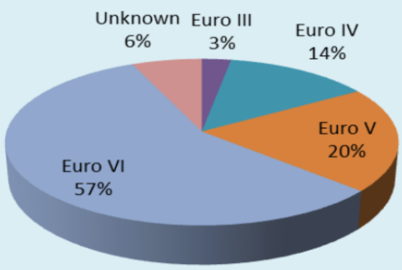
VEHICLE ARRIVAL PROFILE



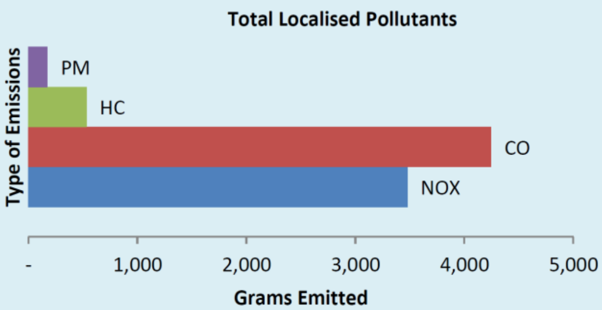
VEHICLE TYPE PROFILE



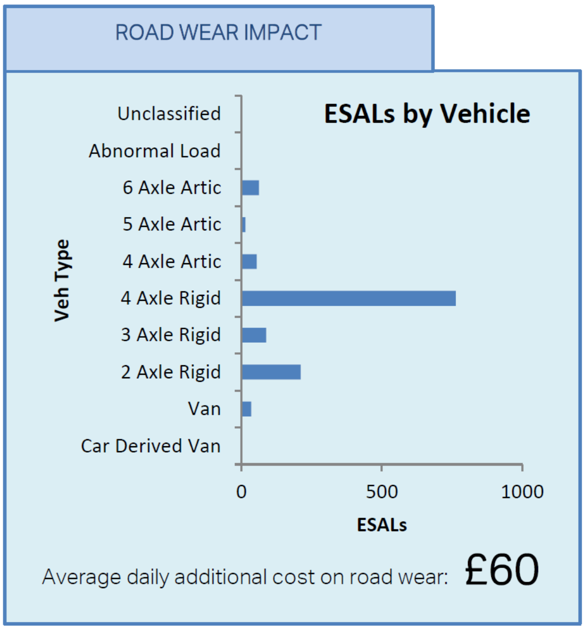
EURO ENGINE STATUS

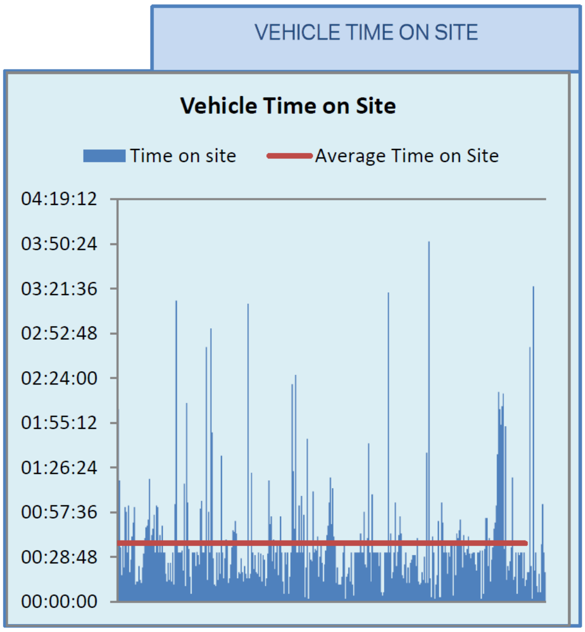


POLLUTION



Daily CO_2 emissions: 174 kg





6.4.1 Summary

This second central London site is also large, receiving on average 74 deliveries per day. The site performs well and maximises its DMS and holding area in order to regulate the arrival times of vehicles. Very few (2%) arrive without a booking and these are often vehicles subcontracted to other logistics operators, suggesting that largely the message around vehicle booking is received by logistics operators and means that waiting times and delays (an average of 34 minutes) are relatively short considering the number of vehicles accessing the site.

That said this site had the highest percentage of vehicle being refused, or choosing to turn away. Around 41% of failed deliveries were due to drivers leaving the queue, seemingly not willing to wait. There were two peaks in vehicle arrivals 0800hrs to 0900hrs and 1100hrs. It was during this period that drivers experienced more chance of delay. Vehicles turning away obviously creates excessive mileage particularly for vehicles with specific loads. Some level of prioritisation and flexibility may be necessary to delay services such as muck-away – that could potentially attend another site in order to provide access for site specific loads. Without visibility of muck-away vehicles in the DMS, this will be difficult to achieve.

There may be some benefits to be gained from altering delivery and receiving windows to later in the day – avoiding the morning peaks, though it may be difficult to shorten the window given the volume of traffic present on the site.

Further benefits could also be gained through working with operators to renew their older Euro IV vehicles to further improve emissions. With substantial economic costs of over **£190,000** per annum for this site, 88% of which is borne by operators and improvements could provide significant economic savings.

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6.5 Site 3

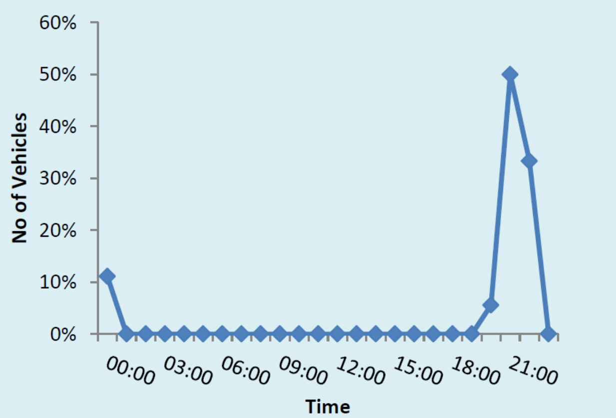
BACKGROUND

Construction stage	Resurfacing
Holding area	NO
Vehicles per day	53
Average delay (Mins)	26:55
Duration performance	GOOD
Delay performance	GOOD

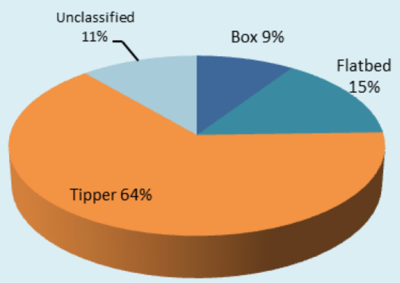
DELIVERY FAILURE and DELAYS

0%
of deliveries were unsuccessful

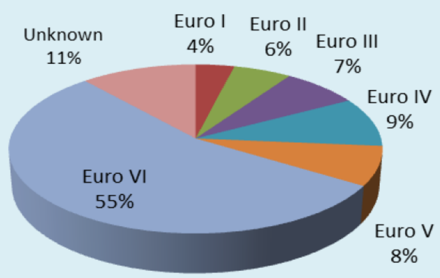
VEHICLE ARRIVAL PROFILE



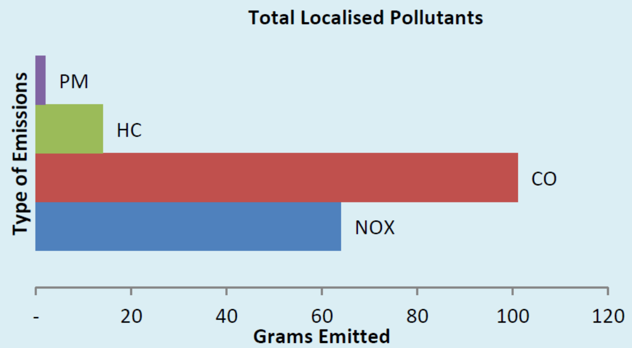
VEHICLE TYPE PROFILE



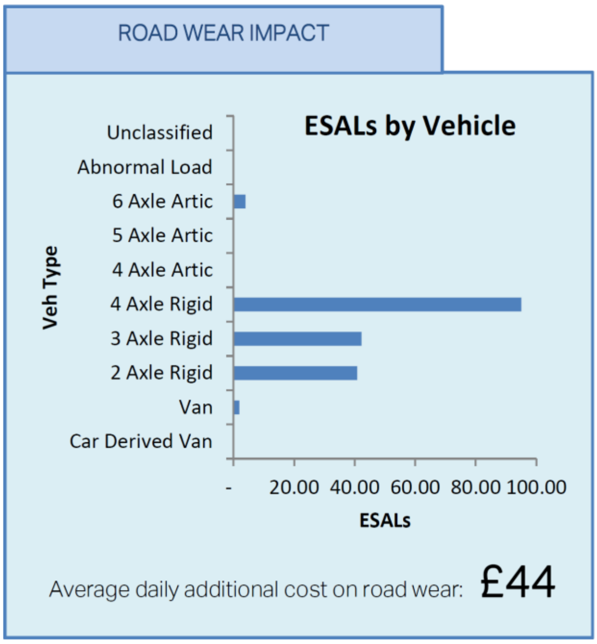
EURO ENGINE STATUS

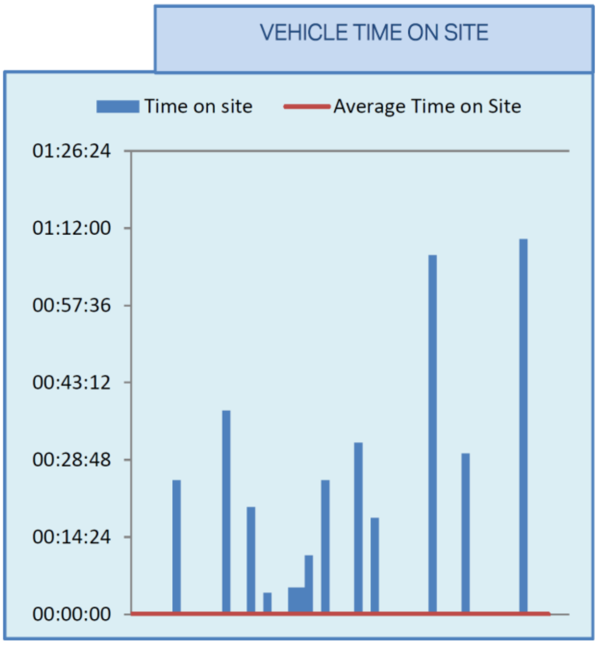


POLLUTION



Daily CO_2 emissions: **15 kg**





6.5.1 Summary

This site was a highway maintenance project with vehicles arriving to resurface a major road at night. The unusual nature of the site meant that there were no failures and few vehicles affected by significant delay.

The majority of vehicles arrived after 1900hrs and this use of out of hours working, whilst not done to facilitate better journey times and reliability, illustrates the clear advantage of doing, road maintenance at night.

Stipulating the use of vehicles under a certain age as part of their contracting and procurement process will further help to improve the air quality of the construction site. Total costs for the site are estimated to be around **£75,209** per annum, 97% of which is borne by the operator.

6.6 Site 4

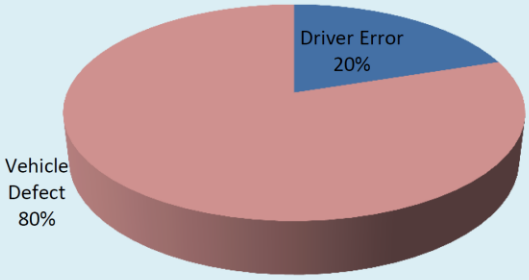
BACKGROUND

Construction stage	Demolition/ excavation
Holding area	YES
Vehicles per day	51
Average delay (Mins)	7:48
Duration performance	GOOD
Delay performance	GOOD

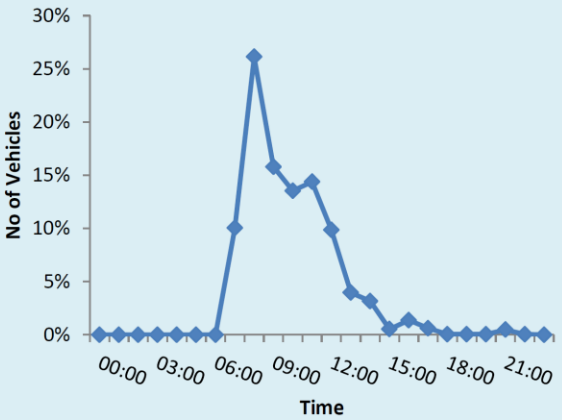
DELIVERY FAILURE and DELAYS

0.78%

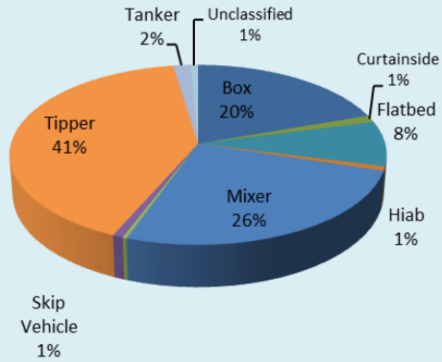
of deliveries were unsuccessful



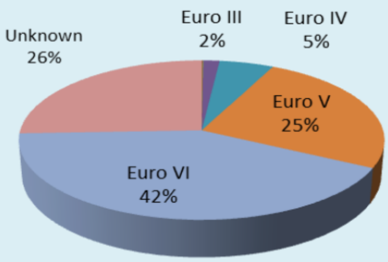
VEHICLE ARRIVAL PROFILE



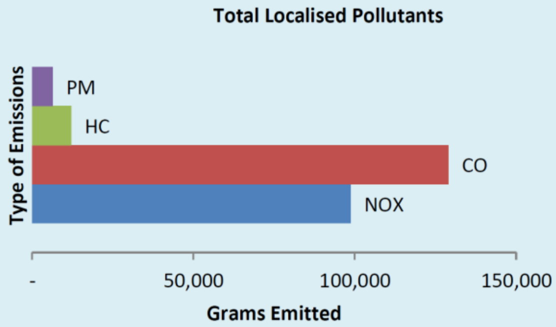
VEHICLE TYPE PROFILE



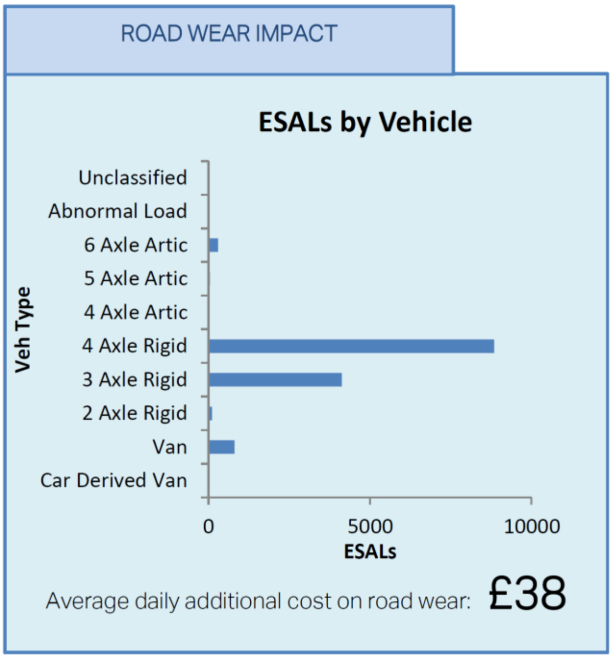
EURO ENGINE STATUS

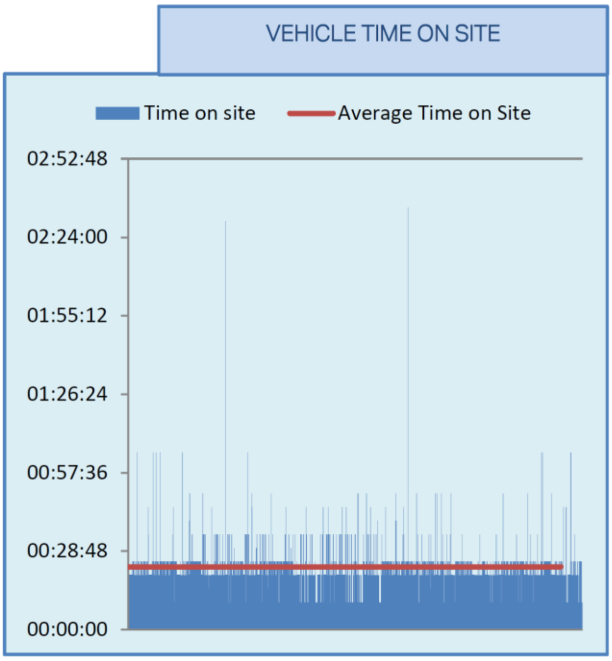


POLLUTION



Daily CO_2 emissions: 6 kg





6.6.1 Summary

This large site, handling 51 vehicles per day had the largest dataset. It also had a number of interesting points around its performance in relation to both direct management factors and external circumstances.

The site’s less than optimal use of its VBMS in conjunction with the large numbers of vehicles accessing the site and external congestion would normally indicate longer delay times and significantly more delivery failures than seen here, However, the opposite is the case with a 1% failure rate and an average delay of less than 8 minutes and this primarily appears to be in light of efficient use of a large loading area that can be used to regulate the flow of traffic. It’s possible that there is some underreporting of delivery failures. Its good performance results in relatively low economic costs for the site, equating to **£22,061** per annum and 92% of these will be borne by the operators.

However a number of lessons can be learned from the site:

- Scheduling vehicle deliveries away from the AM traffic peak could further improve delivery efficiency.
- Better use of VBMS could prevent the need for such large VHAs and allow it to be shared with other sites, reducing management costs and congestion in the surrounding area.
- Use of larger, articulated tippers for muck-away could reduce congestion, emissions and infrastructure damage. They may however have access problems depending on routing.
- Delivery failures were often equipment or training related, better communication to suppliers at all levels could help to reduce these instances. (note, there are a low number of them overall).

6.7 Site 5

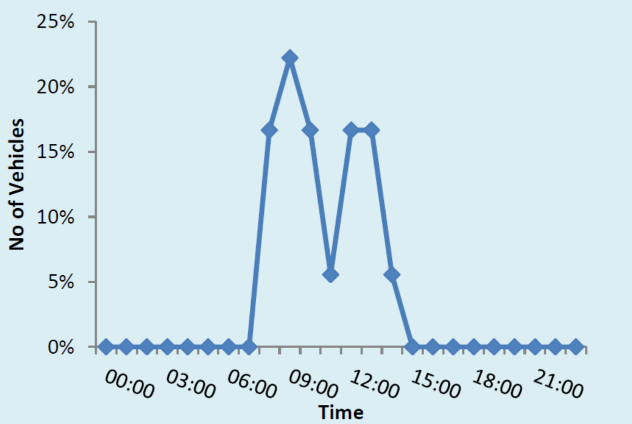
BACKGROUND

Construction stage	Operational
Holding area	YES
Vehicles per day	18
Average delay (Mins)	34:58
Duration performance	AVERAGE
Delay performance	BAD

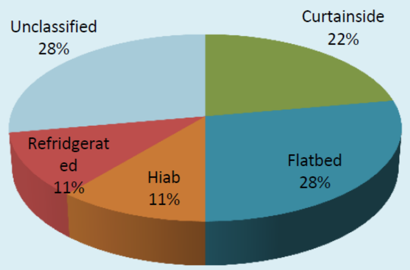
DELIVERY FAILURE and DELAYS

0%
of deliveries were unsuccessful

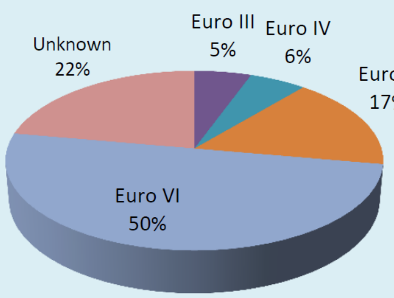
VEHICLE ARRIVAL PROFILE



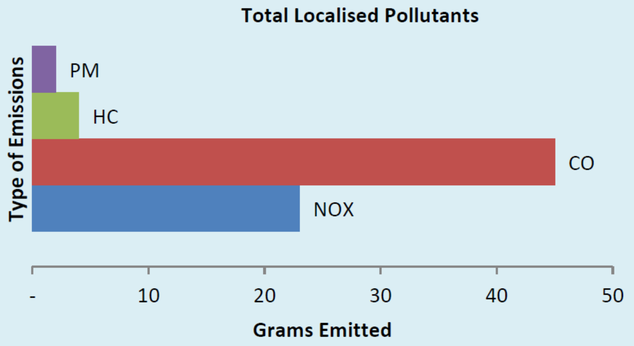
VEHICLE TYPE PROFILE



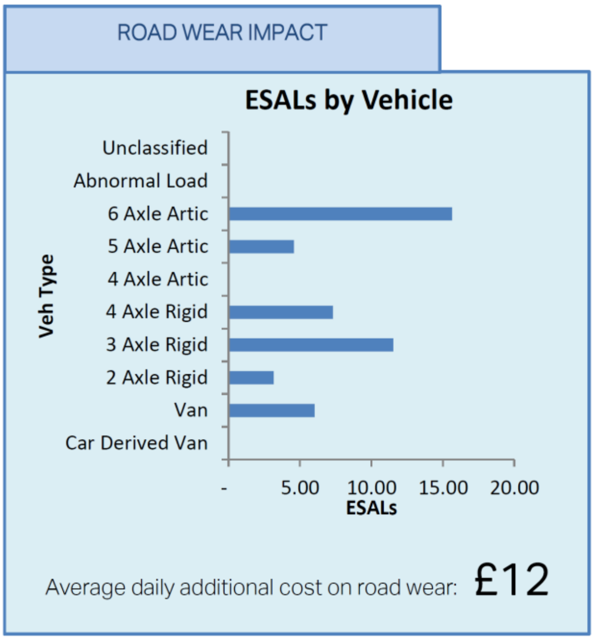
EURO ENGINE STATUS

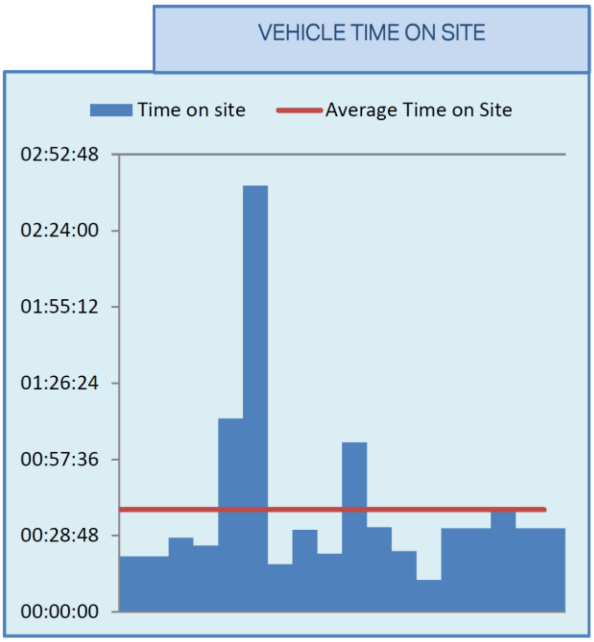


POLLUTION



Daily CO_2 emissions: 9 kg





6.7.1 Summary

The site is a consolidation centre servicing other sites at various stages of construction and observations for the site were taken over the course of one day, in which 18 vehicles were identified as servicing the site. There was both a holding bay and DMS in operation. The site experienced above average delays at over 42 minutes and is one of the few sites for which schedule information was available. The schedule does not correspond to the arrival of any of the vehicles, suggesting these times are largely ignored and the DMS is simply a booking rather than scheduling system.

Vehicles arrived in a relatively narrow portion of the day (between 0600hrs and 1400hrs) given the site is open 24 hours and there could be opportunities to explore broadening this window should the number of vehicles needing to be received increases. The first wave of vehicles also coincided with the morning rush hour – efforts to shift this later may improve delivery time and reliability.

Total costs per annum for the site due to delay and diversion are forecast to be **£ 21,236** per annum**,** and 96% of these are borne by the operator.

6.8 Site 6

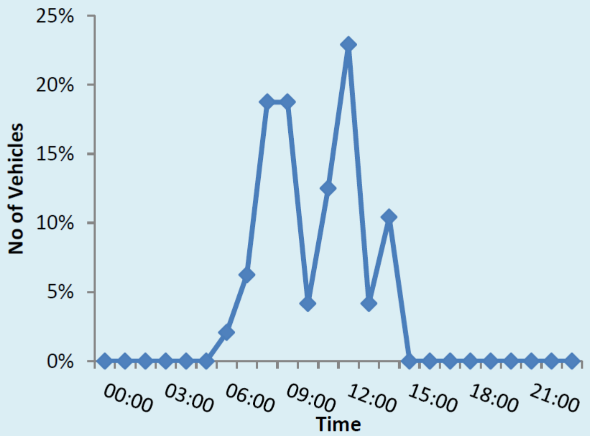
BACKGROUND

Construction stage	Operational
Holding area	YES
Vehicles per day	11
Average delay (Mins)	42
Duration performance	GOOD
Delay performance	BAD

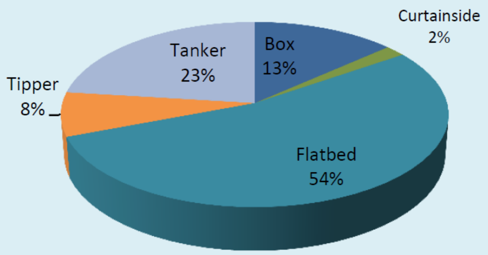
DELIVERY FAILURE and DELAYS

0%
of deliveries were unsuccessful

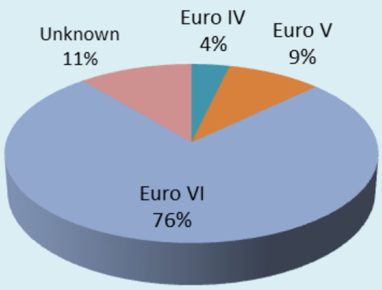
VEHICLE ARRIVAL PROFILE



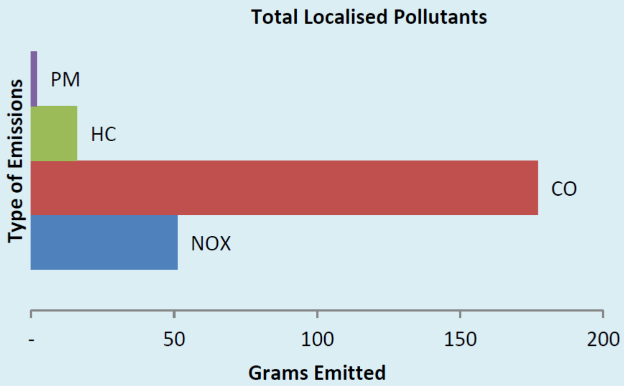
VEHICLE TYPE PROFILE



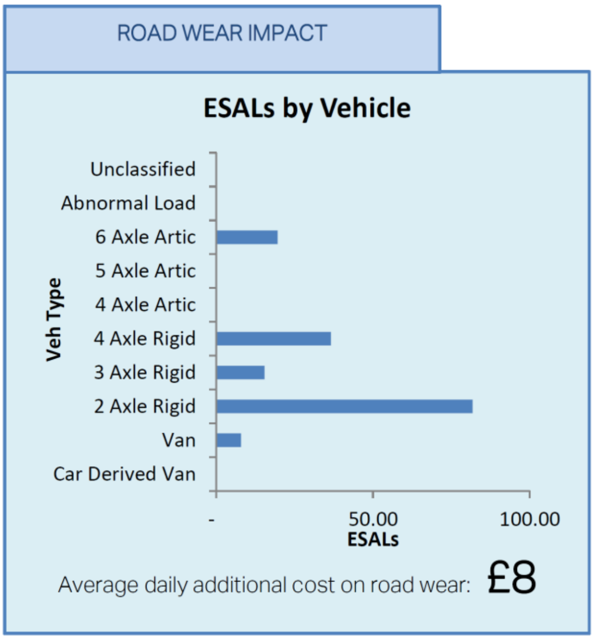
EURO ENGINE STATUS

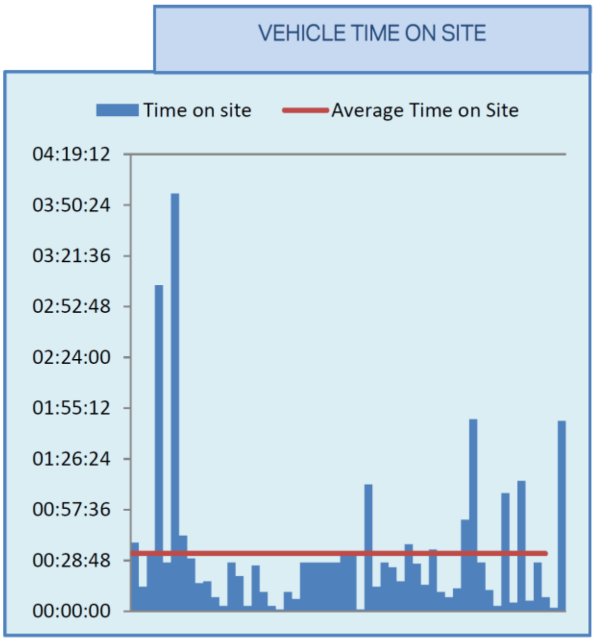


POLLUTION



Daily CO_2 emissions: **6 kg**





6.8.1 Summary

This small site was surveyed over five days and recorded 54 vehicles accessing the site. There was a holding bay with capacity for approximately two vehicles and a DMS was in place.

The site differs operationally from other sites in that there appears to be a mixture of vehicles servicing the operational needs of the site as well as standby vehicles, not specifically related to the site but being positioned there. Outside of these, long dwell times given the level of traffic were also apparent.

Despite this, vehicle arrivals were erratic and peaks coincided with rush hour, primarily between 6am and 1000hrs. Better use of the delivery management schedules to even out deliveries and move them later in the day could create significant benefits for the sites efficiency, particularly if further vehicles are required to be serviced.

The number of two axle rigid vehicles used at the site is a concern and together with evidence from observation suggests that smaller quantities of goods are being delivered to the site. Use of consolidation to enable fewer deliveries can improve efficiency and reduce operator costs, depending on the nature of goods involved.

Total costs of delay and diversion at the site are forecasted to be **£24,565** per annum, of which 98 % is borne by the operator.

6.9 Site 7

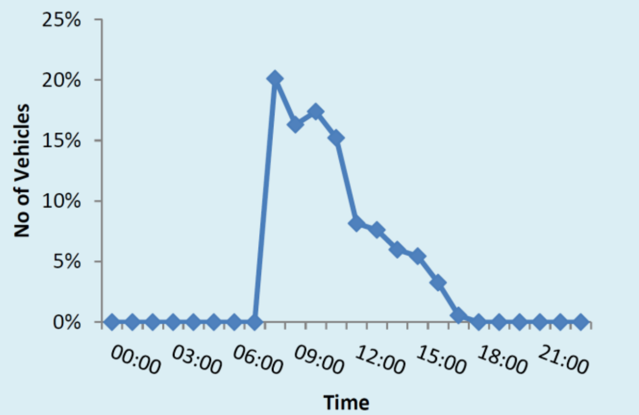
BACKGROUND

Construction stage	Demolition/ excavation
Holding area	NO
Vehicles per day	9
Average delay (Mins)	24
Duration performance	GOOD
Delay performance	AVERAGE

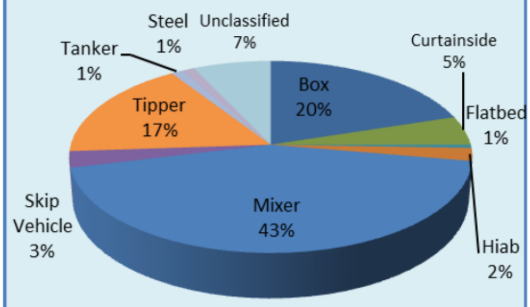
DELIVERY FAILURE and DELAYS

0%
of deliveries were unsuccessful

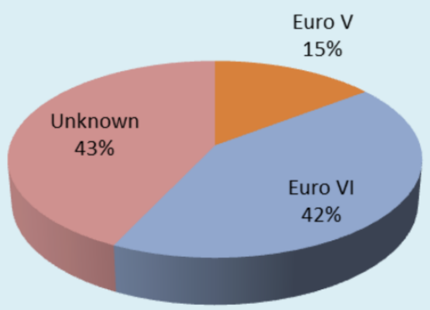
VEHICLE ARRIVAL PROFILE



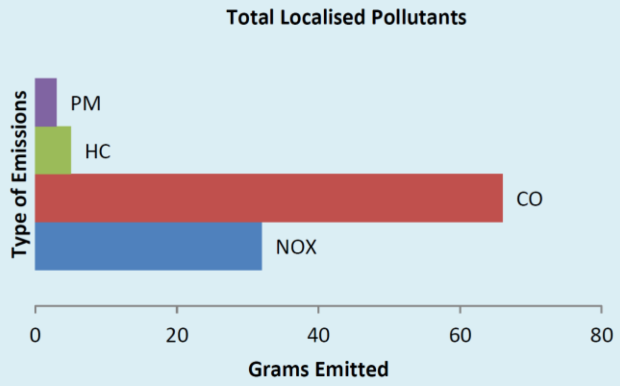
VEHICLE TYPE PROFILE



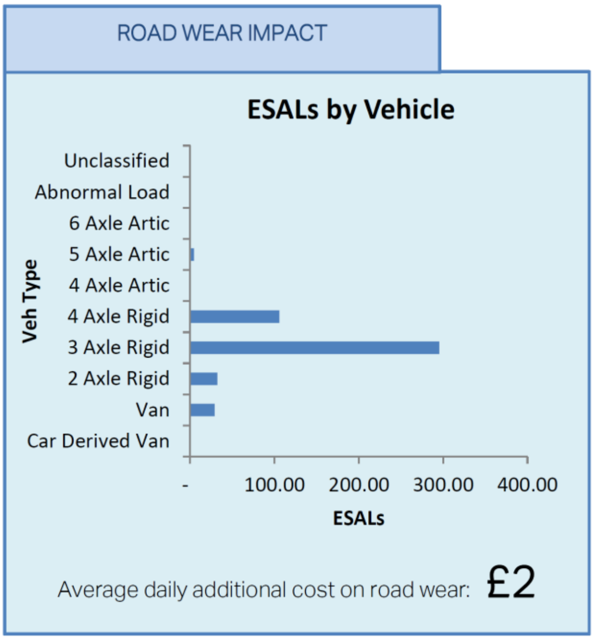
EURO ENGINE STATUS

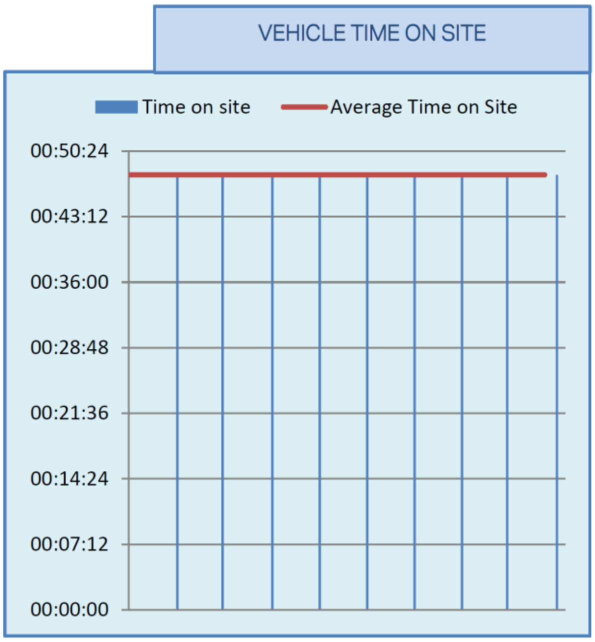


POLLUTION



Daily CO_2 emissions: **20 kg**





6.9.1 Summary

This small site in Inner London is in the demolition/excavation stage. The site receives an average of nine vehicle deliveries per day. Limited information for this site was available although some data such as the distance vehicles had travelled to the site was available. The data demonstrated the clear benefits of deploying newer vehicles in terms of air quality, with all identified vehicles being either Euro V or Euro VI and generating around 109g of localised pollutants per day. The site is being effectively managed as no delivery failures were reported during the survey period. This suggests that suppliers are aware of the requirements for entering the site and management have the right balance of flexibility in terms of accepting unscheduled deliveries. Costs for the site are forecast to be relatively low – around **£5,600** per annum for the site, of which 97% is borne by the operator.

