CONSTRUCTION LOGISTICS

Briefing Report

Technical Report CUED/C-SRF/TR15

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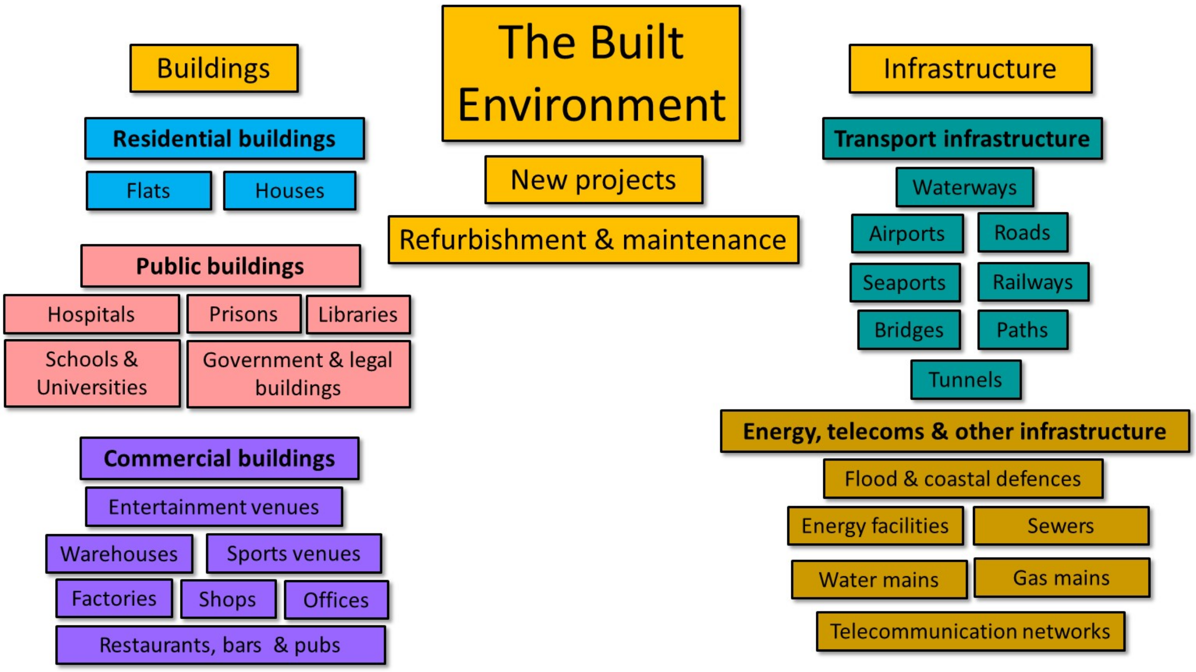
1. The importance of the construction industry

The construction industry is fundamental to our way of life, providing our homes, workplaces, leisure and entertainment facilities, and our accessibility between all of them, as well as providing the infrastructure to provide energy, water and waste service to us.

Construction provides us with the built environment and the wide range of fixed assets it comprises. As **Figure 1.1** indicates these include homes, public buildings such as schools and hospitals, factories, warehouses, shops and offices, transport infrastructure including seaports, airports, bridges, canals, tunnels, and the road and rail networks, and other infrastructure including energy production and supply networks, water supply and sewer networks, various communications networks, and flood and coastal defences. It has been estimated that these outputs of the construction industry account for approximately three quarters of the economic value of the UK's total fixed assets (Chartered Institute of Building, 2020).

Figure 1.1: The Built Environment provided by the construction industry



The importance of construction and construction logistics was indicated as early as the rule of the Roman dictator Julius Caesar in the first century BCE. Whilst he banned heavy goods vehicle operations during the daytime in Rome, he provided an exemption to journeys associated with the building or repair of temples, as well as the removal of demolition waste (Beard, 2015).

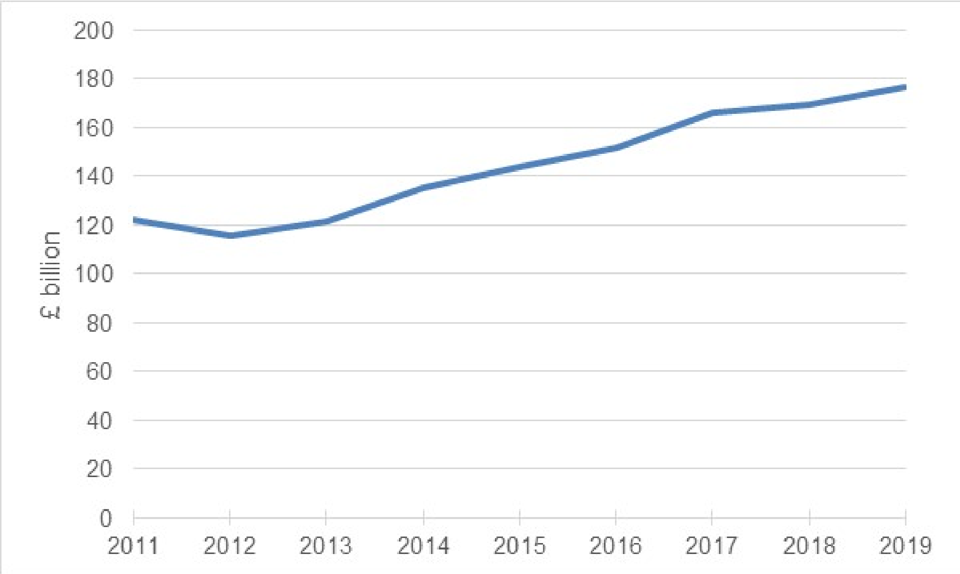
1.1 Size and economic importance of the construction industry

According to official government data, new work in the construction industry contributed £119 billion to the UK economy in 2019 (output gross value added – GVA) and accounted for 6.5% of UK economic output. The economic value of this new construction work grew by 52% between 2011 and 2019 (ONS, 2021a).

In addition to new construction work, repair, refurbishment and maintenance of existing buildings and infrastructure work contributed £57 billion to the UK economy in 2019. The value of this repair and maintenance work increase by 30% between 2011 and 2019 (ONS, 2021a).

Therefore, together new and repair/maintenance work contributed £176 billion in 2019 (approximately 9% of the UK economy, with new work responsible for two-thirds and repair/maintenance one-third), and the output of the entire industry increasing by 44% between 2011 and 2019 (ONS, 2021a). **Figure 1.2** shows the growth in the entire construction industry over this period.

Figure 1.2: Output value of the UK construction industry – new work plus repair and maintenance, 2011-2019



Source: ONS, 2021a.

This measure of the importance of the construction industry is based on the addition it makes to the UK economy and therefore does not include the value of the materials and products used in construction (which are separately accounted for it the UK's GVA accounts). The absolute turnover of companies in the construction industry was £386 billion in 2017 (BEIS, 2019).

The construction industry uses a wide range of building materials from mines and quarries, together with wood as well as metal, glass and plastic products. Various minerals are used in construction including sand and gravel, igneous rock, limestone, sandstone and clays. In 2019, sand produced in the UK had a value of £900 million, while limestone, sandstone, dolomite, chalk, igneous rock, clay and shale had a value of £1.6 billion (Bide et al., 2021). The construction products industry has been estimated to generate a UK GVA of £61 billion (11% of total UK manufacturing turnover and 36% of total construction output), consisting of 24,000 companies and 373,000 jobs (Construction Products Association, 2021a).

Many other companies are also involved in the construction industry, but are not accounted for in the construction industry GVA. These include companies that provide physical distribution and logistics services used to supply and manage all these products, the plant and equipment hired by construction companies, the energy requirements of construction, the professional services involved including surveying, architecture and various branches of engineering, real estate companies, and the financing and educational and development skills required. Professional services of architects and surveyors are estimated to generate approximately £25 billion per year in the UK, construction plant hire industry £6 billion, distribution and logistics services to construction about £5 billion, and real estate and finance for construction about £8 billion. Including all these activities would provide an alternative estimate of the construction industry that is approximately £100 billion greater than the estimated value provided by official GVA data previously quoted (Chartered Institute of Building, 2020; Construction Products Association, 2021a, 2021b).

Figure 2.1 provides further insight into the wide range of companies that are involved in the construction industry and the materials, products and services it makes use of in the provision of new and refurbished buildings and infrastructure. In addition, some companies that are not classified as in the construction industry also carry out construction work on an in-house basis such as utility companies, housing associations, large retailers, and transport organisations such as Transport for London and Network Rail. Do-It-Yourself (DIY) carried out by private individuals and households is also a major activity in the UK. None of these are included in official construction GVA estimates.

Table 1.1 shows the breakdown of the official construction output value (GVA) of £176 billion for new works and refurbishment in 2019 subdivided between its constituent parts. Of this total construction work, housing accounted for 40% of this output value, infrastructure for 40%, and public and commercial buildings (including schools, colleges, universities, hospitals, offices, shops, entertainment venues, factories and warehouses) for 20%. Overall, the private sector accounted for three-quarters of all construction industry work, while the public sector accounted for one-quarter (ONS, 2021a).

Table 1.1: Construction output value in the UK in 2019 by type of construction (% of total construction industry value)

Type of construction	**New works**	**Repair and maintenance**	**Total**
Private housing	23%	12%	***35%***
Public housing	4%	4%	***8%***
Commercial buildings*	21%	8%	***29%***
Public buildings**	6%	3%	***9%***
Infrastructure***	13%	5%	***18%***
TOTAL	**67% (£119 billion)**	**33% (£57 billion)**	***100%* (£176 billion)**

Notes:
* - includes offices, shops, entertainment venues, factories and warehouses
** - includes schools, colleges and hospitals
*** - includes transport, energy, utility, water and telecommunications infrastructure

Source: calculated from data in ONS, 2021a.

Official data can also be used to express the value of the construction industry in terms of the three Standard Industrial Classification (SIC) codes of the companies working in it. These SIC codes reflects the main type of construction work they are involved in, namely: construction of residential buildings and non-residential buildings (SIC 41), civil engineering (SIC 42) which refers to infrastructure construction companies, and specialised construction activities (SIC 43). The latter refers to the providers of all the ancillary construction services that are required in addition to building and infrastructure construction which includes companies specialising in demolition, electrical, plumbing, heat and air-conditioning installation, plastering, carpentry, roofing, floor and wall covering, glazing and painting.

Table 1.2 shows the relative importance of each of these three main construction SIC codes in terms of the industry's output value in 2019. Companies in the specialised construction activities sector accounted for almost half (48%) of the industry output value in 2019, followed by building construction companies (31%), and infrastructure (civil engineering) companies (22%) (ONS, 2021a).

Table 1.2: Construction output value in the UK in 2019 by main trade of companies

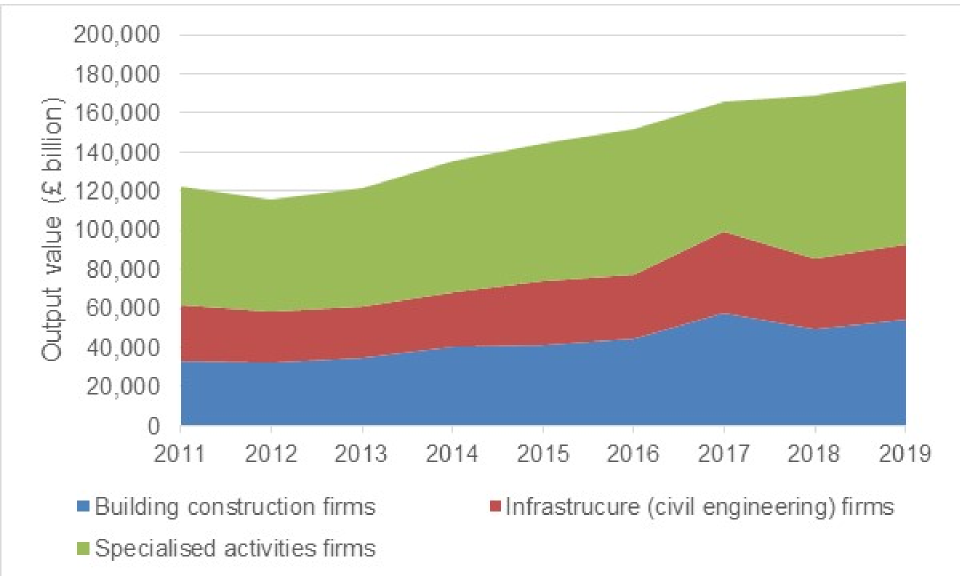
SIC code of construction companies	Output value (£ billion and % of total)
Construction of residential buildings and non-residential buildings (SIC 41)	£54 billion (31%)
Civil engineering (SIC 42)	£38 billion (22%)
Specialised construction activities (SIC 43)	£84 billion (48%)
TOTAL	**£176 billion (100%)**

Source: calculated from data in ONS, 2021a.

It is important to note that building construction companies do not only build properties and civil engineering companies do not only build infrastructure, but the SIC code reflects the main trade of the company. Companies in the construction of residential buildings and non-residential buildings (SIC 41) generated 91% of their turnover from residential and commercial/industrial buildings in 2019 and only 9% from infrastructure, with 77% of their turnover coming from new construction projects rather than refurbishment and maintenance work. By contrast, civil engineering companies generated 56% of their turnover from infrastructure projects, with 77% of their turnover coming from new projects rather than refurbishment and maintenance work. Specialised construction activities companies generated 93% of their turnover from residential and commercial/industrial buildings in 2019 and only 7% from infrastructure, with 58% of their turnover coming from new projects and 42% from refurbishment and maintenance work (calculated from data in ONS, 2021a).

Figure 1.3 shows the change in the value of these three construction SIC codes between 2011-2019. The output value of building construction companies increased by 66% over this period, specialised construction activities companies by 39%, and infrastructure (civil engineering) companies by 30% (ONS, 2021a).

Figure 1.3: Construction output value in the UK, 2011-2019 by main trade of companies



Source: calculated from data in ONS, 2021a.

The three main types of construction companies as expressed by SIC codes can be further disaggregated by main trade of the companies (see **Table 1.3**). This indicates the economic importance of the various specialised activities in the construction industry. Those of particular importance include electrical installation (11% of total construction output in 2019), plumbing, heat and air-conditioning installation (8% of total construction output) and joinery installation (5% of total construction output) (ONS, 2021a).