6.10 Site 8

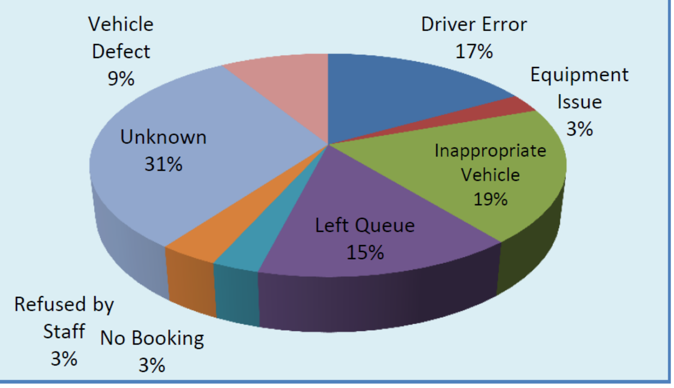
BACKGROUND

Construction stage	Fit out
Holding area	NO
Vehicles per day	21
Average delay (Mins)	29
Duration performance	AVERAGE
Delay performance	AVERAGE

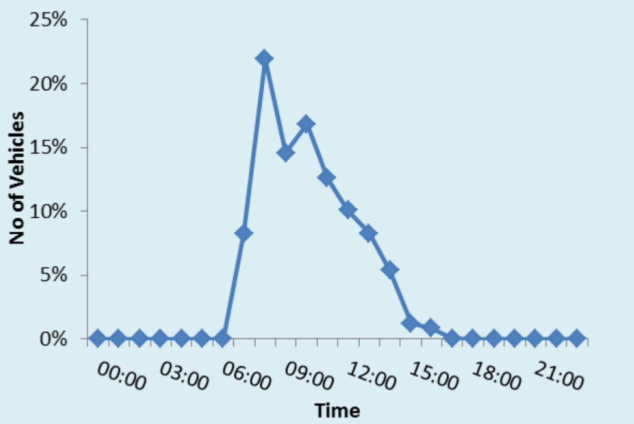
DELIVERY FAILURE and DELAYS

3%

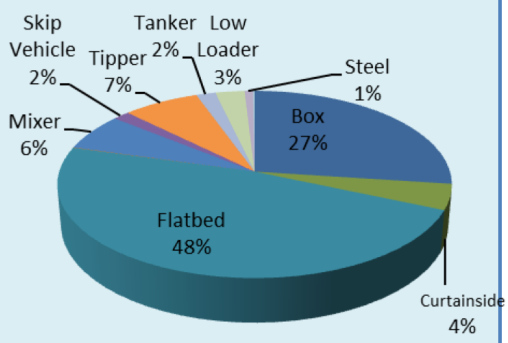
of deliveries were unsuccessful



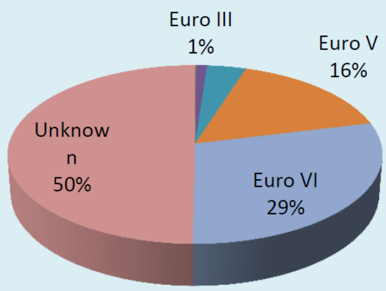
VEHICLE ARRIVAL PROFILE



VEHICLE TYPE PROFILE

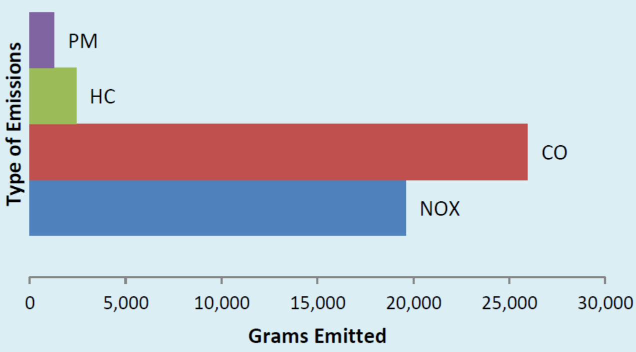


EURO ENGINE STATUS

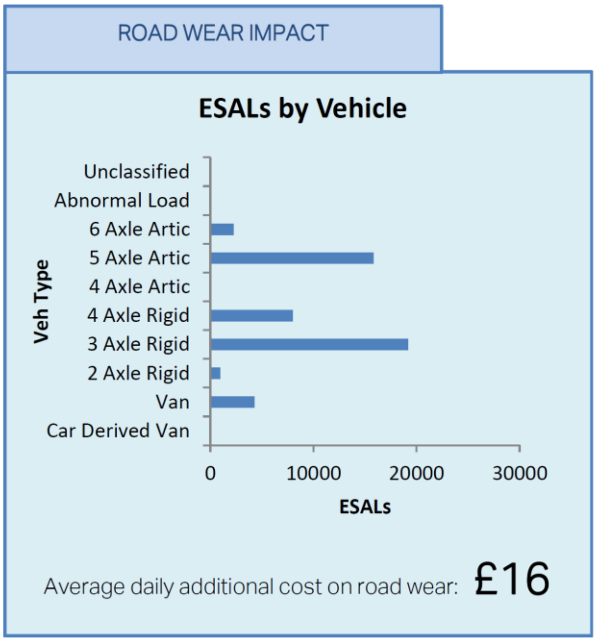


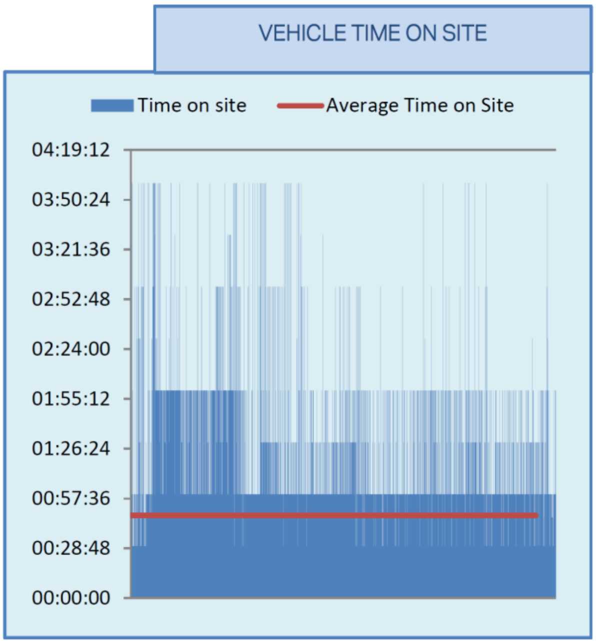
POLLUTION

Total Localised Pollutants



Daily CO_2 emissions: 10 kg





6.10.1 Summary

This site is fairly busy with 21 deliveries per day and hence classified as medium. The large amounts of data provided a reliable set of trends though the lack of details on factors like vehicle age and type limited its value. This highlights a major issue with many of the sites in that few collect data in a uniform manner and often not in the detail required to produce a consistently meaningful analysis There is a significant opportunity to assess the value of construction logistics and further improve performance.

Delays of 25 minutes aren't above average across the sample, and the number of failures was small – at around 3%. Significant sources of failure include failure to book and failure to have an appropriate vehicle, with some deliveries ultimately being turned away.

There are also significant incidences of vehicles leaving of their own accord, possibly due to congestion around the single gate in use. This may be drivers acting independently, or more likely transport managers directing vehicle onto other deliveries/collections where turnarounds are higher.

Better use of the delivery management/vehicle booking system, and efforts to communicate their importance to operators could help to reduce onsite delays.

Total cost of the site due to delay and diversion is forecasted to be **£82,037** per annum, with 98% being borne by the operator.

6.11 Site 9

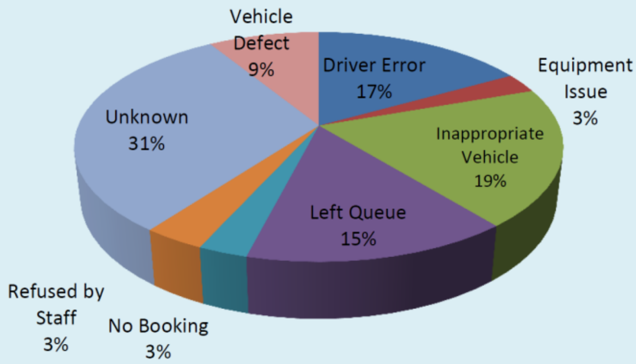
BACKGROUND

Construction stage	Excavations and Pilings
Holding area	NO
Vehicles per day	50
Average delay (Mins)	36
Duration performance	BAD
Delay performance	AVERAGE

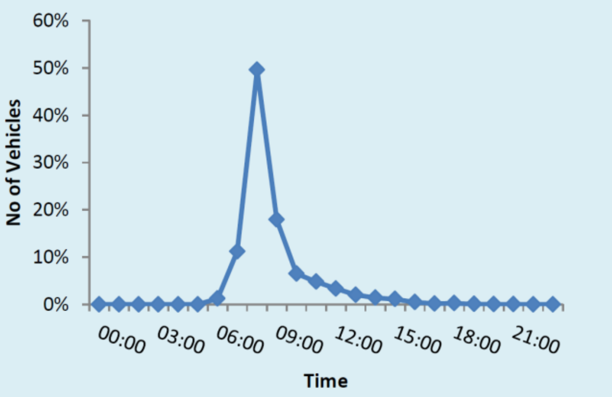
DELIVERY FAILURE and DELAYS

3%

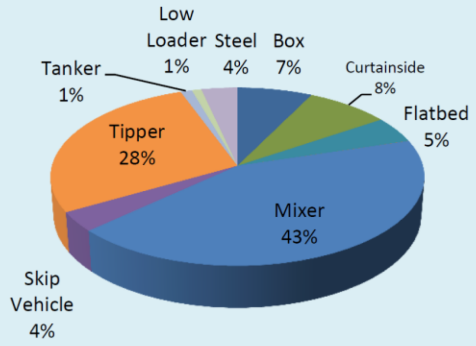
of deliveries were unsuccessful



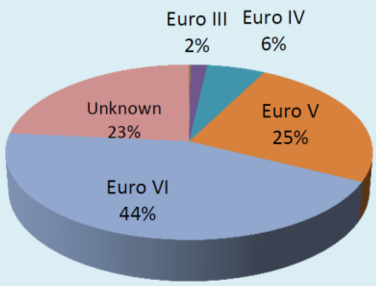
VEHICLE ARRIVAL PROFILE



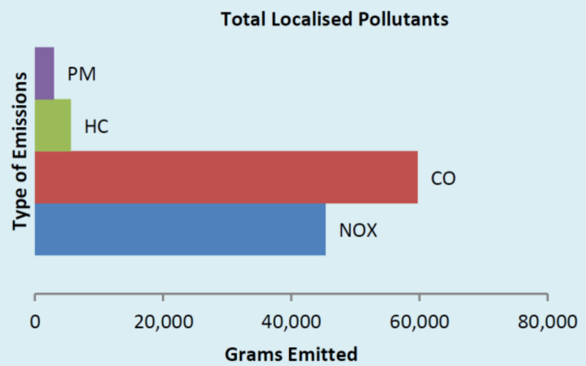
VEHICLE TYPE PROFILE



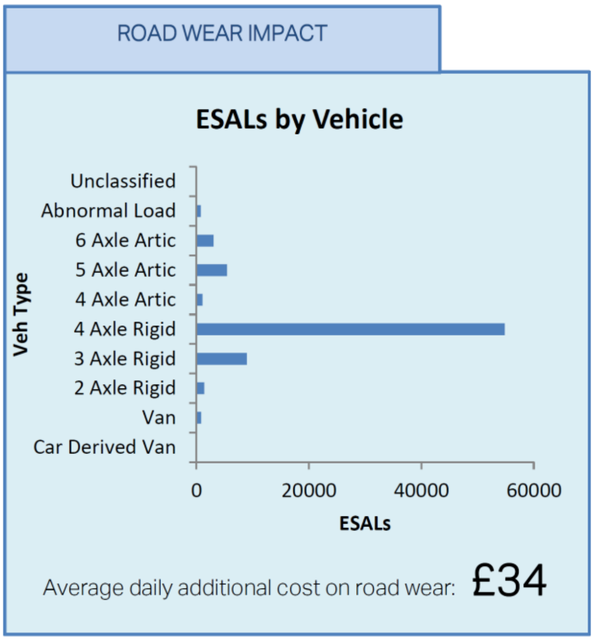
EURO ENGINE STATUS

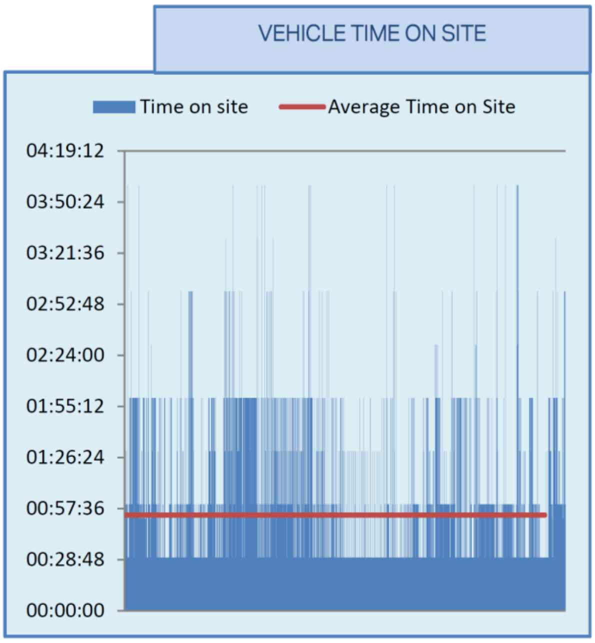


POLLUTION



Daily CO_2 emissions: 8 kg





6.11.1 Summary

The site is one of the largest surveyed, with an average of 50 trucks accessing the site per day. With this level of delivery intensity, and no holding area, careful management of deliveries is important. The site is rated as bad with delays of over 36 minutes, likely to be due to the lack of a holding area. As such there are a number of areas that would benefit from efficiencies. This includes the scheduling of vehicles outside of the AM peak and where possible distributing them throughout the working day, with 71% of vehicles arriving between 0600hrs and 0900hrs though this may not be possible given the type of activity at the site.

Whilst reasons for delivery failures were quite varied, better communications with contractors to solve issues such as failure to book, defective vehicles and driver errors can further help to reduce delays and delivery rejections.

The total economic cost of the site is forecasted to be **£130,398** per annum due to delay and diversion, of which 97% is borne by the operator.

6.12 Sites 10-19 (Small Sites)

There are 10 sites within those surveyed with average daily vehicle counts of 10 or less. There is also little data available in terms of vehicle dwell time or delay and as such only provide limited information on the nature of activities at the site. These are listed is below:

Table 6:5 Small Sites Summary

Site No	Location	Construction Stage	Vehicle Dwell Time	Vehicle Delay	Vehicles Per Day	Size	Duration Performance	Delay Performance
10	Outer	Pending	-	-	0	Small	NA	NA
11	Inner	Pending	-	-	5	Small	NA	NA
12	Inner	Pending	-	-	0	Small	NA	NA
13	Central	Pending	-	-	1	Small	NA	NA
14	Central	Pending	-	-	1	Small	NA	NA
15	Central	Pending	-	-	2	Small	NA	NA
16	Central	Pending	-	-	2	Small	NA	NA
17	Inner	Pending	-	-	0	Small	NA	NA
18	Central	Pending	-	-	3	Small	NA	NA
19	Inner	Pending	-	-	2	Small	NA	NA

6.12.1 Vehicle profile

A wide variety of vehicles serviced the sites, as each were at different stages of construction. **Figure 6.1** shows the breakdown of vehicle types servicing the small sites.

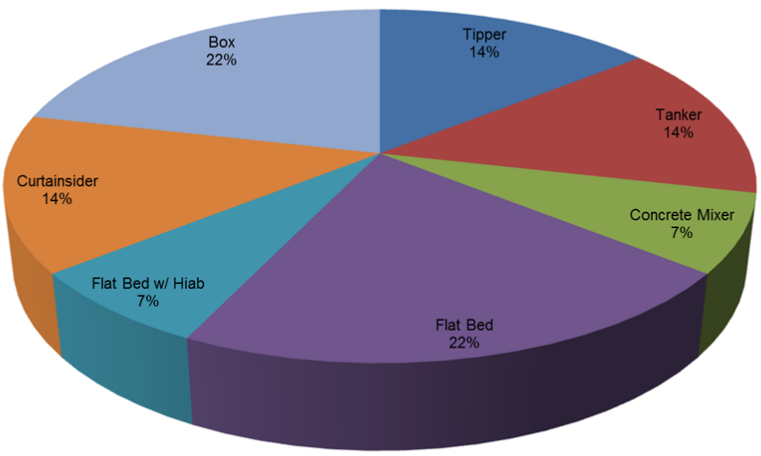


Figure 6.1: Vehicle Body Profile - Small Sites

The most numerous vehicle types were flat bed and tipper suggesting a significant number of sites are in the excavation and piling phase of construction. Others include curtainsiders and tanker vehicles providing deliveries of larger quantities, bulk materials and support services.

Levels of FORS compliance were high across the sites with levels of accredited vehicles between 90 and 100%.

6.12.2 Delivery success / failure rate

Across all 10 sites, 66 failures out of a total of 1553 deliveries were recorded. This leads to a failure rate of approximately 4% **Figure 6.2** shows this in detail.

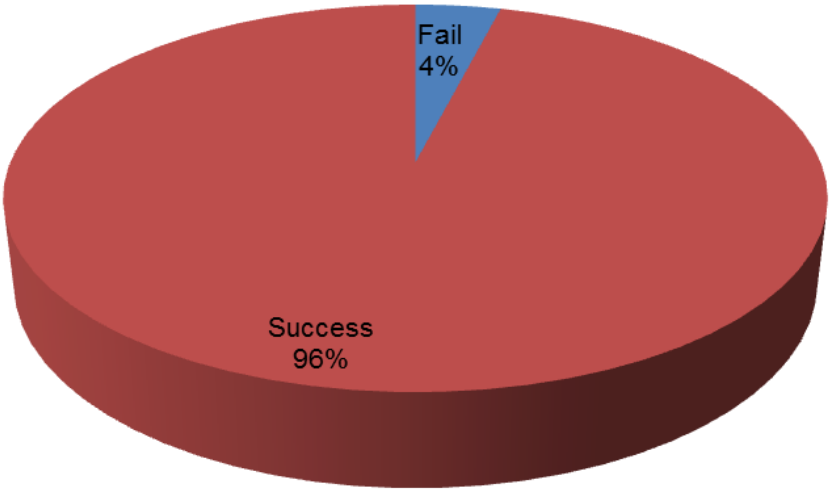


Figure 6.2: Delivery Success - Small Sites

Figure 6.3 shows the reasons for delivery failure, almost half were due to inappropriate vehicles or a lack of vehicle equipment and over a quarter were a result of a lack of driver training. This shows that site requirements under FORS are being adhered to. This is much lower than that seen at other sites.

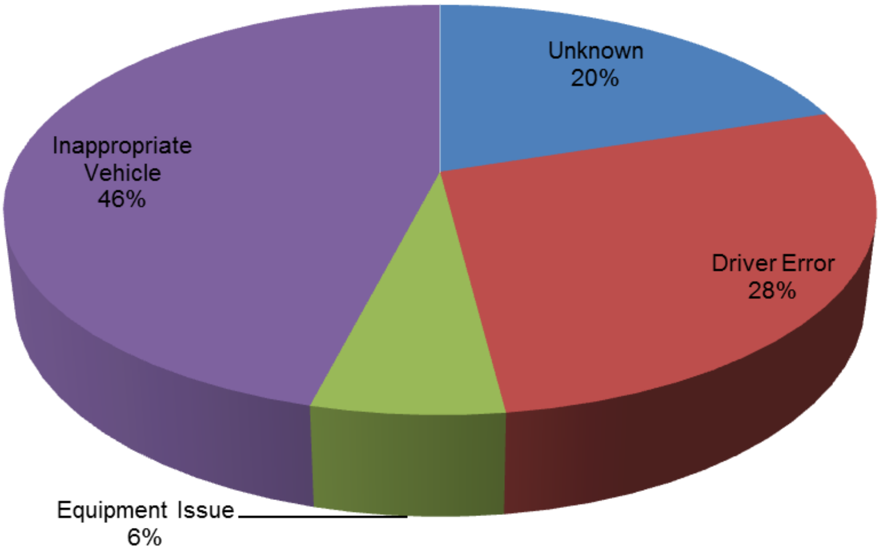


Figure 6.3: Reasons for Delivery Failure - Small Sites

However, a number of vehicles with defects are being let in and this shows that sites strike a balance between procurement rules and site access and allowing critical vehicles onto site, even if not all criteria are met.

6.12.3 Congestion (arrival time / delays) & emissions

Congestion and emissions from each site have therefore been calculated based on averages across the other sites shown. However given the low number of vehicles accessing the sites, such levels of delay are unlikely. As such this is not being reported.

6.12.4 Collisions

No collisions or near misses were recorded for these sites during the measurement period.

6.12.5 Infrastructure Damage

The average gross weight of vehicles servicing the sites was 23.5t and generated 4,570 ESALs across the sites or around 450 ESALs per site. However, this was typically across a period of a month and therefore average ESALs per site, per day were around 15, therefore incurring negligible amounts of road damage.

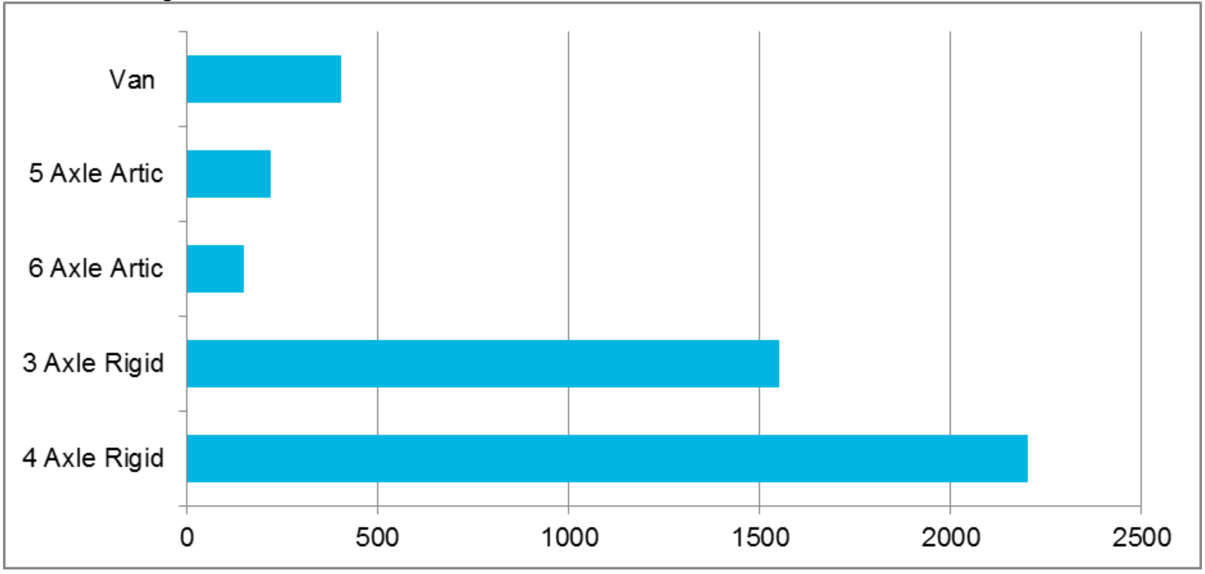


Figure 6.4: ESALs by Vehicle Chassis Types - Small Sites

Figure 6.4 shows the distribution of ESALs across different chassis types. It can be seen that four axle rigid vehicles generate the most ESALs, around 49%, despite only accounting for 39% of the traffic. As such consolidation or the use of articulated tippers that further spread the load may be an option to further limit road damage and improve the efficiency of the sites.

6.12.6 Summary and lessons learned

Due to the low number of vehicles it is unlikely that intervention is required to prevent delay and diversion unless particular road conditions present a hazard or create excessive congestion on the surrounding network and this should be highlighted in the construction logistics plan.

The number of failed deliveries could be underreported and the number of vehicle equipment and driver training issues is significant, despite the relatively low level of vehicle activity. Further engagement with suppliers, around their obligations concerning vehicle equipment may be needed and suppliers should be given a guide and potentially a presentation regarding these obligations at the time of procurement.

7. Findings

7.1 Introduction

This chapter outlines our findings from primary data collection, stakeholder consultation and the analysis and impact modelling.

7.2 Site management

In some cases, significant variance is witnessed between scheduled vehicle arrival time in DMS or VBS and actual arrival time at site, although this did not lead to the vehicle being turned away (if late) or having to wait (if early). It is appreciated that journey times can be significantly influenced by road network conditions and traffic levels. Some sites also used their DMS as a log of vehicles due that day, rather than paying particular attention to the exact time specified. Instead it was more fluid and dynamic, with close interaction between the vehicle holding area and the site entrance controlling entry in a way to reflect site requirements and on-site activity.

Vehicles with no booking were witnessed either being turned away (failed delivery) or having to call the site to make an emergency booking and having to wait to gain entry. The stipulation to turn vehicles away varied from site to site and was dependent upon the sites ability to accommodate the vehicle (at some point) and hold the vehicle safely off site until such time that access could be granted.

Successful use and implementation of the DMS appears to vary by site activity and vehicle type required. Concrete mixers and tipper lorries are more difficult to schedule accurately due to the nature of the construction activity they are associated with and the movement patterns they tend to work to. In most cases they were booked in waves or clusters of vehicles sometimes under one DMS booking.

They were then expected to be returning to site at regular intervals across the rest of the working day. These vehicles are well-accommodated in VHAs as it enables them to arrive across a period of, say, 15 minutes, before being sent on to site at regular intervals for a concrete 'pour' or to respond to muck-away requirements.

The VHAs require careful and assertive management by gate staff / traffic marshals to ensure vehicles / drivers manoeuvre and park up properly and cause minimal disruption to other vehicles and Vulnerable Road Users.

7.3 Delivery management system

In some cases DMS is used to schedule a significant proportion, but not all vehicle trips. It also appears there is some speculative booking of slots to cover all eventualities. This raises possible questions around the level of supply chain forward planning occurring and if more could be done.

Some DMS booking systems required multiple days of notice for deliveries, with booking cut-offs anywhere from 1 to 48 hours in advance of start of day (0800) of delivery. Some logistics operators commented that earlier deadlines often caused them to make 'contingency bookings' when unable to confirm exact date of delivery.

At one of the sites only vehicles with damaged goods or 'unsafe to process loads' results in failed deliveries. Emergency bookings are allowed and could be requested but only by suppliers/clients and not drivers when at site.

DMS can be an effective tool for managing deliveries, especially for medium to large sites. However it is important that operators know that DMS is in use and both management and drivers have appropriate training in what to do. Our findings suggest that the DMS schedules are not always a true reflection of what is happening on the ground and this level of inconsistency must affect several factors including site resourcing, vehicle flow, waiting times and ultimately the number of vehicles that have to be turned away. It is not essential to have vehicle tracking data for DMS to work properly but for large sites having full visibility of vehicle movements would be an advantage.

The type of site management and the number different companies involved with planning, and booking, using DMS can potentially hinder the process. Depending on the nature of the site there can be a number of different companies/stakeholders involved i.e. site owner, main contractor, logistics contractor, main supplier, subcontractors etc. This can potentially lead to a disconnection between the DMS and its use and enforcement and subsequent expectations of each stakeholder. There needs to be clear leadership and ownership of the DMS and the requirements and expectations of its use and enforcement need to be explicit.

There appears to be significant variation between different DMS's, their capabilities and use by stakeholders, ranging from basic vehicle scheduling with little monitoring and enforcement, to full vehicle movement planning with a series of metrics/KPIs and remedial actions for non-compliance. Variations across a wide spectrum of elements including:

- Different terminology used;
- Scope and functionality;
- Data requirements and capture;
- Use at the site/gate and subsequent feedback in to the DMS;
- Different metrics/KPIs;
- Monitoring levels vary;
- Reporting is different; and
- Remedial actions vary.

7.4 Vehicle Holding Areas (VHAs) / Vehicle flow management

Different types of VHAs have been identified:

- Within the construction site itself
- Adjacent or nearby to the construction site both on and off street locations
- Remote from the construction site on or near the main delivery route (including unofficial VHAs such as service stations)
- Consolidation centres – could also be considered as a form of holding area, although it is not their principal function

All of the stakeholders involved in this project indicated that they thought having a vehicle holding area was a very positive measure for vehicle management. In some cases, it was believed that without a holding area the construction site might struggle to cope effectively with vehicle arrivals and departures. Vehicles not arriving when scheduled, increases the likelihood of issues at the site gate such as being turned away, blocking the road and causing issues for other road users.

Externalities including congestion, roadworks, on-site incidents i.e. equipment breakdown, off-site incidents (vehicle collision), bad weather, driver illness etc. can all have an impact on the effectiveness and use of both DMS and VHAs. In particular, VHAs were demonstrably used when such externalities arose and enabled site staff to better manage vehicles.

Some stakeholders mentioned public/development control authorities had negative perceptions of the impacts of VHAs on congestion and workability. Evidence suggests, however, that without these areas there would be significantly higher levels of congestion and negative externalities on related corridors.

Multiple vehicles - e.g. tippers undertaking muck-away can wait in the holding area until needed and allow site activities to progress efficiently with minimal waiting time between vehicle arrivals. “Site managers need to consider the urgency and costs of vehicles coming on site. This also allows greater flex in order to prioritise more urgent deliveries, such as Concrete mixers especially those with “wet mix” that need to be handled quickly during a concrete pour as ready-mixed concrete has quite a short shelf life. Vehicle holding bays/areas are a multipurpose space used to validate deliveries, buffer against peaks in delivery vehicle arrivals, hold delayed or unexpected deliveries, and act as unloading bays when on-site unloading areas are congested.

7.5 Operator engagement

‘Bunching’ of deliveries occurred (i.e. 0700hrs or 1000hrs), throughout the day at some sites as drivers often would start shifts at similar times leading to peaks in number of delivery vehicles accessing each site.

Varying levels of awareness exists amongst contractors, suppliers, logistics operators of using DMS and then subsequently adhering to what they have booked or understanding what the compliance requirements are - i.e. being turned away if they are not on time or booked in etc.

Some drivers commented on the difficulty of using online DMS entry forms.

7.6 KPIs / benchmarking

The current situation appears to consist of a lot of stakeholders using DMS, but not really undertaking much in the way of setting metrics/KPIs, monitoring, reporting, remedial actions etc.

It is useful to think about retail sites as a comparator in terms of process, with larger retail centres you get a tight delivery/collection window, which you have to keep long delays, refused deliveries or even financial penalties are features of certain supply chains within the retail sector. Although construction is a more uncontrolled environment compared to a process based logistics centre, it will depend on the process as to whether you can use just in time or task based deliveries.

7.7 Analysis and impact modelling

The analysis and impact modelling serves to further support the findings across sections 7.2 to 7.6. In addition to that, the analysis highlighted the ability to mitigate the environmental impacts of site delays through the use of newer vehicles, which have reduced emissions. Where delays are expected and cannot be avoided; for example due to site location, or nature of the activity, ensuring that the newest vehicles service the site, can help to reduce the effects of those delays on local air quality. Many newer vehicles have 'stop-start' technology to lessen the amount of engine idling time. Also Euro VI vehicles have much more sophisticated engine technology and exhaust treatment systems which reduce emissions such as NOx and $PM_{10.}$

Secondly, analyses of vehicle types indicate that there is a reliance on rigid vehicles for the majority of deliveries and collections including muck-away. This may be for a combination of reasons such as vehicle availability, site conditions, e.g. good traction or uneven or muddy ground, or access constraints. The business case for using articulated vehicles where possible, to maximise payload, has been proven in some of case studies[2]. With a payload of 29 tonnes versus 20 tonnes on a rigid, articulated vehicles have the potential to reduce the number of deliveries and in turn reduce congestion, emissions and road damage per tonne of payload . But articulated vehicles are not necessarily the answer for all sites as there are manoeuvrability and potential parking issues in constrained sites and indeed in neighbouring streets.

Finally, a significant proportion of delivery failures across a number of sites were related to either driver training or vehicle equipment issues. Better engagement with contractors and likewise their subcontractors to emphasis the requirements for delivery to the site as well as assisting them in providing qualified drivers and equipment can reduce delays on site as well as improve the safety of vulnerable road users in general. The following sections draw out further key trends between the sites in terms of both size and construction phase.

7.7.1 Construction phase comparison

The sites have been split into a total of six different categories in order to enable comparison against different construction phases. **Table 7.1** summarises these below.

Table 7.1 Sites by construction phase

1	Basement Excavation & Piling	11	Site Setup & Demolition
2	Basement Excavation & Piling	12	Basement Excavation & Piling
3	Sub-Structure	13	Site Setup & Demolition
4	Site Setup & Demolition	14	Basement Excavation & Piling
5	Not Applicable	15	Site Setup & Demolition
6	Fit out, Testing & Commissioning	16	Site Setup & Demolition
7	Site Setup & Demolition	17	Site Setup & Demolition
8	Fit out, Testing & Commissioning	18	Site Setup & Demolition
9	Basement Excavation & Piling	19	Site Setup & Demolition
10	Site Setup & Demolition		

The majority of sites are in the initial phases of development – either clearance and setup or excavation and piling.

Figure 7.1 overleaf looks at the average number of vehicles as well as the average delay time for each construction

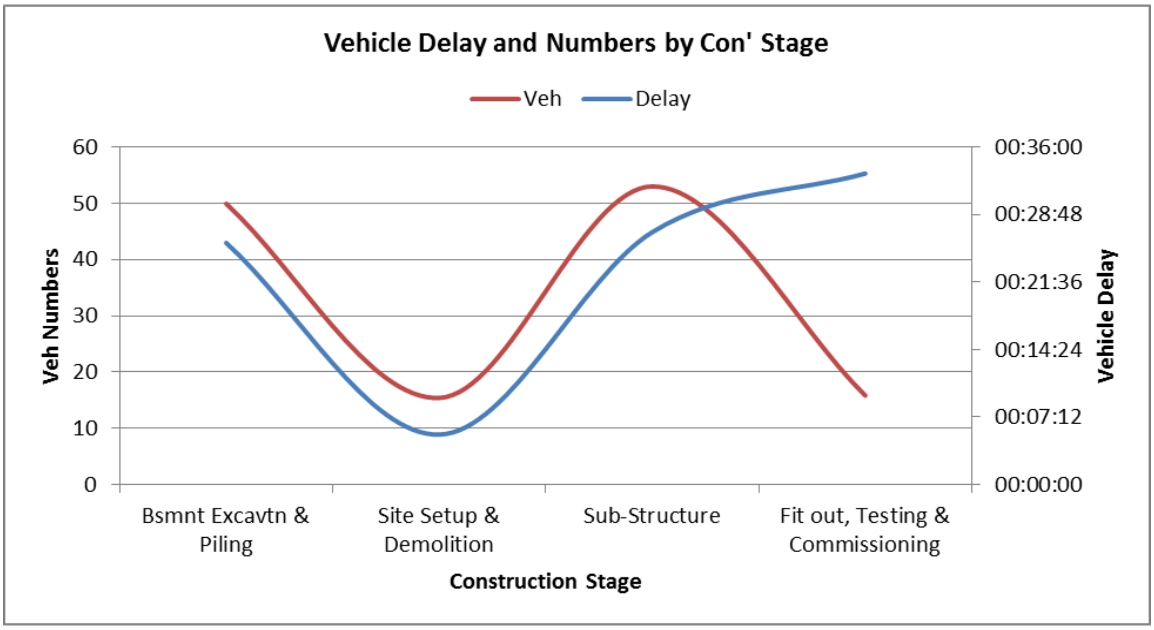


Figure 7.1: Construction vehicles and delay by phase:

Vehicle requirements trace a sine wave pattern through the construction phase and this is expected, with vehicle requirements peaking in the excavation and substructure phases.

In terms of delay, rates mirror increases in vehicle volume up to the fit out stage, which further supports the idea that delays are caused by the sheer number of vehicles entering the site – particularly in waves as is the case with muck-away and concrete pouring. However the rates of delay increase further through the fit out phase, which may be due to the complexity or the fit out, time required on site or indeed other external factors affecting those particular sites. The realtively small sample of sites means limited weight should be attached to the findings as anecdotal evidence from other sectors suggests that operational phases are of greater efficiency than the construction phase.

Looking at the economic cost by phase, shows the direct relationship between delay and the number of vehicles, whilst the level of delay increases during the later, operational phases, the cost decreases due to the lower number of vehicles affected. **Figure 7.2** shows this.

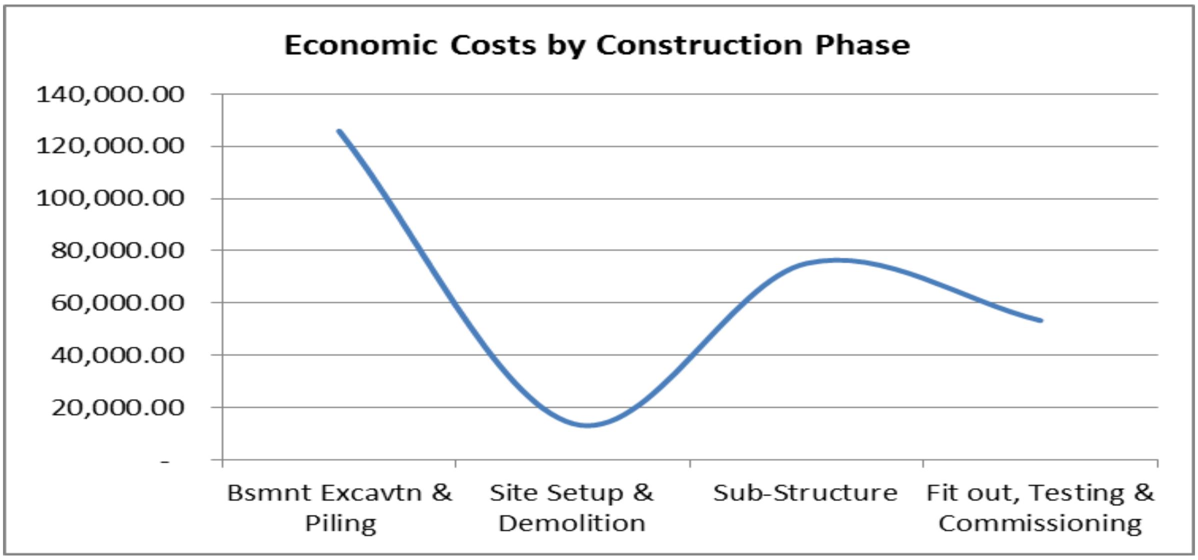


Figure 7.2: Economic Costs by Phase

7.7.2 Site size comparison

As well as construction phase, the sites were also categorised according to size based on the number of vehicles per day. **Table 7.2** shows the sites by size.

Table 7.2: Sites by Size

1	Large	**11**	Small
2	Large	**12**	Small
3	Large	**13**	Small
4	Large	**14**	Small
5	Medium	**15**	Small
6	Small	**16**	Small
7	Small	**17**	Small
8	Medium	**18**	Small
9	Large	**19**	Small
10	Small		

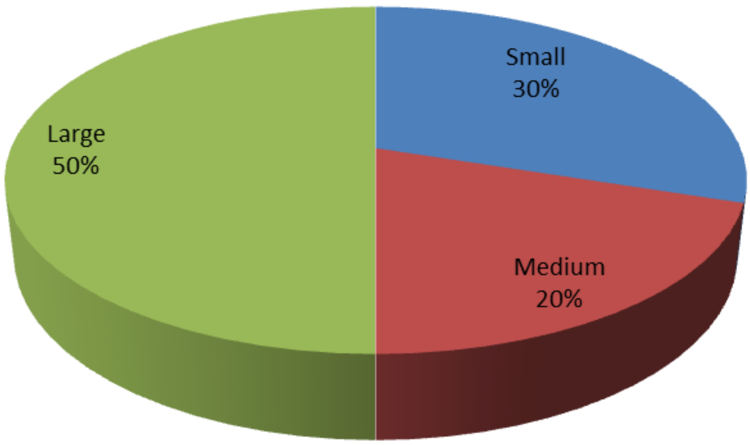


Figure 7.3: Proportion of Sites by Size.

Looking at the spread of sites 1-9, for which the most comprehensive data was obtained, the distribution between small, medium and large is reasonably balanced. **Figure 7.3** shows the proportions. We have removed sites 10-19 as these are all currently small sites in the set-up phase and for which limited data is available.

Looking at the relationship between site size, the number of vehicles and the level of delay experienced, the number of vehicles drops off rapidly, by around 57% and then a further 37% bringing the total vehicles down to three when looking at small sites. This is shown as the blue bars in **Figure 7.4**.

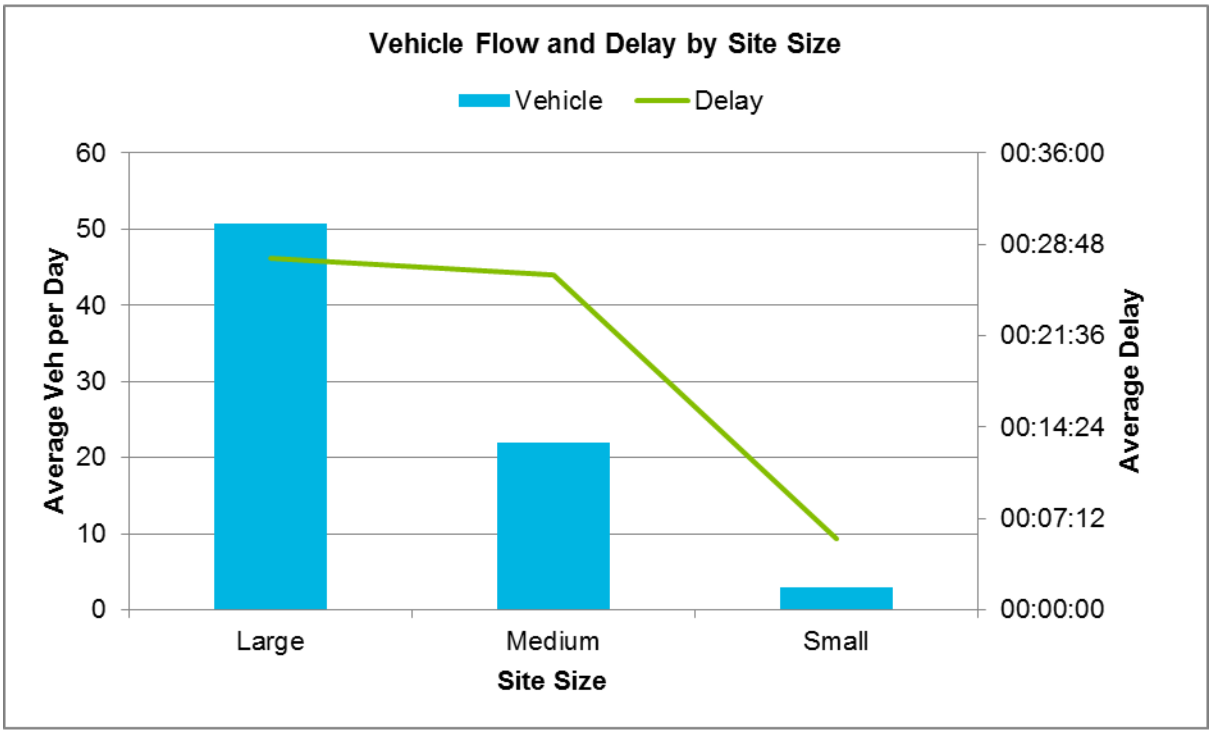


Figure 7.4: Vehicle flow and Delay by Size

However, delay does not follow the same pattern, where vehicles fall by 57%; delay only falls by 5% between large and medium sites, before falling by 74% between medium and small, again shown in **Figure 7.4** as the green line.

Further samples would be required to validate conclusions, however such a pattern suggests that the relationship between vehicle delay and vehicle fleet is not a simple linear relationship. It is likely that the relationship is affected by the construction stage and therefore type of vehicles accessing the site, whether it has a holding area and how effectively the DMS/VBS is used.

Looking at the results from another angle – with sites increasing in size, the results may also point to a threshold where policy/regulatory intervention on things like VHAs can be the most effective, with findings indicating that sites above a certain size implement significant management changes that mitigate the delay caused by large increases in vehicle activity.

In terms of economic cost, they decrease rapidly as vehicle volume reduces as shown in **Figure 7.5** and this is as expected, with costs being a product of vehicle delay and the number of vehicles affected.

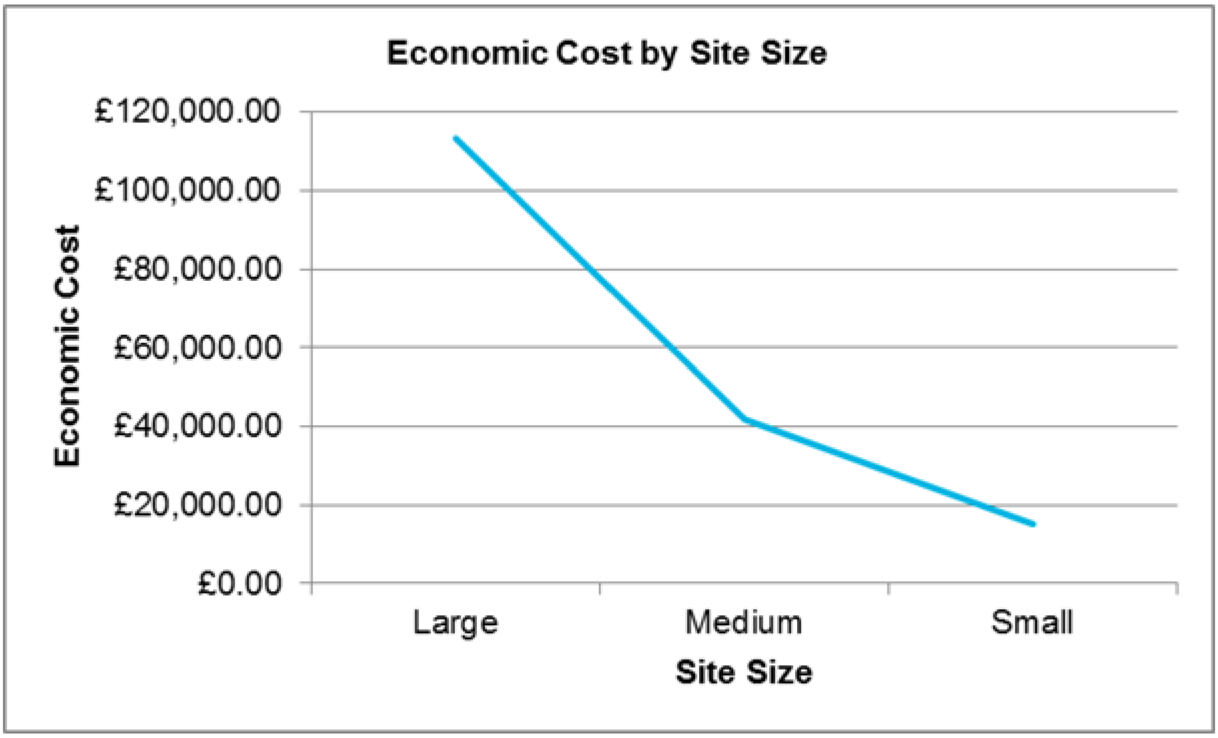


Figure 7.5: Economic Cost by Site Size

It can be seen however, that the rate of cost reduction decreased between medium and small sites, again supporting the idea that the level of delay is not just a product of traffic volume.

Table 7.3 Site 1 to 9 analysis

Site Number	Unsuccessful deliveries	Vehicles per day	Daily CO_2 emissions (kg)
Site 1	11%	38	39
Site 2	14%	74	174
Site 3	0%	53	15
Site 4	0.78%	27	6
Site 5	0%	18	9
Site 6	0%	11	6
Site 7	0%	9	20
Site 8	3%	21	10
Site 9	3%	38	8

In total 5.7% of vehicles from the 9 sites were turned away or chose to pull out of the queue. Of the 10,000 construction related vehicles that are on London's roads a broad assumption could be that 570 vehicles are turned down a day. If on average 27km are driven by a vehicle that is turned away, this amounts to 15,390 km being unnecessarily driven each day.

In terms of estimating results for a year, assuming the observed situation continues at the 9 sites where a significant amount of data was available the following would be outcomes on the basis of a normal working year (240 days).

Unsuccessful deliveries = 5.7% of deliveries = 4,080 based on approximately 17/day.
Additional CO_2 = 68.88 tonnes based on 287kgs/day

If these figures are applied across 10,000 vehicles connected with the construction sector then 3,693,600kms are being driven a year in connection with unsuccessful deliveries.

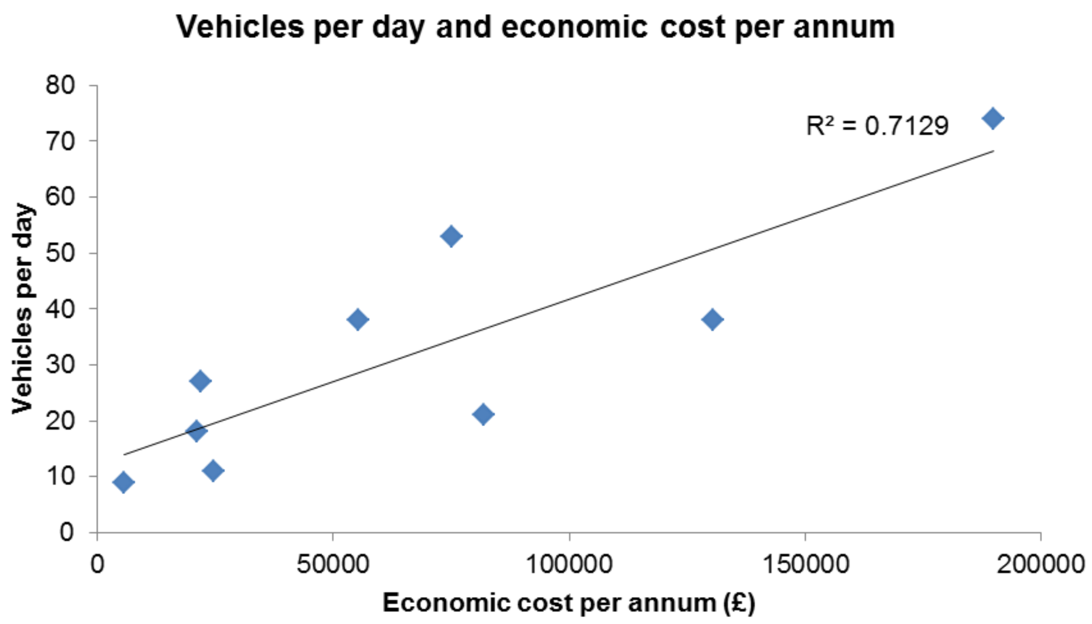


Figure 7.6: Economic Cost by Site Size

Figure 7.6 shows a correlation between economic cost per annum and vehicles per day. The positive relation shows that as the amount of vehicles that visits a site a day increases so does the sites cost per year. The R^2 value of 0.71, the highest of the three graphs, shows the relationship between the two variables is the strongest.

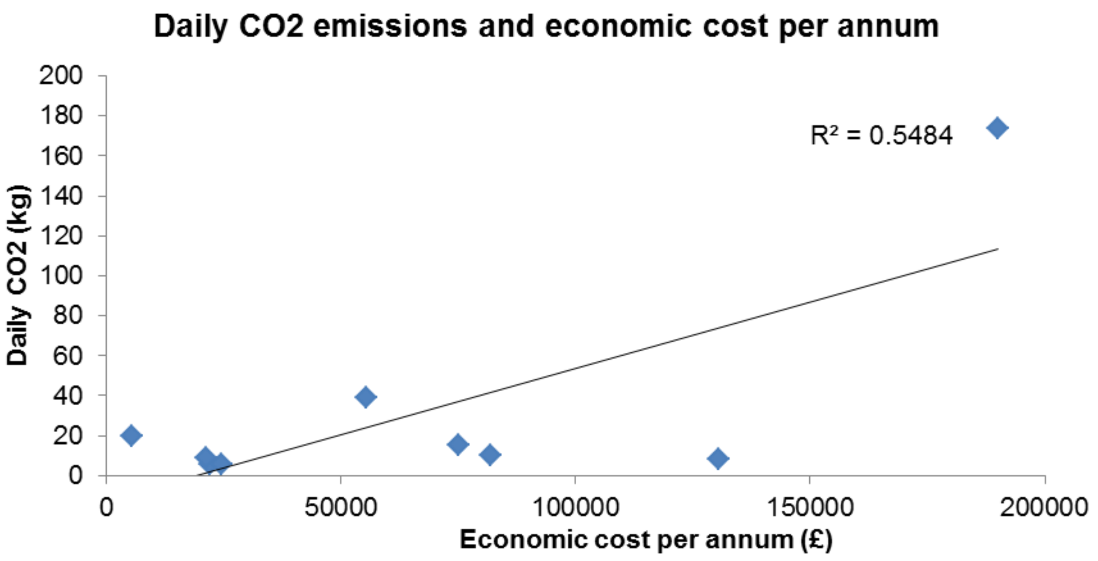


Figure 7.7: Economic Cost by Site Size

Figure 7.7 shows a correlation between daily CO_2 and economic cost per annum. The positive relationship shows that as the cost of a site increases so does the amount of CO2 produced by a site. The high figure from Site 2 causes the positive correlation and creates an R^2 value of 0.54, removing the site creates an R^2 value of 0.002.

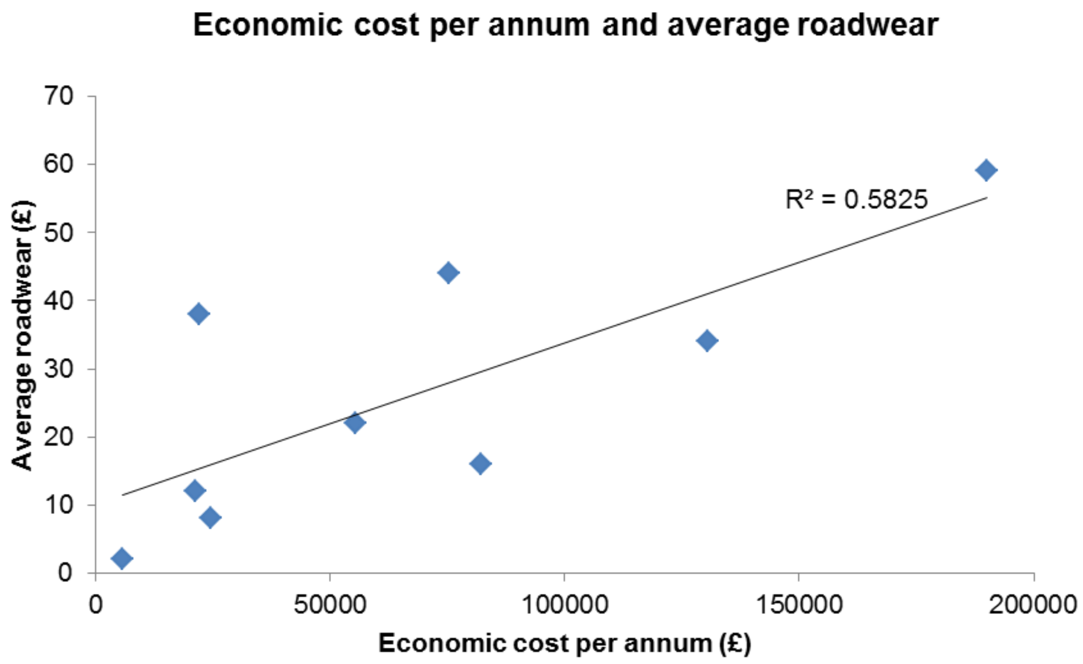


Figure 7.8: Economic Cost by Site Size

Figure 7.8 shows the correlation between economic cost per annum and average road-wear cost. The positive relationship shows that as the economic cost of a site increases so does the cost of damage to road-wear. This relationship is likely to be due to the correlation seen in **Figure 7.6** which shows that there is a relationship between site sizes and economic cost per annum, therefore meaning that as the amount of vehicles using a site increases, so to would the damage to the road. The R^2 value of 0.58 shows that the data conforms to the linear relationship relatively strongly, showing there is a correlation between the two variables.

7.8 Cost to London

From the site analysis, it is clear that costs differ greatly across the sites, dependent on the level of delay and number of vehicles affected. **Table 7.4** summarises and totals the costs across all the sites, coming to around **£608,341** per annum.

Table 7.4: Cost Summary

Site	Congestion Cost	Emissions Cost	Infrastructure Cost	TOTAL Cost
1	£49,107.00	£6,120.29	£214.60	£55,441.89
2	£168,833.00	£22,369.00	£590.60	£191,792.60
3	£73,231.00	£1,978.82	-	£75,209.82
4	£20,429.00	£1,632.28	£0.49	£22,061.77
5	£20,412.00	£824.35	-	£21,236.35
6	£24,151.62	£413.63	-	£24,565.25
7	£5,482.08	£116.55	-	£5,598.63
8	£80,083.84	£1,948.01	£5.36	£82,037.21
9	£125,886.24	£4,500.89	£10.74	£130,397.87
TOTAL	**£567,615.78**	**£39,903.82**	**£821.79**	**£608,341.39**

It is clear that the costs of delays and diversion can be very high and provides empirical evidence to support the importance of efficiency in transport. There is perhaps an interpretation that a truck costs nothing when it is standing still and this could not be further from the truth, with driver wages as well as fixed costs such as maintenance and depreciation all being measured on a time basis, the costs increase as the minutes elapse. When a truck is moving however it generates revenue to offset these costs.

As such, reality is the opposite of perception and it is better to keep vehicles moving than to have them stood still.

Alongside this, damage to people and property as a result of emissions brought about through vehicle delays and diversions cost the London economy almost **£40,000** per annum, meaning the average site costs around **£4,434** per year**.** Air quality has become a hugely important issue in London and across the UK, highlighted by the Governments recently published air quality strategy and the high costs of damager per tonne – over £100,000 in some instances is further testament to this. As such, even small changes to improve efficiency can have a big impact in reducing the costs.

Infrastructure costs have a comparatively low impact, due to stringent vehicle weights legislation and enforcement, meaning that few loads if any exceed the design loading of the road. Planned travel to the site was not included as those road miles would take place regardless of delivery failures. As such, road structure impacts were limited to a total of £822 per annum, across the nine sites and created an average cost of **£91.31.**

Totalling these costs up across the sites, delays and diversions cost the London economy over **£600,000** per annum, or **£67,593** on average per site.

However factoring this up, London accounted for 15% of all construction activity by value, second only to the wider South East. According New London Development[27] there are 421 projects currently under construction with a further 206 granted planning permission. Multiplying these average costs be the total 627 projects ongoing or expected in the near term, the likely annual cost of construction delays and diversion is around **£42,000,000** per annum.

[27] http://newlondondevelopment.com/grid?category=Under+Construction

8. Recommendations

8.1 Introduction

Based on the findings of this study, the project team have identified a wide range of potential actions which TfL could pursue in addressing construction deliveries inefficiencies. The following actions could form a programme of work for consideration. It is possible that some actions are already being developed. It is recommended that the areas requiring further research are conducted first and then this combined learning can feed into the development of a Best Practice guidance document. Following the publication of this, there will be a requirement for training across the construction sector. This should not only include operators and drivers but be extended to pertinent staff in the construction companies and relevant officers in London Boroughs as well. This is illustrated in a flow chart in **Section 8.2.**

A summary of potential actions includes;

Research:

- **KB1**: Consider best practice for management to promote benchmarking and identify gaps between planned and actual performance and encourage performance measurement and applying the PDCA cycle (Plan, Do, Check, Action).
- **KB2:** Investigate the use of Just-in-Time (JIT) and 'pull' logistics. This study would to help to determine commercial logistics practice and also the effect on the environment of different decisions made
- **DMS1**: Investigate options to prevent speculative or contingency bookings on DMS, such as allowing emergency bookings / compliance toolkit.
- **DMS2**: Investigate options to couple vehicle tracking data to DMS data. In other parts of the logistics sector such as retail, vehicle tracking data is used to monitor estimated time of arrival(s) and hence can be matched to resources on site to maximise efficiency.

Best Practice Guidance:

- **ST1:** Planned Measures to include consolidation, use of VHAs and/or DMS.
- **ST2:** Investigate the profiles of vehicles needed throughout the whole project in order to optimise their numbers. This can include opting for vehicles with an increased maximum gross weight.
- **ST3**: Ensure that VHAs are suitably managed and encourage structured programs based on training, consulting and feedback provided to suppliers to improve performance.
- **V1**: Explore opportunities to convert land to VHAs such as encouraging the use of car park areas as temporary holding bay/area.
- **V2:** VHAs seem to be a uniform positive factor in enabling smooth and efficient arrival/departure of vehicles as a result of congestion/delay/regulation whilst also enabling better management of access to site (ensuring compliance, etc.)
- **OE1**: Investigate 'reduce', retime', and 'remode' options for smoothing deliveries throughout the day and pilot retiming on a selection of sites.
- OE2: Improve awareness about DMS among the construction supply chain stakeholders.

Training:

- **OE3:** Provide training as required - e.g. for drivers/operators in the use of the DMS forms and consider testing of end users' perceptions and professionalise the industry through a professional qualification. Train relevant staff in construction companies and in London Boroughs.

These options can be found in detail in **Table 8.1** overleaf.

Table 8.1: Proposed Recommendations

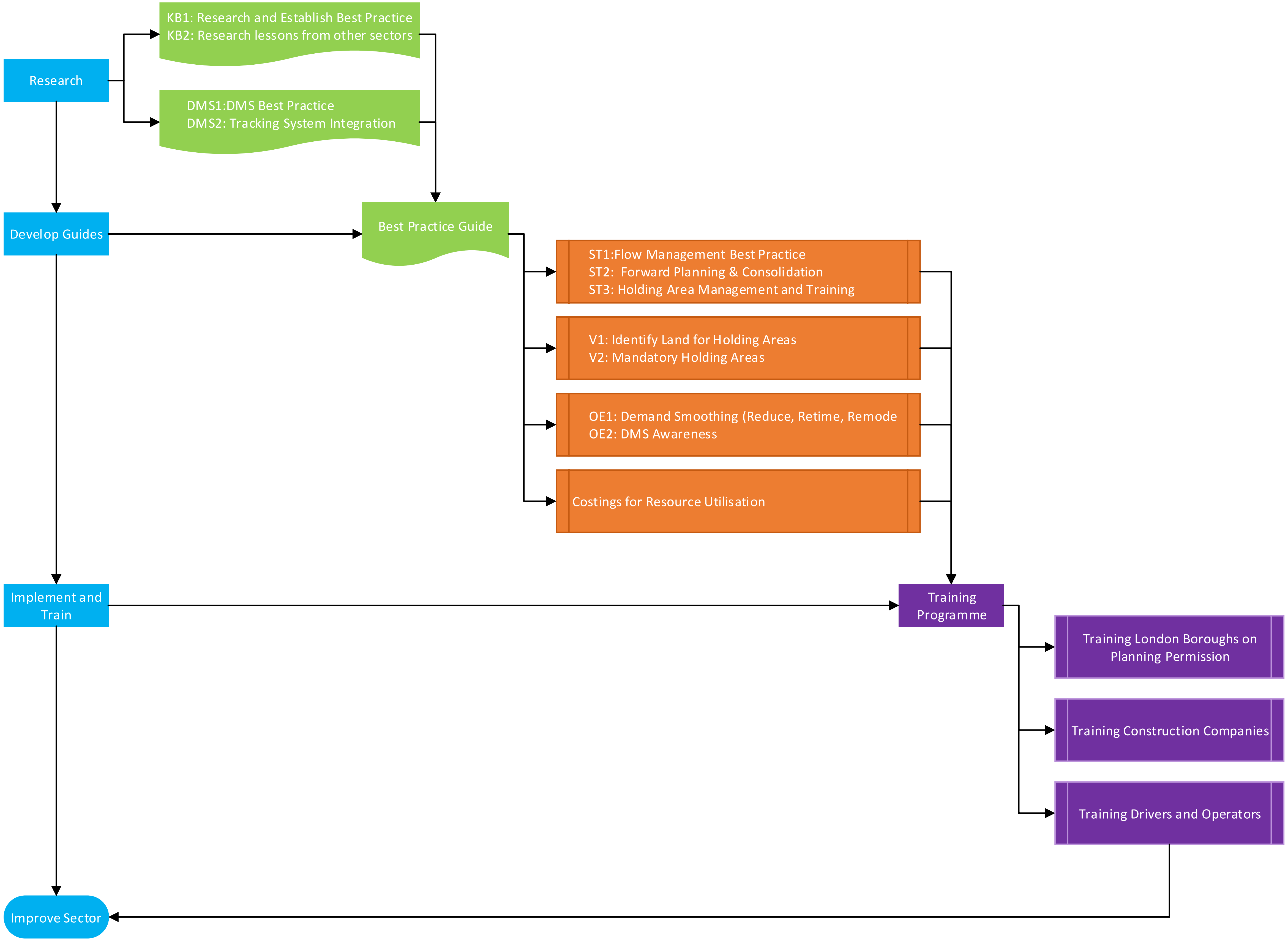
Ref	Recommendation	Issue (s) Identified	Evidence Source				Detailed Description of Recommendation(s)
			Desk Based Research	Consultation	Observations	Data Analysis	
	Site Management						
ST1	**<u>Planned Measures to include consolidation, use of VHAs and/or DMS</u>** 1) Encourage a more controlled acceptance of flows of materials into sites combined with off-site storage (consolidation centres) 2) VHAs to enable control if required. VHAs seem to be a uniform positive factor in enabling smooth and efficient arrival/departure of vehicles as a result of congestion/delay/regulation whilst also enabling better management of access to site (ensuring compliance, etc.). Explore opportunities to convert land to VHAs such as encouraging the use of car park areas as temporary holding bay/area or consolidation centres to collate deliveries. 3) Effective use of DMS in order to improve delivery flow and efficiency	Significant variance witnessed between scheduled vehicle arrival time and actual arrival time at site in some case. Although this did not lead to the vehicle being turned away (if late) or having to wait (if early). Appreciate journey times can be significantly influenced by road network conditions and traffic levels Some sites also used the DMS system as a log of vehicles due that day, rather than paying particular attention to the exact time specified. Instead it was more fluid and dynamic, with close interaction between the vehicle holding area and the site entrance controlling entry in a way to reflect requirements. Vehicles with no booking were witnessed either being turned away (failed delivery) or having to call the site to make an emergency booking and having to wait to gain entry Some vehicles arriving without a booking (such as one that arrived a day late from Sheffield due to a breakdown) were still allowed entry into VHAs and then a scheduled slot could be found for them when there was space later in the day once paperwork had been sorted. Vehicle holding bays/areas are a multipurpose space used to validate deliveries, buffer against peaks in delivery vehicle arrivals, hold delayed or deliveries without bookings, and act as unloading bays when on-site unloading areas are congested. Multiple vehicles i.e. tippers undertaking muck-away and concrete mixers during a concrete pour, can wait in the holding area until needed and allow site activities to progress efficiently with minimal waiting time between vehicle arrivals. Vehicles can be held as necessary to allow other vehicles to clear the site or if a problem occurs on site	X	X	X	X	**Best Practice Guide** Establish a 'best practice' guidance document (related to site size, stage and location) regarding the management of flows to/from site through the use of off-site management processes such as consolidation centres and VHAs for dissemination across the construction industry. This best practice can then be utilised to encourage more efficient deliveries, as well as providing a basis for measuring the operations of individual building sites in comparison to the best practice guidance: 1) Updated Construction Consolidation Centre Guidance Document 2) Holding Area Guide – Setup and management 3) Guide to Effective use of DMS
ST2	Investigate the profiles of vehicles needed throughout the whole project in order to optimise their numbers. This can include opting for vehicles with an increased maximum gross weight.	Successful use and implementation of the DMS appears to vary by site activity and subsequently vehicle type required. Concrete mixers and tipper lorries are more difficult to schedule accurately due to the nature of the construction activity they are associated with and the turnaround vehicles movement patterns they tend to work to. In most cases they were booked in waves or clusters of vehicles sometimes under one DMS booking. They were then expected to be returning to site at regular intervals across the rest of the working day. These vehicles are well-accommodated in VHAs as it enables them to arrive across a period of, say, 15 minutes, before being sent on to site at regular intervals for a 'pour' or to respond to muck-away requirements. In addition, there is a significant reliance on rigid vehicles, this may be for reasons of restricted access, but may also be an opportunity to look at vehicles with an increased payload such as articulated tippers.		X	X	X	**Forward Planning and Consolidation to Reduce Vehicle Numbers** Work with industry to improve forward planning, materials estimates and site ordering processes to enable greater vehicle movement planning. Establish a clear preference for minimising the number of vehicle movements, through either the use of larger vehicles (where appropriate) Further understand vehicle choice and encourage/facilitate the use of articulated vehicles where possible and appropriate.
ST3	Ensure that VHAs are suitably managed Encourage structured programs based on training, consulting and feedback provided to suppliers to improve performance	The VHAs require careful and assertive management by gate staff / traffic marshals to ensure vehicles / drivers manoeuvre and park up properly and cause minimal disruption to other vehicles and VRUs Questions raised over the level of enforcement associated with DMS i.e. level of monitoring of DMS accuracy, penalties for non-compliance, use of metrics to measure contractor / supplier performance and subsequent feedback and remedial measures.		X	X	X	**Holding Area Management and Training** TfL should seek to input into the training of large construction firms, running a course to disseminate best practice in holding area and site traffic management for gate staff / traffic marshals. Use of gate procedure flow diagram to provide clarity on the process and requirements.

	DMS Improvements						
DMS 1	Investigate options to prevent speculative or contingency bookings on DMS, such as allowing emergency bookings.	DMS appear to be used to schedule a significant proportion, but not all vehicle trips. Also appears there is some speculative booking of slots to cover all eventualities. Raises possible questions around the level of supply chain planning occurring. Some DMS required multiple days of notice for deliveries, with booking cut-offs anywhere from 1 to 48 hours in advance of start of day (0800) of delivery. Some logistics operators commented that earlier deadlines often caused them to make 'contingency bookings' when unable to confirm exact date of delivery. At the Colnbrook Logistic Centre, only vehicles with damaged goods or unsafe to process loads will result in failed deliveries. Emergency bookings are allowed and could be requested but only by clients and not drivers.		X	X	X	**DMS Best Practice** Establish DMS standards – work with software providers and construction companies to establish minimum standards for DMS functionality and most importantly monitoring, feedback, reporting and remedial actions. Would allow TfL and LPAs to then require these minimum standards within planning/conditions/CLPs, perhaps dependent on the size and scale of the construction project etc. This could be part of a package of training options developed in conjunction with OE2 & OE3 to develop a comprehensive offer to site operators, logistics operators and drivers.
DMS 2	Investigate options to couple vehicle tracking data to DMS data	Raises potential issues around DMS when used in the manner described i.e. is it an effective tool for managing deliveries, is the DMS schedule a true reflection of what happens on the ground, should DMS systems be static or dynamic, can DMS systems properly operate without vehicle tracking data.			X	X	**Report on System Integration** Commission a report working with DMS and telematics providers in the construction industry to assess the potential for better combining systems so that DMS can provide automatic flagging of issues and enable automatic re-booking or adjustment of schedules if appropriate.
	VHAs / Vehicle Flow Management						
V1	Explore opportunities to convert land to VHAs such as encouraging the use of car park areas as temporary holding bay/area	Multiple vehicles i.e. tippers undertaking muck-away and concrete mixers during a concrete pour, can wait in the holding area until needed and allow site activities to progress efficiently with minimal waiting time between vehicle arrivals. Vehicles can be held as necessary to allow other vehicles to clear the site or if a problem occurs on site		X	X		**Identify and Protect Land for VHAs** TfL and Boroughs to identify potential land/space, on and off-street, that could be used as vehicle holding points/areas for use by different construction projects as required. Incentivise private land owners to do the same.
V2	VHAs seem to be a uniform positive factor in enabling smooth and efficient arrival/departure of vehicles as a result of congestion/delay/regulation whilst also enabling better management of access to site (ensuring compliance, etc.)	Vehicle holding bays/areas are a multipurpose space used to validate deliveries, buffer against peaks in delivery vehicle arrivals, hold delayed or unbooked deliveries, and act as unloading bays when on-site unloading areas are congested.			X		**Mandatory VHAs** Potential policy for mandatory implementation of VHAs for construction projects over a certain size/vehicle movement threshold.
	Operator Engagement						
OE 1	Investigate 'reduce,' 'retime,' and 'remode' options for smoothing deliveries throughout the day Pilot retiming on a selection of sites	'Bunching' of deliveries occurred throughout the day as drivers often would start shifts at similar times (i.e. 0700 or 1000), leading to peaks in number of delivery vehicles accessing each site. This peaking was most pronounced at site 1 with three peaks			X	X	**Demand Smoothing** Key point is to have earlier start times at certain delivery points to enable the 1st delivery of the day to be done before the morning rush hour (8-9am). It seems wrong to have deliveries starting at the same time as the journey to school is beginning! Similarly sites could use the s'houlder' of the day for deliveries 7-8am and 5-9pm. This would help spread deliveries through the day.
OE 2	Improve awareness about DMS among the construction supply chain stakeholders.	Varying levels of awareness amongst contractors, suppliers, logistics operators of using (booking) via a DMS and then subsequently adhering to what they have booked or understanding what the compliance requirements are i.e. being turned away if they're not on time or booked in etc.			X	X	**Driver and Operator Training** Develop a programme (potentially inked to DMS1 and OE3) which will enable suppliers and logistics operators to better understand the DMS process and how it should be utilised, as well as the penalties and issues with failed deliveries, both in direct and indirect terms.

OE 3	Provide training for drivers in the use of the DMS forms and consider testing of end users' perceptions Professionalise the industry through a professional qualification	Some drivers commented on the difficulty of using online DMS entry forms.		X	X		Develop a training programme ((potentially linked to DMS1 and OE2) which will cover the benefits of DMS for drivers as well as the key processes involved for the main providers to ensure better compliance.
	KPI's / Benchmarking						
KB 1	Consider best practice for management to promote benchmarking and identify gaps between planned and actual performance Encourage performance measurement and applying the PDCA cycle (Plan, Do, Check, Action)	Variation between different DMS systems, their capabilities and use by stakeholders ranging from basic vehicle scheduling with little monitoring and enforcement to full vehicle movement planning with a series of metrics/KPIs and remedial actions for non-compliance. The current situation appears to have a lot of stakeholders using DMS, but not really undertaking much in the way of setting metrics/KPIs, monitoring, reporting, remedial actions etc.	X	X	X	X	**Inputs into Best Practice Guide** Research and establish best practice for dissemination across the industry (in association with ST1) and develop a series of key PIs for benchmarking performance based on site size, stage and location.
KB 2	Investigate the use of JIT pull logistics	We have been thinking about retail sites as a comparator in terms of process, where you get a tight delivery/collection window, which you have to keep. Although this is a more uncontrolled environment compared to a process based logistics centre. It will depend on the process as to whether you can use just in time or task based deliveries.	X		X		**Report on Lessons from Other Sectors** Commission a report investigating the suitability of IT pull logistics for use by the construction sector, and whether the entire process or only certain elements would be suitable for construction site based on stage, size and location.