Table 1.3: Construction output value in the UK in 2019, by main trade of companies

Type of construction company	Output value (£ billion)	Proportion of total construction output value
Construction of commercial buildings	19.3	11%
Construction of domestic buildings	34.9	20%
Building construction sub-total	***54.2***	***31%***
Construction of transport infrastructure*	8.3	5%
Construction of other infrastructure**	30.1	17%
Infrastructure construction sub-total	***38.3***	***22%***
Demolition	1.1	1%
Site preparation	1.6	1%
Test drilling and boring	0.3	0%
Electrical installation	19.6	11%
Plumbing, heat and air-conditioning installation	13.5	8%
Other construction installation	4.8	3%
Plastering	2.0	1%
Joinery installation	8.2	5%
Floor and wall covering	3.2	2%
Painting	3.4	2%
Glazing	1.0	1%
Other building completion and finishing	9.7	6%
Roofing activities	4.1	2%
Scaffold erection	2.8	2%
Other specialised construction activities	8.6	5%
Specialised construction activities sub-total	***83.9***	***47%***
TOTAL	***176.4***	**100%**

Notes:

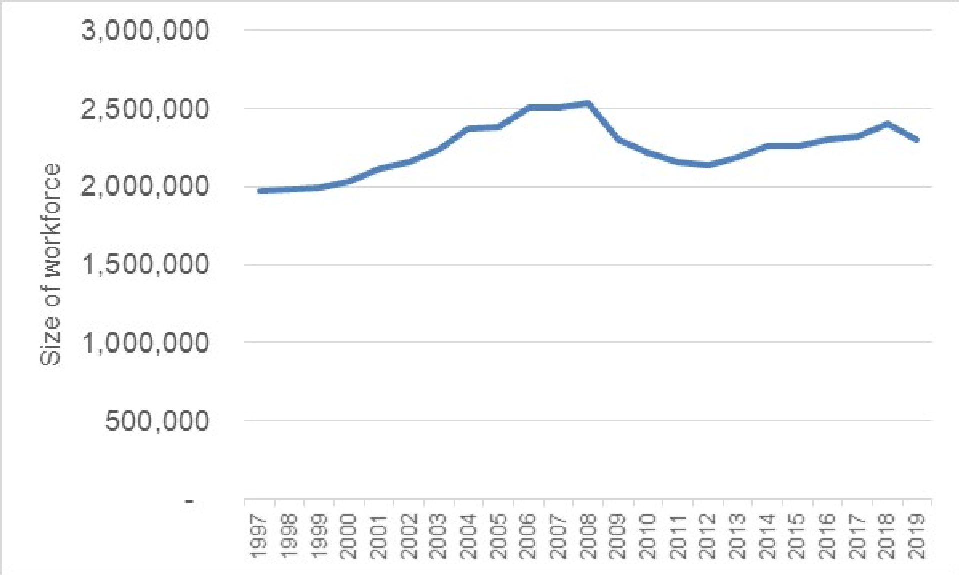
* - includes roads, railways, waterways, bridges and tunnels
** - includes infrastructure for electricity, telecommunications, water, fluids and other purposes

Source: calculated from data in ONS, 2021a.

1.2 Companies and workforce in the construction industry and its sectors

According to official statistics, the construction industry directly provided work for 2.1 million people in the UK in 2019 (6.5% of the total UK workforce). There were 290,000 construction companies in Britain in 2018 (ONS, 2021a). Eighty eight percent of this construction workforce in 2019 was male (ONS, 2021b). **Figure 1.4** shows the UK construction industry workforce from 1997 to 2019.

Figure 1.4: UK construction industry workforce, 1997-2019



Note: Data is for Oct-Dec each year.
Source: ONS, 2021a.

Table 1.4 shows the main trades of the companies in the UK construction industry and their employees, together with the average number of employees per company for each trade. The data indicates that the construction of buildings sector accounted for 20% of companies and 24% of employees, the infrastructure sector accounted for 8% of companies and 19% of employees, and the other specialist trades sector accounted for 69% of companies and 55% of employees. Therefore, the average number of employees per company in greatest is the infrastructure construction sector (9.6), and smallest in the other specialist trades sector (3.4). Average employees per company are especially low in sub-sectors including plastering (2.2), floor and wall covering (2.7) and joinery installation (2.8).

All of these construction sectors and the construction industry as a whole (which had an average of just over four employees per company) have a lower average number of employees per company than UK industry as a whole, which had an average of 11.8 employees per company in 2019 (ONS, 2021c).

Table 1.4: Construction companies and employees in the UK in 2018 by main trade of companies

Type of construction company	% of all construction companies	% of all construction employees	Average number of employees per company
Construction of commercial buildings	4.8%	6.4%	5.8
Construction of domestic buildings	15.0%	17.9%	5.1
Building construction sub-total	***19.8%***	***24.3%***	***5.3***
Construction of transport infrastructure*	2.5%	3.8%	6.6
Construction of other infrastructure**	5.8%	14.8%	10.9
Infrastructure construction sub-total	***8.3%***	***18.6%***	***9.6***
Demolition	0.2%	0.5%	8.9
Site preparation	1.1%	1.0%	3.9
Electrical installation	15.3%	14.8%	4.1
Plumbing, heat and air-conditioning installation	12.7%	10.7%	3.6
Plastering	1.9%	1.0%	2.2
Joinery installation	9.0%	5.9%	2.8
Floor and wall covering	0.0%	0.0%	2.7
Painting	4.1%	3.2%	3.3
Glazing	1.0%	0.9%	3.9
Other building completion and finishing	11.9%	5.7%	2.1
Roofing activities	3.1%	2.4%	3.3
Scaffold erection	2.0%	2.8%	5.9
Other specialised construction activities	6.7%	6.4%	4.1
Specialised construction activities sub-total	***69.1%***	***55.2%***	***3.4***
TOTAL	**100% (290,000)**	**100% (2.3 million)**	**4.2**

Notes:

* - includes road, railway, bridge and tunnel infrastructure
** - includes infrastructure for electricity, telecommunications, water, fluids and other purposes

Source: calculated from data in ONS, 2021a.

Of the 290,000 construction companies in Britain in 2019, 52% had either only a sole proprietor or one employee, 39% had 2-7 employees, 8% had than 8-79 employees, and only 0.4% (approximately 1,300 companies) had 80 employees or more. This indicates the small average size of UK construction companies. Twenty three percent of all those employed in the construction industry in 2019 worked for companies with 3 or fewer employees, 22% worked for companies with 3-13 employees, 19% worked for companies with 14-59 employees, 14% worked for companies with 60-299 employees, 8% worked for companies with 300-1199 employees, and 13% worked for companies with 1200 or more employees (see **Table 1.5**) (ONS, 2021a).

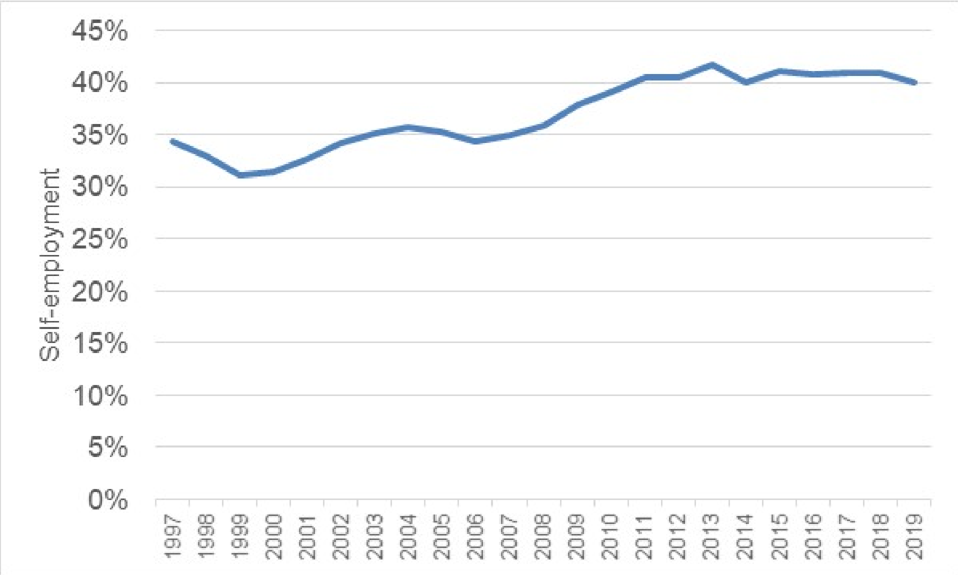
Table 1.5: The employee size of companies in the UK construction industry, 2019

Size of Company (number of people employed)	Companies (%)	Employees (%)
0 (sole proprietors)	12%	-
1	40%	9%
2-3	28%	14%
4-7	11%	13%
8-13	4%	9%
14-24	2%	8%
25-34	1%	4%
35-59	1%	7%
60-79	0.18%	3%
80-114	0.16%	3%
115-299	0.17%	8%
300-599	0.05%	5%
600-1,199	0.02%	4%
1,200 and over	0.02%	13%
TOTAL	**100% (290,374)**	**100% (1.28 million)**

Source: calculated from data in ONS, 2021a.

Forty percent of the construction industry workforce was self-employed in 2019, which was three times higher than the UK self-employment average of 15%. Levels of self-employment vary across the sub-sectors of the construction industry. Those working in specialised construction activities sub-sector were more likely to be self-employed (50%) compared with those working in the construction of buildings (40%) and the civil engineering / infrastructure (15%) sub-sectors in 2016. An even higher proportion of non-UK nationals in the construction industry were self-employed (56% in 2016 – ONS, 2018). Those who were self-employed in the construction industry represented 18% of the total self-employment in the UK (ONS, 2021d; 2021e). **Figure 1.5** shows the change in self-employment in the UK construction industry since 1997. The data in **Table 1.4** showing the employees per company together with this self-employment figure indicates the workforce fragmentation that exists in the construction industry.

Figure 1.5: Self-employment in the UK construction industry, 1997-2019



Note: Data is for Oct-Dec each year.
Source: calculated from ONS, 2021d.

Table 1.6 shows size of company data for two sectors with the least and most average employees per company, namely plastering and infrastructure construction companies, respectively. There were no plastering companies in the UK in 2019 with more than 299 employees, whereas there were 68 such infrastructure construction companies.

Table 1.6: The employee size of companies in plastering and infrastructure construction in the UK, 2019

Size of Company (number of people employed)	Plastering companies (%)	Infrastructure construction companies (%)
0 (sole proprietors)	13%	11%
1	45%	43%
2-3	29%	24%
4-7	8%	11%
8-13	2%	4%
14-24	1%	3%
25-34	0.4%	1%
35-59	0.2%	1%
60-79	0.1%	0.4%
80-114		0.3%
115-299		0.5%
300-599	0%	0.1% (32)
600-1,199	0%	0.1% (15)
1,200 and over	0%	0.1% (21)
TOTAL	**100% (5,567)**	**100% (23,879)**

Source: calculated from data in ONS, 2021a.

Table 1.7 shows the construction value output in the UK in 2019 by number of employees in companies. This indicates that across the industry as a whole, companies with less than 10 employees generated 29% of UK construction output, emphasising the economic importance of these micro businesses. By contrast, companies with 100 or more employees (or an annual turnover that exceeded £60 million) accounted for 41% of UK total construction output. As **Table 1.7** illustrates, the economic importance of micro and small businesses varies by main trade of construction companies. Businesses with less than 10 employees account for a far greater proportion of output value in certain specialised trades (for instance, 61% in plastering, 56% in painting, 55% in floor and wall covering, 45% in scaffolding erection, 40% in plumbing and roofing, heat and air-conditioning installation, and 30% in electrical installation) than in the construction of buildings (18%) and infrastructure (15%) (ONS, 2021a).

Table 1.7: Construction output value in the UK in 2019 by main trade and size of companies

Type of construction company	***Number of employees***					
	0-4	***5-9***	***10-19***	***20-99***	***100+****	***All firms***
Construction of commercial buildings	11%	7%	6%	13%	63%	**100%**
Construction of domestic buildings	12%	5%	5%	14%	64%	**100%**
Building construction sub-total	12%	6%	5%	14%	63%	**100%**
Construction of transport infrastructure**	14%	3%	6%	27%	45%	**100%**
Construction of other infrastructure***	12%	4%	5%	14%	67%	**100%**
Infrastructure construction sub-total	12%	3%	5%	17%	62%	**100%**
Demolition	18%	11%	29%	24%	17%	**100%**
Site preparation	15%	8%	12%	32%	33%	**100%**
Test drilling and boring	7%	3%	4%	49%	36%	**100%**
Electrical installation	17%	13%	14%	26%	31%	**100%**
Plumbing, heat & air-conditioning installation	22%	18%	16%	30%	14%	**100%**
Other construction installation	21%	14%	25%	23%	16%	**100%**
Plastering	48%	13%	13%	16%	10%	**100%**
Joinery installation	30%	16%	14%	28%	12%	**100%**
Floor and wall covering	37%	18%	19%	22%	5%	**100%**
Painting	36%	20%	14%	23%	6%	**100%**
Glazing	17%	38%	19%	19%	6%	**100%**
Other building completion and finishing	51%	19%	7%	11%	13%	**100%**
Roofing activities	24%	16%	17%	33%	10%	**100%**
Scaffold erection	33%	12%	12%	28%	15%	**100%**
Other specialised construction activities	23%	14%	14%	27%	21%	**100%**
Specialised construction activities sub-total	27%	16%	15%	25%	18%	**100%**
TOTAL	**19%**	**10%**	**10%**	**20%**	**41%**	**100%**

Notes:

* - or more than £60 million turnover
** - includes roads, railways, waterways, bridges and tunnels
*** - includes infrastructure for electricity, telecommunications, water, fluids and other purposes

Source: calculated from data in ONS, 2021a

1.3 Company size by annual turnover in the construction industry

Eighty two percent of UK construction companies had an annual turnover of less than half a million pounds in 2019, 16% had a turnover of £500,000 to £5 million, 1% had a turnover of £5 million to £10 million, and 1% had a turnover of over £10 million (see **Table 1.8** - ONS, 2021c).

Table 1.8: The turnover of companies in the UK construction industry, 2019

Company annual turnover band	Companies (%)
£0 - 49 (thousand)	10.7%
£50 - 99 (thousand)	22.1%
£100 - 199 (thousand)	34.4%
£200 - 499 (thousand)	15.0%
£500 - 999 (thousand)	8.1%
£1 – 1.999 (million)	4.7%
£2 – 4.999 (million)	3.0%
£5 -9.999 (million)	1.1%
£10 – 49.999 (million)	0.8%
£50+ (million)	0.2%
TOTAL	**100%**

Source: calculated from data in ONS, 2021c.

Of those 1% of UK construction companies with an annual turnover of £10 million of more in 2019 (approximately 2,700 companies), approximately half of them had a turnover between £10-20 million, only 0.1% of construction companies (272 companies) had a turnover or £100 million of more, and only 0.01% (sixteen companies) 14% had a turnover £1 billion or more (see **Table 1.9** - ONS, 2021a).

Table 1.9: The turnover of the largest companies in the UK construction industry, 2019

Company annual turnover band	Proportion of all UK construction companies (%)
£10m - <£20m	0.46%
£20m - <£30m	0.14%
£30m - <£40m	0.09%
£40m - <£50m	0.04%
£50m - <£100m	0.09%
£100m - <£500m	0.08%
£500m - <£1000m	0.01%
£1000m +	0.01%
TOTAL	**100% (290,374)**

Source: calculated from data in ONS, 2021a.

Table 1.10 shows the average value of work per type of company. This can be seen to differ, with these differences due to the type of service offered and differences in average company size in these different construction sectors.