8.2 A Systematic Approach to Implementation

The following diagram shows how the recommendations fit together into a cohesive structured plan:



Appendix A

Site 1

Category	Value
Location	Central London
Size	Large
Performance	Good
Construction Phase	Basement/Excavation
Holding Area	Yes
Booking System	Yes
Hours of Work	07:00 – 15:00
Average Vehicles per Day	38

Vehicle Profile

This large central London site is currently in the initial stages of excavation and subsequent piling for foundations. Manual observations of the site across the week enabled a detailed picture of the traffic profile to be built up. As would be expected, site traffic is primarily tipper traffic (primarily 4 axle, 32 tonne) (83%) to facilitate muck-away. These are supported by flatbed and other vehicles to transport plant and ancillary equipment. **Figure A1** shows the vehicle distribution.

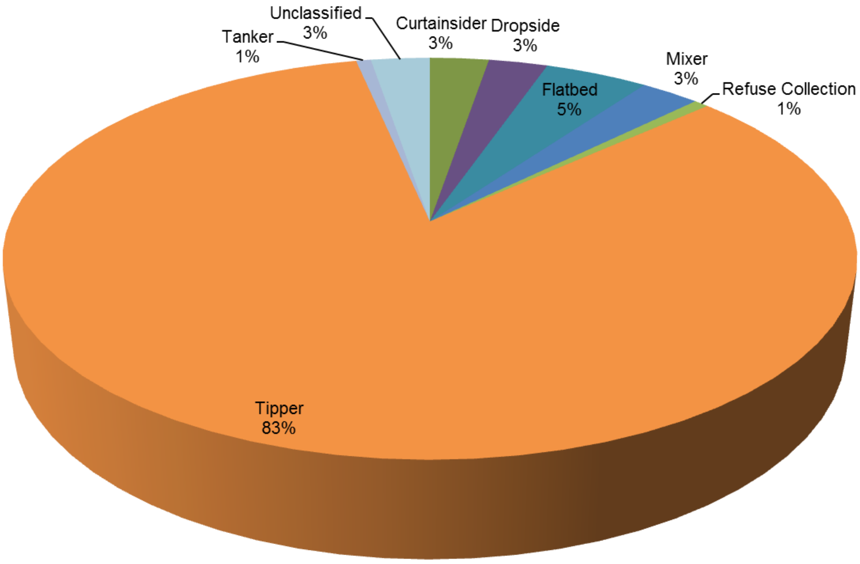


Figure A1: Vehicle Profile - Site 1

These vehicles often make two to three repeat trips between the site and tipping location beyond the M25. Vehicles typically take between six and seven minute to fill provided an excavator is available.

85% of vehicles were identified as FORS members, with the remaining 15% unknown.

11% of deliveries were unsuccessful, well above the average seen across all sites of around 4%. This was for a number of reasons but primarily due to deliveries and collections requiring approval via the booking system. As such there was little room for flexibility. This resulted in a number of emergency bookings being made as vehicles arrived as well as excessive block booking – particularly for muck-away vehicles.

Other reasons included inappropriate or defective vehicles as well as driver issues as shown in **Figure A2**

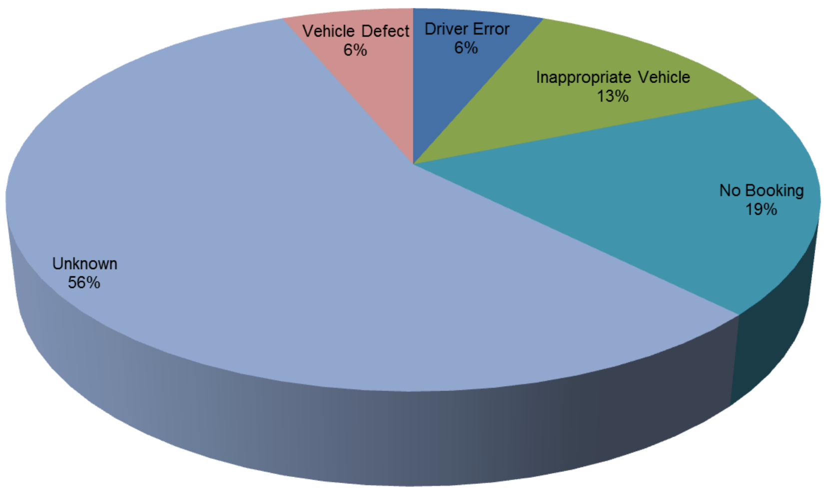


Figure A2: Reasons for Failure - Site 1

Such rules may well be necessary for busy sites, and whilst the vast majority of vehicle movements are not time sensitive on fast turnarounds it is important to have bookings which are then reasonably simple to enforce. At other sites, where the nature of deliveries is more critical to progressing the development, we see a different picture, with more 'non-compliant' vehicles being let on to site. Site failures were assumed to either return to the depot or move onto another destination. Distances for these trips was not available for this site, so an average of 16.27km was used based on data from Site 7 – the only site with such data available.

In reality, the diversion distance will be dependent on whether the vehicle needs to return to base or can go on to another delivery/collection and so diversion distance could be substantially longer or shorter than 16.27km. This also fits with a 2003 study of construction within London that estimates journey distances to be between 10 and 25 km. Similarly, significantly longer distances would be ruled out as this would likely affect the number of trips the vehicle could make within a day and therefore impact on the revenue generated. Taking these factors into account, coupled with limited data availability, the study assumes this to be a realistic midpoint.

Congestion

For site 1, **Figure A3** shows the profile of deliveries. The average time on site was around 29 minutes and this includes time both in the holding area and on site. Average delay is around 18 minutes and 33% of vehicles experience some level of delay. Looking in more detail at **Figure A3** shows that these average mask a wide variation in dwell time and that in fact many of the vehicles were on site for much less than 18 minutes.

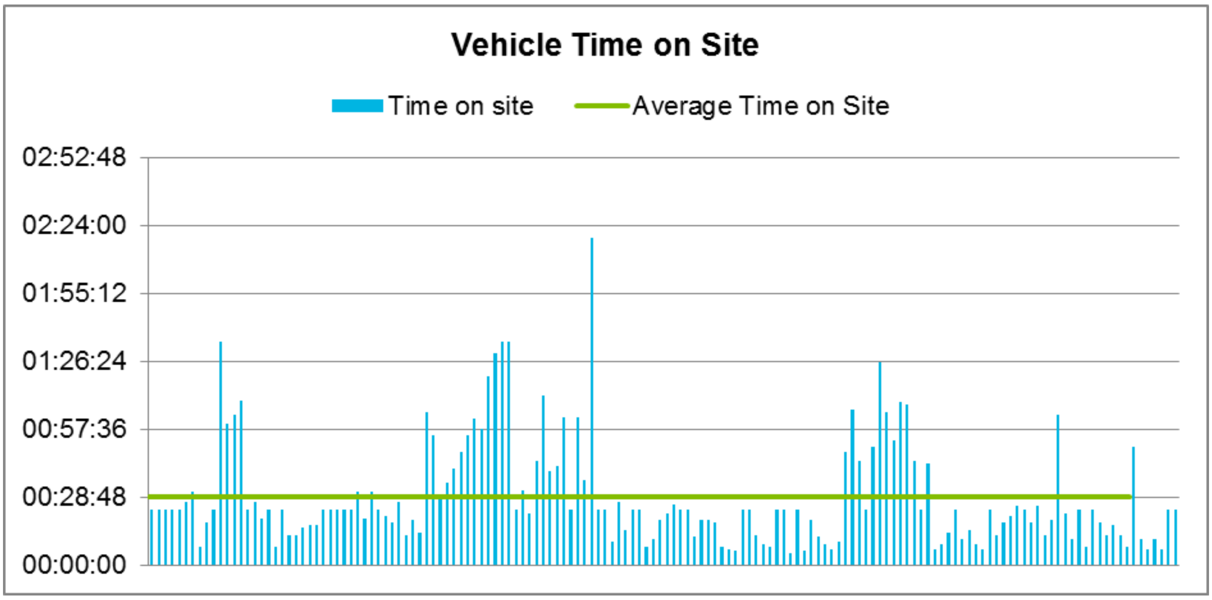


Figure A3: Dwell Time Profile -Site 1

However, a few vehicles experienced large delays, down to the breakdown of an excavator. Additional delay was also caused by a wave of muck-away vehicles arriving at site. Whilst the holding area will help to smooth some peaks in delivery profile, it is relatively small and large numbers of simultaneous arrivals, as illustrated in **Figure A4** contributed to delays.

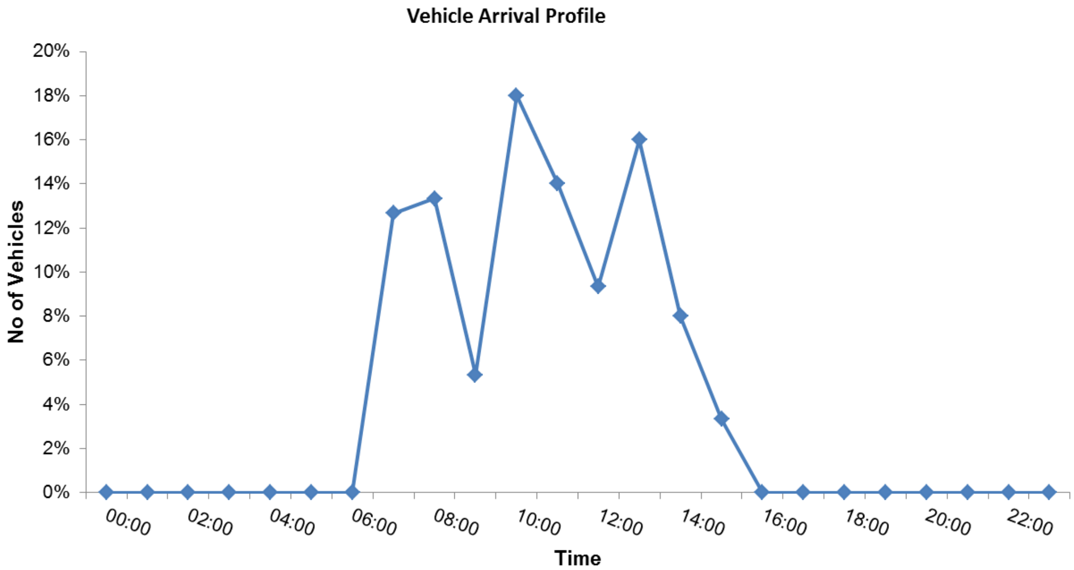


Figure A4: Delivery Profile - Site 1

Figure A4 shows the pattern of deliveries on an average day, and illustrates the wave-like nature of deliveries, with peaks at 7am, 10am and 1pm. Traffic is particularly notable between 08:00 and 10:00 which are also the most congested times of day on the roads of the capital. Better use of the vehicle booking system to eliminate such peaks may therefore help to further improve delivery performance.

Other reasons for delay include site access being closed for 20 minutes each hour to allow for pedestrian access as well as between 1150hrs and 1410hrs to allow for lunchtime pedestrian traffic.

Despite these issues, Site 1 has some of the best site duration and delay figures amongst all the sites assessed. This is largely a product of the nature of activities on site, requiring little other than an excavator and the rapid loading of vehicles, as well as the presence of the holding area and booking system that can regulate the flow of vehicles.

Based on delays of 18 minutes and 33% of vehicles involved in some sort of delay, total delay time per day would be as shown in **Table A1.** Costs are calculated based on a daily operating cost of £350 per day and a 10 hour working day with 45mins-1 hour break, putting costs as 38.88 per hour.

Table A1 – Economic Costs of Delay – Site 1

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	13	3:49	£148.81
Annual	4,290	1,263 Hours	£49,107

Should the same conditions continue across the year, total costs of delay could cost operators **£49,107 per annum.**

Emissions

Emissions have been measured on the basis of the delay information illustrated in the previous section and the delays in accessing the site. An emissions profile of the vehicles based on their date of registration is illustrated in **Figure A5.**

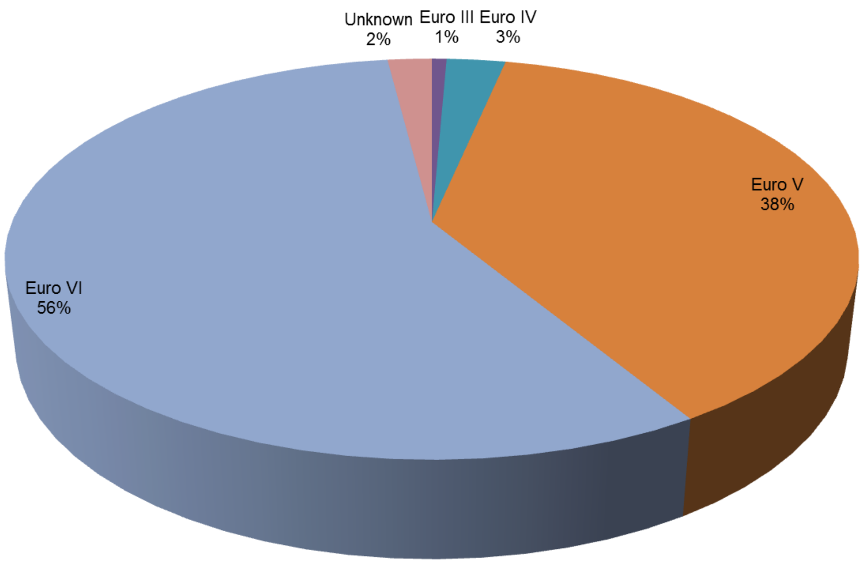


Figure A5: Emissions Profile - Site 1

94% of vehicles were either Euro V or Euro VI and more than half being Euro VI, suggesting a profile of newer vehicles than the national average.

Without and significant information on diversion, Idling is the key factor in determining excess fuel consumption as a result of congestion and delay on site and its economic costs. The amount of idling taking place was assumed to be 50% of the total amount of delay time based on the fact that the latest vehicles have stop start technology that prevents accidental idling and these vehicles account for around 50 percent of those visiting the sites. A typical truck burns around 2 litres of diesel per hour when idling and around 0.63 litres per hour for a van.

CO_2 emissions are calculated on the basis of 2.64 kg of CO_2e per litre of diesel burnt.

Local emissions are calculated based on emissions standards and therefore real world emissions may vary. Emissions for lorries are calculated per KWh and a figure of 11.92 KWh per litre of diesel is used in conversion. Emissions for Vans and other light vehicles are based on the distance driven, therefore a figure of six litres per 100km is used in conversion.

Total delay time at the site was 7 hours 36 minutes per day, resulting in a potential waste in fuel of around five litres due to delay and diversion. Factoring in diversion for vehicle failures, this increases to 13 litres. **Figure 6.6** shows the daily net localised emissions for the site.

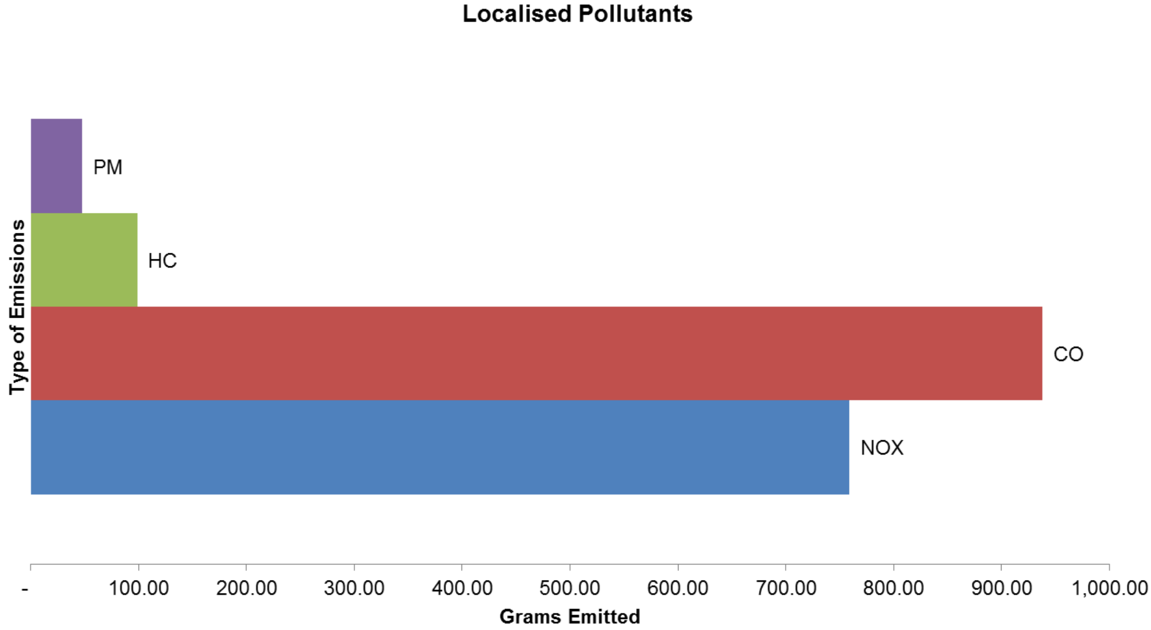


Figure A6: Net Emissions per day

In addition, this led to around 34 kg of CO_2e being emitted each day and 462g of localised emissions

It can be seen that as a result of the low numbers of delays, as well as a relatively modern fleet, low levels of emissions have resulted from the delays incurred on site. Assuming a similar level of activity and delay over a year, this adds up to over 11 tonnes of CO_2e and 152 kg of localised pollutants per annum.

In order to provide an estimate of economic costs of such emissions, the following values based on WebTAG for CO_2 and Defra – Damage Costs by Location and Source for PM and NOX were used to evaluate the cost of damage to property and persons in London's outer conurbation. 2010 values were used and uplifted for inflation by 2% compound per annum and gives the following values. **Table A2** shows the values used:

Table A2: Economic Values for Emissions

Emission	Damage Cost (£ per tonne)
CO_2e	£31
NOX	£80,658
PM	£178,447

Looking at the relative emissions, the site creates economic costs of around **£6,120.29** per annum and these are broken down in **Table A3**

Table A3: Economic Values for Emissions

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£31	356.38
NOX	£80,658	5,057.26
PM	£178,447	706.65

Collisions

No collisions or near misses were recorded during the measurement period.

Infrastructure Damage

The use of strict weight regulations as well as active enforcement, help contain potential infrastructure damage as a result of lorries though the damage incurred can alter depending on the types of roads the vehicles are using. Lower quality local roads are far more susceptible to damage from frequent use by lorries than high quality trunk roads and motorways due to build characteristics and surface quality.

Clearly if there is inefficiency in the delivery system with for example 4% of vehicles being turned away, these wasted trips are causing unnecessary road wear. Whilst accurate weight information was not available for all vehicles servicing the sites, assumptions have been made based on legal weight limits and the axle configuration of the vehicles identified. All vehicles were assumed to have maximised their gross weight in at least one direction and so this is likely to present a worst case scenario.

The average gross weight (weight of the vehicle, driver and payload) of vehicles accessing the sites was calculated.

In order to understand the level of wear to the pavement, engineers convert the weights of vehicles into an equivalent number of axles all weighing the same – typically around 8 tonnes (t). It should be noted that front steer axles with just two wheels are plated less (e.g. around 7t or 8t) than typical drive axles which usually have four wheels (e.g. around 10t). The calculations take the differences into account and are known as Equivalent Standard Axle Loads or ESALs. Therefore, the more a vehicle weighs, the more ESALs it has and the more damage is done to the road. However, the relationship is not linear but is in fact a ‘power 4’ relationship. At its most basic assuming an average 8t axle, the relationship is defined as:

$$N_{ESAL} = \left(\frac{Load}{8\ tonnes} \right)^4$$

Using the formula above, the number of ESALs is determined by 2 factors, the gross weight of the vehicle and the number of axles. Each vehicle type was assigned a max gross weight based on the legal limit of that particular axle configuration. Empty legs were not accounted for since journey distances were not available. As such each vehicle is assumed to generate the number of ESALs equivalent to its fully laden leg.

ESALs are determined by looking at the ratio of real axle weights to the theoretical 8t standard axle. As such, each lorry had its gross weight spread between a steering axle taking a load of 8t, and the remaining weight spread equally among the residual non-steering axles. Vans had their weight distributed evenly amongst both axles. For example:

- A typical 3 axle rigid has a maximum gross weight of 26t (incurred at least once on access/egress and assuming it’s filled to the maximum).
- 3 axles = 1 steering (8t) and 2 non-steering (26-8 = 18t spread over 2 axles). Therefore weight distribution on each axle is 8, 9, 9t.
- Each axle is then processed according to the formula above to work out the number of equivalent axles.

Figure A7 overleaf shows the total number of ESALs generated by vehicles of each chassis type.

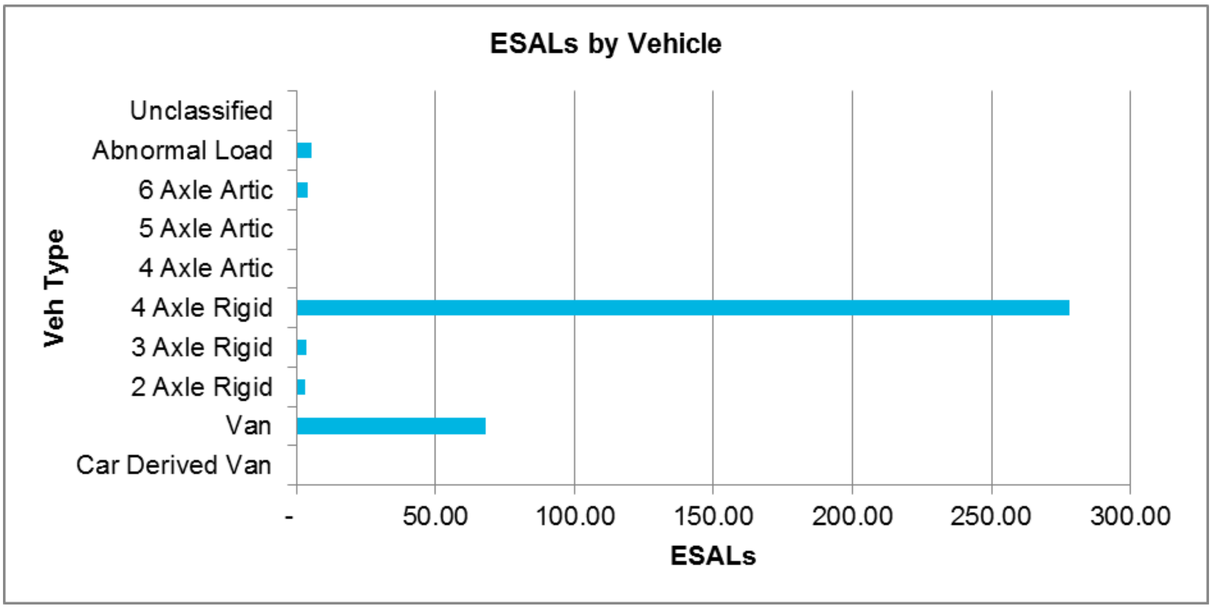


Figure A1: Infrastructure Damage – Site 1

The serviceability of the roads is again important in working out the true impact of the traffic however; this data was not available for this project. However, it provides a method of analysing the relative impact on the infrastructure of each site.

In terms of economic costs, based on the number of wasted kilometres, the total annual cost of infrastructure damage is **£214.76** based on a damage cost of £0.001 per KM and 4 deliveries per day travelling an additional 16.27 KM.

Summary & lessons

The use of the vehicle booking system and VHAs is keeping delays low at the moment. However as the development progresses and requires more complex servicing activities and time sensitive deliveries, it may become more difficult to maintain this level.

Despite strict enforcement of bookings, the management of it may need to be revised as large block bookings are creating waves of vehicles arriving that are causing delays on the site itself and likely to cause further congestion to the surrounding road network, given the relatively small size of the holding area. As such, site managers may need to better liaise with operators in order to spread the peaks in vehicle arrivals. This will become more important for the concrete pour where large numbers of vehicles are required to arrive and cannot be held for long periods.

Emissions are being kept low due to a modern fleet and low delay times; this may increase as a result of the issues described above if they cause delay to increase.

With economic costs in terms of delays and emissions for the site of **£55,441** per annum, of which a significant proportion (89%) is borne by the operator themselves, such action therefore could result in significant savings to operators and the wider economy.

Site 2

Category	Value
Location	Central London
Size	Large
Delay Performance	Average
Construction Phase	Excavation & Piling
Holding Area	Yes
Booking System	Yes
Hours of Work	08:00 – 16:00
Average Vehicles per Day	74

Vehicle profile

This second central London site is also large, receiving 74 deliveries per day on average. Observations were taken over five days and accounted for 369 vehicles in total. The site, in excavation and piling, sees a much greater mix of traffic than that seen at site one, though just over half (55%) of the traffic is still muck-away and concrete related. Flatbeds also feature heavily, carrying a variety of equipment and materials including steel and pre-cast concrete components. **Figure A8** shows the profile of vehicles accessing the site.

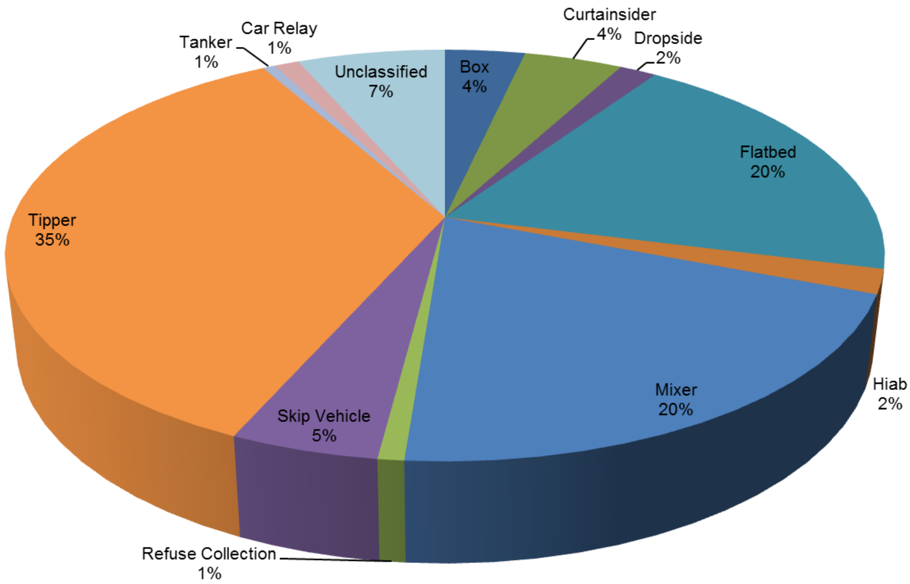


Figure A8: Vehicle Profile - Site 2

Similar to Site 1, muck-away vehicles make two or three trips to site within a day, shuttling back and to between the site location and a tipping area outside of the M25. Concrete vehicles, display similar behaviour but are only likely to make a maximum of two trips as the discharge time for concrete is significantly longer – between 60 and 90 minutes.

85%of vehicles were confirmed as accredited under FORS, 5% were not and 10% were unknown.

Delivery success

14% of deliveries were unsuccessful, again, well above average seen across all sites of around 4%. **Figure A9** shows the breakdown of reasons recorded for delivery failure. Whilst a number of failures were due to unknown reasons, a large proportion is seemingly resulting from the driver leaving the queue or arriving but not joining the queue at all.

This is not seen at other sites however, there was no particular pattern in terms of vehicle type or operator in terms of leaving the queue and may be a product of excessive congestion within the site and holding area. Site 2 is by far the largest in the sample, handling an average of nine deliveries per hour 28% more deliveries than the next largest site.

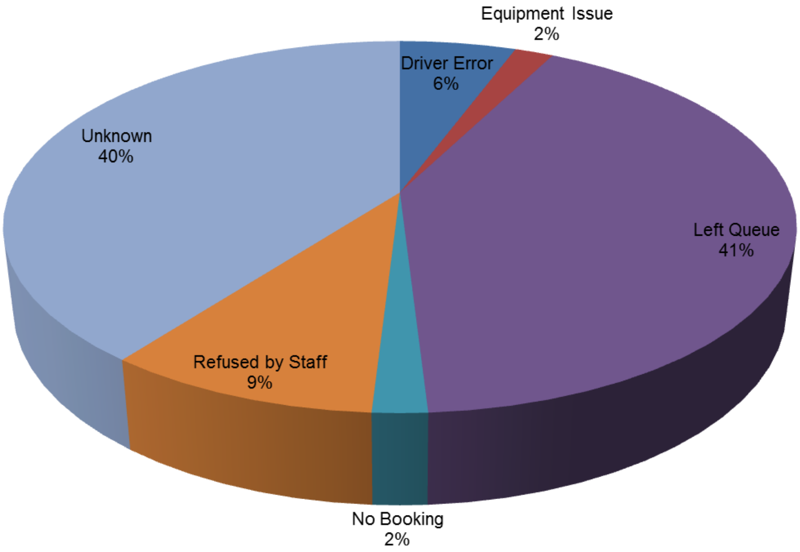


Figure A9: Delivery Failures - Site 2

Other reasons including refusal by staff and driver error are key. Relatively few were found to not have a booking suggesting that the system worked well in terms of compliance. Anecdotal evidence also suggests that there was often enough flexibility to accommodate last minute bookings though those vehicles may have experienced some delay.

Congestion

The site experienced some delay and diversion for a number of reasons including weather conditions limiting crane use, reliability issues with manual handling equipment and site congestion.

Telematics data was unavailable for vehicles using Site 2 therefore diversion information was not present. In terms of delay however, the assessment measured mean average dwell time and the deviation from such time for each vehicle. **Figure A10** shows the distribution of vehicle dwell times on site and the average time spent.

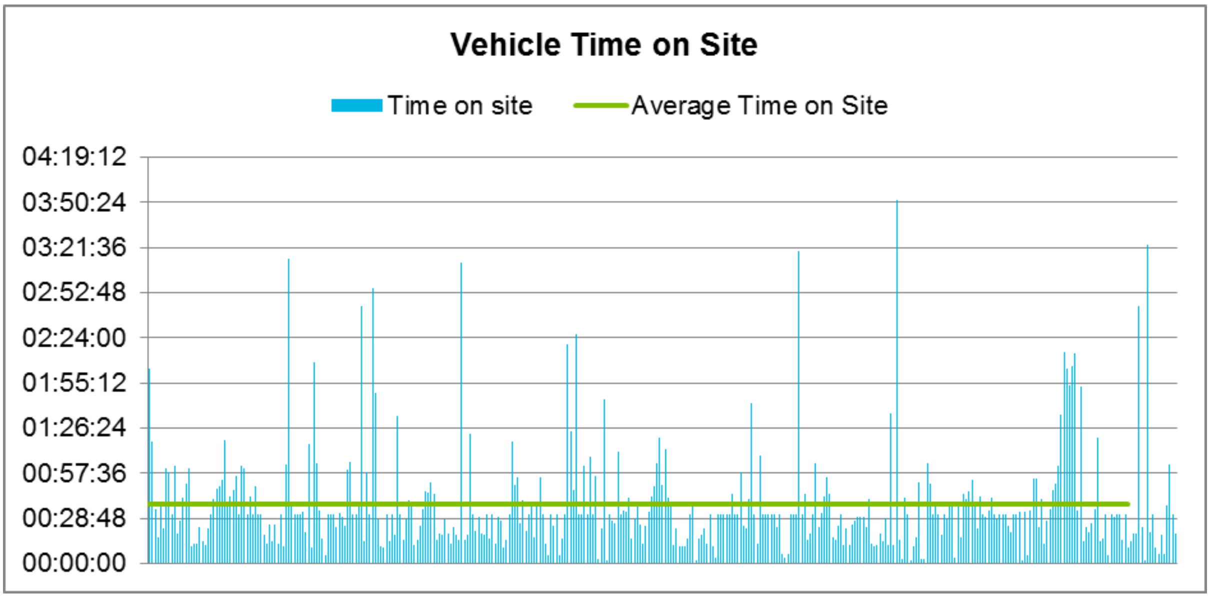


Figure A10: Delay - Site 2

Average time on site of around 40 minutes was longer than Site 1 and slightly above average. This increase in dwell time may largely be due to the increase in concrete vehicles that take longer to discharge their loads.

Delay time was also longer at around 29 minutes, likely caused by the levels of vehicles on site as well as some external issues such as equipment reliability. However, delays were still below the average seen across all sites.

In terms of economic cost, using the same methodology as site 1, the site received on average 74 vehicles per day, of which 36% experienced some form of delay – on average lasting 34 minutes. **Table A3** shows the cost breakdown.

Table A3 – Economic Costs of Delay – Site 2

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	26	13:04	£ 508.59
Annual	8,580	4,316 Hours	£167,833.51

Annually therefore, assuming conditions continue, delays at the site cost operators around **£168, 000** per annum.

Vehicle arrival profile was less variable throughout the day (discounting the lunchtime reduction), suggesting a more effective management of vehicle flow through the booking system and VHAs, and this is the likely reason for the site's good performance despite the large number of vehicles per hour.

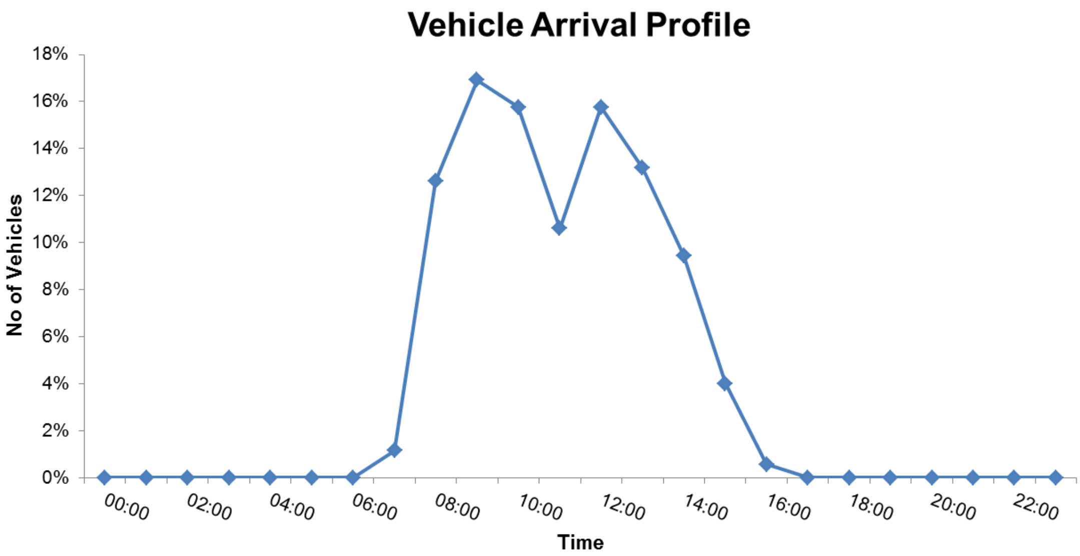


Figure A11: Vehicle Arrival Profile - Site 2

Figure A11 shows the profile for a typical day. It suggests how other sites could and should look if they manage the booking and holding area effectively. Further improvements could be made by shifting deliveries later in the day in order to reduce vehicles arriving during peak travel times.

Emissions

Emissions have been measured on the basis of the delay information illustrated in the previous section and the delays in accessing the site.

An emissions profile of the vehicles based on their date of registration is illustrated in **Figure A12**. It depicts a similar distribution to Site 1 with 77% of vehicles being either Euro V or VI and over half being Euro VI.

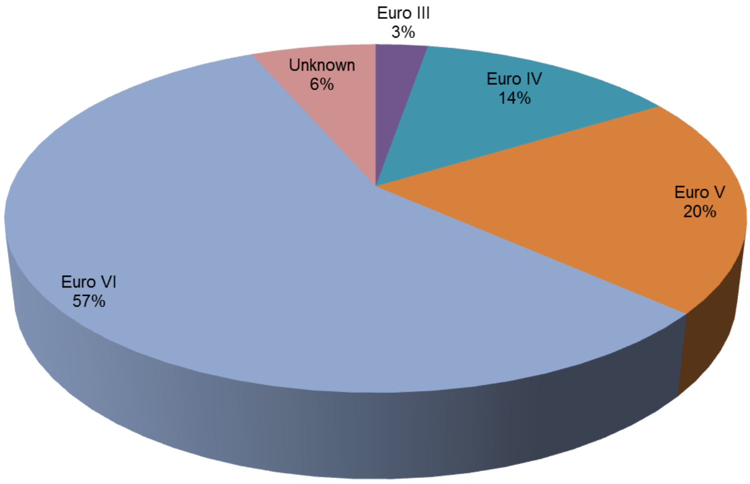


Figure A12 Emissions Profile - Site 2

Slightly larger numbers of Euro IV vehicles are also present, which may have a knock on effect for levels of emissions.

Fuel consumption and emissions were calculated. The total delay time at the site was 7 hours and 38 minutes per day, resulting in a potential waste in fuel of around 66 litres

Figure A13 shows the net localised emissions due to delay, for a typical day at the site. The ratio of NOx to other pollutants is higher as a result of the increased number of Euro IV vehicles servicing the site.

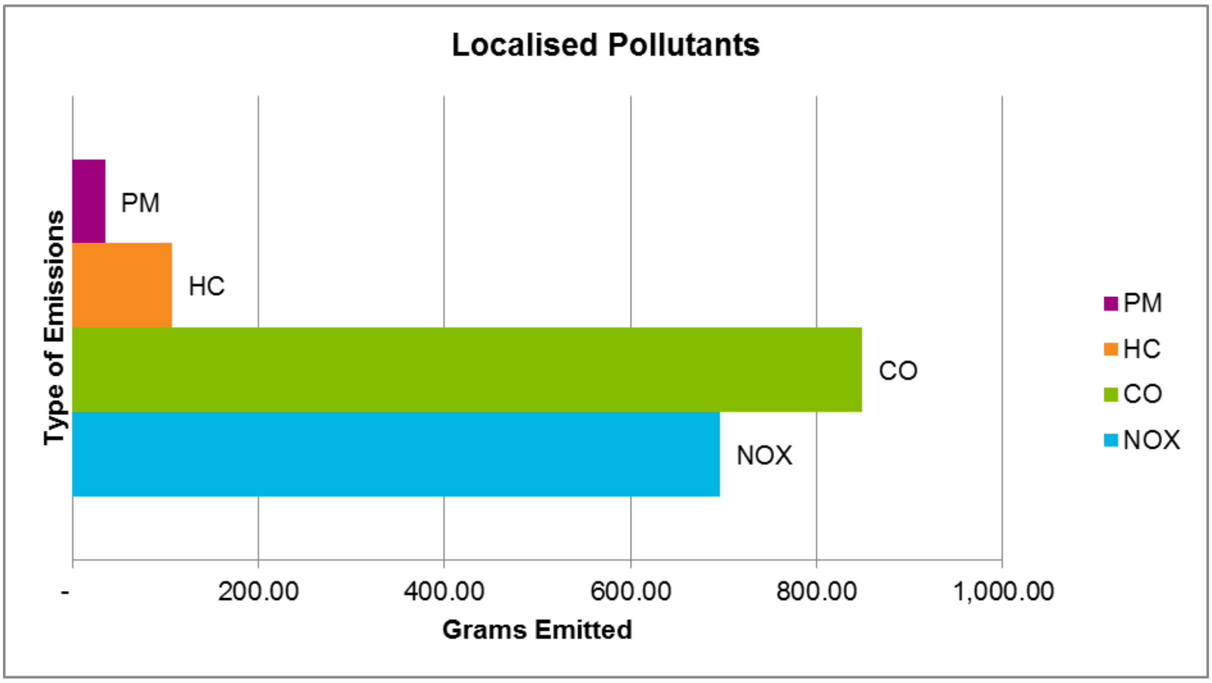


Figure A13: Emissions per day - Site 2

Alongside localised emissions, 174 kg of CO_2e were emitted, assuming a similar pattern over a year (330 working days) a total of 57 tonnes of CO_2e and 556Kg of localised pollutants would be produced as a result of the delays.

Looking at the relative emissions, the site creates economic costs of around **£6,120.29** per annum and these are broken down in **Table A4.**

Table A4: Economic Values for Emissions

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£31	£ 356.38
NOX	£80,658	£18,525.54
PM	£178,447	£ 2,061.06

This makes the annual cost of emissions from the site in terms of delay and diversion **£22,369**

Collisions

No collisions or near misses were recorded during the measurement period.

Infrastructure Damage

Damage to the roads was calculated according. The average gross vehicle weight of a vehicle servicing the site was 27 tonnes, considerably more than site 1. The total number of ESALs seen over the course of the analysis was 1,228, almost three times as many than site 1, despite only seeing double the amount of traffic.

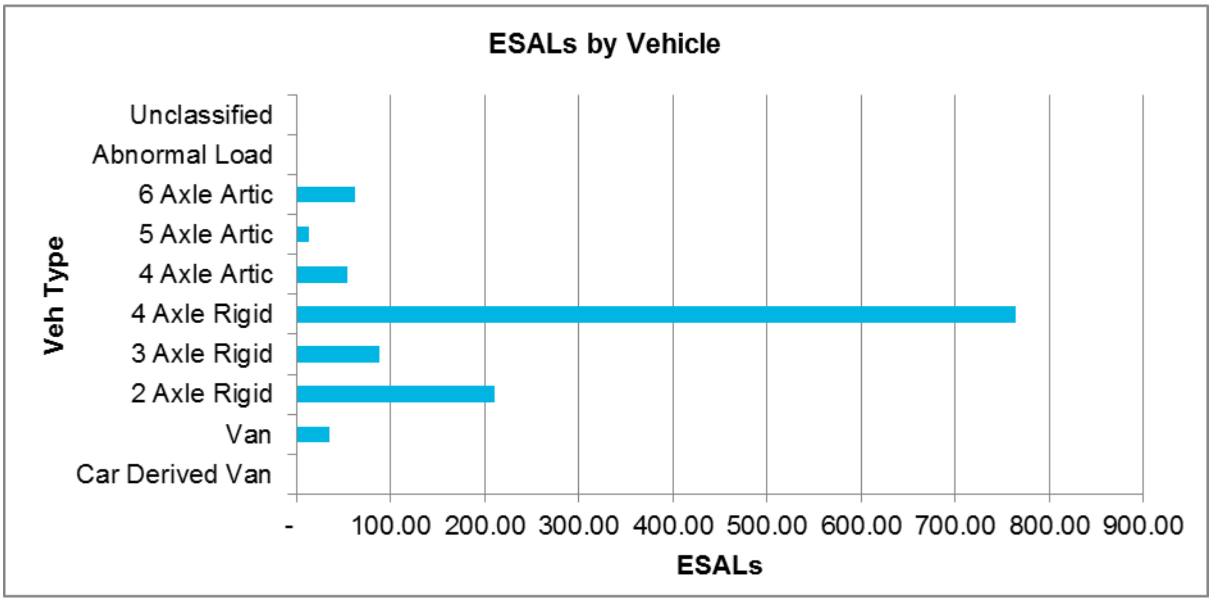


Figure A14: Infrastructure Damage - Site 2

From **Figure A14** it's clear that as well as the additional number of axles, they are spread across a greater number of axle configurations, however the four axle rigid remains dominant in terms of impact, accounting for both tippers and concrete vehicles.

In terms of costs, using the same method as Site 1, 11 vehicles per day travelling an average of 16.27 KM creates **£590.60** per annum

Summary and Lessons

The site performs well and maximises its DMS and holding area in order to regulate the arrival times of vehicles. Very few arrive without a booking and these are often vehicles subcontracted to other logistics operators, suggesting that largely the message around vehicle booking is received by logistics operators and means that waiting times and delays are relatively short considering the number of vehicles accessing the site.

That said a number of drivers are leaving the queue, seemingly not willing to wait. This obviously creates excessive mileage particularly for vehicles with specific loads. Some level of prioritisation and flexibility may be necessary to delay services such as muck-away – that could potentially attend another site in order to provide access for site specific loads. Without visibility of muck-away vehicles in the DMS, this will be difficult to achieve.

There may be some benefits to be gained from altering delivery and receiving windows to later in the day – avoiding the morning peaks, though it may be difficult to shorten the window given the volume of traffic present on the site.

Further benefits could also be gained through working with operators to renew their older Euro IV vehicles to further improve emissions. With substantial economic costs of over **£190,000** per annum for this site, 88% of which is borne by operators, and improvements could provide significant economic savings.

Site 3

Category	Value
Location	Inner London
Size	Large
Delay Performance	Average
Construction Phase	Resurfacing
Holding Area	No
Booking System	Yes
Hours of Work	21:00-03:00
Average Vehicles per Day	53

Site 3 is fundamentally different to other sites in that it relates to road maintenance as opposed to construction and vehicles arrive at night as opposed to throughout the day, enabling minimum disruption to traffic. Observations were made for one day and counted 53 vehicles or around 9 vehicles per hour.

The site does not have a formal holding bay; however, the on-slip to the roadworks site is used prior to the road closure as a de facto holding bay to allow for an immediate start to roadworks after the road closure was enacted.

Vehicle Profile

Vehicles were primarily made up of 4 axle tippers, designed to either extract spoil from the site or latterly bring in tarmac for the resurfacing operation. These were supported by Flatbed and box vehicles carrying ancillary plant and equipment. **Figure A15** shows the distribution of vehicle types

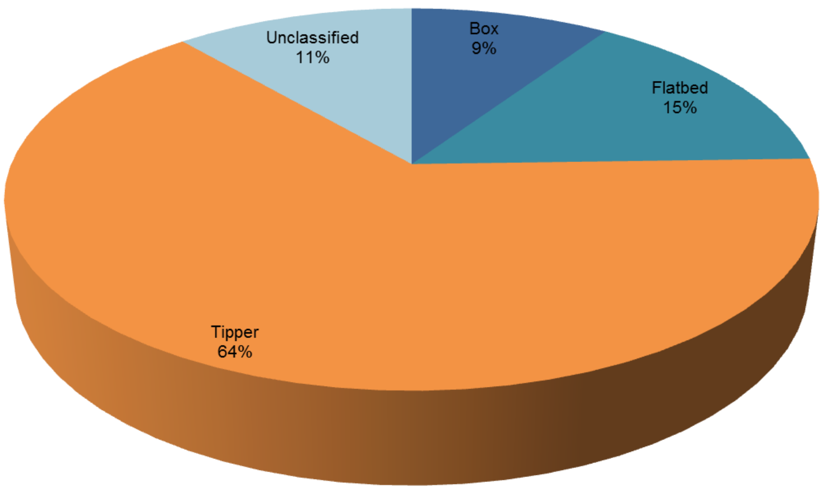


Figure A15: Vehicle Profile - Site 3

Two thirds of vehicles were confirmed as FORS accredited, 4% were not FORS accredited and the remainder were unconfirmed.

Delivery Success

The site experienced no failures in delivery, during data collection; this is potentially due to the nature of the site. Additionally, the site DMS is used more as a timetabling system and less as a site access management tool, however, significantly more vehicles arrived than were recorded in the DMS data. Vehicles that did not arrive on time could still access the site in all cases. Evidence from the delivery manager suggested it was very rare for vehicles to access the site without a booking, in actual fact only 74% of vehicles had bookings.

Congestion

Unlike other sites, scheduling information was available for this site. As such deviation of arrival time in relation to the schedule, as opposed to average dwell time was used to calculate the amount of delay experienced. It was assumed that vehicles left their depot at the correct time. Information regarding departure times from site was not recorded. No information of diversions or excess distance travelled was available.

24% of vehicles experienced some level of delay against their schedule with each experiencing an average of 27 minutes delay.

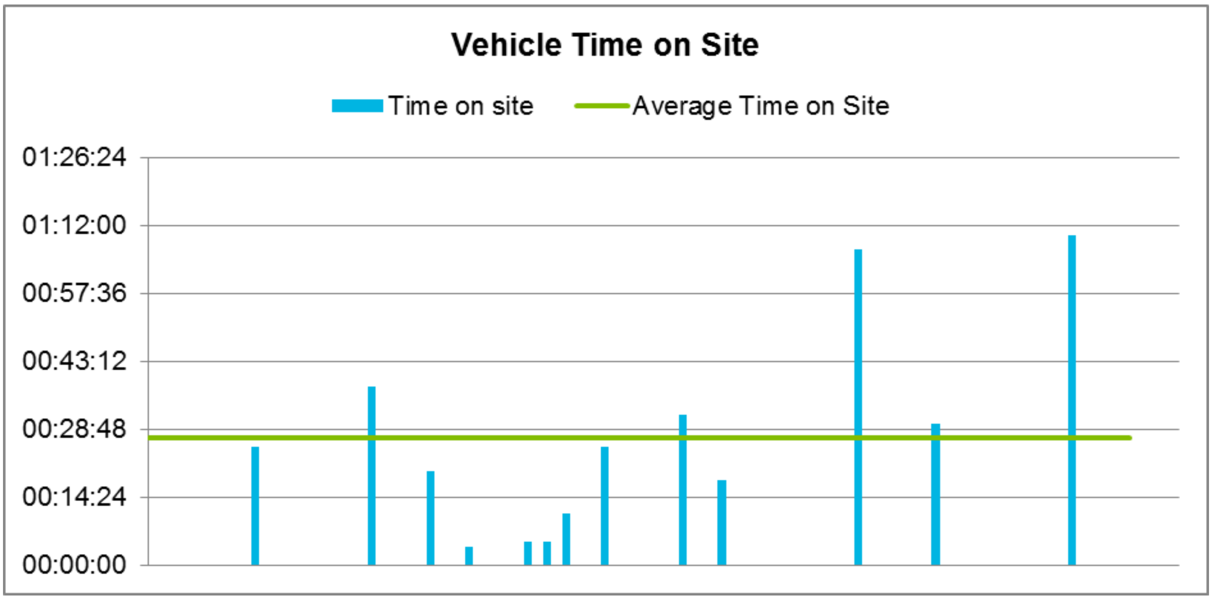


Figure A16: Vehicle Dwell Time - Site 3

Based on the costing methodology for site 1, 53 vehicles delivered to site and 24% experienced delay, which on average lasted 27 minutes. Table 6.10 sets out the delay costs

Table A5 – Economic Costs of Delay – Site 3

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	13	5:42	£221.92
Annual	4290	1883.5 hours	£ 73,231.98

Costs of £73,232 per annum are large but it should be acknowledged that the site existed for 1 night only and therefore did not have the level of logistics planning a long term construction site has. Therefore it is unlikely this level of costs would be realised.

The vehicle arrival profile, highlights a single wave of vehicles arriving as the road closure is enacted and material is extracted and brought onto site, however all activities appear to be condensed into 4 of the six hours available for deliveries. This may be for operational reasons; however, vehicle delay may be able to be reduced through spacing vehicle arrivals throughout the possession period. **Figure A17** shows this.

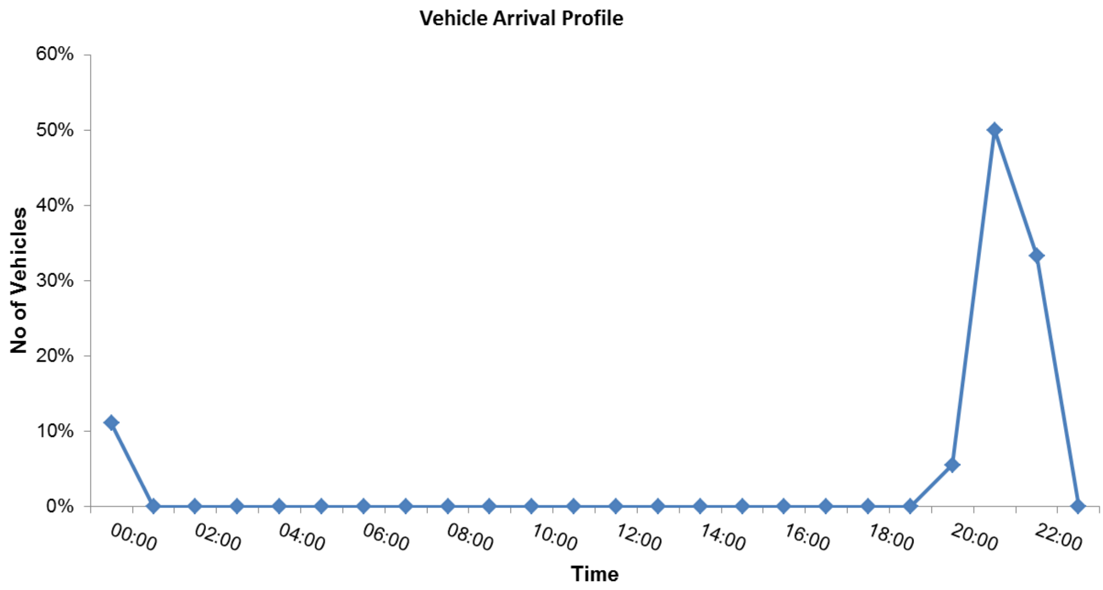


Figure A17: Vehicle Arrival Profile - Site 3

The expected double wave of vehicles, arriving to remove spoil and then provide tarmac is not apparent from **Figure A17**, however a more detailed look at arrivals in **Figure A18** shows bunching around 21:30 and 23:00 (green boxes) that indicates this double wave phenomenon.

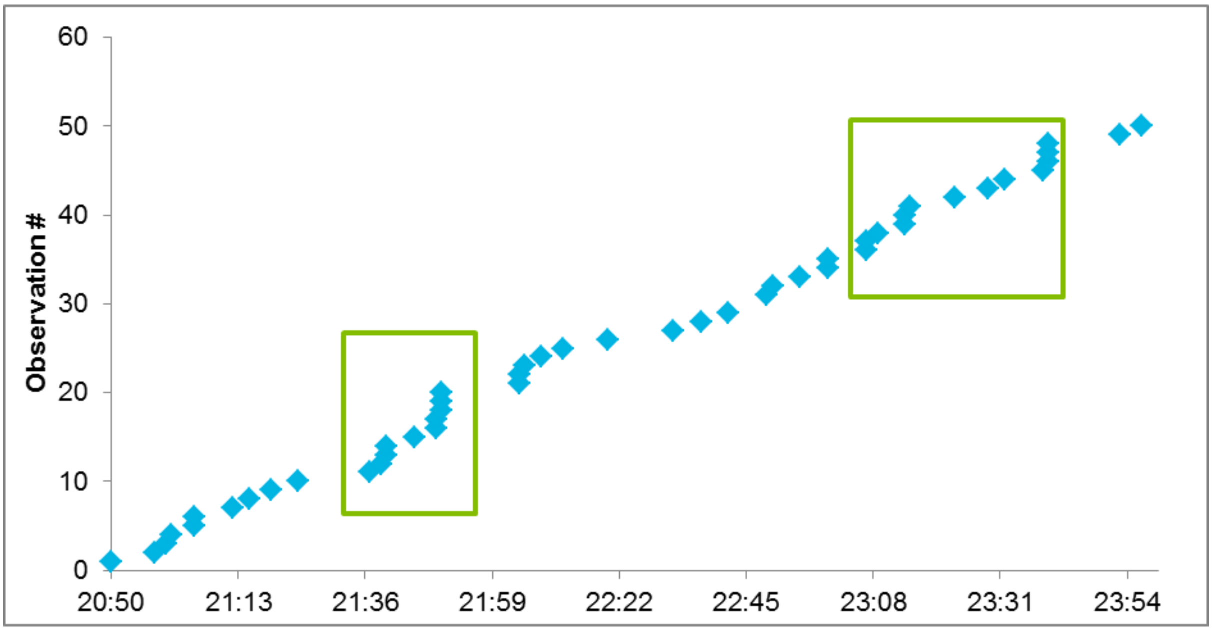


Figure A18: Detailed Arrival Pattern - Site 3

Emissions

Emissions have been calculated in the basis of the delays outlined above. **Figure A19** shows the profile of emissions. Similarly to other sites, 57% of vehicles were Euro VI. However, in contrast to the other sites, a quarter of vehicles were split approximately evenly between Euro III and V, and the remaining 2 % either unknown or Euro I or II.

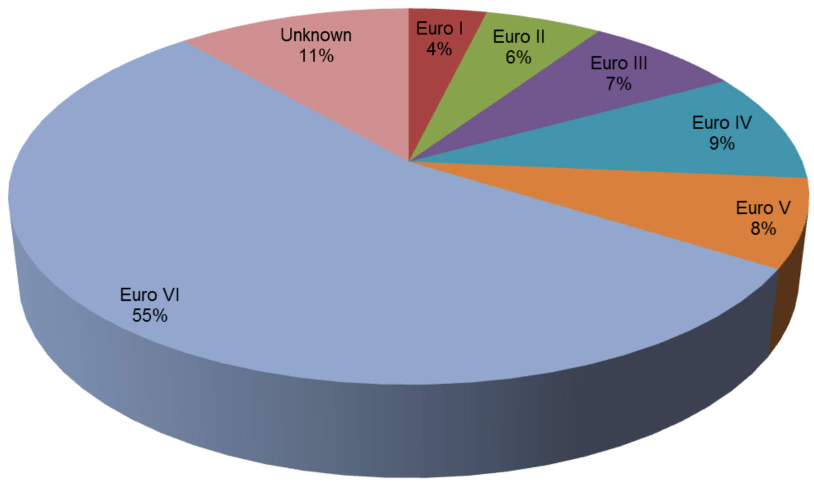


Figure A19: Emissions Profile - Site 3

The majority of these older vehicles were aggregate tippers, rather than specialist equipment, which is unexpected given the low emissions zone restrictions. Further investigation of vehicle registrations may be required to check their validity.

Fuel consumption and emissions were calculated. Average delay time per day at the site was 2 hours and 55 minutes, resulting in 5.83 litres of wasted fuel.

This resulted in localised emissions as shown in **Figure A20** Few of the older vehicles experienced delays therefore the ratio of pollutants is similar to that shown in site 1 that benefited from a modern vehicle fleet. However one Euro II vehicle was delayed for 30 minutes and was responsible for more than 50% of the total NOx emissions for the day. This highlights the importance of modernising the fleet and the huge impact that Euro engine technology has had.

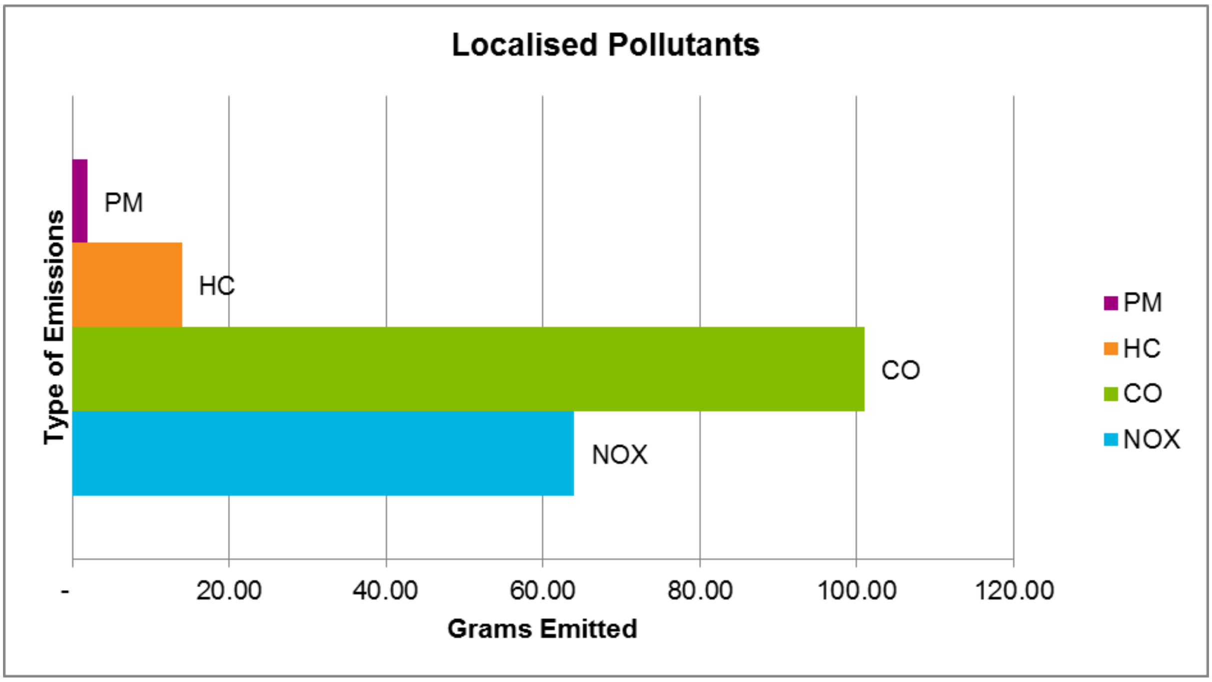


Figure A20: Localised Pollutants - Site 3

In addition to localised pollutants, 15 Kg of CO_2e were emitted as a result of delays and diversion. Assuming a similar pattern of delays across the year (based on 330 working days), the site would be responsible for 5 tonnes of CO_2e emissions and 60 Kg of localised pollutants. In terms of economic costs, Table 6.11 shows the breakdown per annum.

Table 6.11: Economic Values for Emissions

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£31	157.54
NOX	£80,658	1,703.50
PM	£178,447	117.78

This makes the annual cost of emissions from the site in terms of delay and diversion **£1,978.82.**

Collisions

No collisions or near misses were recorded for this site during the measurement period.

Infrastructure Damage

Damage to the roads was calculated according to the methods described in section 6.3.2. The average gross vehicle weight of a vehicle servicing the site was 27 tonnes. The total number of ESALs created was 171.46.

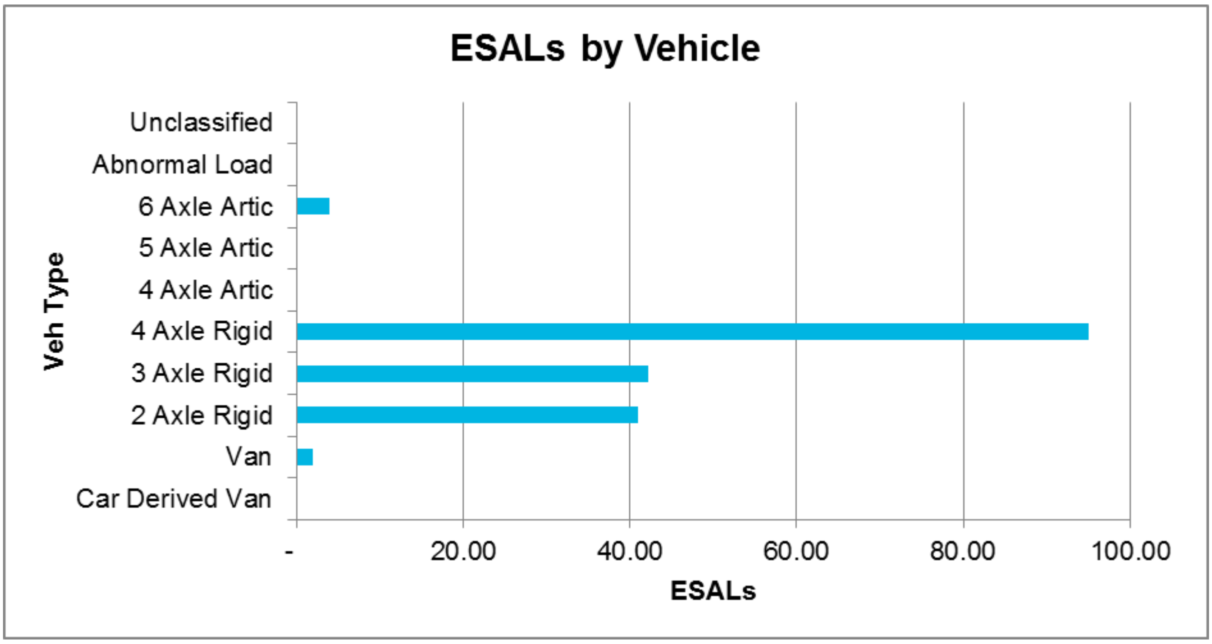


Figure A21: Infrastructure Damage as a Result of Site 3

Figure A21 shows the distribution of ESALs across the different chassis types. Like Sites 2 and 3, a large proportion of ESALs were generated by 4 axle tippers. However, there were no delivery failures and no unnecessary infrastructure wear.

Summary and Lessons

This site was a highway maintenance project with vehicles arriving to resurface a major road at night.The unusual nature of the site means that there were no failures and few vehicles affected by significant delay.

The use of out of hours working, whilst not to facilitate better journey times and reliability, illustrates the clear the clear advantage of doing road maintenance at night.

Stipulating the use of vehicles under a certain age as part of their contracting and procurement process will further help to improve the air quality of construction site. Total cost for the site are estimated to be around **£75,209** per annum, 97% of which is borne by the operator.

Site 4

Category	Value
Location	Inner London
Size	Large
Delay Performance	Good
Construction Phase	Demolition/Excavation
Holding Area	Yes
Booking System	Yes
Hours of Work	08:00-18:00
Average Vehicles per Day	51

The following site provides one of our largest datasets with over 4,498 deliveries over 88 days and combines both digital and manual data. In light of this, some parameters appear in the manual data but not in the digital and vice versa. Where this is the case, each has been taken and applied to the remaining data.

Vehicle Profile

As would be expected for a site at this stage, the site is dominated by tipper and, to a lesser extent, concrete mixer vehicles, accounting for 67% of all movements to the site. **Figure A22** shows this in detail.

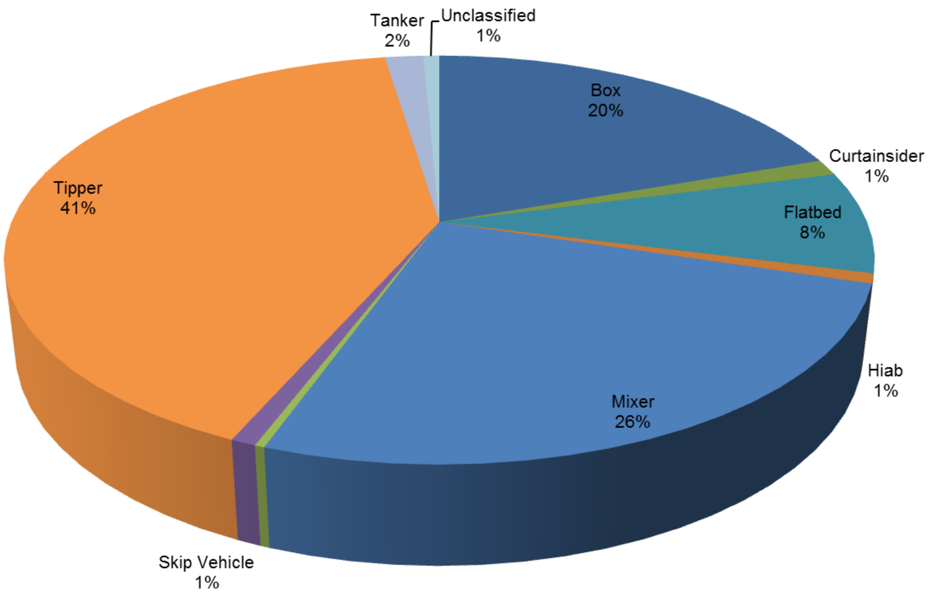


Figure A22: Vehicle Profile - Site 4

Box vehicles and flatbeds are also present providing supporting ancillaries and deliveries such as steel, prefab concrete, and welfare for staff. 96% of vehicles were accredited under FORS, 4% were not.

Delivery Success

Approximately 51 vehicles per day accessed the site, over 99% of which were successful. This is extremely high in relation to other sites of a similar size, which had figures of around 90%. Little was turned away and evidence suggests the VBMS system, whilst present only provided a loose guide as to the vehicles expected that day and though scheduled, operations bore little resemblance to those scheduled times. However vehicles turning up on the wrong day were held, rather than refused.

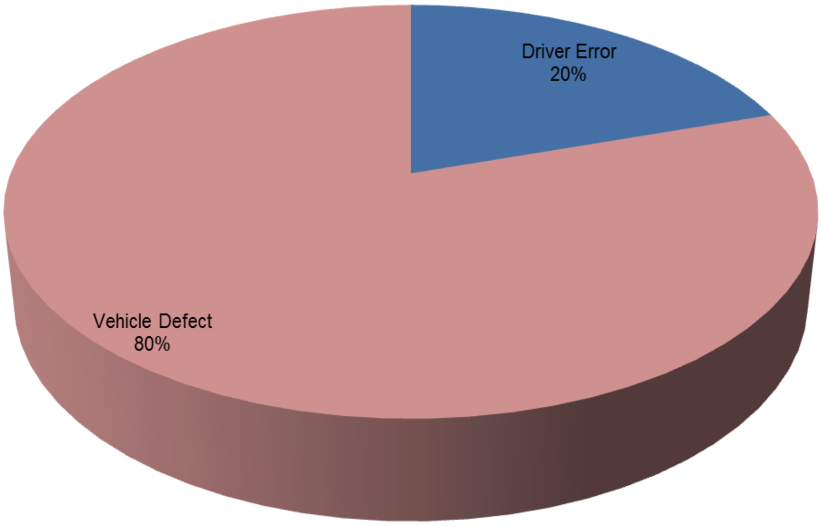


Figure A23: Reasons for Failure - Site 4

Where vehicle deliveries did fail, the vast majority were due to defects with the vehicle or shortfalls in driver training. **Figure A23** shows how this is broken down.

Congestion

Despite handling large numbers of deliveries, site performance was good with average delay being under 8 minutes. However some delay was experienced by 46% of deliveries. Average dwell time on site was 23 minutes, again below average for the other sites. **Figure A24** shows the distribution of dwell times.

Based on the methodology for previous sites, with 51 deliveries per day experiencing some level of delay of which the average is 7 minutes, **Table A5** sets out the costs to operators. From the table it can be seen that costs to operators is around **£20,428 per annum.**

Table A5 – Economic Costs of Delay – Site 4

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	23	1:35	£ 61.88
Annual	7,590	525 hours	£ 20,428.98

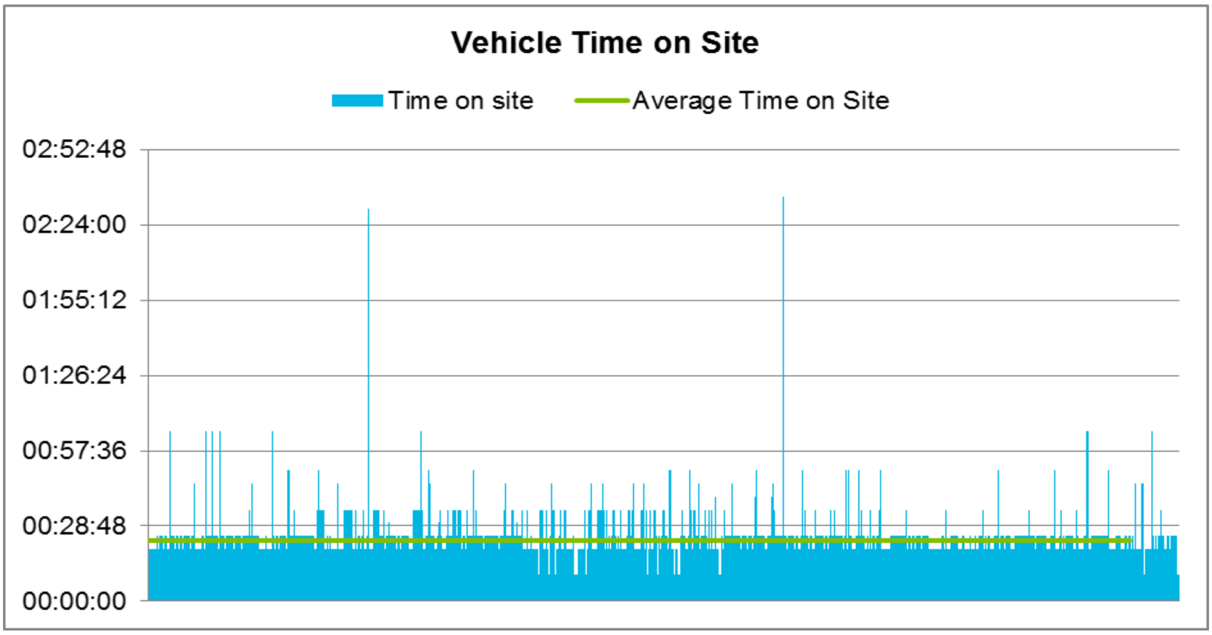


Figure A24: Vehicle time on site - Site 4

There are a number of factors working for and against the site that create such figures, without optimal VBMS use. However, these figures mask reports of congestion caused firstly, by the wave like behaviour of vehicles on site as shown in **Figure A25.**

1) Large number of Muck-away vehicles on fast turnaround
2) Effective use of a large holding area helps to regulate the flow of vehicles accessing the site and deal with any problem vehicles

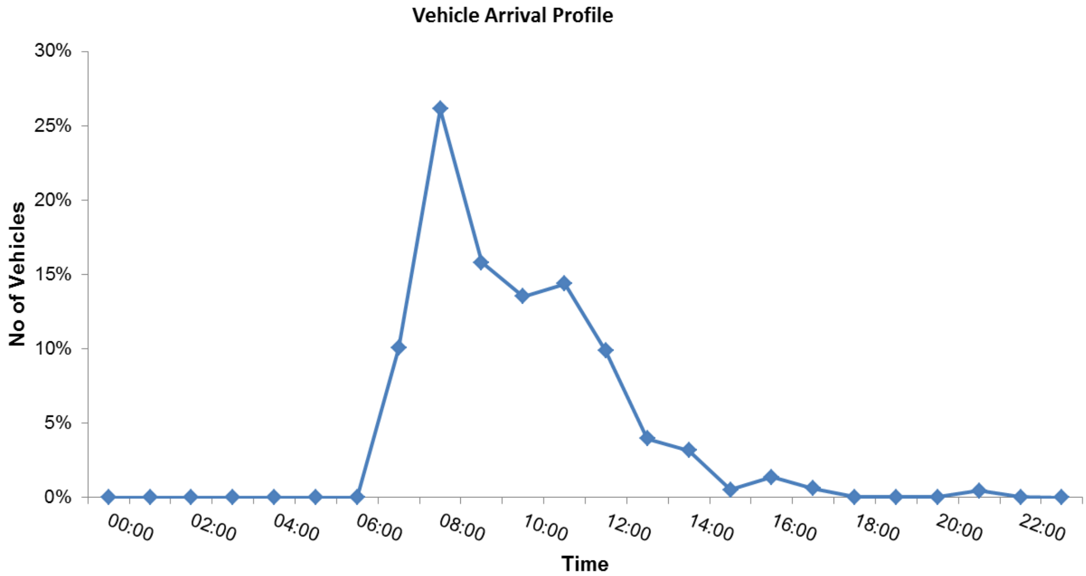


Figure A25: Vehicles Arrival Profile - Site 4

It shows a clear peak at around 8am – also coinciding with the morning rush hour on the surrounding network. Secondly there was considerable congestion from vehicle waiting to access adjacent sites that have no holding area. This is an important finding, as it notes congestion beyond the control of direct site management but also highlights the wider consequences of bad delivery management.