Table 1.10: The output value of construction companies and employees in the UK in 2018 by main trade of companies

Type of construction company	Average value of work per company (£million)
Construction of commercial buildings	1.40
Construction of domestic buildings	0.81
Building construction sub-total	**0.96**
Construction of transport infrastructure*	1.23
Construction of other infrastructure**	1.76
Infrastructure construction sub-total	**1.60**
Demolition	1.53
Site preparation	0.50
Electrical installation	0.44
Plumbing, heat and air-conditioning installation	0.37
Plastering	0.35
Joinery installation	0.32
Floor and wall covering	0.40
Painting	0.29
Glazing	0.35
Other building completion and finishing	0.43
Roofing activities	0.45
Scaffold erection	0.49
Other specialised construction activities	0.45
Specialised construction activities sub-total	**0.41**
TOTAL	**0.54**

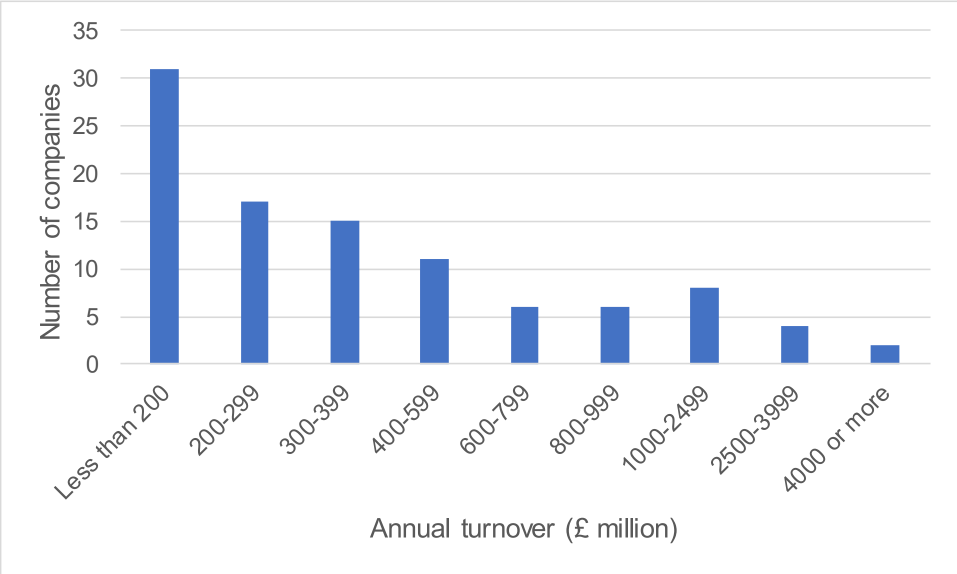
Notes:

* - includes roads, railways, waterways, bridges and tunnels
** - includes infrastructure for electricity, telecommunications, water, fluids and other purposes

Source: calculated from data in ONS, 2021a

Analysis of the top 100 construction companies by turnover in the UK in 2018 shows that while the median turnover was £313 million, 14% of these companies had a turnover of £1 billion or greater (calculated from data in Construction News, 2019). **Figure 1.6** shows the annual turnover of these top 100 companies by turnover band.

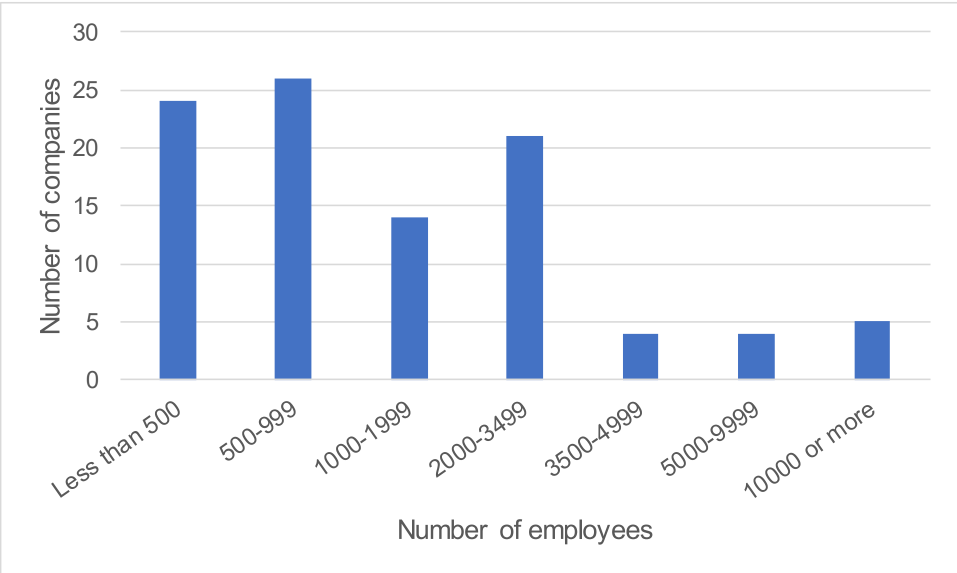
Figure 1.6: Annual turnover of the top 100 UK construction companies in 2018



Source: calculated from data in Construction News, 2019.

In total the top 100 UK construction companies employed 249,000 people in 2018, which represented approximately 19% of total construction industry employees and 12% of total construction industry employment. These top 100 companies had a median of 925 employees. Fifty percent of these companies had less than 1000 employees, while 9% had more than 5000 employees (calculated from data in Construction News, 2019). **Figure 1.7** shows the number of employees in these top 100 companies by employee size band.

Figure 1.7: Number of employees of the top 100 UK construction companies in 2018



Source: calculated from data in Construction News, 2019.

For information, Table 1.11 provides the annual turnover and pre-tax profit margin of the leading twenty of these top 100 UK construction companies in 2018. Balfour Beatty can be seen to have a considerably larger annual turnover than other construction companies. Pre-tax profit margins can be seen to be relatively low for most of these companies (below 3% for all but two of them), with three of the top twenty companies making a pre-tax loss (see **section 3.5** for further discussion of company profit margins).

Table 1.11 Top twenty UK construction companies by annual turnover in 2018

Company	Turnover	Pre-tax profit margin (%)	Reporting date
Balfour Beatty Plc	7,802.0	2.3	Dec-18
Kier Group Plc	4,512.8	2.4	Jun-18
Interserve Plc	3,225.7	-3.4	Dec-18
Galliford Try Plc	3,132.3	4.6	Jun-18
Morgan Sindall Group Plc	2,971.5	2.7	Dec-18
Amey UK Plc	2,667.8	-16.0	Dec-18
Mace Ltd	2,350.0	1.4	Dec-18
ISG Plc	2,237.6	1.2	Dec-18
Keller Group Plc	2,224.5	0.4	Dec-18
Laing O'Rourke Plc	1,985.7	-1.3	Mar-18
Skanska UK Plc	1,935.4	2.3	Dec-18
Wates Group Ltd	1,601.0	2.2	Dec-18
Costain Group Plc	1,489.3	2.7	Dec-18
Willmott Dixon Holdings Ltd	1,323.2	2.7	Dec-18
Multiplex Construction Europe Ltd	1,064.9	1.7	Dec-18
M Group Services Ltd	1,027.8	-0.5	Mar-18
Homeserve Plc	1,003.6	13.9	Mar-19
VolkerWessels UK Ltd	984.0	2.9	Dec-18
BAM Construct UK Ltd	949.8	2.0	Dec-18
Bowmer & Kirkland Ltd	937.6	2.3	Aug-18

Source: Construction News, 2019.

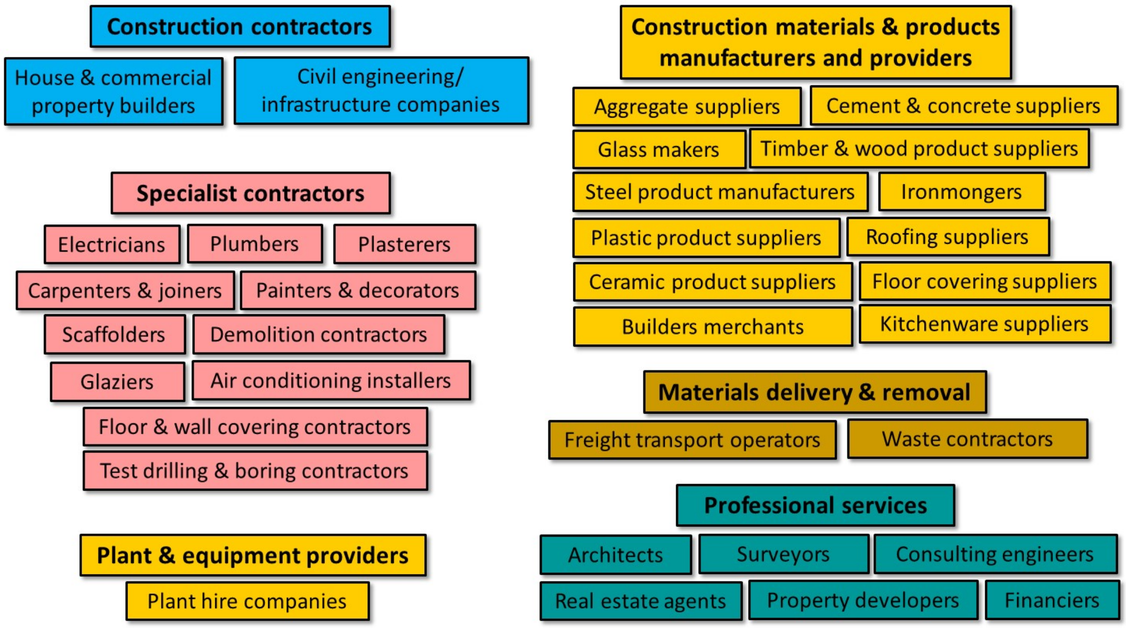
2. The organisation of the construction industry and its supply chain

2.1 Organisations in the construction industry

Construction, whether it be of a building or infrastructure, is usually referred to as a 'project'. Each construction project consists of a set of tasks or activities that together result in the successful completion of the construction. The construction industry therefore differs from many other industries in that it is project-based with each project being unique and having a specific start and end point, and therefore being temporary.

In order to carry out a construction project many different skills and organisations are required. The extent of skills and companies required usually increases with the scale of the project. **Figure 2.1** shows the range of skills and services that can be required for a construction project. These skills and services are provided by a range of companies.

Figure 2.1: Contractors, professional services, product and service providers involved in construction



Construction projects are initiated by a client (often a property developer, a public sector body or a private individual) and involve both a design phase and a building phase. These two phases are typically separate and distinct from one another, and often involve different organisations and individuals. The design phase of a construction project usually begins with the translation of a client's requirement into a tangible vision and project which is achieved through the work of architects who will appoint consulting engineers to assist them in developing a brief, a design and calculate costings, and depending on the scale of the project, may initiate feasibility and option studies. Prior to construction activity commencing it is necessary for planning permission to be sought and granted.

The client, often with the help of the architect, will usually appoint a principal construction company (or an alliance of major contractors take have come together for the purposes of the project tender in the case of very large projects). This construction company is referred to as a Tier One contractor. This Tier One contractor is usually then responsible for acquiring the services of other companies to provide the work needed for the project that they cannot provide themselves. These companies are referred to as Tier Two contractors, who in turn subcontract aspects of the work to Tier Three contractors. Some construction contractors will work on the project throughout its entire duration, while others will only have a fleeting involvement, briefly providing their services at a specific point of the project.

No two construction projects are exactly alike in terms of client specification or personnel involved. The project-based nature of construction also results in a need to provide detailed proposals in order to gain work. These proposals and quotations by architects, consulting engineers, principal and other contractors are time-consuming and expensive to produce, often requiring research and calculations, the compilation of much information, and site visits. Due to the unique, temporary nature of construction, and the number of different companies involved, projects typically involve contracts between these organisations. For this reason, construction companies are usually referred to as construction contractors.

Contracts are often awarded on the basis of competitive tendering processes, with companies then coming together to work on the construction project in temporary, short-term coalitions. Lesser contractors (e.g. second and third tier contractors) are not usually part of the contract between the client and principal contractor and this adds to the complexity involved in managing construction projects and ensuring that the project proceeds to the correct timescale, quality and cost. This fragmented organisational structure can lead to difficulties with information flow and communication in the construction supply chain which has the potential to result in delays, waste and duplication. This contractual nature of the construction industry, together with the many companies that can be involved, tends to lead to fragmented and adversarial relationships between the many parties involved. These tensions most obviously manifest themselves when projects timescales and cost limitations come under pressure. Other causes of disagreement between parties arise over factors that are not clearly defined in the contract such as lack of clarity in roles and responsibilities, when various parties have different aims and objectives, when parties disagree about important decisions or the sequencing of events. Such tensions often result in conflict, disputes between parties and even litigation.

Due to nature of construction projects and their contractual and temporary basis, the relationships between parties in construction projects are frequently relative unstable and difficult to manage. This tends to stifle innovation and joint problem solving. Even when projects are innovatory, it can be difficult to take this experience and learning forward into other projects as these organisations and individuals may never work together again on other projects. The only construction project setting in which this is easier to achieve is the case of companies that have a consistent team of contractors working on multiple, repeat projects, such as house builders and supermarkets, or on individual projects with very long timescales due to scale of the work involved.

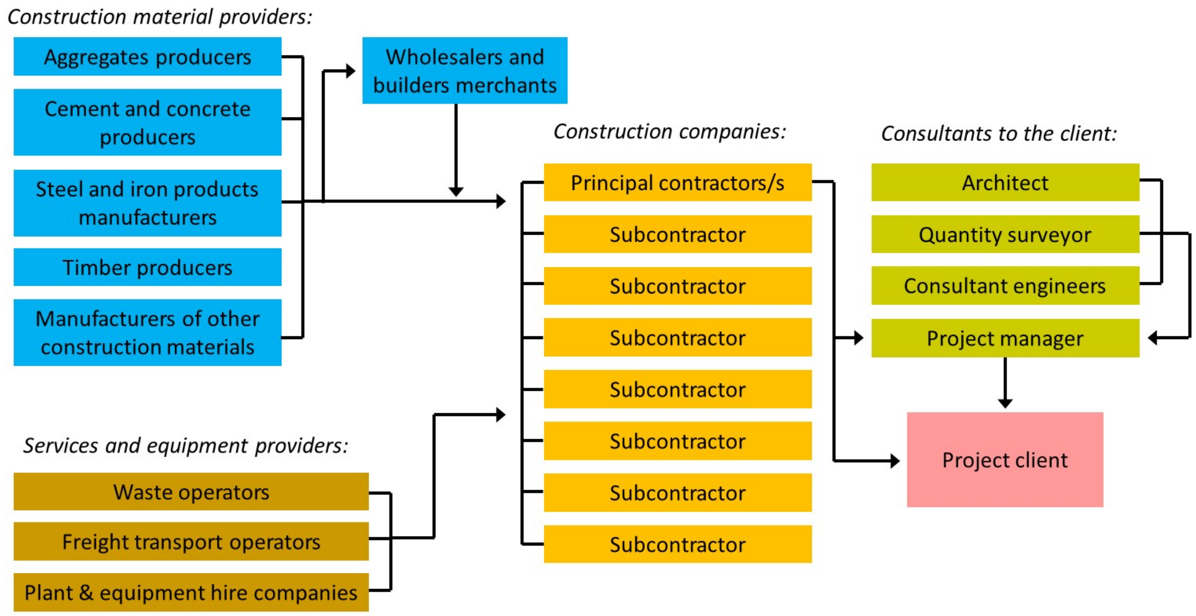
2.2 The construction supply chain

The construction supply chain and its management can be considered and viewed in several ways. When talking about the construction supply chain, this could refer to i) the various organisations involved in a construction project, ii) the management of the materials and products used in the construction process (and any waste arising) and ensuring that they are available on the construction site when they are required, and iii) the various facilities and sites involved in the entire construction process from the point at which the materials arise to the construction site. Each of these aspects of the construction supply chain is discussed below.