Emissions

An emissions profile is shown in **Figure A26** Large numbers were unknown, as their registration details were not provided in the electronic data. Of the remainder, one third were Euro VI and an additional 22% were Euro V, which largely reflects the profile of other sites.

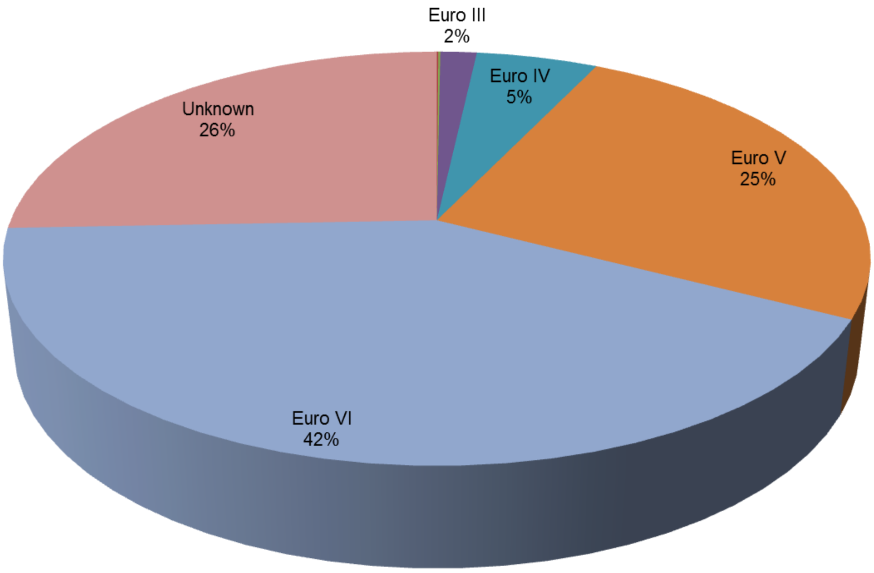


Figure A26: Euro Emissions Profile - Site 5

Around 13 minutes of idle time were cumulatively generated per day, which coupled with diversions resulted in around 13.64 litres of fuel wasted. **Figure A27** shows the localised emissions, amounting to a total of 107g per day. In addition to this, 36kg of CO_2e were generated.

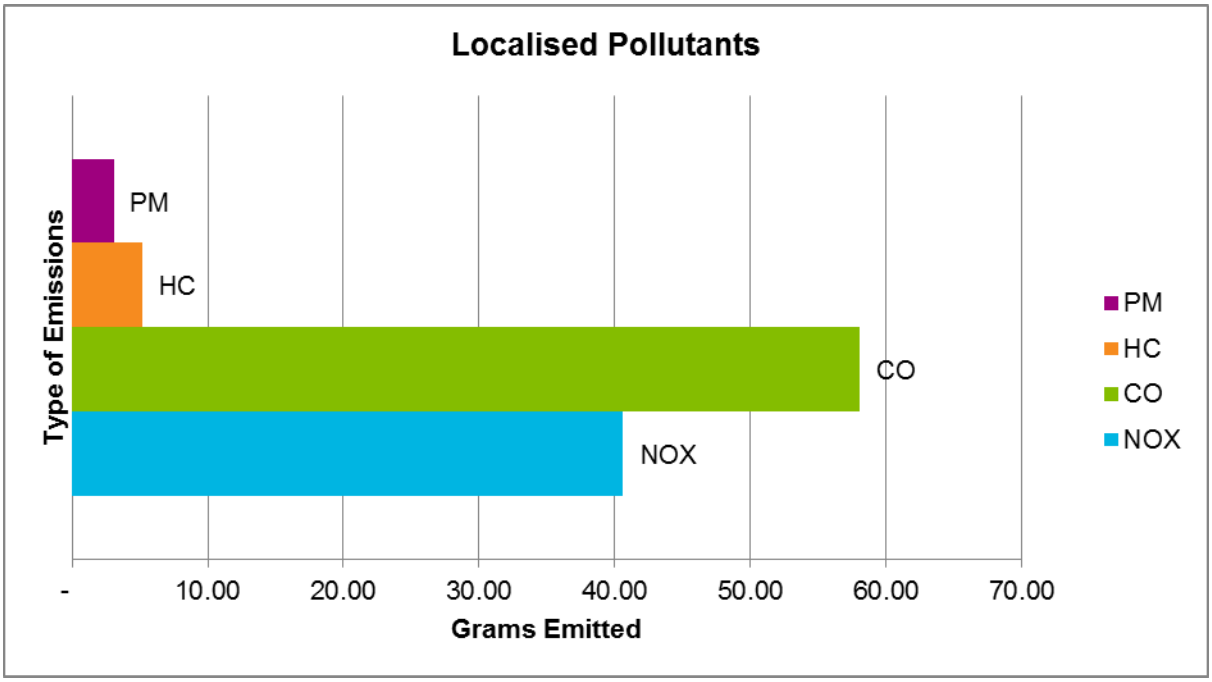


Figure A27: Localised Emissions – Site 4

Annualising these figures, assuming the situation remains the same and a 330 day working year, the site produces 11 tonnes of CO_2e and 35 Kg of local pollutants.

Putting a value on these figures, using the same methodology as the previous sites, **Table A6** shows the breakdown

Table A6: Localised Emissions – Site 4

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£31	£ 368.35
NOX	£80,658	£ 1,081.15
PM	£178,447	£ 182.79

As such total cost due to emissions will be around **£1,632.28**

Infrastructure Damage

The average gross weight per vehicle servicing the site was 24.83 tonnes and this generated 161.85 ESALS per day on the road network. **Figure A27** shows the distribution of ESALs across different chassis types.

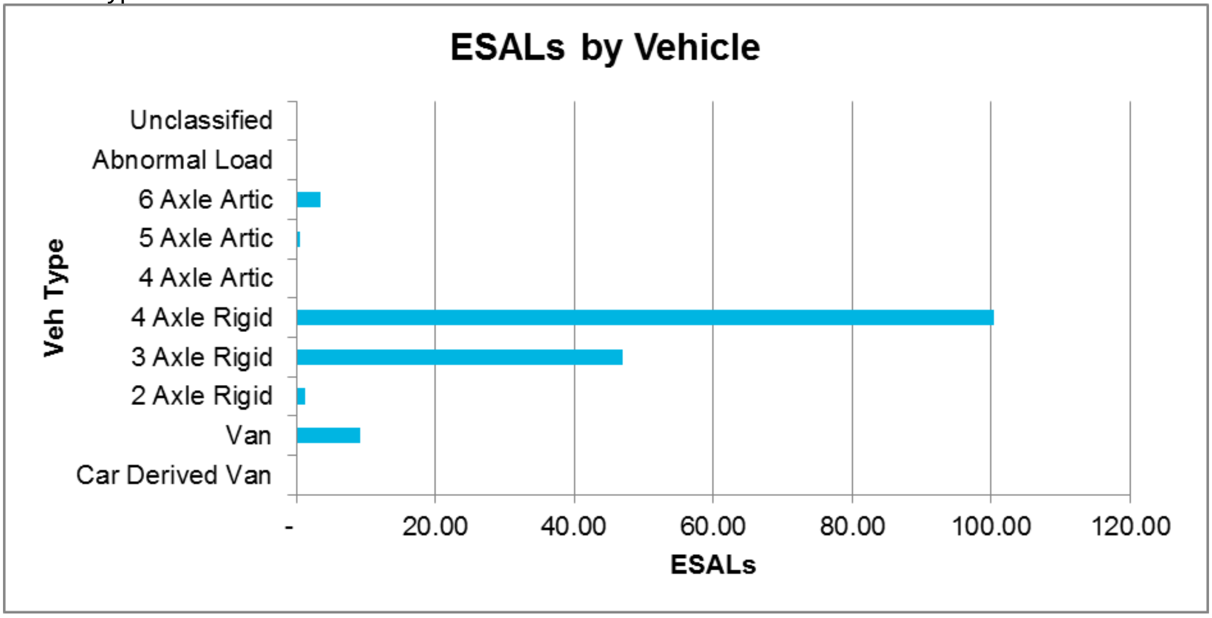


Figure A27: ESALs by Vehicle - Site 4

Four axle rigid vehicles dominate the ESALs as would be expected given the vehicle profile and construction stage of the site.

Of the 88 days surveyed, 8 failures were recorded or 1 every 11 days. Based on this there will be 30 failures across the year. Using the same method to calculate infrastructure damage as the previous sites, is equivalent to a negligible damage cost of around **£0.49**

Summary and Lessons Learned

This site is key to the study due to its size as well as performance in relation to a number of both direct management factors and external circumstances.

The site's less than optimal use of its VBMS in conjunction with the large numbers of vehicles accessing the site and external congestion would normally indicate longer delay times and significant delivery failures than seen here. However, the opposite is the case and this primarily appears to be in light of efficient use of a large loading area that can be used to regulate the flow of traffic. It's possible that there is some underreporting of delivery failures. Its good performance results in relatively low economic costs for the site, equating to **£22,061** per annum, and 92% of these will be borne by the operators.

However a number of lessons can be learned from the site:

- Scheduling vehicle deliveries away from the AM traffic peak could further improve delivery efficiency.

- Better use of VBMS could prevent the need for such large VHAs and allow it to be shared with other sites, reducing management costs and congestion in the surrounding area.
- Use of larger, articulated tippers for muck-away could reduce congestion, emissions and infrastructure damage. They may however have access problems depending on routing.
- Delivery failures were often equipment or training related, better communication to suppliers at all levels could help to reduce these instances. (note, there are a low number of them overall).

Site 5

Category	Value
Location	Outer London
Size	Medium
Performance	Bad
Construction Phase	Operational
Holding Area	Yes
Booking System	Yes
Hours of Work	24 hrs
Average Vehicles per Day	18

The site is in its operational phase and observations for the site were taken over the course of one day, in which 18 vehicles were identified as servicing the site. There was both a holding bay and DMS in operation.

Vehicle Profile

Unlike previous sites that were in the initial phases of construction, Site 5 is serviced by a much greater variety of vehicles including flatbeds, curtain sided vehicles and tippers. **Figure A28** shows the breakdown of different vehicle types.

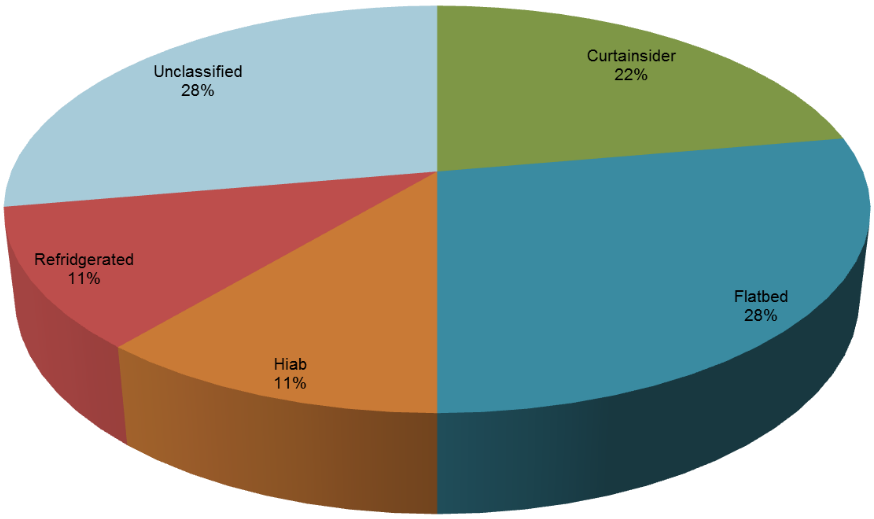


Figure A28: Vehicle Profile - Site 5

50% of vehicles were confirmed as FORS accredited, with the remaining 50% unknown. This lower number of FORS accreditations is expected due to the lower number of construction vehicles servicing the site.

Delivery Success

The site experienced no delivery failures during the period of analysis. This could be for a variety of reasons including the relatively low number of vehicles visiting the site as well as the use of the holding area meaning that there were relatively low levels of congestion and that may have enabled operators to make emergency bookings to facilitate access.

Congestion

Scheduling as well as actual arrival and departure time was available for this site. However, it was clear from the variance – between 1-2 hours early, that this was not adhered to. Typically such behaviour may be due to the anticipation of long turnaround times or congested loading/unloading areas. However neither of those circumstances applies here, suggesting that scheduling is ignored and the system solely used as a booking facility.

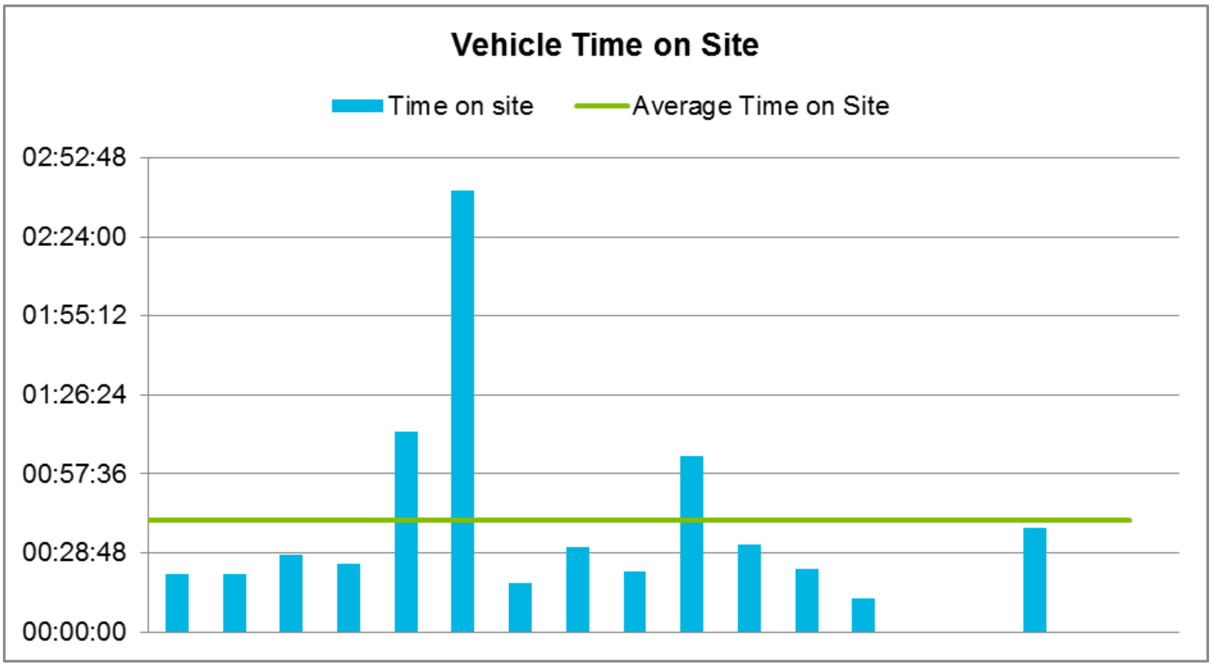


Figure A29 : Dwell Time Distribution - Site 5

Based on average dwell time at the site of around 38 minutes, 28% of vehicles experienced delay and average delay was 42 minutes. **Figure A29** shows the distribution of dwell times for the vehicles seen. It shows that the majority of vehicles were serviced more quickly than average, but three vehicles had very long dwell times. **Table A7** shows the costs of such delays, based on 18 vehicles per day, with 28% experiencing a level of delay, which on average was 42 minutes.

Table A7 – Economic Costs of Delay – Site 4

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	5	2:31	£ 97.87
Annual	1,650	525 hours	£ 20,412.00

Total costs of **£20,412.00** shows the impact of delay for such a small site; Contrasting this with site 4, which had 2.5 times more deliveries but lower overall delay costs.

Figure A30 shows the arrival profile of vehicles visiting the site. Despite the site being open 24hrs per day, all vehicles serviced the site in a relatively narrow window between 06:00 and 15:00. Whilst this is not an issue given the low number of vehicles accessing the site – around 3 per hour, should volumes increase it shows significant scope to spread arrivals across a longer period.

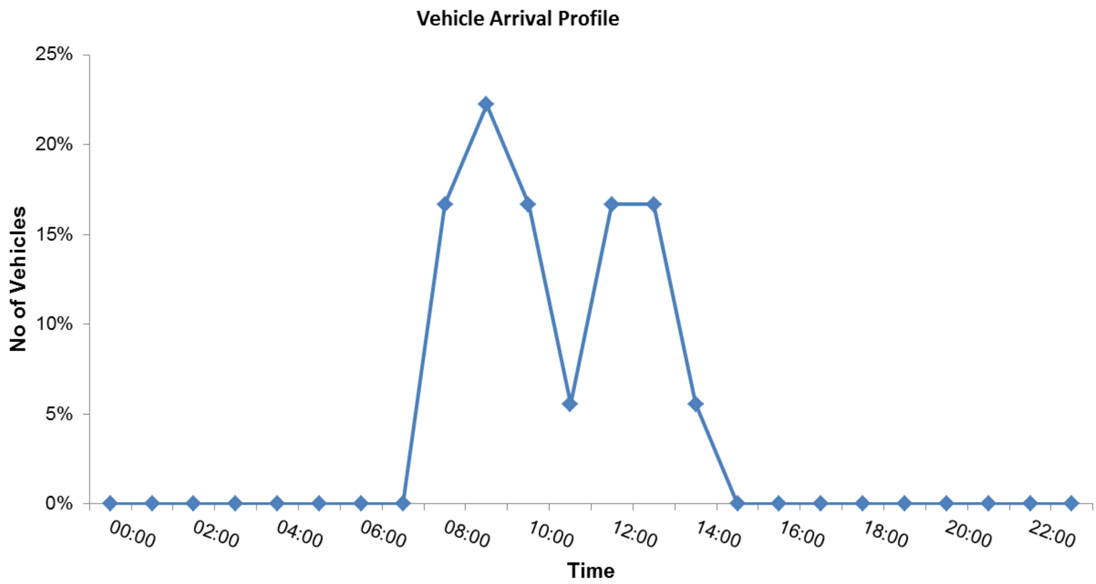


Figure A30: Vehicle Arrival Profile - Site 5

Figure A30 also highlights traffic arrivals split into two distinct waves, with a reduction between 10:00 am and 12:00pm. This could be for a variety of reasons, including drivers avoiding a break time of shift change at the logistics centre, or drivers themselves taking breaks, having started at 6am – a typical start time for drivers.

Emissions

24% of vehicles were of an unknown age and have been discounted from **Figure A31**. Of the remaining number, 64% were Euro VI and an additional 22% Euro V meaning that emissions as a result of any delays are likely to be lower than average for this site.

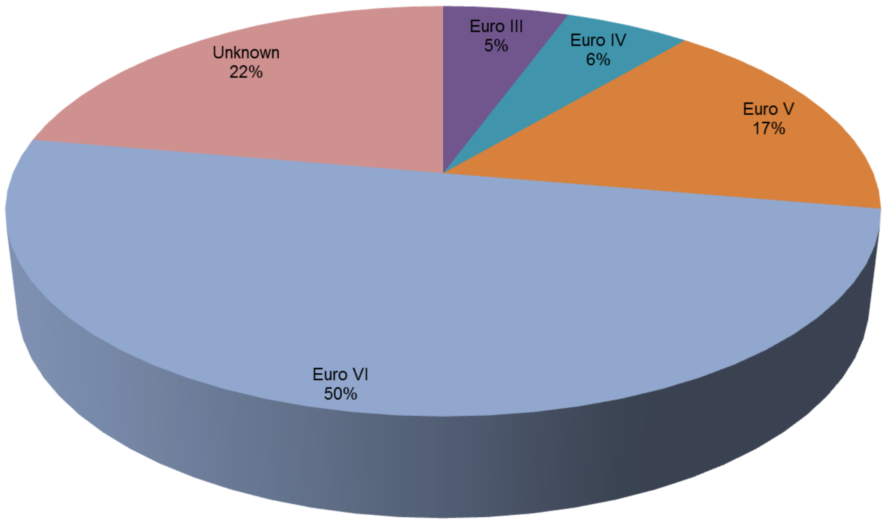


Figure 0.2: Euro Emissions Profile - Site 5

Fuel consumption and emissions were calculated as described in section 6.3.2. Idling time per day was one hour and 45 minutes, resulting around 3.5 litres of wasted fuel.

Figure A32 shows the total emissions generated that day. Carbon Monoxide is the dominant emission as opposed to NOX due to the large number of Euro VI and Euro V vehicles.

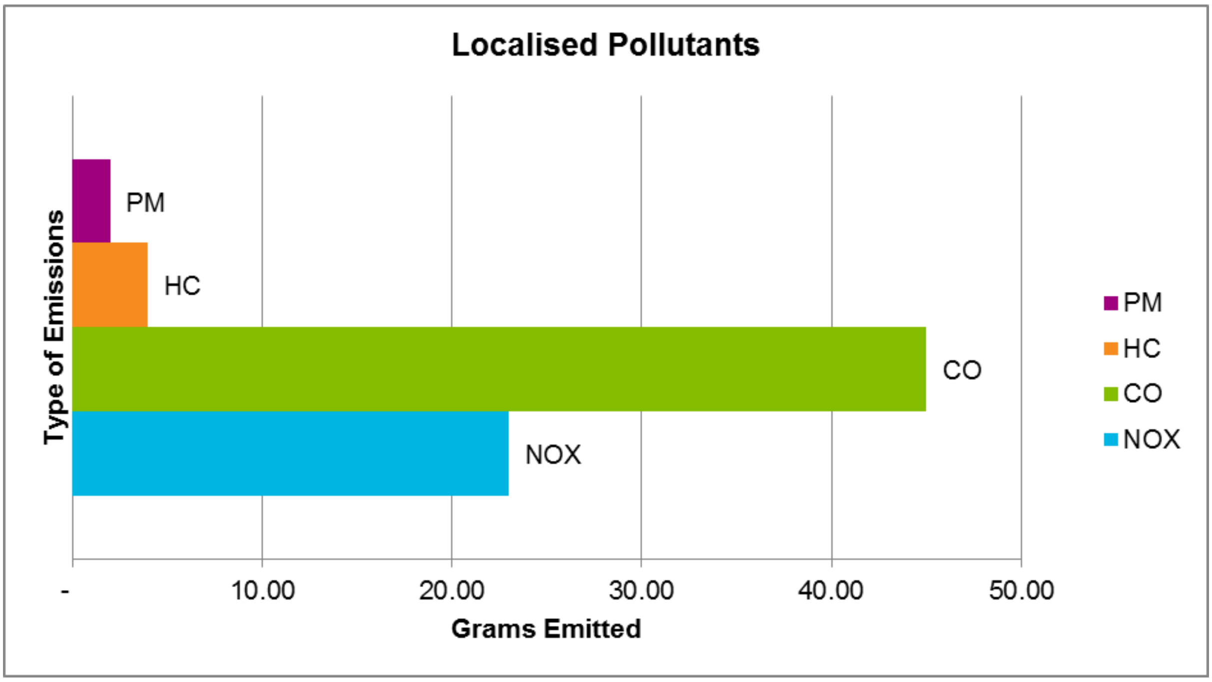


Figure A32: Localised Pollutants - Site 5

In addition to 74g of localised emissions, 9.2 kg of CO_2e were emitted due to delay and diversion. When annualising these emissions (based on 330 working days) three tonnes of CO_2e will be produced as well as 25 kg of localised pollution due to delays at this site.

Using the methodology as described in site 1 and used on previous sites, **Table A8** shows the cost breakdown

Table A8: Localised Pollutant Costs - Site 5

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£ 31	£ 94.38
NOX	£ 80,658	£ 612.19
PM	£178,447	£ 117.78

This shows total costs due to emissions as **£824.35** per annum.

Collisions

No collisions or near misses were recorded for this site during the measurement period.

Infrastructure Damage

Damage to the roads was calculated according to the methods described in section 6.3.2. The average gross weight of vehicles servicing the site was 23.44 tonnes and generated 48 ESALs.

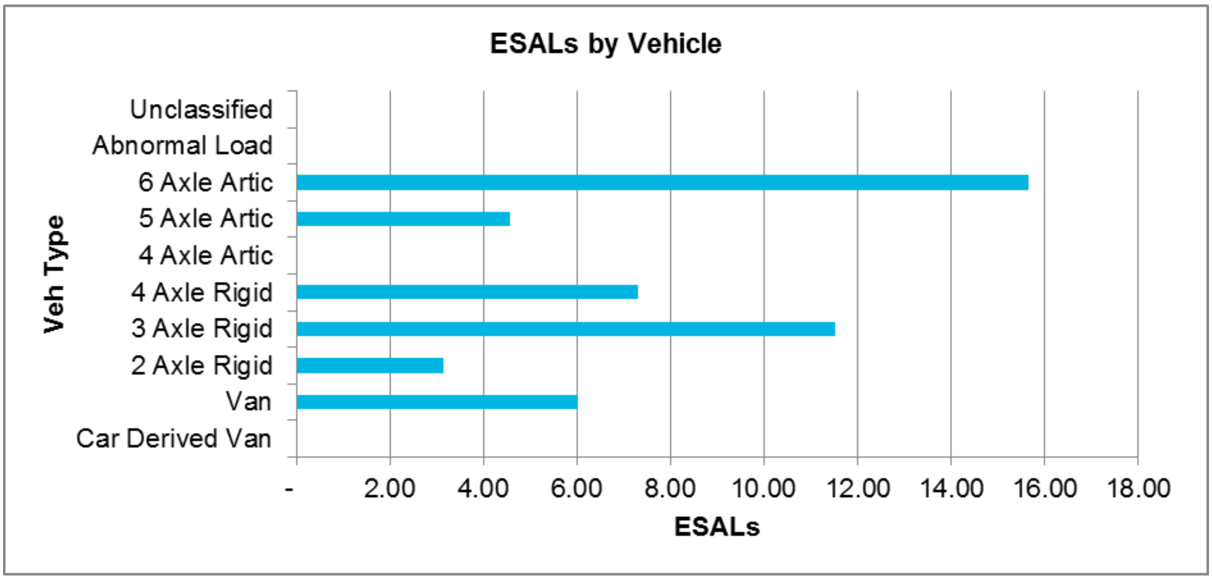


Figure A33: Localised Pollutants - Site 5

Figure A33 indicates the distribution of ESALs between vehicle chassis types. They are more evenly spread than other sites though the largest is six axle articulated vehicles, which may account for the relatively low number of ESALs in relation to the average payload.

No vehicles were diverted however, meaning no costs were incurred in terms of wasted mileage.

Summary and Lessons Learned

The site is a consolidation centre servicing other sites at various stages of construction and observations for the site were taken over the course of one day, in which 18 vehicles were identified as servicing the site. There was both a holding bay and DMS in operation. The site experiences above average delays and is one of the few for which schedule information was available. The schedule does not correspond to the arrival of any of the vehicles, suggesting these times are largely ignored and the DMS is simply a booking rather than scheduling system.

Vehicles arrived in a relatively narrow portion of the day given the site is open 24 hours and there could be opportunities to explore broadening this window should the number of vehicles needing to be received increases. The first wave of vehicles also coincided with the morning rush hour – efforts to shift this later may improve delivery time and reliability.

Total costs per annum for the site due to delay and diversion are forecast to be **£ 21,236** per annum and 96% of these are borne by the operator.

Site 6

Category	Value
Location	Outer London
Size	Small
Performance	Bad
Construction Phase	Operational
Holding Area	Yes
Booking System	No
Hours of Work	06:00-18:00
Average Vehicles per Day	11

This small site was surveyed over five days and recorded 54 vehicles accessing the site. There was a holding bay with capacity for approximately two vehicles and a DMS was in place.

Vehicle Profile

The dominant vehicle type at the site was flatbed, accounting for 54% of arrivals. The remainder varied widely but included Box vehicles, tankers and some tipper vehicles. **Figure A34** shows the distribution of vehicle types.

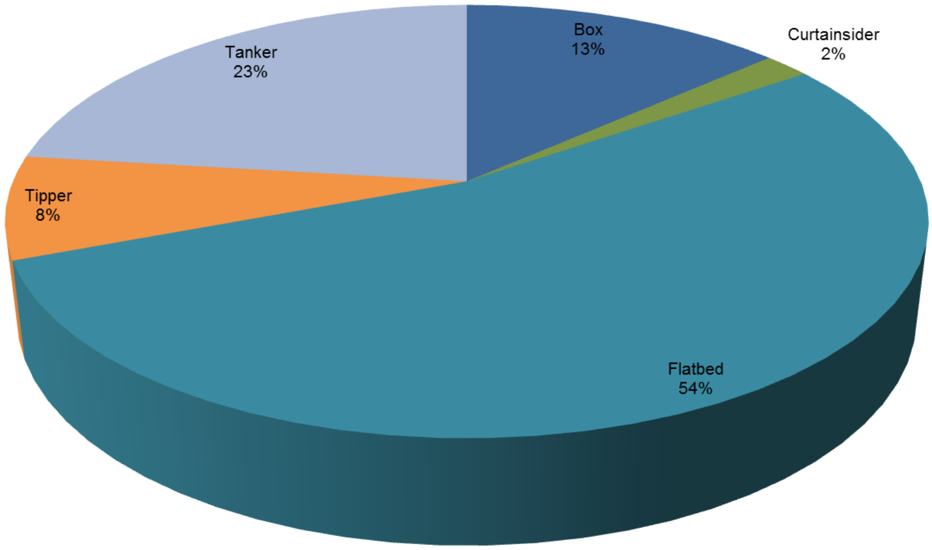


Figure A34: Vehicle Profile - Site 6

The level of FORS accreditation was not recorded, though is expected to be similar to Site five given the nature of operations and therefore likely to account for around 50 % of the vehicles seen at the site.

Delivery Success

The site experienced no delivery failures during the period of analysis. This could be for a variety of reasons including the relatively low number of vehicles visiting the site as well as the use of the holding area meaning that there were relatively low levels of congestion and that may have enabled operators to make emergency bookings to facilitate access.

Congestion

Scheduling information was not available for this site and so the levels of delay have been based on the variance from the average duration of vehicles on site. The site has been categorised as bad with an average dwell time of an hour and 20% of vehicles experiencing a higher than average dwell time, i.e. delay. The average delay was one hour and 18 minutes. **Figure A35** shows the distribution of vehicle dwell times against the average.

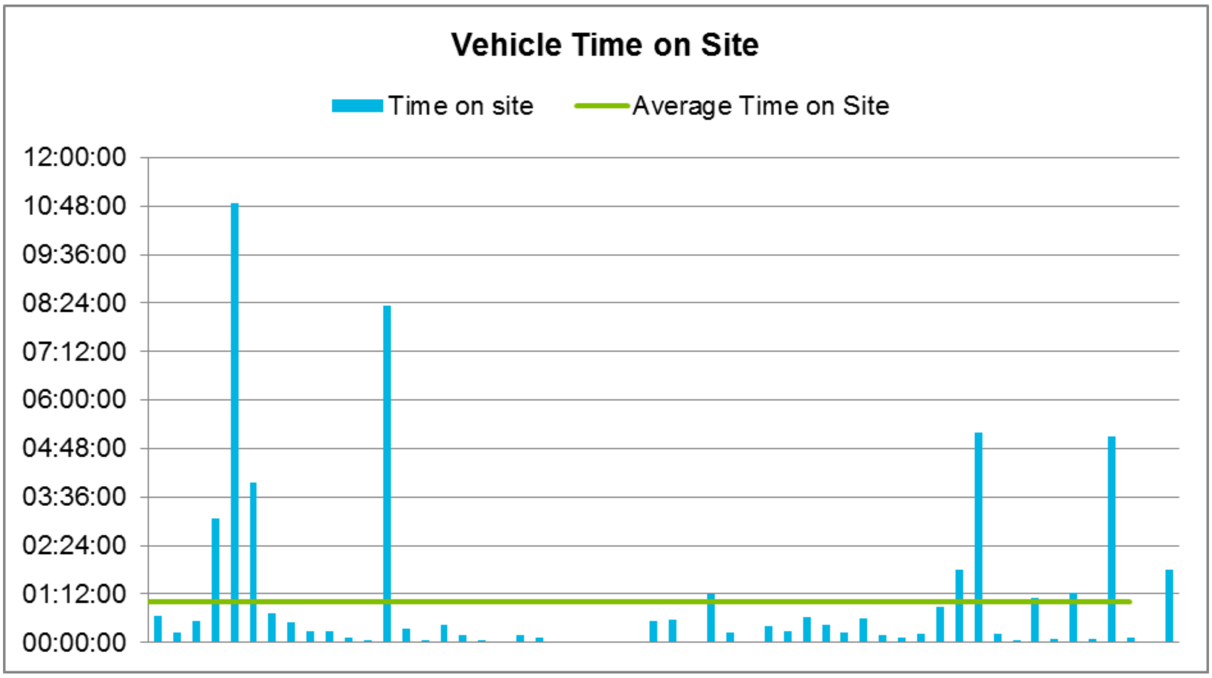


Figure A35: Vehicle Dwell Times - Site 6

From **Figure A35** it is clear that the majority of vehicles are serviced well below the average time. However a number of vehicles are on site for much longer – up to 11 hours. Whilst some vehicles may have suffered a delay, others appear to be on standby and so stationed deliberately on site. As such the categorisation of the site may need further review.

In terms of the costs of delays to the operator, **A9** sets out the annual impact, using the same methodology as described in site 1. 30% of 11 deliveries per day – around 4 experience some sort of delay. On average this can be up to 46 minutes.

Table A9: Vehicle Delay Costs - Site 6

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	4	1:53	£ 73.19
Annual	1,320	621 hours	£ 24,151.62

Again this demonstrates the impact of long delays on operators, costing £73.19 per day or **£24,151.62** per year.

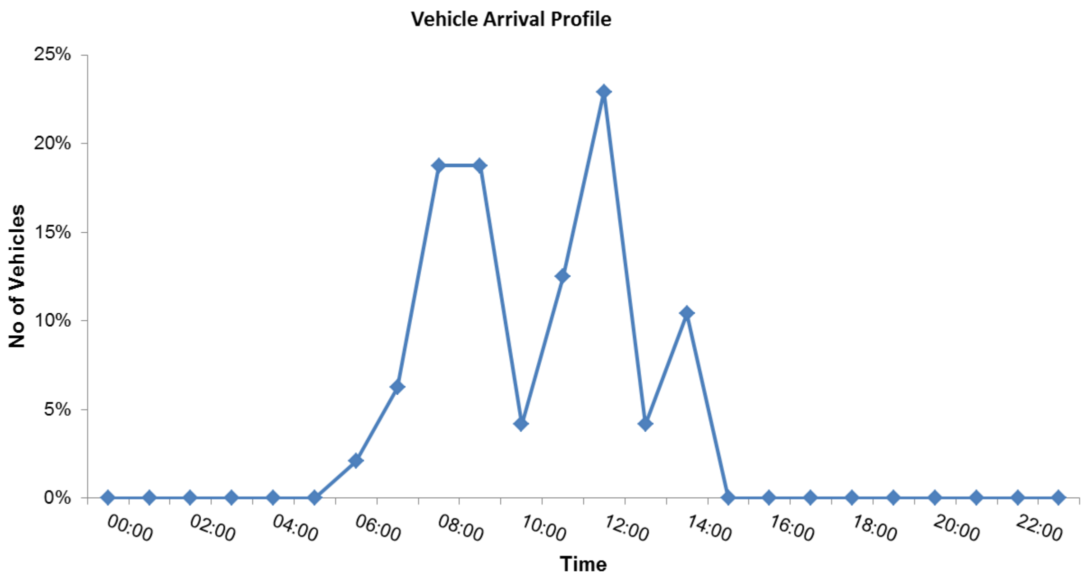


Figure A36: Vehicle Arrival Profile - Site 6

Analysing the arrival profile of the vehicles highlights an erratic profile rather than distinct waves, suggesting the DMS may be used purely for booking rather than scheduling of arrivals. **Figure A36** shows the profile of arrivals. Vehicles arrive throughout the delivery window, though tail off towards the end of the day. Like many sites, there is a peak during the AM rush hour. Shifting deliveries later on in the day may improve performance in terms of journey time and reliability.

Emissions

Figure A37 shows the emissions profile for the site, 80% of vehicles accessing the site were Euro VI, with an additional 10% being Euro V. This profile of extremely new vehicles will be highly beneficial in counter-acting the delay times created by the site. Such a profile is unusual and could potentially indicate agreements with suppliers as part of an air quality strategy for the site.

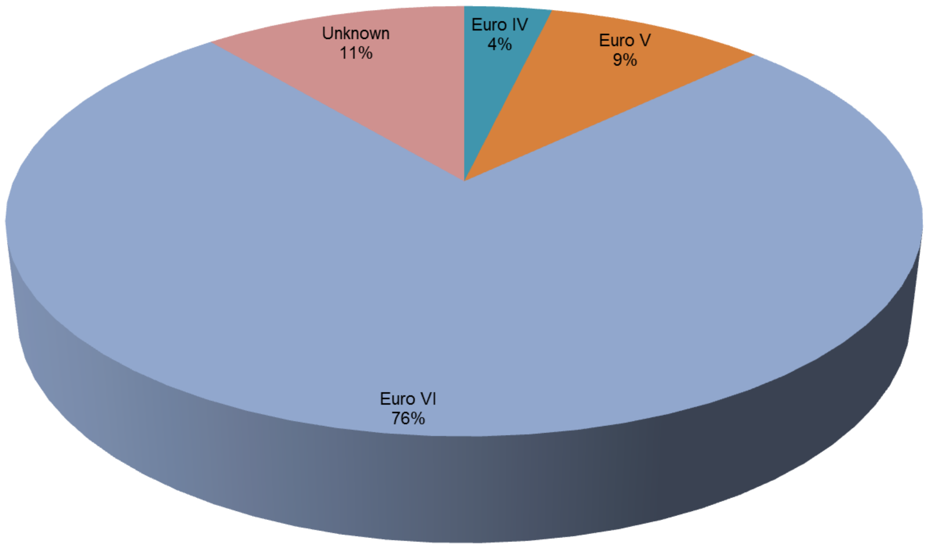


Figure A37 Emissions Profile - Site 6

Average daily idle time for the site was 1 hour 14 minutes, wasting around 2.29 litres of fuel. **Figure A38** shows the breakdown of localised emissions from the site. Again NOX and PM are low compared to other pollutants given the high number of :Euro V and Euro VI vehicles

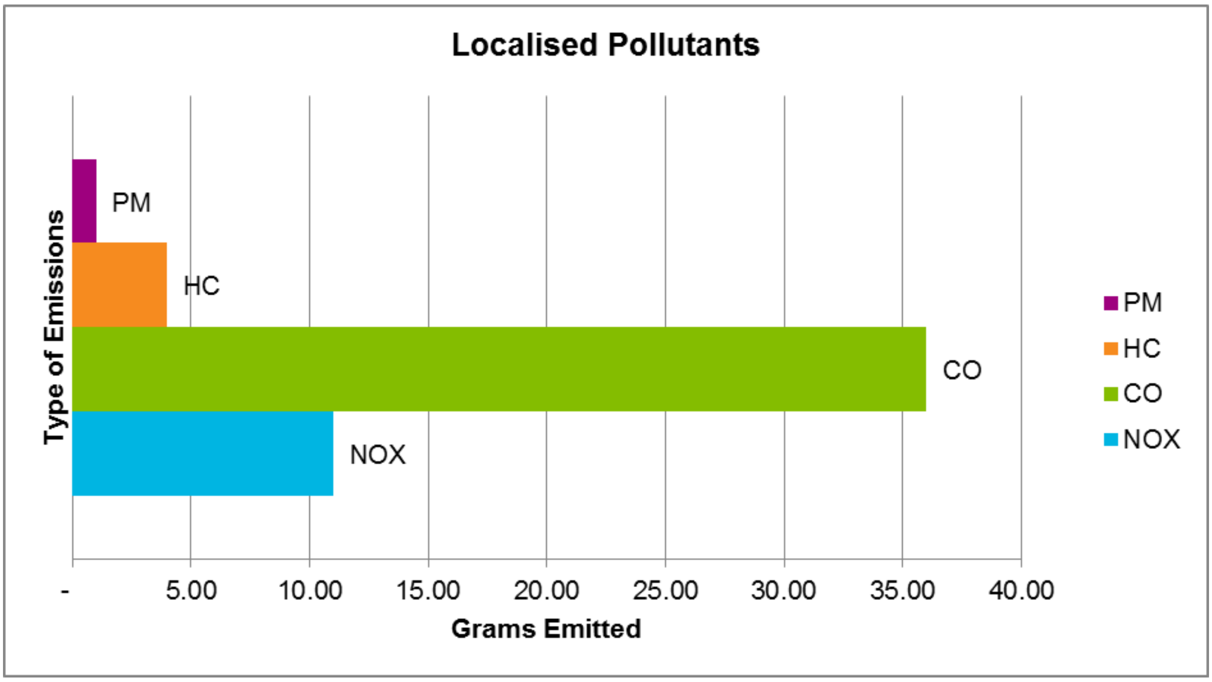


Figure A38: Localised Emissions Profile - Site 6

52g of localised emissions, alongside 6kg of CO_2e were emitted as a result of delays on site, annualising these totals results in 1.9 tonnes of CO_2e and 17.6 Kg of localised emissions.

Looking at the economic cost of these emissions, based on the methodology explained for site 1, **Table A10** shows the annual cost per emissions type.

Table A10: Emissions Costs – Site 6

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£ 31	£ 61.96
NOX	£ 80,658	£ 292.79
PM	£178,447	£ 58.89

This equates to a total of **£413.63**. The combination of modern vehicles and no diversions means that the consequences of delays are relatively low.

Collisions

No collisions or near misses were recorded for this site during the measurement period.

Infrastructure Damage

Damage to the roads was calculated according to the methods described in section 6.3.2. The average gross weight of each vehicle was 21.22 tonnes and the site resulted in 161 ESALs being generated as a result of the site's activity.

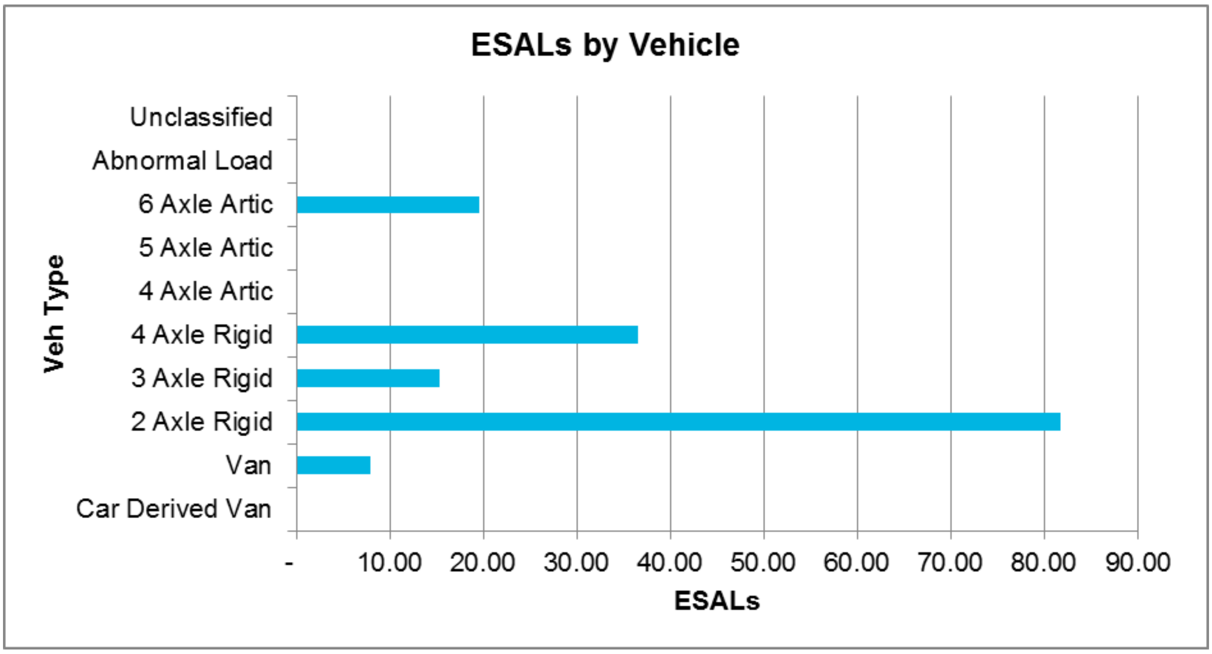


Figure A39: Infrastructure Damage - Site 6

Figure A39 shows that ESALs are distributed across a number of different chassis types; however the most numerous are 2 axle rigid, indicating the relatively high number of ESALs generated for the average payload.

With no delivery failures, there was no infrastructure damage due to wasted mileage.

Summary and Lessons Learned

The site differs operationally from other sites in that there appears to be a mixture of vehicle servicing the operational needs of the site as well as standby vehicles not specifically related to the site but being positioned there. Outside of these, long dwell times given the level of traffic were also apparent.

Despite this, vehicle arrivals were erratic and peaks coincided with rush hour. Better use of the delivery management schedules to even out deliveries and move them later in the day could create significant benefits for the sites efficiency, particularly if further vehicles are required to be serviced.

The number of two axle rigid vehicles used at the site is a concern and together with evidence from observation suggests that smaller quantities of goods are being delivered to the site. Use of consolidation to enable fewer deliveries can improve efficiency and reduce operator costs, depending on the nature of goods involved.

Total costs of delay and diversion at the site are forecasted to be **£24,565** per annum of which 98 % is borne by the operator.

Site 7

Category	Value
Location	Inner London
Size	Small
Performance	Good
Construction Phase	Demolition/Excavation
Holding Area	No
Booking System	Yes
Hours of Work	08:00 – 18:00
Average Vehicles per Day	9

Vehicle Profile

This small site in Inner London is in the demolition/excavation stage. The site receives an average of nine vehicle deliveries per day. As would be expected during this stage of works, the majority of deliveries are of cement and made by mixer vehicles, however the quantities are low compared to other sites at the same stage; it is not clear why this is and could be due to under reporting. **Figure A40** shows the breakdown of vehicle body profiles at this site.

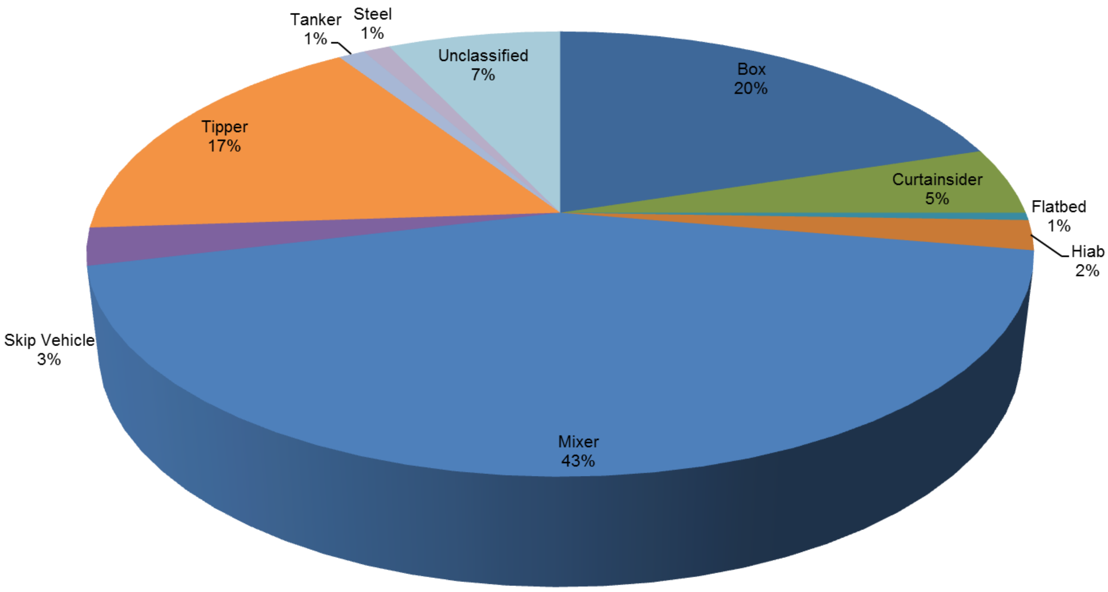


Figure A40: Vehicle Profile – Site 7

Given the small number of deliveries per day, the breakdown of vehicles at this site only includes three identifiable body types: mixer, tipper and box. Due to limited information on vehicle types, a number of assumptions had to be made around vehicle types based on a description of activities.

100% of vehicles arriving at the site were FORS accredited. This suggests that this is a 'FORS site' and suppliers must use accredited fleet to make deliveries.

Delivery Success

There were no failed deliveries at this site.

Congestion

Data was not available or collected for this site, so an average of the timings for other sites has been used for site 7. The average time that vehicles spent on site was 47 minutes, with an average delay of 25 minutes; an assumption was made that 10% of vehicles will experience a delay. **Figure A41** shows the average time that vehicles spent on site.

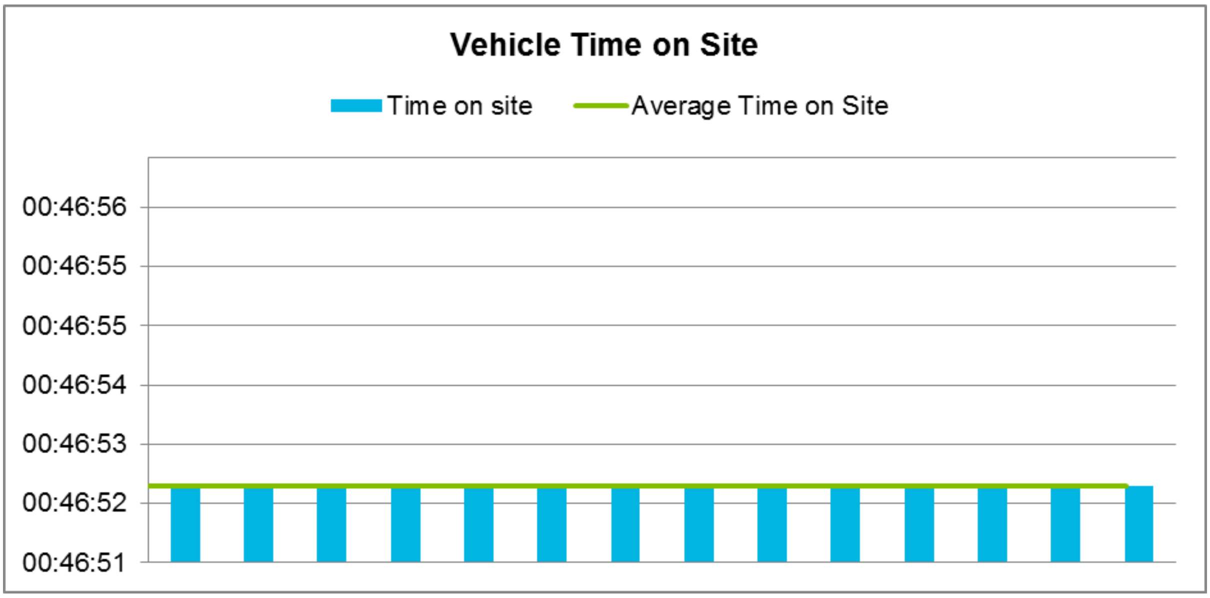


Figure A41: Vehicle Time on Site – Site 7

In terms of putting a value on the delay, using the same method as described for site 1, 10 deliveries per day and 10% delay rate, means that 1 vehicle per day will be delayed, on average by 25 minutes. **Table A11** provides detail.

Table A11: Vehicle Delay Costs - Site 7

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	1	00:25	£ 17.49
Annual	330	141 hours	£ 5,482.08

Total costs due to delay are around £5,500, demonstrating how costs can be minimised for a well-managed site.

Figure 6.42 shows the distance from depot to site across all deliveries recorded. Average distance was around 16.27 km and 22% had above average distances to site.

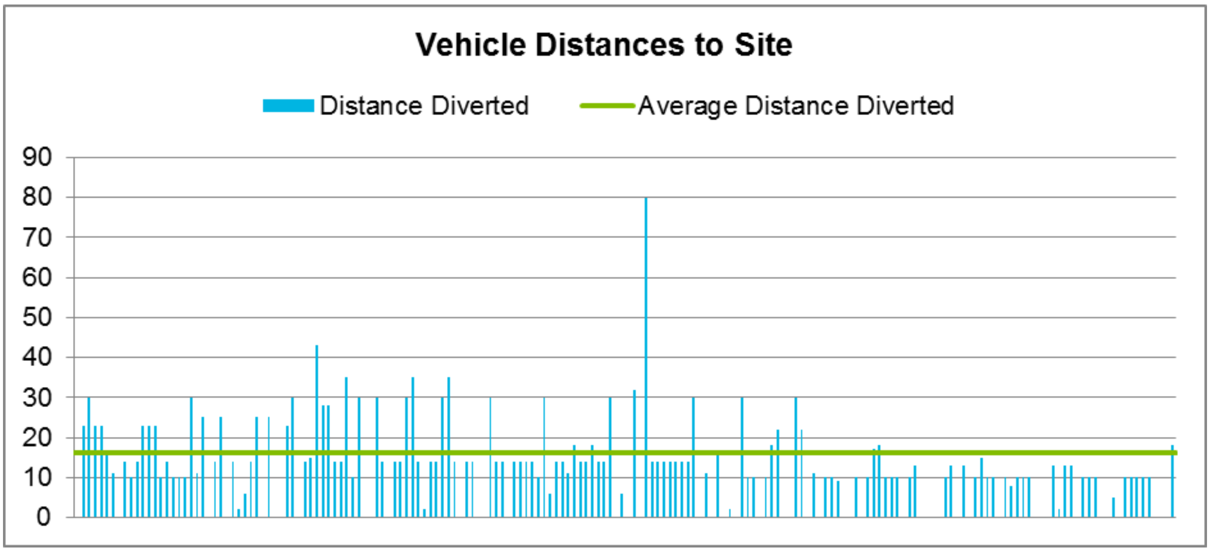


Figure A42: Distance to site - Site 7

This site was the only site to provide distance information and so the average has been used as a measure of diversion for other sites should deliveries fail. This has been worked into the fuel estimates as appropriate.

Figure A43 shows the arrival profile of vehicles accessing the site. Whilst there is a significant uplift at around 8 am when the site opens, deliveries are spread more evenly throughout the day.

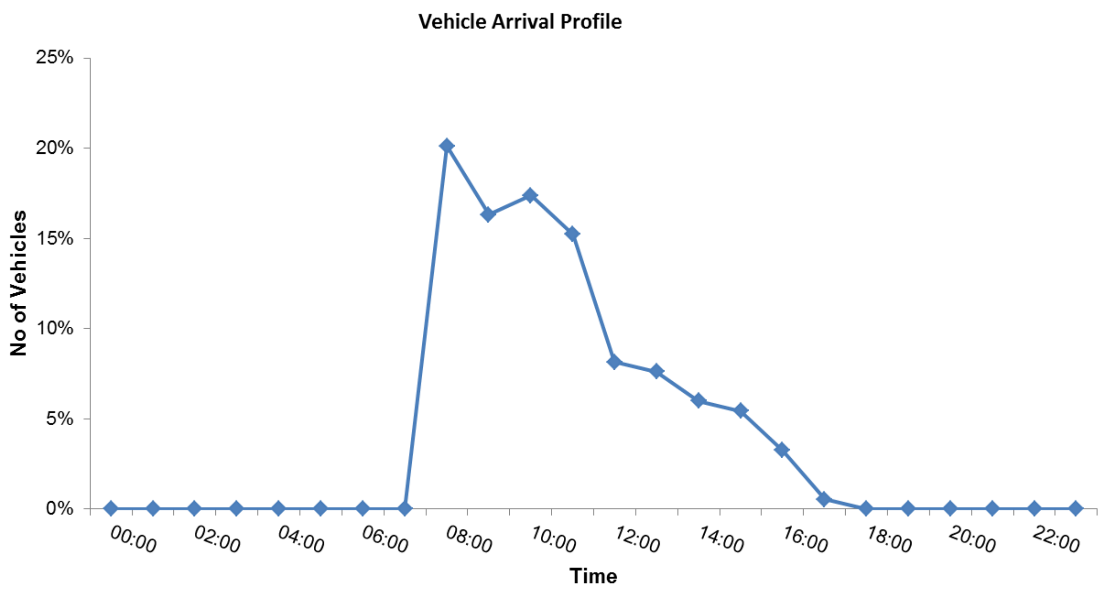


Figure A43: Arrival Time on Site

Emissions

Figure A44 shows the split of emissions. Whilst, 43% had no registration and therefore vehicle age information, 42% were Euro VI and the remaining 15% Euro V hence producing low levels of emissions compared with other sites.

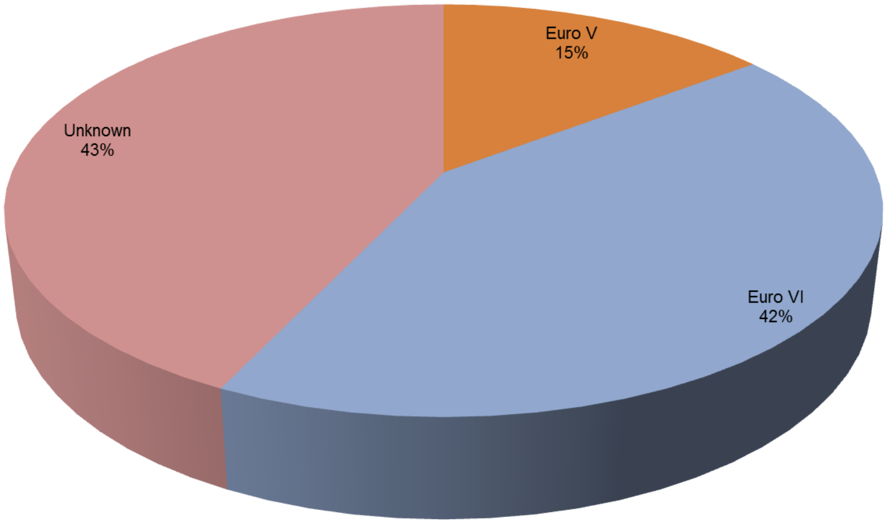


Figure A44: Euro Emissions – Site 7

Based on 10% of vehicles experiencing an average delay of approximately 29 minutes, Over 7 litres of fuel are wasted as a result of idling. **Figure A45** shows the local emissions generated which are low compared to other sites and reflects the large numbers of newer trucks accessing the site.

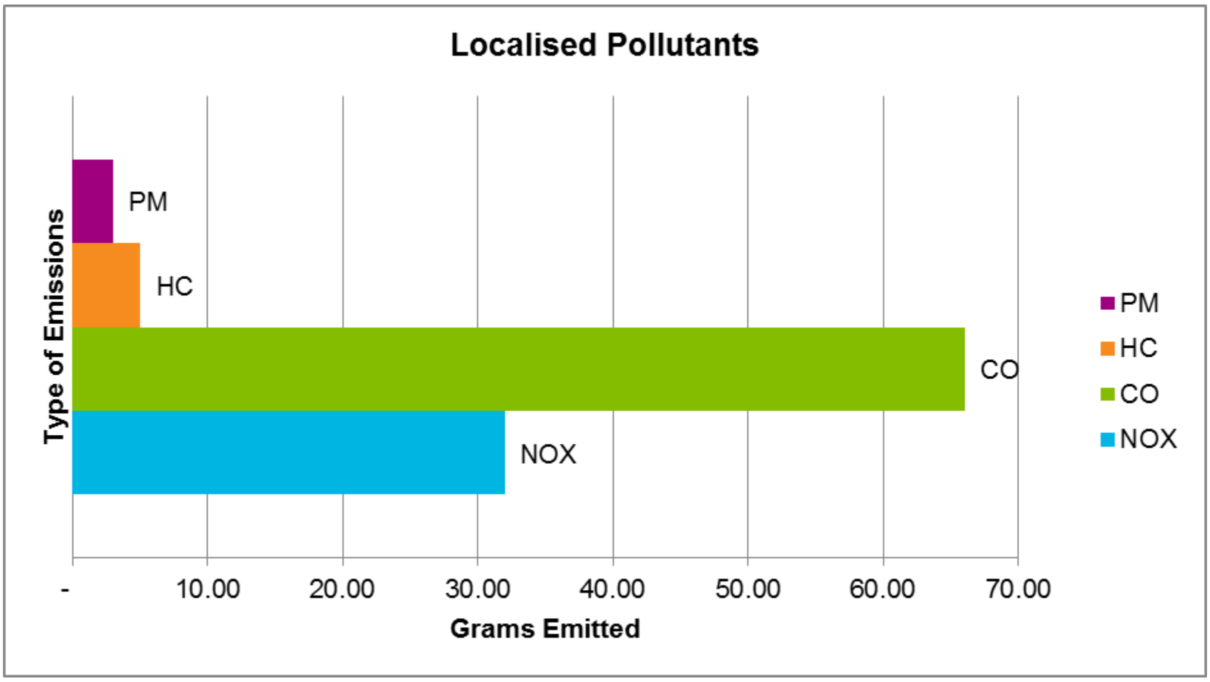


Figure A45: Local Emissions. - Site 7

Annualising these figures shows that 142 Kg of CO2e and 2.64 kg of localised pollutants will be generated should the same rates for delay continue. **Table A12** shows the economic cost of such emissions.

Table A12: Emissions Costs – Site 7

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£ 31	£ 4.43
NOX	£ 80,658	£ 53.23
PM	£178,447	£ 58.89

Infrastructure Damage

Average gross vehicle weight for the site was 21.5 tonnes, below average from the sites surveyed. This was spread across mostly rigid vehicles, and in particular 3 axle rigid vehicles. **Figure A46** shows the breakdown on ESALs by Chassis configuration.

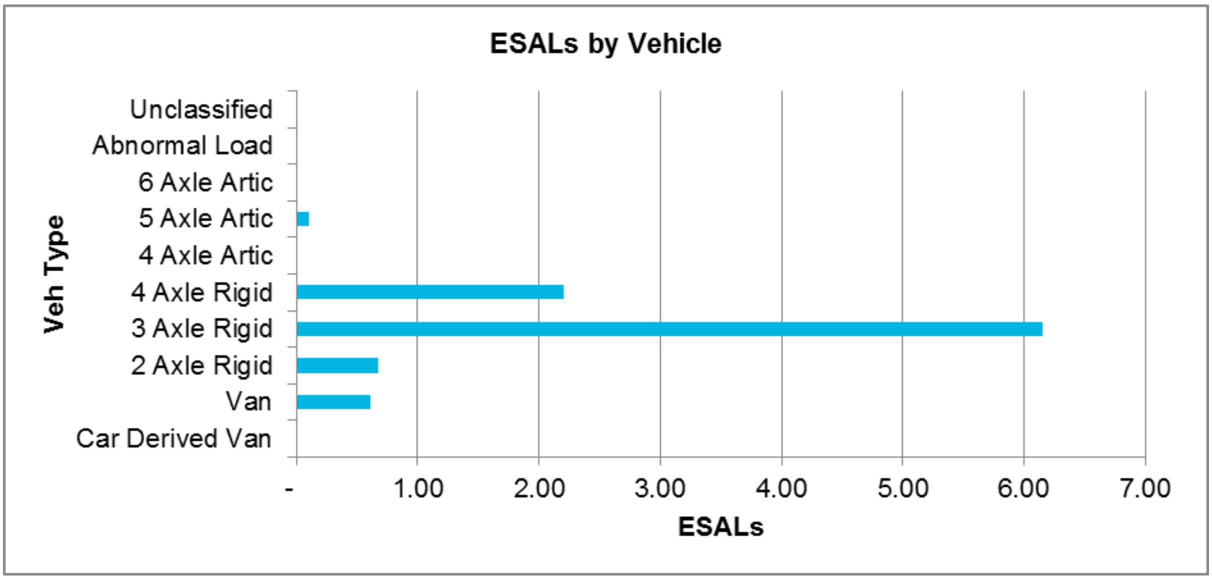


Figure A46 – Infrastructure Damage – Site 7

Greater use of articulated vehicles, or the ability to consolidate deliveries, may help to reduce infrastructure damage and over all deliveries to the site.

No vehicles were diverted and therefore no infrastructure costs were incurred as a result.

Summary & Lessons

This small site in Inner London is in the demolition/excavation stage. The site receives an average of nine vehicle deliveries per day. Limited information for this site was available although some data such as the distance vehicles had travelled to the site was available. The data demonstrated the clear benefits of deploying newer vehicles in terms of air quality, with all identified vehicles being either Euro V or Euro VI and generating around 109g of localised pollutants per day. The site is being effectively managed as no delivery failures were reported during the survey period. This suggests that suppliers are aware of the requirements for entering the site and management have the right balance of flexibility in terms of accepting unscheduled deliveries. Costs for the site are forecast to be relatively low – around **£5,600** per annum for the site, of which 97% is borne by the operator.

Site 8

Category	Value
Location	Outer London
Size	Medium
Performance	Average
Construction Phase	Fit out
Holding Area	No
Booking System	Yes
Hours of Work	08:00 – 18:00 Weekdays 08:00 – 13:00 Saturdays *Plus up to 1 hour before/after for mobilisation
Average Vehicles per Day	21

Vehicle Profile

This medium sized site in the Outer London district of Brentford is a relatively busy site receiving an average of 21 deliveries per day. Data is based on a period of 759 days and accounts for 15,809 vehicles in total. The site is currently in the 'fit-out' stage.

The most commonly observed vehicles at this site are flatbed and box, which when combined account for 75% of vehicles at the site. Vehicles with this body type are commonly used for haulage of a wide range of materials and would be expected during the 'fit-out' stage. i.e. those vehicles making deliveries are often associated with general haulage rather than construction (e.g. tippers or mixers). **Figure A47** shows the body profile of vehicles delivering to the site.

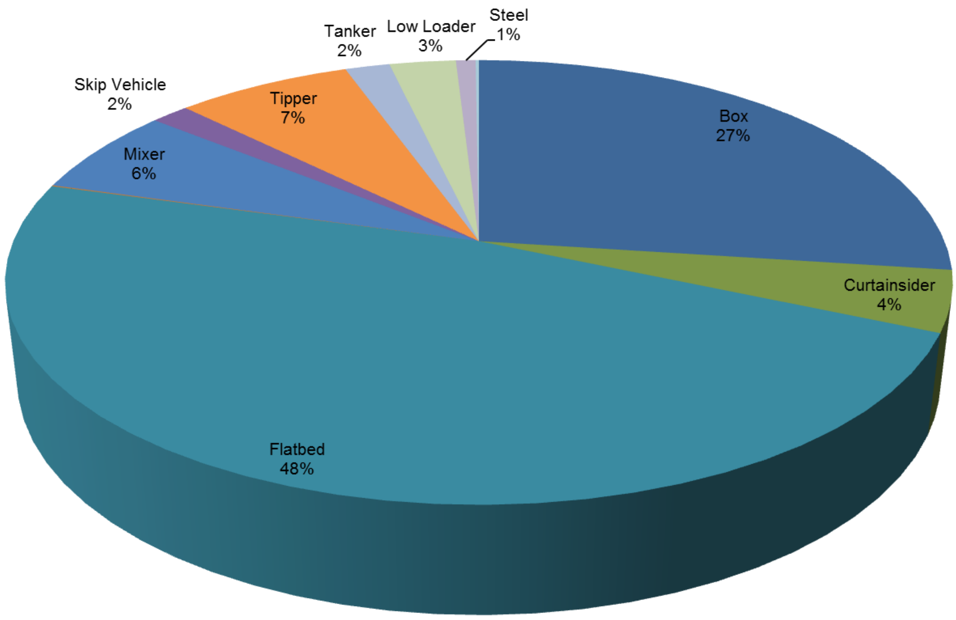


Figure A47 – Vehicle Profile – Site 8

At this site, data relating to FORS membership was not available.

Delivery Success

Less than 3% of deliveries to this site were unsuccessful which is slightly lower than the average figure of 4% across all sites. Delivery failures at this site are infrequent however; on the occasions they have occurred the reasons have been wide-ranging.

The low number of failures suggests the site is managing deliveries well and not contributing to unnecessary vehicle mileage and associated emissions or inappropriate waiting nearby. **Figure A48** shows the reasons for failed deliveries to Site 8.

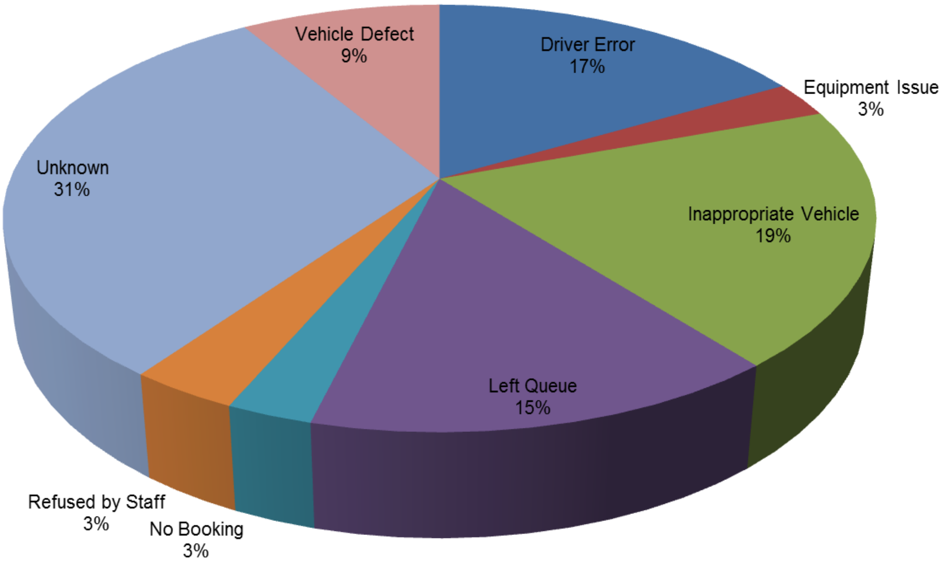


Figure A48: Failed Delivery Reasons – Site 8

Congestion

Telematics data for this site shows that the average time that vehicles spent at this site was 48 minutes and the average delay has been calculated as 25 minutes. **Figure A49** shows the distribution of vehicle dwell times on site and the average time spent on site.

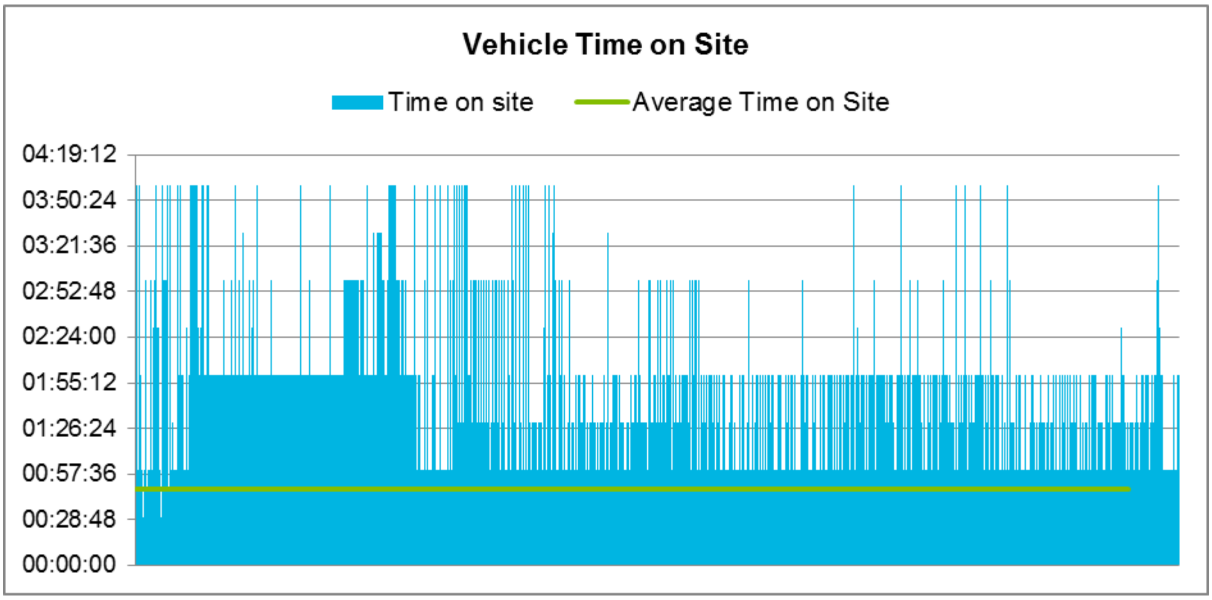


Figure A49: Vehicle Time on Site – Site 8

The average time spent on site of around 48 minutes is in line with the average across all sites and the delay time of 29 minutes has been rated average. It is lower than the delay time at Site 5 (35 minutes) but roughly 3.5 times greater than that of Site 4 (8 minutes) both of which are other medium sized sites.