2.2.1 The construction organisation supply chain

Many involved in the construction industry refer to its supply chain as the relationships between the client and the construction and other companies that are involved in the carrying out and completion of the project. These companies include: i) construction-related professional services (such as architects, engineers, surveyors etc.) ii) construction contracting companies including the principal contractor, iii) contractors providing of other construction-related services (e.g. tradespeople providing allied services such as electricians, plumbers, plasterers, decorators), iv) suppliers of construction materials and products used in the project, v) suppliers of plant and equipment needed at the construction site, and vi) freight transport companies that deliver these materials and products to construction sites, and waste companies that remove spoil and other wastes arising from the project. However, relatively little account is often taken of product suppliers and freight transport companies by those in the construction industry when considering their supply chain, with them regularly limiting their considerations to those companies involved in the direct construction work on site. These supply parties are depicted in **Figure 2.2**, which provides a simplified, diagrammatic representation of the organisations involved in the construction supply chain and their relationships.

Figure 2.2: Construction supply chain: organisational perspective



In reality, the construction supply chain for any one project is far more complicated and fragmented than that shown in **Figure 2.2 and** may rely of tens of service providers and product suppliers, or hundreds in the case of large construction projects. This is due to the wide range of different services required on construction sites, together with the small size of many companies in the construction industry and related trades and services (with a high proportion of self-employment) **(see chapter 1)**. The construction industry makes use of a high extent of sub-contracting between the various companies involved.

The larger the construction project, the greater the number of organisations typically involved in it. Due to the sub-contracting that takes place, many of these organisations and individuals may well be unknown to each other. A 2013 UK Government study of the construction supply chain confirmed its fragmented nature and found that for a construction contract of £10 million or more, the main contractors (Tier One) often made use of over forty sub-contractors and suppliers for its delivery; that the majority of the value of the construction work was accounted for by a small number of (often 4-5) large, complex Tier Two sub-contractors (which in turn typically made use of more than thirty Tier Three subcontractors in their delivery); and that the remaining project value was accounted for by often construction services and finishes provided by smaller contractors (BIS, 2013a).

Key factors that determine successful supply chain management and hence delivery of a construction project include: equitable financial arrangements and certainty of payment; early contractor engagement and continuing involvement of the supply chain in design development; strong relations and collaboration with subcontractors; and capability for effective construction site management including the ability to respond to change rapidly and flexibly (BIS, 2013b). Project clients and their management teams attempting to improve the productivity and efficiency of large construction projects have tended to take growing interest in establishing relationships beyond those they have with principal contractors (i.e. Tier One providers).

2.2.2 The construction materials and products supply chain

Many different building materials are required in construction. These include both natural products (such as gravel, stone, and wood) and man-made ones (such as steel, iron and other metal products, cement, concrete, bricks, ceramics, glass and plastics). Man-made construction products require various processes. For instance, bricks are usually made from clay or shale mixed with water that is fired in a kiln; cement is typically made by heating limestone with other materials to very high temperatures in a kiln and then mixing this with a small quantity of gypsum; concrete is made by mixing cement with aggregates such as sand and crushed stone with water; steel is made by heating iron ore using coke and coal and melting it at very high temperatures in a furnace, obtaining the correct carbon content and removing the impurities; glass is made from a combination of sand and other minerals that are melted together in a furnace and then shaped and cooled. Even many natural materials used in construction require some preparation or treatment before their use in a structural application. For instance, trees require felling, debarking, sawing and treating, while stone requires quarrying, cutting into slabs, calibrating and polishing. These processes and preparations for construction materials and products (with the exception of concrete batching on very large construction sites) take place at specialist facilities rather than at the construction site. See **chapter 4** for further discussion of these materials and products and their respective supply chains.

2.2.3 The facilities and sites in the construction supply chain

The various facilities and sites in the construction supply chain include:

- Sites from which materials are sourced and extracted (including quarries, mines, forests, and marine-dredged off-shore aggregates)
- Product processing facilities (including steel works, glass making facilities, cement works, sawmills)
- Warehouses and storage facilities (run by product manufacturers, suppliers and builders' merchants)
- Construction sites
- Waste handling / processing facilities

Freight transport is required between these various facilities to deliver materials and products and to collect waste materials and transport them to waste facilities and for recycling in other products and construction projects. This freight transport most commonly takes place by road, but in the case of some facilities that are rail- or water-connected these alternative modes may be used. **Figure 2.3** shows a simplified, diagrammatic representation of the facilities and sites in the supply chain for a construction project.

Figure 2.3: Facilities and flows in the construction project supply chain

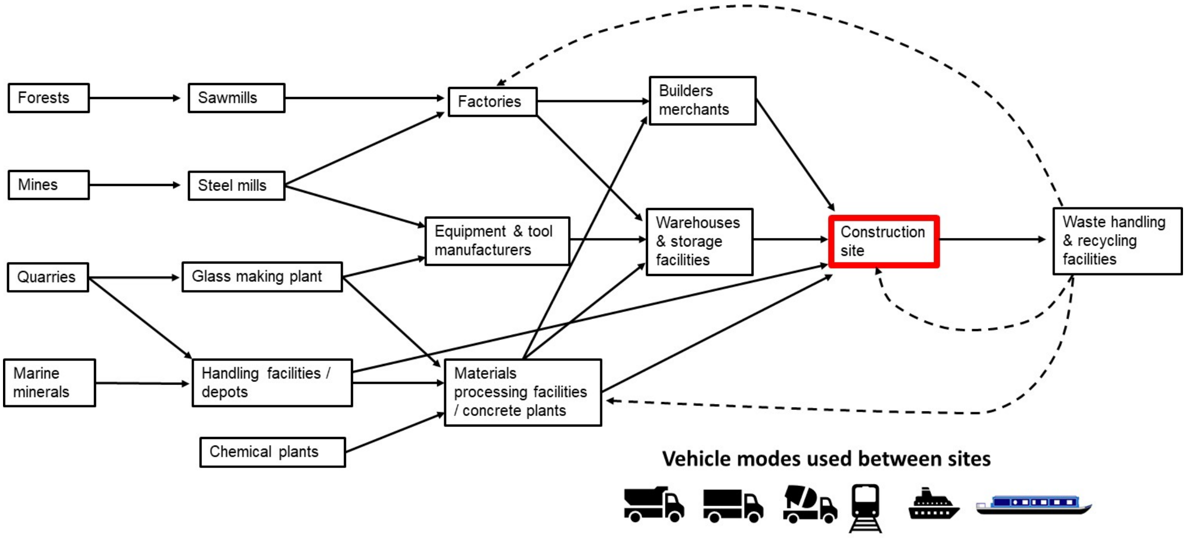
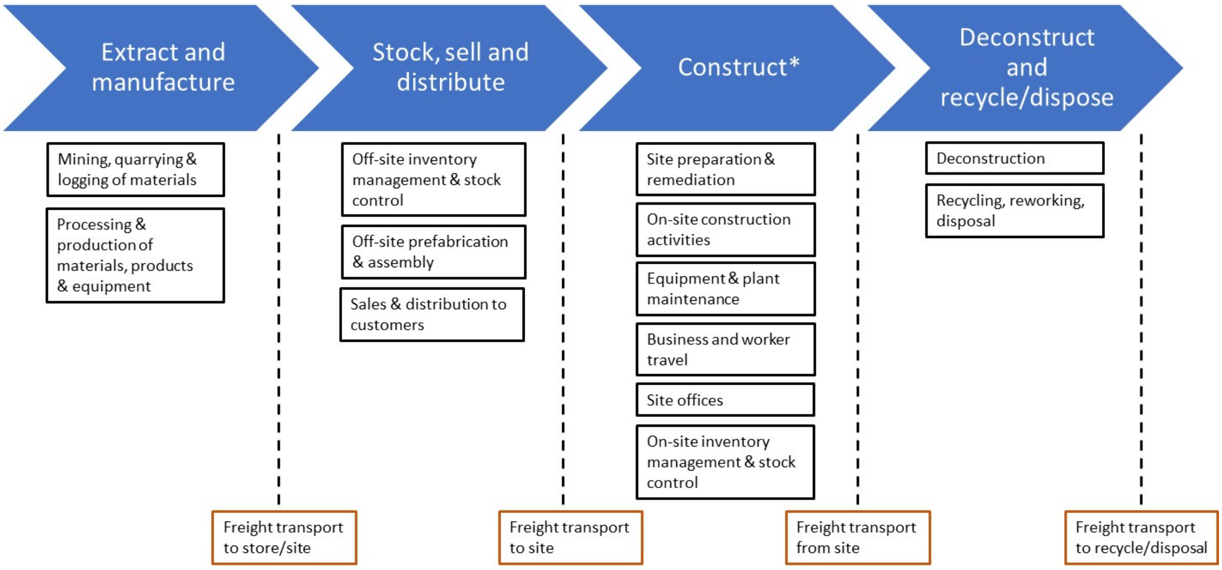


Figure 2.4 provides insight into the various processes and activities that take place in the construction supply chain, sub-divided into those associated with: i) extraction and manufacturing, ii) sales, stockholding and distribution, iii) construction and refurbishment, and iv) deconstruction and recycling/disposal.

Figure 2.4: Processes and activities across the lifecycle of a construction project



Note: * - could also involve repairs, maintenance, major refurbishment and renovation of existing building/infrastructure

3. Workforce, productivity and supply chain issues facing the construction industry

3.1 Introduction

The UK construction industry has for many years and continues to face many challenges that affect its economic and organisational performance and supply chain. These include:

- The fragmented nature of the industry (both horizontally and vertically) with many small, specialist companies and self-employed workers involved in construction projects
- That construction projects are unique and temporary, making it difficult to take innovation and learning into new projects and achieve greater productivity and efficiency
- The competing interests and motivations of different organisations in the construction supply chain leading to lack of trust between supply chain parties
- The lack of integration between design and construction phases and teams in many construction projects and the lack of cost transparency
- The lack of co-ordination and activity planning often provided by the lead contractor
- Limited availability and use of data and information for planning and co-ordination processes
- Poor training and workforce skills as a result of fragmentation, company size, self-employment levels and temporary nature of construction projects

These long-standing challenges are discussed in this chapter. These existing challenges are added to at present by Brexit and the construction workforce supply pressures it has resulted in, and the Covid-19 pandemic and its likely impact on the need to repurpose shops and offices, together with the UK government's focus on building and infrastructure projects as a means by which to stimulate growth and achieve its levelling up agenda.

In a survey carried out among 398 contractors, consultants and assets owners in the construction industry in August 2020, in addition to Covid-19, the next three most significant challenges that they felt their company faced were Brexit (56% of respondents), achieving the government's target of Net Zero emissions by 2050 (49% of respondents), improving productivity (37% of respondents). These were followed in importance by price competition (30% of respondents) and rapid pace of technological advance (26% of respondents) (Savanta ComRes, 2020).

The difficulties faced by the construction industry also affect the social and environmental impacts of its activity. Efforts by the UK government, industry trade associations and construction companies to identify and address these challenges have taken take over several decades. These efforts have led to many studies that have attempted to suggest the changes required to modernise the construction industry and improve its performance. These challenges are discussed in the following sections.

3.2 Productivity in the construction industry

Labour productivity in the UK construction industry, as measured by the rate of output per unit of input, has been notoriously poor over many decades. Data indicates that since 1994 productivity in the UK construction industry has shown little change, while at the same time it has increased in the service industry and in manufacturing, in which output per hour worked in 2015 was over 50% greater than 1994 levels. A similar lack of productivity improvement has been identified in other countries including the USA, Germany, France and Italy (Chartered Institute of Building, 2016; Farmer, 2016).

A study of construction industry productivity in 18 countries found that productivity was not uniform across construction sectors. Large companies involved in civil engineering/ infrastructure and industrial and residential building construction were found to have substantially higher productivity than companies involved in specialised construction trades such as plumbing and electrical sectors that act as subcontractors or work on small construction projects (McKinsey & Company, 2017).

Productivity improvements in the UK construction industry were very small between 1995 and 2017 (increasing by an annual compound growth rate of only 0.6% over this period – CBI, 2020). Government survey results indicate that the proportion of construction companies that were 'innovation active' (30%) in the most recently available results from 2016-18 was lower than in all other industry sectors studied with the exception of 'Accommodation and Food Services' (BEIS, 2020a).

Explanations suggested for this poor productivity in UK construction include: the fragmented nature of the industry, the lack of collaboration and transferring of risk between parties, poorly defined project briefs by clients that lead to problems later in the project, the regularity with which clients alter their requirements late in the construction process, the separation between design, tendering and construction phases in construction projects, and the quality of construction that leads to the need for frequent re-working and defects rectification on a large-scale (Farmer, 2016).

Some have argued that the labour productivity of construction workers is not a good measure of the performance of the industry, as it fails to reflect the performance of the construction materials and products industries that supply construction sites, the increased use of 'pre-manufacture' (also known as 'off-site assembly'), as well as the professional services involved in designing, planning and financing construction projects. Instead, critics argue, the labour productivity of construction only reflects the process of assembling the building on the construction site. Improvements in the working conditions of construction site workers to enhance their safety and wellbeing are similarly not taken into account in productivity data and may lead to reductions in traditional measures of labour productivity in construction (Chartered Institute of Building, 2016).

3.3 Industry fragmentation

Prior to the mid-19th century, the construction industry was both horizontally and vertically integrated, with 'master builders' proficient in all aspects of building craft performing all the necessary roles in a project from architect, to engineer, to builder, and carrying out all aspects of building. Over time, the number and complexity of construction materials and products increased and new methods and technologies were introduced resulting in greater need for specific knowledge (Sheffer and Levitt, 2012).

This resulted in increasing specialism within the industry, both in terms of the separation of the design and construction phases of projects involving different personnel, as well as the emergence of many different building trades. As a result, both vertical and horizontal fragmentation took place within the construction industry.

Vertical fragmentation took place as the design, tendering (bidding), and building phases became separate. Architects and engineers are typically involved with the design phase and construction companies the appointed via a competitive tendering process to carry out the building work. As a result, the different phases of a construction project are now often carried out separately from one another with different companies with differing specialisms and personnel involved in each.

Rather than companies employing all the tradespeople with the necessary skills to carry out a construction project, instead many companies with different specialisms are involved in each project, with a large project requiring many specialist companies. This is referred to as horizontal fragmentation. This is reflected in the fact that, as discussed in section 1.2, the construction industry comprises approximately 290,000 companies, 91% of which have 7 or less employees, and approximately 40% of those working in construction are self-employed.

Construction work is also longitudinally fragmented with its work taking place across successive, unique projects. Competitive bidding processes often mean that each project consists of different companies working together. Even if companies do work together again on different projects, the personnel involved typically differ.

This vertical and horizontal fragmentation results in many construction companies having little if any contact with the client and limited involvement in project design. It also leads to the widespread use of sub-contracting in the construction supply chain with tiered transactional relationships between construction companies in which only tier one contractors have direct relationships with the client's team during the construction phase. These Tier One suppliers sub-contract most of the work on a project to other companies. A study of tier one UK homebuilders found that depending on their size, they subcontracted 75-90% of the labour requirements of their projects (Skyblue Research, 2015). This organisational structure, together with the contractual nature that underpins it, is associated with lack of collaboration between parties, risk transfer, a focus on costs rather than quality and value, and poor productivity (Farmer, 2016). This fragmentation in the construction industry together with the one-off nature of projects also inhibits innovation in specific processes and across the supply chain (Sheffer and Levitt, 2012).

3.4 Project timescales, costs and quality

Many government-led and government-commissioned reports refer to the poor track record of the construction industry in managing to keep to project timescales and costings and to achieve satisfactory levels of construction quality (see **section 3.12**).

Survey work carried out in the UK in 2017 with construction clients, consultants (e.g. architects), and contractors investigated the factors that prevented construction projects from running smoothly. Respondents reported the following reasons: client variation (68%), slow pace of construction (45%), provision of client information (39%), scheduling and construction programmes (32%), contractor's variation (30%), poor specification (27%), assessment of delay and extension of time (27%), lateness in payment (17%), testing and quality of materials (12%), finance issues (11%), force majeure (6%), use of incorrect contracts form (5%), and suspension for non-payment (4%) (NBS, 2018). As can be seen, clients account for two of the top three factors as well as several others, while contractors are clearly responsible for some of these factors. These survey findings indicate the lack of collaborative working in the construction industry and suggest that greater teamworking between client, the client's consultant, the principal contractor and sub-contractors to plan for, predict, mitigate and overcome these factors is likely to help reduce the frequency with which they arise and the extent of the difficulties they cause.

Given the project-based nature of construction, efforts by architects, consulting engineers, principal and other contractors to gain work require the provision of detailed proposals in order to gain work. These are time-consuming and expensive to produce. In addition, the purchasing of building materials requires the placement of multiple orders by construction contractors, sometimes with many different suppliers, and consequent account management, payment and order tracking, all of which require time and effort, and generate costs.

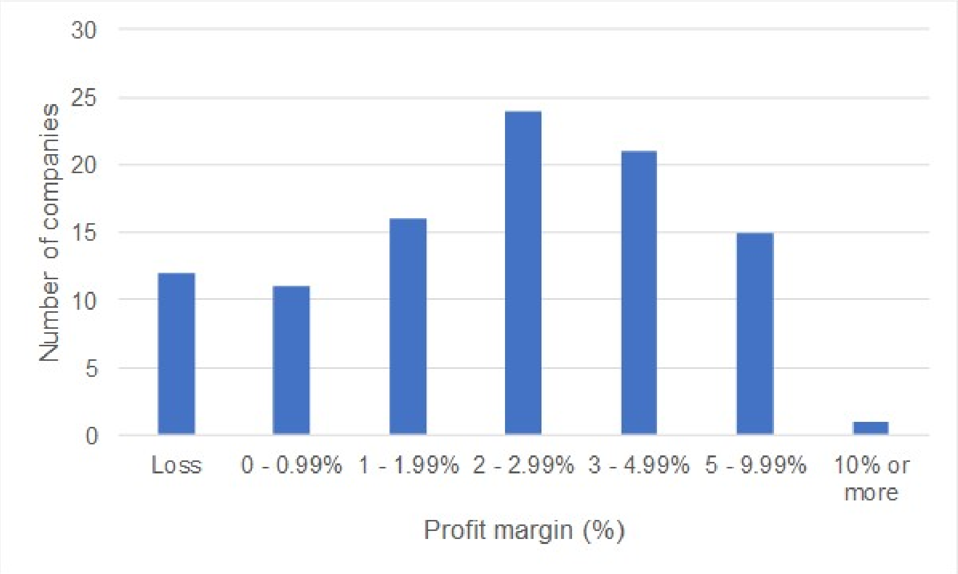
3.5 Profit margins, contract disputes and company insolvency

3.5.1 Profit margins

Companies in the UK construction industry, both large and small, tend to have low profit margins. Profits before tax among companies in the industry were 2.8% in 2018 (Glenigan, 2019). In 2018, the 100 largest UK construction companies by revenue made an average negative profit margin of -0.9%. In 2019, this average negative profit margin was -0.1%, compared to an average of 2.6% across the top 100 firms in the UK (CN100 - Construction News quoted in CBI, 2020).

Profit margins even among the top 100 UK construction companies by turnover was relatively low, with a median pre-tax profit margin of 2.6% in 2018. Among the top 100, 12% of companies made a loss, and a further 11% had a pre-tax profit margin of less than 1%. Only 16% of the top 100 companies made a pre-tax profit margin of 5% or greater (calculated from data in Construction News, 2019). **Figure 3.1** shows the annual pre-tax profit margin of these top 100 companies by profit margin band.

Figure 3.1: Pre-tax profit margin of the top 100 UK construction companies in 2018



Source: calculated from data in Construction News, 2019.

3.5.2 Contract disputes and payments

Construction projects are typically based on contractual relationships between construction clients and principal contractors, and also between principal contractors and the subcontractors that they in turn use. There are several standard contracts that are used in the construction industry that are provided by official organisations. The most commonly used include those forms of contract provided by: The Joint Contracts Tribunal (JCT), the Association of Consultant Architects (ACA), the Chartered Institute of Building, the Fédération Internationale des Ingénieurs-Conseils (FIDIC), and The New Engineering Contract (NEC). In addition, purpose-written bespoke contracts are also used, but these have a greater likelihood of not making provision for all circumstances and are not supported by a history of case law (Designing Buildings, 2021a).

The competitive tendering process involved in contractors winning projects is usually based on lowest cost. This tendering approach is commonly used rather than more collaborative models in which client and contractor organisations work more closely together in design and construction phases, and in which other factors such as quality and supply chain wide performance play an important role.

Survey work carried out in the UK in 2017 with construction clients, consultants (e.g. architects), and contractors shows that traditional procurement contracts (46%) and design and build procurement contracts (41%) account for the vast majority of construction contracts (NBS, 2018). Traditional procurement contracts set out distinct roles for the project designer and for the principal construction contractor, with the project designer usually dealing directly with the client. Design and build procurement contracts refer to those in which the principal contractor carries out both the design and construction phases of the project and is therefore responsible for both. Other types of construction procurement arrangements only accounted for 13% of all contracts (these include partnering and alliance contracts (3%), contractor approved without tendering process (2%), measured term contracts (1%), cost plus contracts (1%), Public Private Partnership contracts (1%), and management contracting (1%). Of all construction contracts put in place by respondents, 81% were fixed price/lump sum, followed by re-measurement (7%), target cost (5%), guaranteed maximum price (3%), cost reimbursement (2%) and cost 'plus' reimbursement (2%). Approximately one-third of construction contracts were only signed after construction work had commenced according to respondents, with 2% of contracts only signed after completion of the project, and 1% never signed (NBS, 2018).

Thirty-eight percent of respondents reported that UK construction contract disputes had increased over the previous twelve months, while 18% felt they were decreasing, and 49% reported no change. Approximately 30-40% more respondents reported that contract disputes were on the rise rather than decreasing on each occasion these surveys have been carried out (in 2011, 2012, 2015 and 2017) (NBS, 2018).

The main causes of these UK construction contract disputes in 2017 according to respondents were: extension of time (50%), valuations of the final account (45%), valuation of variations (42%) and defective work (42%), loss and expense (34%), failure to comply with payment provisions (22%). Respondents reported that 64% of these disputes occurred during construction work, while 36% took place after the construction work had been completed. The contract dispute resulted in construction work halting in 20% of cases (NBS, 2018).

Research indicates that between 2015-2019 the average value of a construction industry contract dispute in the UK was $25.7 million, with an average length of contract dispute of 11 months (Arcadis, 2020). The top three causes of construction contract dispute in the UK in 2019 according to this work were (in order of importance): i) failure to make interim awards on extensions of time and compensation, and ii) client/contractor/subcontractor failing to understand and/or comply with its contractual obligations, and iii) poorly drafted or incomplete and unsubstantiated claims (Arcadis, 2020).

Legal costs due to contract disputes between parties in the construction supply chain cost the UK construction industry 1.6% of its total expenditure on services and goods in 2015 (approximately £1.37 billion – Oxford Economics analysis quoted in CBI, 2020). This equates to approximately two-thirds of the average margin made by the 100 largest contractors. This expenditure on legal services is far greater than in other UK industries, which have a median spend that is half that in construction (0.8% of total expenditure - Oxford Economics analysis quoted in CBI, 2020). The UK construction industry expenditure on legal services far outstrips its expenditure on research and development (which was £417 million in 2019). This represented only 1.6% of the UK total research and development investment by private sector companies whereas the construction industry contributed 6.5% to the UK economy, indicating an under-investment in research and development (ONS, 2020a).

The construction industry is cash flow rather than profit margin focused. Some clients and contractors are notoriously bad at settling their payments to subcontractors on time, thereby assisting their own cash flow. Given that subcontractors have to purchase construction materials (which typically account for 25% of construction project value with labour accounting for the remaining 75% – Skyblue Research, 2015) prior to being paid, many commonly experience cash flow difficulties. Under the 1996 Construction Act and subsequent reforms in 2011, the UK Government put in place payment and dispute resolution legislation for the construction industry. In addition, the Public Contracts Regulations 2015 require all public sector construction clients to include 30-day payment terms in new contracts, pay undisputed invoices in 30 days or less, and require that these payment terms be passed down the supply chain (BEIS, 2017). The Government committed to carrying out a post-implementation review five years after the introduction of these 2011 changes to establish how effective they were proving to be in practice. It included a consultation exercise as part of its work; the review is on-going (BEIS, 2020b).

As well as late payments, clients and principal contractors may hold back payments until work has been completed and defects rectified. Called a ‘retention’ this refers to a “percentage of the value of a construction contract which is held by the client as an assurance of project completion and as a safeguard against defects which may subsequently develop and which the contractor may fail to remedy. Retentions can be held first by the client employing the main contractor and this typically filters down into all sub-contracted work on the project throughout the supply chain. The retention is retained from payments made throughout the length of the contract” (Pye Tait Consulting, 2017). Survey work in 2017 indicates that about three-quarters of contractors had experienced such retentions in the previous three years, either with retentions held against them and/or holding retentions against subcontractors. These contractors with experience of retentions reported that retentions are held on an average of 65% of all their contracts. By contrast, 85% of clients surveyed had used retentions on all or some of their contracts over the previous three years, with those clients holding such retentions using them on an average of 84% of all their construction contracts. The average amount of retention typically held from contractors by these clients is approximately 5% of the contract value. Seventy one percent of these surveyed contractors surveyed that had experience of retentions had also experienced delays in receiving retention monies, with some experiencing delays of over a year. Average delays were several months but were longer for Tier 2 and 3 contractors compared to Tier 1 contractors. Over half of contractors surveyed reported having experienced non-payment of these retentions, either partially or in full, over the previous three years, with tier 2 and 3 contractors being more likely to have experienced this than Tier 1 contactors. Late or non-payment of retention monies, could occur for several reasons including disputes over defects, contractors becoming insolvent, and contractors not asking for their retention money. Almost all small construction businesses in this survey viewed retentions as a means by which Tier 1 contractors boosted their cash flow (by paying late), or as a means of achieving a discount on the overall cost (by not paying back some or all of the retention). Survey results indicated that 37% of Tier 1 contractors in the survey that held retentions used it as working capital (such as labour costs), while 29% used it as part of general expenditure. Contractors in the survey stated that such retentions led to higher business overheads (due to time spent pursuing unpaid or late retention monies, and higher borrowing fees or overdraft charges), held back the growth of their businesses due to not having access to this working capital, as well as negatively affecting their relationships in the construction supply chain (due to tensions and disagreements that arise as a result of delayed or non-payment of retention monies). Meanwhile, while clients reported that that some contractors increase their tender prices to offset the retention thereby increasing project costs (Pye Tait Consulting, 2017).

Clients and their consultants often alter the requirements mid-project, and sometimes flaws in their designs may come to light during the construction phase. All of these factors tend to lead to adversarial relationships between companies in the construction supply chain. Some principal contractors have been using so-called 'supply chain financing' as a means by which to extend their repayment periods to suppliers and subcontractors. This involves subcontractors and suppliers receiving payments from a bank earlier than they would under the standard payment terms, but at a discounted rate (i.e. receiving less money than was owed to them). The contractor then reimburses the bank at the time agreed in the standard payment terms, thereby assisting their working capital. See the case of Carillion in **Box 1** for an example of this. Research by the Federation of Small Businesses in 2018 showed that 84% of small companies (in all sectors) report being paid late, with 33% reporting that one in four payments made to them is late, and 37% reporting that agreed payment terms had lengthened in the preceding two years, affecting their cash flow. Only 4% of small companies expected these payment terms to improve (Federation of Small Businesses, 2018).

3.5.3 Insolvencies

Cash flow difficulties often experienced by contractors result in the construction industry being subject to many company insolvencies. In 2019, it had the highest insolvency rates of all industries in Britain, indicating its economic volatility. There were 3,502 company insolvencies in the construction industry in 2019 (ONS, 2021b), which represented approximately one-fifth of all company insolvencies in the country, and 1.2% of all construction companies (calculated from data in ONS, 2021a, 2021b).

Box 1 provides a summary of the insolvency of one of the UK's largest construction companies, Carillion, its treatment of subcontractors and suppliers with respect to payment, and the consequences.

Box 1: Carillion: its payment behaviour and impacts of its insolvency

Carillion was a British multinational company. It started life in 1999 as a demerger from Tarmac, the building materials, road building and facilities maintenance company; with Carillion taking the construction and facilities management part of the business professional services. It operated in the UK, Canada and the Middle East. It employed a total of 43,000 people, 18,000 of whom were in the UK. Before its collapse, Carillion was the second largest construction company in the UK. During its existence it had purchased many other well-known construction companies including Mowlem (for £350 million in 2006), and Alfred McAlpine (for £565 million in 2008). It worked for both public and private sector organisations. In 2016, its work for the UK government accounted for 38% of its reported annual revenue. This ranged from building roads and hospitals to providing school meals and defence accommodation. In 2018 Carillion was declared insolvent and at that point had about 420 contracts with the UK public sector.