The main sources of delay included vehicles not being booked in and having to be turned away or booked in when they arrived if it was possible to accommodate them on-site. Additionally, vehicles and/or drivers not adhering to the required standards incurred delays whilst this was corrected or they were turned away.

Looking at the economic costs, using the same methodology as described for Site 1, 38% of vehicles suffer some level of delay. **Table A13** shows the annual impacts

Table A13: Vehicle Delay Costs - Site 8

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	21	7:45	£ 242.68
Annual	6,930	2,562 hours	£ 80,083.54

Whilst the delay is average, a large percentage of vehicles experience the delay, hence the costs to the operator mount up quickly, to over **£80,000**

The vehicle arrival profile for this site, shown in **Figure A50**, shows that there is a clear morning peak in arrivals between 08:00am and 11:00am. After this period, vehicle arrivals decline into the afternoon period.

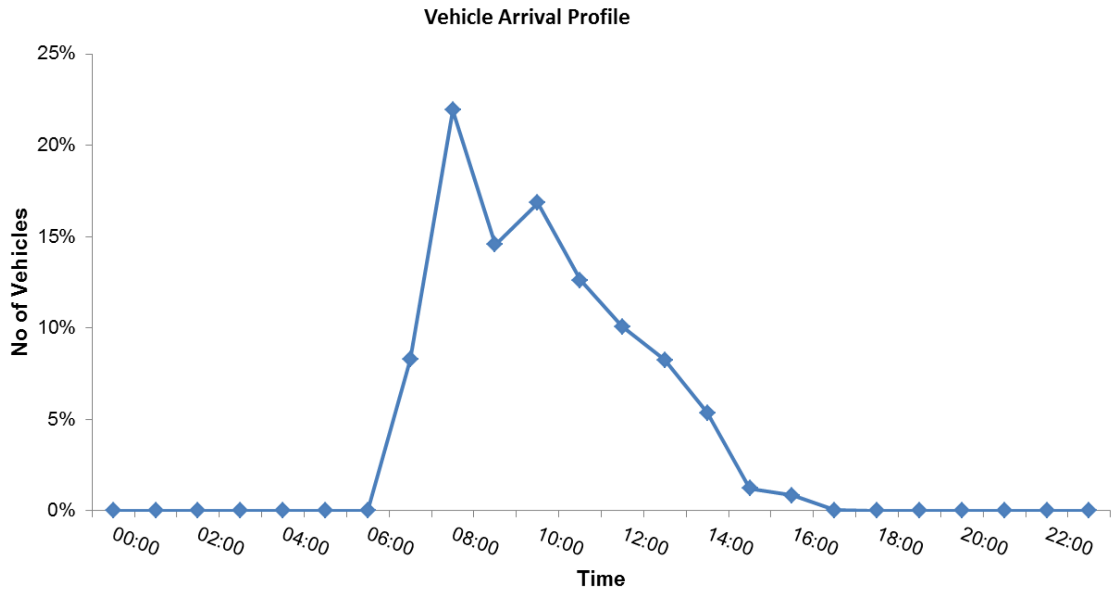


Figure A50: Vehicle Arrival Profile – Site 8

Emissions

No Euro information was available for the site and so the average proportion of vehicles from other sites was used to provide an estimate. This is shown in **Figure A51.**

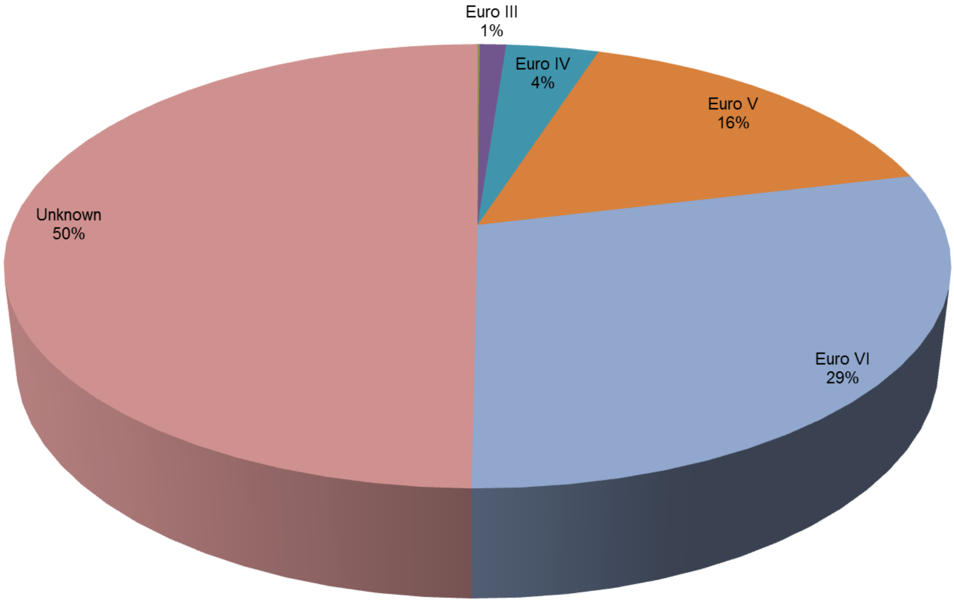


Figure A51: Emissions Profile - Site 8

On average, the collective time vehicles spent idling was 4:53 minutes, factoring in diversion this wasted around 6 litres of fuel. **Figure A52** shows the breakdown of localised emissions from the site. NO_X and CO are high compared to other pollutants.

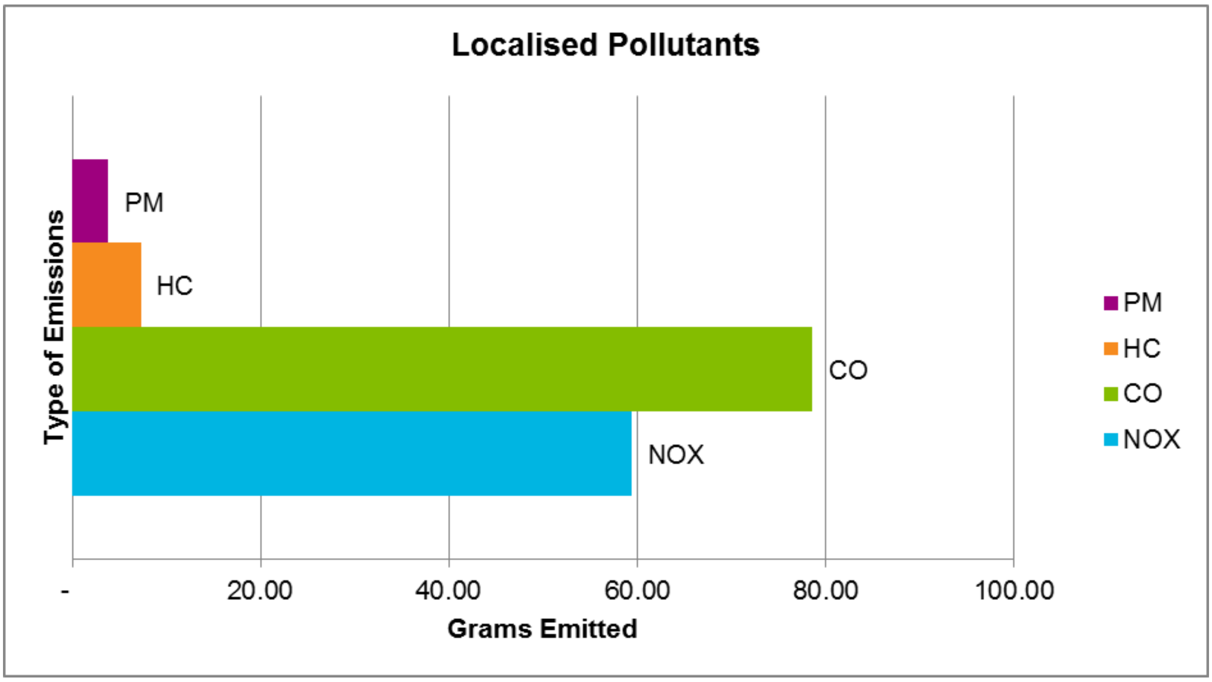


Figure A52- Localised Emissions Profile – Site 8

149g of localised emissions, along with 13kg of CO_2e was also emitted as a result of delays and diversions, annualising these totals results in 4.5 tonnes of CO_2e and 49kg of localised pollutants. In terms of a value, **A14** provides annual costs based on the methodology described in site 1.

Table A14: Emissions Costs – Site 8

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£ 31	£ 140.32
NOX	£ 80,658	£ 1,580.49
PM	£178,447	£ 227.20

Total Costs due to emissions therefore will be **£1,948.01** per annum

Infrastructure Damage

Average gross weight for vehicles accessing the site was 12.07 tonnes, significantly below the average seen across the sites and reflects the phase that the site is in. **Figure A53** shows the breakdown of axles against chassis configuration.

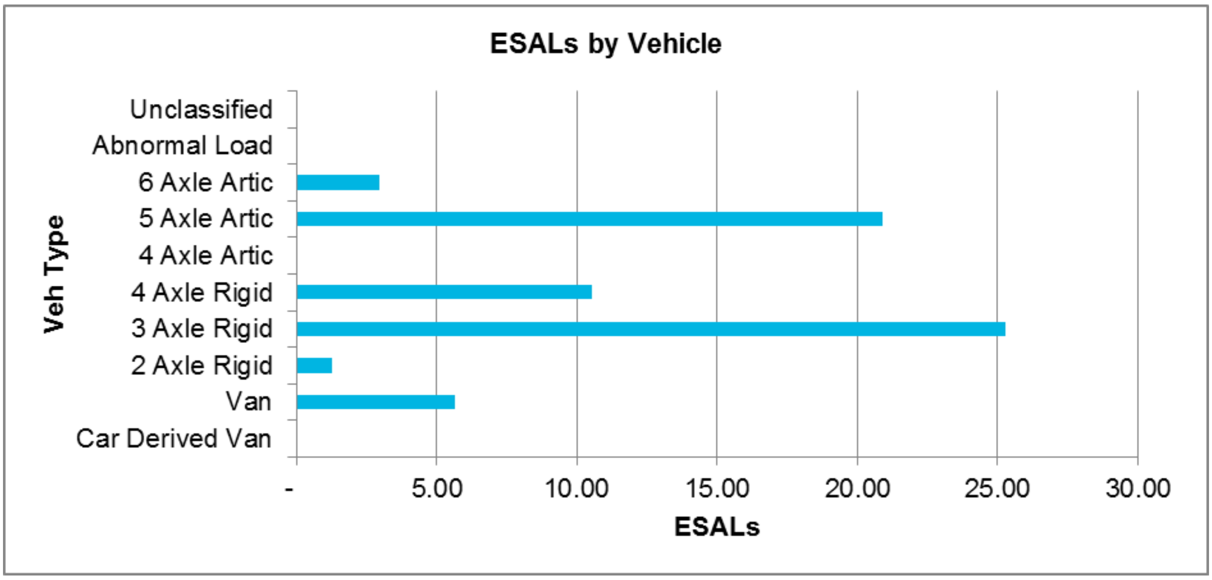


Figure A53: Infrastructure Damage – Site 8

It can be seen that the damage is spread over a relatively large number of chassis types, with significant use of articulated vehicles as well as larger rigid vehicles, suggesting that the vehicle is often appropriate to the specific delivery.

On average 1 delivery per day fails, resulting in an average diversion of 16.27 KM. Should this continue, 330 vehicles per year will divert 5,369km, costing around **£5.36** per annum.

Summary & Lessons

This site is fairly busy with 21 deliveries per day and hence classified as medium. The large amounts of data provided a reliable set of trends though the lack of details on factors like vehicle age and type limited its value. This highlights a major issue with many of the sites in that few collect data in a uniform manner and often not in the detail required to produce a consistently meaningful analysis, overlooking a significant opportunity to assess the value of construction logistics and further improve its performance.

Whilst delays aren't above average across the sample, significant sources include failure to book and failure to have an appropriate vehicle, with some deliveries ultimately being turned away.

There are also significant incidences of vehicles leaving of their own accord, possibly due to congestion around the single gate in use. This may be drivers acting independently, or more likely transport managers directing vehicle onto other deliveries/collections where turnarounds are higher.

Better use of the delivery management/vehicle booking system, and efforts to communicate their importance to operators could help to reduce onsite delays.

Total cost of the site due to delay and diversion is forecasted to be **£82,037** per annum, with 98% being borne by the operator.

Site 9

Category	Value
Location	Inner London
Size	Large
Performance	Bad
Construction Phase	Excavation and Piling
Holding Area	No
Booking System	Yes
Hours of Work	08:00 – 18:00 Weekdays 08:00 – 13:00 Saturdays *Plus up to 1 hour before/after for mobilisation
Average Vehicles per Day	50

Vehicle Profile

This large central London site receives an average of 50 vehicle deliveries per day. At the time of audit, the site was in the sub-structure stage. Data was provided for 544 days and accounts for almost 21,000 deliveries in total.

Activity at this site is dominated by mixer (43%) and tipper (30%) type vehicles. These types of vehicle can be linked to cement and bulk deliveries and muck-away. **Figure A54** shows the profile of vehicles accessing the site.

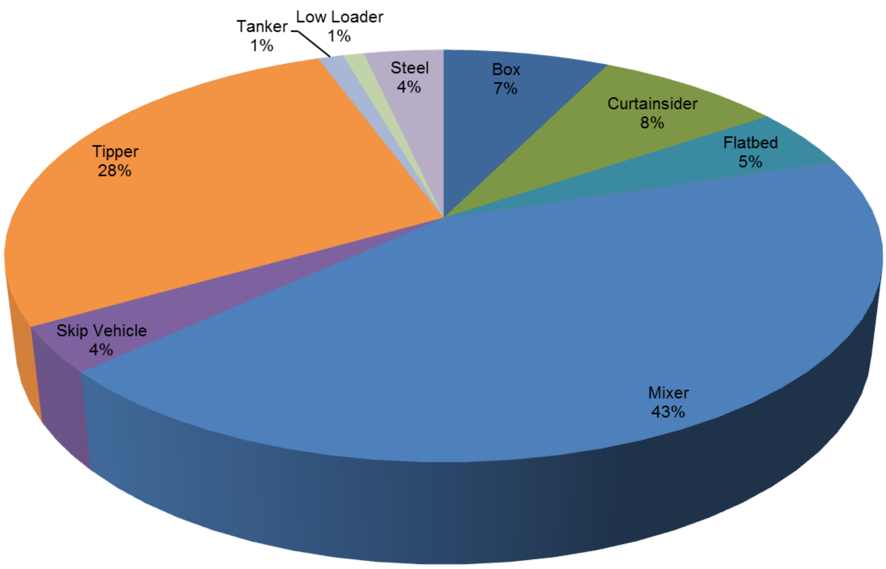


Figure A54 Vehicle Profile – Site 9

As seen at other sites, cement mixers tend to make multiple deliveries to the site during the day. Given that tipping times for mixers can be in the region of 60-90 minutes, a mixer might make between two and three trips per day depending on the location of the cement plant it is operating from. Tippers can make similar numbers of trips albeit with a faster turnaround.

At this site, data relating to FORS membership was not collected/ available.

Delivery Success

4% of deliveries at this site were unsuccessful which is equal to the average across all sites. **Figure A55** shows the reasons for non-deliveries.

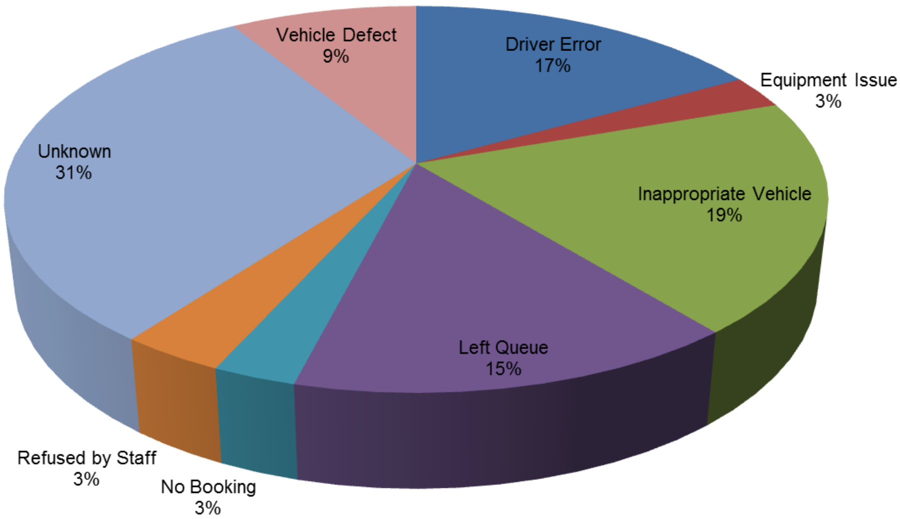


Figure A55: Delivery Failures - Site 9

The breakdowns of reasons for non-delivery at Site 9 are wide ranging and shows that delivery failures at the site occur for a wide variety of reasons across the site, suggesting no specific issues are present.

Congestion

Telematics data for this site shows that the average time spent on site by vehicles is 88 minutes including an average delay is 36 minutes. **Figure A56** shows the distribution of vehicle dwell times on site and the average time spent on site.

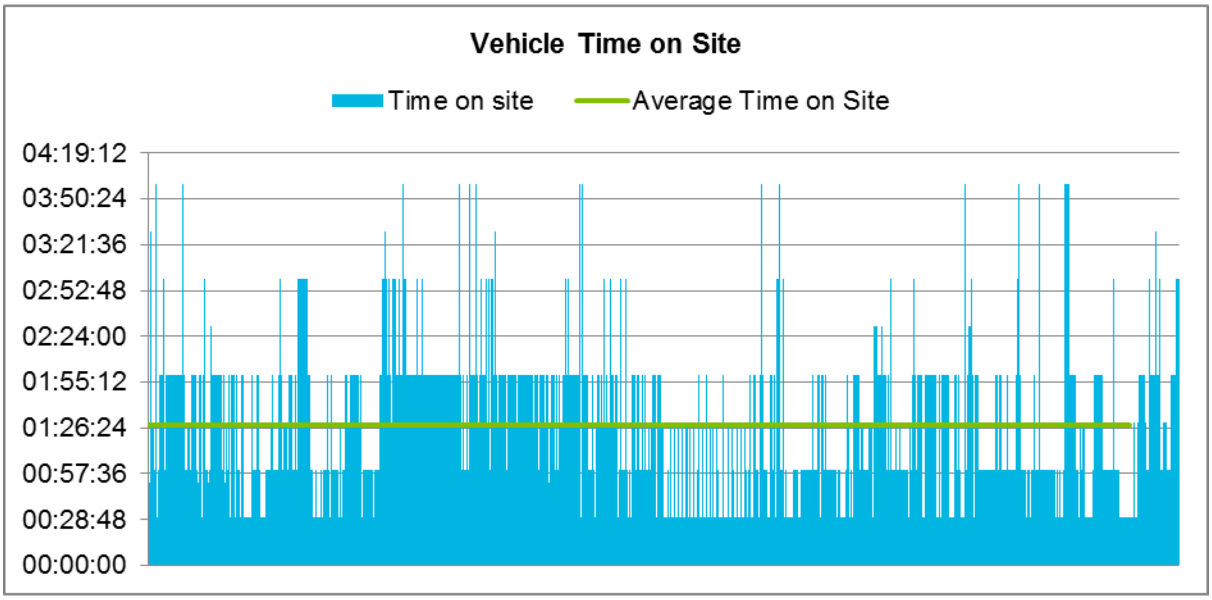


Figure A56: Delay – Site 9

The duration performance is the greatest seen across all sites and has been rated as bad. However, the large proportion of cement deliveries will undoubtedly have increased this average in comparison to other sites as such deliveries take between 60 and 90 minutes.

The average delay time at this site of 36 minutes, with anything over 30 minutes rated as bad.. Such performance reflects heavily on the costs to operators shown in **Table A15.**

Table A15 Delay Costs – Site 9

	Number of Vehicles Delayed	Total Delay	Economic Cost
Daily	20	9:36	£ 381.47
Annual	6,600	3,169 hours	£125,886.24

Total costs per annum are estimated to be **£126,886** in additional operating costs, resulting from a total of 3,169 hours of delay per annum.

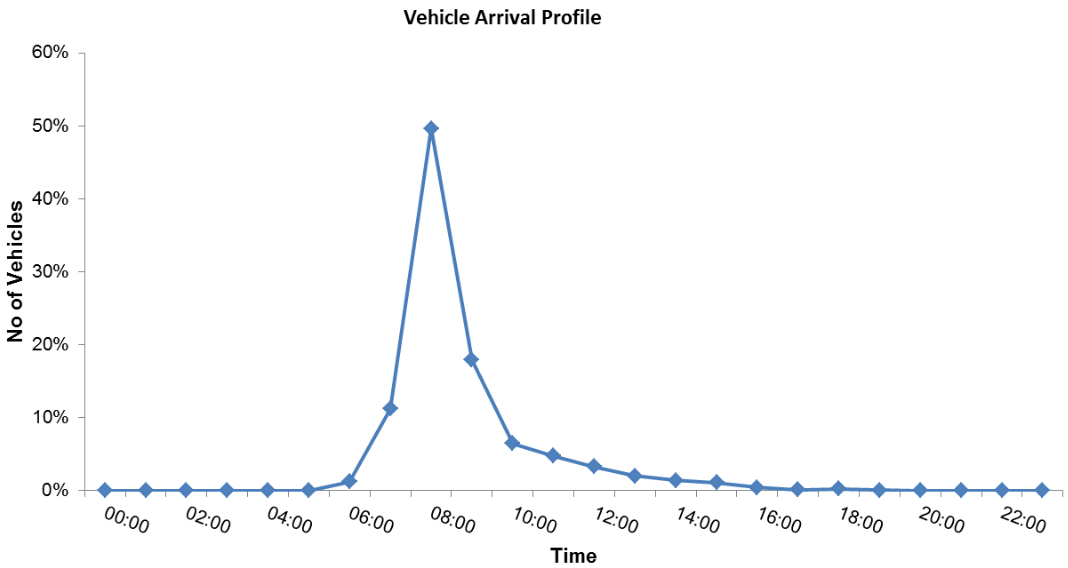


Figure A57: Arrival Time Profile – Site 9

Without specific reasons for delay being apparent, it may be solely due to the polarised nature of deliveries, with 79% of all vehicles arriving between 7am and 10am, which also co-ordinates with the morning rush hour. **Figure A57** shows the arrival profile.

Emissions

Almost three quarters of identified vehicles visiting this site are Euro V or Euro VI vehicles. This is positive in terms of pollution as these engines are newer and less polluting than older variations. **Figure A58** shows the breakdown of Euro Engine Ratings.

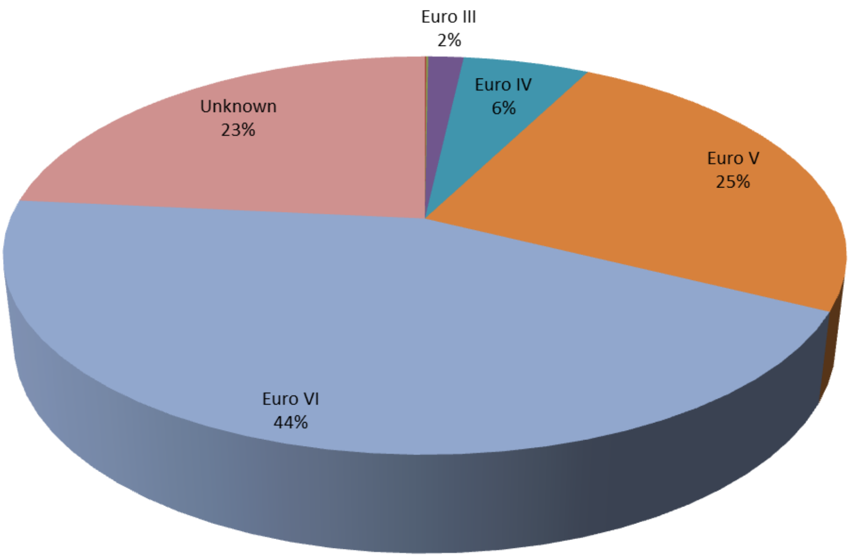


Figure A58: Emissions Profile – Site 9

In terms of emissions the total amount of time spent idling was around 3:22 minutes wasting 11.93 litres of fuel as a result of both delay and diversion. This resulted in a daily total of 31kg of CO_2e and 344g of localised pollutants. **Figure A59** shows this.

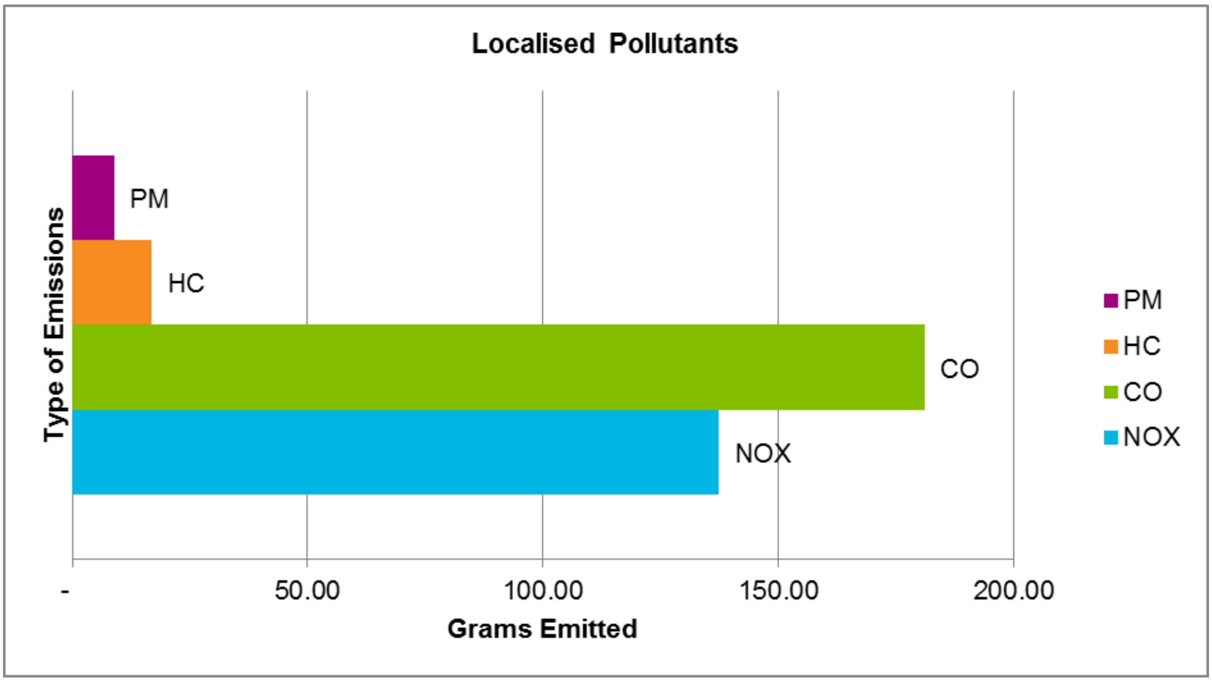


Figure A59: Localised Pollutants – Site 9

Annualising these totals (based on 330 working days) amounts to around 10.4 tonnes of CO_2e and 113 kg of localised pollutants.

In terms of value**, Table A16** provides a breakdown of the economic costs of such emissions.

Table A16: Emissions Costs – Site 8

Emission	Damage Cost (£ per tonne)	Annual Cost
CO_2e	£ 31	£ 322.30
NOX	£ 80,658	£ 3,654.70
PM	£178,447	£ 523.89

In total therefore, emissions had a cost of over **£4,500** per annum as a result of delay and diversion.

Infrastructure Damage

The average gross vehicle weight for the site was 23.83 tonnes. **Figure A60** shows the breakdown of equivalent axles according to the chassis configuration. As expected for the site phase, road wear is dominated by four axle rigid vehicles

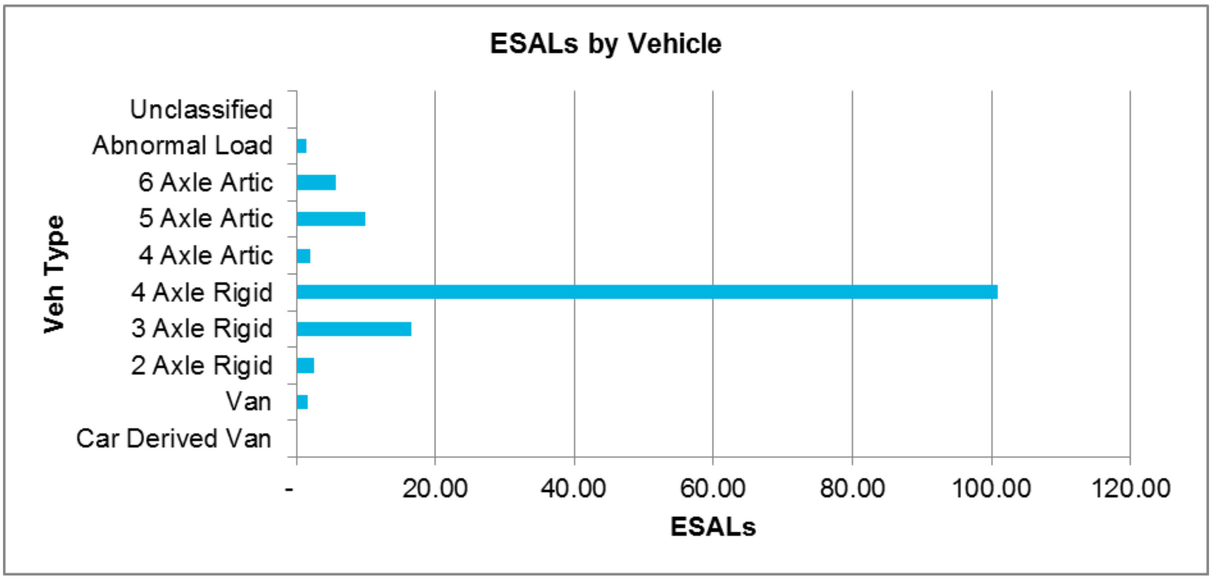


Figure A60: Infrastructure Damage – Site 9

Given the phase and the dominance of mixers delivering to the site, changes to vehicle configuration are limited. Depending on the size and space available, on site storage/production may be an option to reduce the number of deliveries. Similarly the use of articulated tippers may help to reduce numbers of vehicles required.

On average, the site experience two failed deliveries per day or 660 per year. This generated 10738 km of excess distance travelled resulting in a cost of **£10.74.**

Summary & Lessons

The site is one of the largest surveyed, with an average of 50 trucks accessing the site per day. With this level of delivery intensity, and no holding area, careful management of deliveries is important. The site is rated as bad likely due to a lack of holding area, As such; there are a number of areas that would benefit from efficiencies. This includes the scheduling of vehicles outside of the AM peak and where possible distributing them throughout the working day, though this may not be possible given the type of activity at the site.

Whilst reasons for delivery failures were quite varied, better communications with contractors to solve issues such as failure to book, defective vehicles and driver errors can further help to reduce delays and delivery rejections.

The total economic cost of the site is forecasted to be £**130,397** per annum due to delay and diversion, of which 97% is borne by the operator.

Glossary

Term(s)	Definition
Delivery Management Systems (DMS)	A system used to schedule deliveries to and from site.
Abnormal Indivisible Load (ACL)	An "abnormal indivisible load" is defined in The Road Vehicles (Authorisation of Special Types) (General) Order 2003 * as – • " a load that cannot, without undue expense or risk of damage, be divided into two or more loads for the purpose of being carried on a road and that – • on account of its length or width, cannot be carried on a motor vehicle of category N3 or a trailer of category O4 (or by a combination of such vehicles) that complies in all respects with Part 2 of The Construction and Use Regulations; or • on account of its weight, cannot be carried on a motor vehicle of category N3 or a trailer of category O4 (or by a combination of such vehicles) that complies in all respects with • Authorised Weight Regulations (or, if those Regulations do not apply, the equivalent provisions in Part 4 of the Construction and Use Regulations); and • Part 2 of the Construction and Use Regulations
Building Modelling Software (BIM)	BIM is a process that involves creating and using an intelligent 3D model to inform and communicate project decisions. Design, visualisation, simulation and collaboration enabled by Autodesk BIM solutions provide greater clarity for all stakeholders across the project lifecycle. BIM makes it easier to achieve project and business goals.
Construction Consolidation Centres (CCC)	A construction consolidation centre (CCC) is a distribution facility that can be used in the process of managing project logistics, channelling material deliveries to a large, single construction site or a number of different sites. It facilitates the efficient flow of materials through the supply chain, reducing waste and other issues such as congestion. Construction materials are delivered from suppliers to the CCC where they are stored until call-off from the site, at which point the CCC operator makes up and delivers a consolidated load. This is done on a 'just in time' basis, for enhanced efficiency.
Construction Logistics and Community Safety (CLOCS)	CLOCS brings the construction logistics industry together to revolutionise the management of work related road risk (WRRR) and ensure a road safety culture is embedded across the industry. By working together we can help protect pedestrians, cyclists, motorcycles and other users who share the roads with construction vehicles.
European Economic Area (EEA)	The European Economic Area (EEA) is the area in which the Agreement on the EEA provides for the free movement of persons, goods, services and capital within the European

Term(s)	Definition
	Single Market, as well as the freedom to choose residence in any country within this area.
Fleet Operator Recognition Scheme (FORS)	The Fleet Operator Recognition Scheme (FORS) is a voluntary accreditation scheme encompassing all aspects of safety, fuel efficiency, vehicle emissions and improved operations. FORS helps fleet operators to measure and monitor performance and alter their operations in order to demonstrate best practice. It is open to operators of vans, lorries, mini-buses, coaches and other vehicles, and to the organisations that award contracts to those operators.
Geographic Information Systems (GIS)	A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. By relating seemingly unrelated data, GIS can help individuals and organizations better understand spatial patterns and relationships
Greater London Authority (GLA)	The Greater London Authority (GLA) is a top-tier administrative body for Greater London, England. It consists of a directly elected executive Mayor of London, currently Sadiq Khan, and an elected 25-member London Assembly with scrutiny powers.
Just In Time (JIT)	Just-in-time (JIT) is an inventory strategy companies employ to increase efficiency and decrease waste by receiving goods only as they are needed in the production process, thereby reducing inventory costs.
Key Performance Indicator (KPIs)	KPIs help us to measure how well companies, business units, projects or individuals are performing compared to their strategic goals and objectives. Well-designed KPIs provide the vital navigation instruments that give us a clear understanding of current levels of performance.
Local Planning Authorities (LPA)	A LPA is the local authority or council that is empowered by law to exercise statutory town planning functions for a particular area of the United Kingdom. Although, in Scotland, where all of the local authorities are unitary, the term 'planning authority' is used without the 'local' prefix.
Low Emission Zones (LEZ)	The Low Emission Zone (LEZ) operates to encourage the most polluting heavy diesel vehicles driving in London to become cleaner. The LEZ covers most of Greater London and is in operation 24 hours a day, every day of the year.
Supply Chain Management (SCM)	In commerce, supply chain management (SCM), the management of the flow of goods and services,[2] involves the movement and storage of raw materials, of work-in-process inventory, and of finished goods from point of origin to point of consumption. Interconnected or interlinked networks, channels and node businesses combine in the provision of products and services required by end customers in a supply chain.

Term(s)	Definition
Transport for London (TfL)	Transport for London (TfL) is a local government body responsible for the transport system in Greater London, England
Vehicle Booking System (VBS)	Vehicle booking systems can be manual or electronic systems for pre-booking vehicles into busy delivery service yards. They are commonly used as a way of smoothing demand throughout the working period.
Vehicle Holding Areas (VHAs)	These are a controlled vehicle parking area often with security for monitoring systems and they help facilitate the smooth arrival of vehicles at the main delivery point.
Euro Standard	European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in EU and EEA member states. The emission standards are defined in a series of European Union directives staging the progressive introduction of increasingly stringent standards.
Radio Frequency Identification (RFID)	Radio-Frequency Identification (RFID) is the use of radio waves to read and capture information stored on a tag attached to an object. A tag can be read from up to several feet away and does not need to be within direct line-of-sight of the reader to be tracked.
Equivalent Single Axle Load (ESALs)	ESAL is used to understand the level of wear to the pavement; engineers convert the weights of vehicles into an equivalent number of axles all weighing the same – typically around 8 tonnes. It should be noted that front steer axles with just two wheels are plated less (e.g. around 7 or 8 tonnes) than typical drive axles which usually have four wheels (e.g. around 10 tonnes). The calculations take the differences into account.

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