Even prior to its demise, Carillion had a history been making the many subcontractors and suppliers it worked with wait long periods of time for payments, well in excess of the payment periods in its contracts. This was despite the fact that it had signed the Government's Prompt Payment Code in 2013, which should have resulted in it paying others on time, with 95% of invoices paid within 60 days, and working towards 30-day payment terms, and avoiding practices that adversely affect others in the supply chain. Instead, Carillion's suppliers and subcontractors were asked to sign up to 120-day payment terms. They were offered an 'early payment facility' option in which they could receive payments from a bank after 45 days, but at a discounted rate (i.e. receive less money than was owed to them – this is often referred to as 'supply chain factoring', 'reverse factoring', or 'supply chain financing'. Carillion did not have to reimburse the bank until the standard payment terms (120 days) had expired, providing them with a long repayment period which assisted their working capital. This ‘supply chain financing’ won support from industry bodies and the government in 2012, Carillion was a founding participant in this initiative (which was also promoted and offered by Greensill Capital, which in 2020 also became insolvent and is being investigated over its close links to Government and the Civil Service).

Carillion relied on an extensive network of suppliers to deliver materials, and subcontractors to provide services across its work. At the time of the company’s collapse, it was estimated that Carillion’s supply chain included 30,000 suppliers and subcontractors. Another estimate put the number of construction product suppliers to Carillion at 11,600. It is said that some of the indirect subcontractors may have been unaware that they formed part of Carillion’s supply chain until the insolvency resulted in them not receiving payments. Following its insolvency, many suppliers and subcontractors owed money by Carillion did not receive payment

Sources: BEIS and Work and Pensions Committees, 2018; National Audit Office, 2018.

3.6 Skills and training

The construction industry has long been viewed as having an inadequately trained and skilled workforce. In a 2018 survey, the most frequently mentioned constraint to business sales and output among construction companies in the UK was labour shortages (mentioned by 13% of employers). Seventeen percent of employers reported that for some period during the previous twelve months they had not had enough skilled workers, and a further 9% reported that for all or most of the last 12 months they had not had enough skilled workers in relation to the work they had or could have had. Of the 31% of employers that that had tried to recruit skilled direct or self-employed staff, almost half (47%) of them experienced difficulties in filling the positions (Construction Industry Training Board, 2018a).

Employers responding to this 2018 survey who had experienced difficulties in filling construction vacancies were asked about the causes. They were provided with a list of possible causes and asked to mention those that applied. The most frequently cited cause of hard-to-fill vacancies is that ‘applicants lack the skills required’ (73% of respondents mentioned this, followed by ‘not enough young people are being trained in the construction industry’ (64% of respondents). These are the same top two causes of difficult to fill vacancies as in the 2014 and 2016 survey results. In addition, 59% of employers responding to the survey mention a lack of relevant work experience among applicants, while 56% mention the limited number of applicants, 48% mention the lack of motivation among applicants, 45% mention a lack of applicants with relevant qualifications, and 42% mention competition from other employers (Construction Industry Training Board, 2018a).

This same survey found that two-thirds of construction sector employers had funded or arranged some training for staff in the last 12 months (which could have been on-the-job or off-the-job, informal or formal) (Construction Industry Training Board, 2018a).

The Construction Industry Training Board (CITB) is a non-departmental public body of the Department for Education which for 50 years has imposed a statutory levy on employers in the construction industry which the CITB then uses to provide grants and other support to employers that undertake eligible training in the industry. The fragmentation in the industry, together with the degree of sub-contracting and high levels of self-employment creates disincentives for employers to train and develop the construction workforce (Department for Education, 2018).

Construction industry employers with a wage bill that is £80,000 or more per annum are required to pay the training levy. In 2019/20 the CITB levy raised £186 million after costs were deducted, while approximately £135 million was distributed (£95 million in apprenticeship and qualification grants, and £39 million in other forms of funding including the Construction Skills Fund). The levy funded 22,530 apprenticeships in 2018/19 (Construction Industry Training Board, 2020).

However, the CITB's stakeholder research found that in 2019/20 only 34% of employers "believe that content and method of training and assessment reflects industry's need, only 22% of employers "say there is a talent pool sufficient to meet industry's recruitment needs", only 34% of employers say "they can access the training they need in a timely manner", and only 26% of respondents viewed the CITB seen "as credible and reputable, adding value to the industry" in 2019/20 (Construction Industry Training Board, 2020).

In addition, analysis has shown that smaller companies recover proportionately less of the levy that it pays than larger employers, and smaller companies find it harder to retain employees following their training and attainment of qualifications (Farmer, 2016). Also, a £135 million annual training budget in 2019/20 is small compared to the £176 billion output value of the UK construction industry (accounting for only 0.07%).

A separate training levy scheme operates in the engineering construction industry for oil and gas, nuclear and renewables sectors, as well as major process industries, such as chemicals, pharmaceuticals, food processing, water and waste treatment. This scheme is run by the Engineering Construction Industry Training Board (ECITB) (Engineering Construction Industry Training Board, 2020). Survey work in 2020 indicates that the ECITB levy is more popular with those paying it than is the case for the CITB levy. Seventy five percent of employers who use ECITB products said they meet their needs, 73% of employers said that ECITB support helped them address skills shortages and gaps, and approximately 80% of employers were satisfied with the quality, accessibility and affordability of ECITB training (IFF Research, 2020).

Labour shortages in the UK construction industry due to an ageing workforce and the impacts of Brexit on non-UK-born workers could be addressed through vocational education and training facilities. However, previous such training initiatives have highlighted several challenges to addressing the labour shortages in the construction industry. These include: i) that such training programmes are require long-term commitment from all involved, but this is difficult to achieve in an industry which is based on temporary projects that are geographically mobile and given the extent of casual work, thereby reducing employers' incentives for, and workers' commitment to, training, ii) wages of some construction workers are low, especially those doing general manual work, and a dependency on low-cost labour discourages employers' investment in skilling workers and to pay higher wages when such skills are acquired, iii) few youngsters aspire to construction work because of its image, wage rates and the insecure nature of the work, and iv) the many small subcontracting companies have limited capacity to organise and provide firm-level training (Sancak, 2020).

On the demand-side, the reduction in the UK of the public sector's role as client for construction projects over recent decades is likely to have played an important part in the reduction in workplace training, given that public sector works are more likely to be associated with stable employment and hence provides a good opportunity for training. On the supply-side, some have argued that the growth in labour-only subcontracting and self-employment has undermined workplace training, and that as large contractors have given up the direct employment of labour, they have reduced their responsibility for training and skilling of the workforce. An additional concern is that as construction trades have become ever-more specialised, which is a by-product of subcontracting, this limits the range of skills that can be acquired in any one organisation. This makes it difficult to train people in all-round construction skills (International Labour Organisation, 2001).

3.7 Workforce demographics

In a 2018 survey, the most frequently mentioned constraint to business sales and output among construction companies in the UK was labour shortages (mentioned by 13% of employers) (Construction Industry Training Board, 2018). The construction industry has an ageing workforce and is struggling to attract younger workers. **Table 3.1** shows this problem has been accelerating since 2004, with the proportion of the construction workforce aged 16-24 falling from 13.3% in 2004 to 10.1% in 2018 (compared to 13.4% of the total UK workforce in 2018). Those aged 50 or over have increased from 26.9% of the construction workforce in 2004 to 32.3% in 2018 (Nomis, 2018). Industry analysis suggests that the level of new entrants to the industry is insufficient to meet future workforce needs (Construction Leadership Council, 2019). This is concerning for the industry given that over the coming decade or so many current workers in their late 40s and early 50s will reach retirement age, which typically occurs earlier in construction than the normal state pension age given the effect of manual labour on workers' bodies (Chartered Institute of Building, 2020).

Table 3.1: Workforce age groups, construction and all UK (% of workers by age group)

Year	Age group							
	16-19		20-24		25-49		50+	
	Construction	All workers	Construction	All workers	Construction	All workers	Construction	All workers
2004	4.2	6.4	9.1	7.9	59.9	44.2	26.9	41.5
2009	3.5	6.4	9.2	8.2	60.4	43.6	26.9	41.7
2014	2.0	6.0	8.1	8.3	60.2	42.2	29.6	43.7
2018	2.2	5.5	7.9	7.9	57.6	41.1	32.3	45.5

Source: Nomis (2018) Data April to March except 2004 which is Jan to December, quoted in Construction Industry Training Board, 2018b.

Similarly, research carried out in 2017 in the homebuilding sector of the construction industry identified a similar age profile issue, with 50.6% of the UK house building workforce being aged 45 or older, compared to 46.3% in the total UK workforce (see **Table 3.2** - NHBC Foundation, 2017).

Table 3.2: Age group distribution of workers in house building compared with all workers

Age group	House builders	All workers
16-24	7.8%	10.3%
25-34	19.6%	20.3%
35-44	22.0%	23.2%
45-54	27.2%	25.5%
55-64	19.1%	16.7%
65 or older	4.3%	4.1%
TOTAL	**100%**	**100%**

Source: NHBC Foundation, 2017

Female workers are significantly under-represented in the UK construction industry, only comprising 18% of employees, 6% of self-employed workers, and 14% of the total construction workforce in 2019 (ONS, 2021e). Female representation has hardly changed over the last two decades, with females accounting for 13% of the total construction workforce in 1997 (ONS, 2021e).

Black, Asian and minority ethnic (BAME) workers are also significantly under-represented in the UK construction industry, comprising only 4% of the construction industry workforce in 2015, compared to the national average of 10**%** (Construction Industry Training Board, 2015). This had hardly changed since 2009, when 3.3% of construction sector workers were from a BAME background (Caplan et al., 2009).

In addition to the problem of attracting younger workers and an ageing workforce, in particular regions of the UK the construction industry also faces potential workforce challenges due to Brexit. Non-UK nationals accounted for 15% of the total UK construction workforce in 2016. The majority of non-UK born construction workers are based in London (54% of the total non-UK-born construction workers), and account for 44% of London's construction workforce. If a sizeable proportion of these non-UK-born workers decide not to remain in the UK in the longer -term as a consequence of Brexit, and it also becomes difficult for the construction industry to continue to attract workers from overseas as a result of new restrictions on working arrangement for non-UK nationals this will have significant impacts on construction work in London (Construction Industry Training Board, 2018c; ONS, 2018).

The ageing construction workforce and the threats to non-UK-born workers due to Brexit pose serious challenges to the potential for growth in the UK construction industry, especially given the UK Government's ambition of building 300,000 homes a year by the mid-2020s (HM Government, 2019). One method by which labour shortages could be addressed is through vocational education and training in construction but, as discussed in **section 3.6**, this has proved problematic to date and, even if successful, such education and training programmes would take considerable time to result in an increase in the recruitment of young workers.

UK construction companies may therefore attempt to meet future labour requirements through the informal employment of migrants. Half of the workers in the London construction industry are already lacking a written contract. This would pose risks for worker safety and wellbeing (Sancak, 2020).

3.8 Lack of collaboration and innovation

Innovation in construction products and construction techniques and management practices are of key importance to economic performance and quality. However, due to the one-off nature of construction projects, innovation achieved on one project is not necessarily translated into more general use in the company or construction supply chain. For the more widespread application of innovation, it needs to become a process that is systematically applied and managed across projects and supply chain parties.

The reluctance of the construction industry to embrace collaboration is preventing innovation, data sharing, risk sharing, project certainty and value creation. R&D spend in the construction industry is extremely low, representing only approximately 0.1% of construction output value, far lower than in many other industries (Farmer, 2016).

Two key technological innovations in the construction industry are off-site manufacturing and Building Information Modelling (BIM). Both of these have the potential to improve the productivity of construction work and to improve supply chain performance, thereby improving quality and reducing waste and costs.

Off-site manufacturing (also referred to as pre-manufacturing, pre-fabrication and modular construction) involves the production, preparation and assembly of building products in factories upstream of the construction site that are then delivered to the site and are simply assembled. This removes the need to carry out complicated building processes on site that require many different building contractor specialists and complicated sequencing of tasks in an often small and non-optimal working environment. Off-site manufacture can therefore both reduce construction project waste levels, time taken and costs, as well as preventing on-site project delays and defect rates, and improving on-site safety, noise and air pollution. Products that that be manufactured off-site include factory-made concrete, steel and cross-laminated timber components through to precast wall panels and modules, and facade units complete with windows and balconies. Off-site manufacturing can also facilitate the use of a greater proportion of bespoke items and a greater selection of outer wall finishes than are available when made on-site. The use of off-site manufacturing can simply the flow of materials and products required at a building site but changes the material handling, transportation, and installation requirements on the construction site which require revised planning and management systems compared to on-site manufacture.

BIM is modelling software that allows the creation of a virtual 3D building or infrastructure, the virtual testing of that building and the processes to be used for its production and the management of that production process, including the data associated with this. By virtually generating such processes through 3D modelling it is possible for all the stakeholders in the construction supply chain (including architects, engineers and construction contractors) to gain the required insight and information to plan, design, construct, and manage the sequence of activities required in building and infrastructure construction more efficiently before physical construction commences, thereby improving productivity and quality, and reducing waste, time taken and project costs. Studies have indicated that BIM can reduce time taken and costs in both the design and construction phase (World Economic Forum and Boston Consulting Group, 2018). BIM is intended to ensure that appropriate information is created and stored in a suitable, accessible format at the right time so that better decisions can be made throughout the design and building of construction projects.

For BIM to be used requires collaborative working and data sharing between the construction supply chain parties in a way that has not traditionally occurred. The benefits of BIM are that it facilitates, “essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them” (BIM Task Group, 2016).

BIM and off-site manufacturing of products are two innovations in construction that work well in tandem. BIM is intended to facilitate the move to pre-manufacture as well as improved supply chain productivity. However, those companies that have invested in innovation tend to experience difficulties in getting uptake for their new products and business models due to concerns about change and risk among clients, designers, other supply chain parties, and insurers and financiers. This has been the case with prefabrication / pre-manufacture as well as with BIM, the adoption of which is being held back by lack of willingness to invest and collaborate (Farmer, 2016).

3.9 Industry image

Media coverage of the devastation caused by building collapses following earth tremors, due to poor construction and inadequate inspection, are commonly shown on television news. The Grenfell Tower tragedy in London in which the use of flammable cladding led to the deaths of many people has heightened such concerns. The public is also familiar with news reports of the failure of major construction companies such as Carillion, corruption involving contractors and government officials, as well as reports about modern slavery among renegade elements in the construction industry. These perceptions have been further reinforced by frequent television documentary series featuring 'cowboy builders' and the suffering they bring to those individuals using them to work on their homes. Even in the arts and drama, the behaviour of those in the construction industry is often portrayed as ruthless, untrustworthy and even criminal. The 1948 American comedy film 'Mr. Blandings Builds His Dream House' provides a light-hearted overview of the problems encountered when hiring contractors for house building. In the far-grittier 1957 British film noir 'Hell Drivers' a recently released convict who obtains work transporting aggregates by road from a quarry is faced with pressure from his boss to drive recklessly and illegally. The 1991 film 'Riff Raff' portrays extortion, tax evasion and the ignoring of safety regulations in the construction industry through the lens of a large building site. Health and safety rules are routinely flouted and overlooked by management, leading to the dismissal of one worker who takes a stand against them and the subsequent death of a young worker who falls from the roof of the building. The long running British TV comedy drama, 'Auf Wiedersehen, Pet' (1984-2003) also presents the viewer with the seamier sides of building site work, including corruption, criminality and a general disregard for safety. One of the few films to provide a more positive view of the construction is 'Locke'. Released in 2013, this quirky film, based on a conscientious construction manager responsible for organising one of the largest-ever concrete pours in Europe on a project in Birmingham, only ever presents the viewer with the man in his car and the voices of those he talks to by phone. The audience see and hear him discussing types of concrete, traffic management and road closures for the hundreds of concrete mixer lorries required, and remotely guiding his anxious on-site colleague. But at the same time, we learn that he is not at work and is instead driving from Birmingham to London due to the moral dilemma he faces in which a woman he once slept with has informed him that she is pregnant and about to give birth and wants him with her. Despite being married with a family and the importance of the next day's work on the construction project, he has decided to drive to be with her due to his own past in which he never forgave his father for abandoning him as a child.

In addition to having a poor perception among the general public, the construction industry also has a poor image in the eyes of its workforce and potential workforce in terms of its health and safety, working conditions, culture and diversity, and job security. There has been extensive media coverage in recent years of 'blacklisting' in which construction workers who were trade union members were illegally prevented from working in the industry without their knowledge, with no system for review, appeal, correction or redress. This blacklisting system was run on behalf of many leading construction contractors. Uncovering of the scheme led to legal action and substantial payments by contractors to those individuals affected. The media has also covered the widespread fraudulent use of Construction Skills Certification Scheme cards. These cards are intended to provide proof that individuals working on construction sites have the appropriate training and qualifications for the job they do on site).

A survey of workers in the construction industry found that 23% of female respondents, 31% of black respondents, and 34% of people with a disability were discouraged from entering the construction industry. While only 34% of white respondents said they had experienced an occasion in which they felt their chance of being accepted for a job had been reduced due to their ethnicity, disability, sexual orientation, age, gender or mental health, 76% of black respondents, 55% of Asian respondents, 66% of other ethnic groups, and 62% of disabled respondents stated that they had had this experience. Only 42% of black respondents and 37% of people with a disability said they felt secure in their job, compared with 60% of total white respondents to the survey. Overall, 60% of respondents felt that the leaders in their workplace had a bias towards people who look, think or act like themselves, and only 35% of respondents trusted their leaders to deliver change on their diversity and inclusion agenda (Ray, 2019).

All these factors are likely to harm the industry's ability to recruit potential workers, especially among the young, women and those from minority groups.

3.10 Self-employment, worker status and security

Prior to the 20th century, the general labouring in the UK construction industry was closely associated with casual employment, along with other industries such as dock and warehouse work, gas production and clothing. People may only be hired for a few weeks, a few days, a day, half a day or an hour at a time as demand required (Whiteside, 2017). During the 19th century conditions for general labourers were extremely tough, consisting of poorly paid, dangerous itinerant work. For example, railway construction in the 19th century relied on casual labourers from Britain, Ireland, mainland Europe and traveller communities, who lived and worked in appalling conditions, without compensation for death or injury. Social reformers such as Charles Booth investigated casual labour and the problems it caused for those reliant on it. They discovered that this early form of flexible labour market was unreliable, expensive and inefficient.

From the early 20th century through until the 1960s, labour market reforms including employment law and contracts, the rise of the public sector and nationalisation of industries and the creation of a welfare state resulted in a diminishing of casual labour in construction and other industries and a rise in direct employment by contractors. However, since the start of the decline of the public sector's involvement in construction as both client and contractor in recent decades, important changes have taken place in construction sector work in the UK and around the world. There is evidence of a reduction in employment by contractors (and subcontractors) in favour of outsourcing and the use of self-employed workers. The UK construction industry is now characterized by what has been referred to as the "hollowed-out firm" which relies on "nominally self-employed labour, most of which is supplied through labour agencies or labour subcontractors" (International Labour Organisation, 2001).

The extent of subcontracting in the construction industry has increased, as has the degree of self-employment. Approximately 40% of the construction industry workforce in the UK is self-employed. Self-employed workers have fewer rights than employees. This has led to the UK construction industry being given a unique tax regime by the government. Called the 'Construction Industry Scheme' (CIS), this scheme allows employers to deduct and send tax to HMRC directly from self-employed workers' wages, but without deducting National Insurance or making National Insurance payments. This makes self-employed workers cheaper to hire than employees. Some have argued that this has encouraged self-employment, and that in many instances the self-employed are not really working for themselves, with some working through agencies who chose their work, administer their pay and deal with their taxes (FLEX, 2018).

Self-employed workers are not entitled to the National Minimum Wage, are not covered by the Working Time Regulations, which place limits on the maximum working week, breaks and paid holidays, and they are not entitled to sickness pay. Some refer to this as 'bogus' or 'false' self-employment and argue it undermines workplace health and safety, training and trade union organisation. In 2009, the UK government estimated that the tax revenue loss due to this was about £350 million annually (HM Treasury & HMRC, 2009). In 2013, it was estimated that 25% of the 780,000 construction workers designated as self-employed were wrongly classified (Office of Tax Simplification, 2015).

Since 2014, as a result of government efforts to address false self-employment, so called 'umbrella companies' have been used in the construction industry. These provide a payroll service and effectively act as the employer on behalf of agencies or companies. In the 2017 Budget, the UK government proposed to reform National Insurance contributions as paid by the self-employed in order to address this anomaly in the construction and other sectors. However, it was subsequently announced on 15 March that the Government would not proceed with these reforms (Seely, 2018). In 2018, the UK government announced plans to introduce reforms to amend workers' rights (HM Government, 2018a). In April 2021, the UK

Government introduced changes to tax arrangements for those workers not on the payroll of those companies and organisations they provide services to, instead providing their services through their own limited company or another type of intermediary to the client. These new rules (referred to as 'IR35') are intended to ensure that workers, who would otherwise have been an employee, pay approximately the same Income Tax and National Insurance contributions as employees. Public sector organisations, medium and large-sized companies, and the worker's intermediary have been made responsible for deciding if these new rules apply to workers (HM Revenue and Customs, 2021).

A study comparing self-employed construction worker hourly pay rates (using data from one of the construction industry's largest freelance labour payroll service providers) with construction sector employee hourly pay rates (using ONS employee pay data) indicates similar mean and median rates for both groups when employee holiday pay is taken into account. The analysis indicates that for the 30% of workers in both groups with the lowest hourly pay rates, self-employed workers fare slightly better. By contrast, for the 30% of workers in both groups with the highest hourly pay rates, the employed workers have higher pay rates than self-employed (Burke and Vigne, 2018).

However, within the construction industry, as within the wider UK economy, there is substantial diversity in the income and well-being of those who are self-employed sector. Analysis has shown that those self-employed personnel working in construction management are usually well paid, most consider themselves to have a job, with 30-40% having a pension, only about 5% are looking for additional or a different job, and less than 2% became self-employed as they could not find other employment. By contrast, self-employed construction labourers usually receive low pay, are less likely to consider themselves to have a job, with only 10-15% having a pension, only about 15% are looking for additional or a different job, and approximately 25% became self-employed as they could not find other employment (CSRE, 2017).

Therefore, self-employed general labourers, and especially migrant workers are the least secure workers in the construction industry. Some of these workers gather daily outside builders merchants hoping to gain informal day labouring from contractors who hire and collect those required. Migrant workers accounted for 11% of the UK construction workforce in 2016 (ONS, 2018). However, analysis indicates that they comprise 44% of the low-wage 'building' workforce, 21% in completion and finishing and only 2% on utility projects. This implies they are overrepresented low paid construction work and under-represented in higher paid roles (National Institute of Economic and Social Research, 2016).

3.11 Supply chain management issues and relationships

As can be surmised from the previous sections in this chapter there are many supply chain issues and challenges that affect the economic and operational performance of the construction industry in the UK. These include fragmentation due to the existence of many small companies and high levels of self-employed workers, the unique and temporary nature of construction projects that tends to hinder innovation and learning, the varying objectives and interests of the different organisations in the construction supply chain which affects trust between them, the lack of integration between design and construction phases and teams in many construction projects and the lack of cost transparency, the lack of co-ordination and activity planning often provided by the lead contractor, the limited availability and use of data and information for planning and co-ordination processes in many projects, and the poor training and workforce skills that result from all these factors.

Table 3.3 summarises the conflicting incentives for the various parties in the construction supply chain that exist under traditional adversarial contract relationships.

Table 3.3: Incentives for construction supply chain parties under traditional contract relationships

Party	Motivation	Clashing behaviours
Client/Owner	Reliably deliver project in timely fashion	Constantly push contractors and suppliers to expedite production and delivery; engage expediters for critical path items
	Receive value for money	Seek cost savings throughout (e.g., contractors, suppliers, labour, utilities, etc.)
	Avoid high-profile setbacks or failures	Engage best contractors and offload complete risk onto them
Main contractor	Maximize profit margin	Charge for any scope changes and submit claims, variations, and project extensions
	Ensure financial stability	Get milestone-based payments; stall work until instalment is paid
Designer/architect	Illustrate creative edge and reputation	Submit drawings and designs in random order and not the way required by construction contractors
	Minimize effort and resources	Work according to their own resource availability and timeline, rather than under project timelines
Subcontractor	Optimize resources	Deploy cheapest available labour and machinery; in case of any issues, submit claims
Materials supplier	Financial stability	Make high margin on raw materials, logistics, etc.
OEMs2 for long lead items	Financial stability	Try to sell technology or product that is most profitable instead of the most appropriate solution for owner
Other equipment supplier	Maximize profit margin	Squeeze subcontractor cost by negotiations, claims, variations, and project extensions Low motivation to adhere to quality, health, safety, and environment standards unless tight third-party inspection done by main contractor or owner

Source: adapted from McKinsey & Company, 2017.

Clearly, greater collaboration in the construction supply chain is a necessary pre-condition to greater productivity and efficiency. Improved data sharing and use of computer-based planning available to all parties are important facilitators in such improvements in supply chain collaboration. Greater transparency of information and data would permit improved planning and greater teamwork between parties, and the potential to identify where changes and innovations could be made.

3.12 Government reports and strategies

The UK Government has commissioned studies and published reports into the problems experienced in the construction industry that go back as far as the 1940s, with the publication of the Simon Committee Report in 1944. This 1944 report which focused on public sector housing, given the importance of public sector expenditure on residential development at the time, explained the weaknesses of how construction projects were approached (with the design phase separated from the construction phase) and criticised the open-tendering system used to appoint a principal contractor, and that this appointment was often based on cost considerations alone. The report recommended that greater collaboration and earlier contractor involvement at the design phase was required to help avoid the otherwise regular cost cutting measures adopted by constructors during the construction phase which often led to sub-standard work and their resorting to time consuming and expensive claims against clients and other contractors (Hillebrandt, 2003).

The same themes continue to recur throughout these UK government reports over the decades since the 1940s indicating the lack of fundamental change that has taken place in the industry. In the 1990s, the government commissioned two major studies into underachievement in the construction industry. The so-called Latham Report was commissioned jointly by government and industry to investigate the concerns of the various parties in the construction process including clients and identify how problems could be addressed and industry performance improved (Latham, 1994). The report led to changes in standard contracts used in the construction industry and the led to the creation of the Considerate Constructors Scheme intended to help improve the image of the construction industry, but many of its recommendations were not taken up.

The so-called Egan Report aimed to "advise the Deputy Prime Minister from the clients' perspective on the opportunities to improve efficiency and quality of delivery of UK construction, to reinforce the impetus for change and to make the industry more responsive to customer needs." The background to the study was the industry's low profitability, training crisis, and clients' dissatisfaction with project timescales, costs and quality (Egan, 1998). The report recommended that competitive tendering should be replaced with long term collaborative relationships based on performance measurement. It set challenging targets for reductions in project timescales and costs and improvement in quality.

In reality, both of these reports in the 1990s achieved relatively little change in the industry, the major outcome of them both was the formation of a number of bodies responsible for raising and monitoring performance in the industry, which in 2003 coalesced into a single not-for-profit body, Constructing Excellence, which in 2017 merged with the Buildings Research Establishment.

In 2011 the UK Government published the first Government Construction Strategy (Cabinet Office, 2011). The main aim of this strategy was to reduce the cost of public sector construction by up to 20%.

In 2013, the UK Government, in conjunction with the industry-led Construction Leadership Council, published 'Construction 2025' in which it set out its vision for 'how industry and Government will work together to put Britain at the forefront of global construction' (HM Government, 2013). This report set jointly held government and industry targets by 2025 for a:

- 33% reduction in the initial cost of construction and the whole life costs of built assets.
- 50% reduction in the overall time, from inception to completion, for newbuild and refurbished assets.
- 50% reduction in greenhouse gas emissions in the built environment.
- 50% reduction in the trade gap between total exports and total imports for construction products and materials.

The industry has failed to meet the target of a 50% reduction in the trade gap on production materials and products, and instead this trade deficit has widened from widened from £6 billion in 2013 to £10.4 billion in 2019 (BEIS, 2021a). Meanwhile, others have questioned the achievability of the other targets for lower costs, reduced project timescales and greenhouse gas emissions reduction given the current state of the construction industry (Farmer, 2016).

The second UK Government Construction Strategy was published in 2016. It made clear that instead of the 20% savings in public sector construction targeted in the 2011 Strategy only 7.5% had actually been saved. It set out plans to deliver efficiency savings of £1.7 billion (compared to the planned £8.8. billion in the 2011 report) and 20,000 construction apprenticeships (Infrastructure and Projects Authority, 2016).

In 2016, the government the asked the Construction Leadership Council (CLC) to investigate the labour market and skills in the construction sector. The CLC commissioned Mark Farmer to carry out the review. Known as the Farmer report, it provided a highly critical insight into the state of the construction industry, covering its productivity, innovation and workforce issues (Farmer, 2016).

In 2018, the UK Government published the 'Construction Sector Deal', part of its Industrial Strategy (partnerships between industries and government), in which it attempts to implement some of the Construction 2025 and Farmer Report recommendations. It includes policies to support the training of construction workers, faster payments for suppliers and contractors, and its 'Transforming Construction' programme which will provide competitive funding to encourage the use of modern methods of construction materials (i.e. off-site construction) (HM Government, 2018b). It notes the issues facing construction raised in the Farmer Report (Farmer, 2016) and aims to transform it through shared between the industry, its clients and the government. It reiterates the quantified targets set in the Construction 2025 and adds another known as the Buildings Mission objective, which is that using innovative and more efficient technologies in infrastructure will help reduce by at least 50% the energy use of new buildings by 2030 (based on industry research and response to this challenge to it from government - Green Construction Board, 2019; HM Government, 2018b). The report also states an ambition for the construction industry to achieve (HM Government, 2018b):

- Better-performing buildings that are built more quickly and at lower cost;

- Lower energy use and cheaper bills from homes and workplaces;

- Better jobs, including an increase in apprenticeships;

- Better value for taxpayers and investors from the infrastructure and construction pipeline; and

- A globally-competitive sector that exports more, targeting the global infrastructure market.

It says that these ambitions will be achieved through focusing on three strategic areas (HM Government, 2018b):

- Digital techniques deployed at all phases of design will deliver better, more certain results during the construction and operation of buildings. Clients, design teams, construction teams and the supply chain working more closely together will improve safety, quality and productivity during construction, optimise performance during the life of the building and better our ability to upgrade and ultimately dismantle and recycle buildings.

- Offsite manufacturing technologies will help to minimise the wastage, inefficiencies and delays that affect onsite construction, and enable production to happen in parallel with site preparation – speeding up construction and reducing disruption.

- Whole life asset performance will shift focus from the costs of construction to the costs of a building across its life cycle, particularly its use of energy.

The report emphasises the importance of innovation in technology and techniques, environmental sustainability, building and workplace safety, worker training and skills, the need for a more diverse workforce in the construction industry. It also acknowledges the need to reform contractual and payment practices that transfer legal and economic risk in relation to cash flow and which disadvantage small companies (HM Government, 2018b).

In 2021, the UK government published its ‘Build Back Better’ agenda which includes its plans for capital investment in roads, rail, cities and telecommunications infrastructure projects. This funding, together with the Levelling Up Fund and UK Shared Prosperity Fund, the Towns Fund and High Street Fund, is intended to help stimulate the economy and meet its levelling up agenda in the country to invest in local areas (HM Government, 2021).

The thrust of all these government commissioned and/or written reports over the years since the 1940s is that the UK construction industry has under-performed in terms of project delivery timescales, costs and quality. These reports therefore appear to have achieved little in terms of improving the construction industry. The perception persists, both in these reports and more widely, that the construction industry is adversarial, unproductive and wasteful. One commentator has noted that either: i) the industry may operate more effectively than it appears from the outside, or ii) the expectations laid out in these reports are unrealistic, or iii) the recommendations in these reports have been consistently poorly implemented (Designing Buildings, 2021b). Some suggest that there has been little progress in the construction industry despite all these government policies and recommendations due to the conservative attitude towards innovation and a lack of challenging the status quo from within the construction industry (Murray and Langford, 2003).

It should also be noted that despite the government leading all these investigative reports, the public sector only accounts for 25% of the industry’s output and that in its role as client, the public sector is fragmented at national and local levels across a range of bodies that commission buildings including hospitals, schools, housing, and transport infrastructure. The vast majority of the industry’s output (75%) is not in the direct control of government and this limits the ability of government strategies and recommendations to bring about widespread change (Farmer, 2016). For this to happen, the government would have to find ways of working more closely with private sector clients of the industry and persuade them of the need to change and the appropriateness of the measures they recommend.

It is also worth noting that the term ‘supply chain’ is first used in UK government strategies for the construction industry strategies in the Latham Report in 1994 which uses the term three times. The term has been far more widely used in all the strategy reports published since then. However, the same is not true of the terms ‘logistics’ or ‘freight transport’.

The Latham Report does not use the term ‘logistics’, while the Egan Report, Construction 2025, Farmer Review and the Construction Sector Deal, published in 1998, 2013, 2016 and 2018 respectively, each use the term ‘logistics’ only once. None of these reports use the term ‘freight transport’, with the Farmer Review making one reference to ‘haulage coordination’. This goes beyond a merely semantic point that these two terms are not in common parlance in construction. When discussing the ‘supply chain’ these reports do not extend their consideration beyond clients, principal contractors, subcontractors and product manufacturers. The operations and companies that provide the physical transportation of these goods are not discussed and neither are the operations and companies that specialise in providing logistics management within the construction supply chain. The lack of reference to these two critical aspects of the construction supply chain reflects an undervaluing of their importance in the productivity, efficiency and sustainability of the industry.

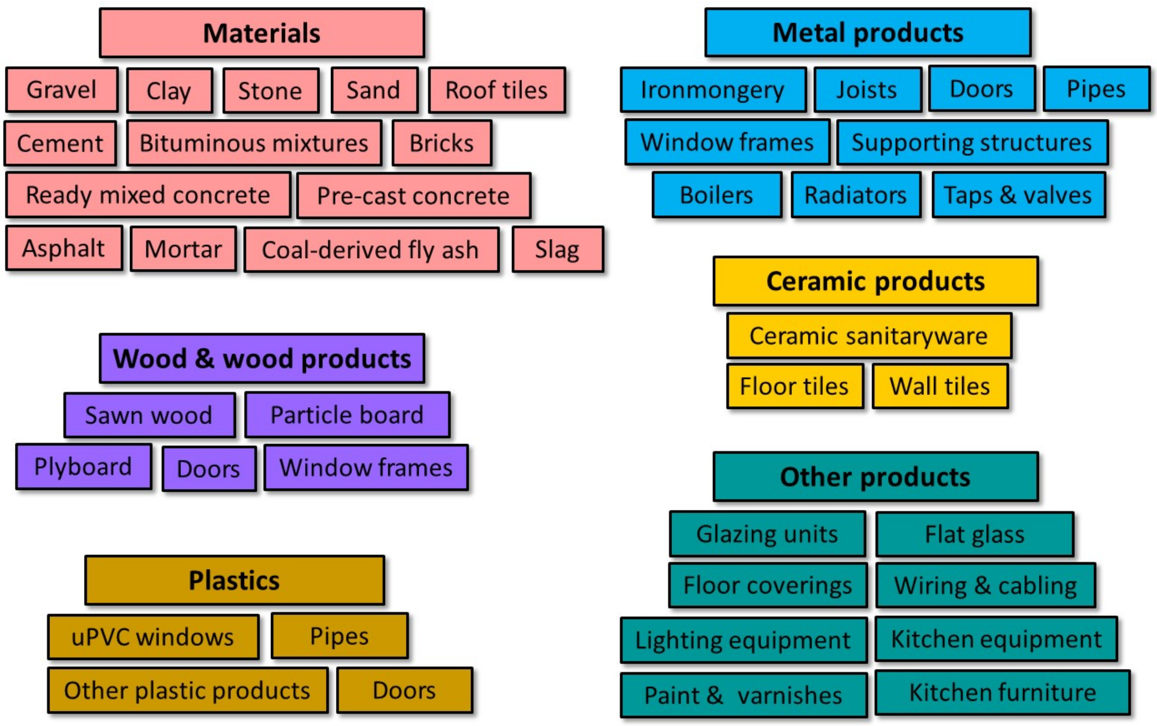
4. Materials and products used in the construction industry

4.1 Introduction

It has been estimated that globally the construction industry uses three billion tonnes of raw materials and consumes 50% of global steel production (United Nations Environment Programme, 2020; World Steel Association, 2020a).

The construction industry uses a wide range of building materials from mines and quarries, together with wood as well as metal, glass and plastic products. **Figure 4.1** provides an overview of the main categories of materials and products used in construction projects. The industry is also a substantial generator of waste materials.

Figure 4.1: Materials and products used in construction



Construction materials and products can be subdivided into categories that reflect to which they are produced. For its data collection purposes, the UK Government uses three categories, namely i) raw materials, ii) semi-manufactures, and iii) products and components. **Table 4.1** shows some of the types of materials and products included in each category.

Table 4.1: Categories of construction materials and products

Category	Materials and products
Raw materials	Sand, gravel, gypsum, building stone, slate
Semi-manufactures	Sawn wood, particle board, laminated wood, fibreboard, steel and aluminium for fabrication, tar and & bituminous mixtures
Products and components	Processed stone, roof tiles, cement, ready-mixed concrete, concrete reinforcing bars, concrete blocks, bricks, pipes and tiles, prefabricated concrete products, steel and aluminium structural units and tubes, insulating materials, building plasters and plasterboard, pipes and products made from copper, lead and zinc, plastic pipes and other products, builders ironmongery, nails and screws, putty, paints and varnishes, ceramic tiles, sanitaryware made from ceramics, plastics and metal, flat glass and galls products, wood veneers and flooring, doors and windows, linoleum floor coverings, wallpaper and wall coverings, fitted kitchens, taps and valves, circulating pumps, central heating boilers, radiators, water and space heaters, fan systems, air conditioning and purifying equipment, hand driers, meters, plugs and sockets, electrical wires, electrical insulators, lamps and fittings, fire and security alarms, lifts and escalators.

Source: BEIS, 2021b.

4.2 Aggregate, bricks, cement and concrete

Various minerals are used in construction including sand and gravel, igneous rock, limestone, sandstone and clays. In 2019, sand produced in the UK had a value of £900 million, while limestone, sandstone, dolomite, chalk, igneous rock, clay and shale had a value of £1.6 billion (Bide et al., 2021). The mineral products and quarrying industry is the largest producer in the UK economy by weight at 400 million tonnes per year. It supplies cement, ready-mixed and precast concrete, lime, asphalt, aggregates, industrial sands and clays and stone to construction and many other industries. These activities take place at 2,400 quarries, mines and production sites in the UK, making a £5.8 billion contribution to the UK economy and supporting 81,000 jobs (Mineral Products Association, 2021). **Table 4.2** shows the gross value added (GVA) of the constituent parts of the mineral products industry in 2018. Unlike the construction industry, the provision of raw materials used in construction in the UK is a highly concentrated industry. An investigation by the Office of Fair Trading found that while there were about 230 non-major independent suppliers which either produce or import material, five major vertically integrated companies accounted for 90% of the cement market, 75% of aggregates sales and 70% of ready-mix concrete production, with complaints from smaller competitors that these majors refused to supply or discriminated against them (Office of Fair Trading, 2011). Due to interventions by the Competition Commission, the share of the UK cement market held by the five major suppliers was 78% in 2018 (Competition Commission, 2014; MPA Cement, 2019).

Table 4.2: Gross value added generated by the mineral products industry in the UK in 2018

Sector	GVA (£ million)	% of total
Rock (igneous rock, limestone & dolomite, sandstone)	680	12%
Sand & gravel, China clay, Ball clay	636	11%
Sub-total: Resource Extraction	***1,316***	***23%***
Cement, lime and plaster	247	4%
Concrete products for construction	1,163	20%
Ready-mixed concrete & mortar	889	15%
Concrete, plaster and cement products	50	1%
Dimension stone	308	5%
Asphalt	257	4%
Sub-total: Product Manufacture	***2,913***	***50%***
Asphalt contracting by Mineral Producers	200	3%
Road freight by Mineral Producers	1,375	24%
Sub-total: Contracting and Road Freight	***1,575***	***27%***
Total GVA	**5,804**	**100%**

Source: ONS, BGS and MPA, quoted in Mineral Products Association, 2021.

The UK Government collects statistics on building materials and components statistics via a statutory survey which are used by the government and private organisations for policy development, market analysis and business planning (BEIS, 2021b). These statistics have been made use of to provide much of the data presented in this section. **Table 4.3** provides details of the construction materials produced in Britain in 2019.

Table 4.3: Construction materials produced/delivered in Britain for construction in 2019

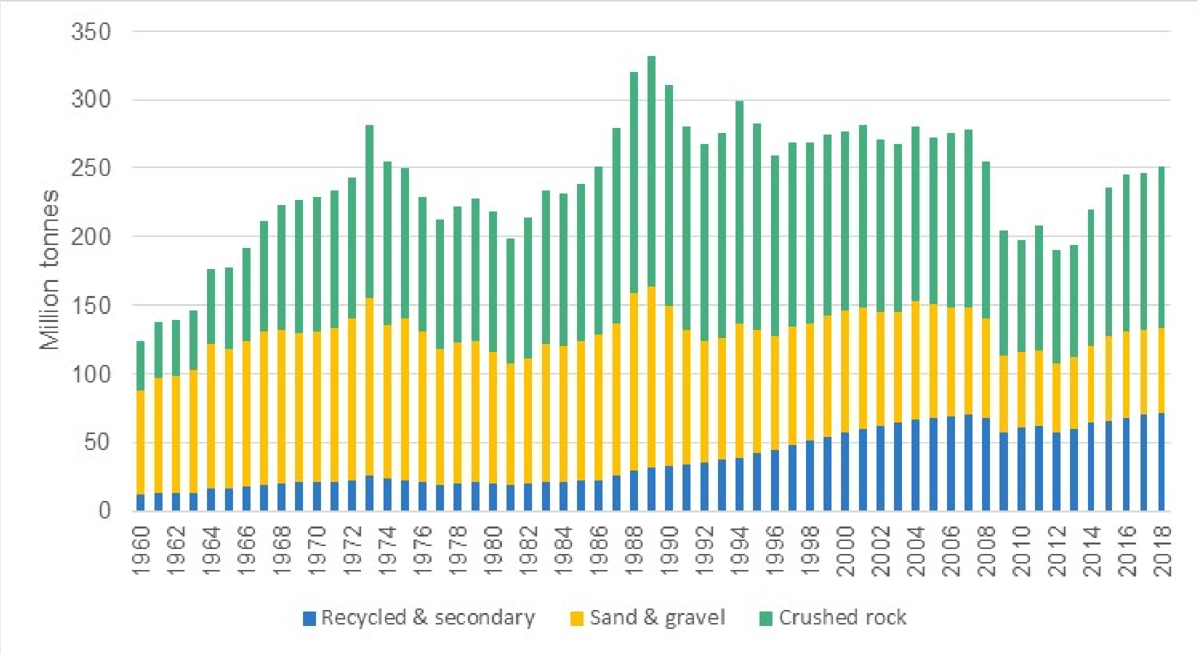
Material or product	Quantity
Land-won sand and gravel	46.8 million tonnes
Marine-dredged sand & gravel	11.8 million tonnes
Clay & shale	4.5 million tonnes
Gypsum	1.6 million tonnes
Cement	9.1 million tonnes
Bricks	2.0 billion bricks
Concrete blocks	70.3 million square metres
Concrete roofing tiles	27.8 million square metres
Ready mix concrete	16.2 million cubic metres

Sources: BEIS, 2021b; Bide, 2021.

A total of 221 million tonnes of non-metallic minerals were extracted in the UK in 2015 (DEFRA, 2018). This is equivalent to 3.4 tonnes per person.

Figure 4.2 shows the total supply of aggregates in Britain since 1960. The most important by weight is crushed rock, followed by sand and gravel. Total supply fluctuates according to economic conditions and hence demand from the construction industry. The importance of recycled and secondary materials has increased over time, which has been incentivised in more recent years by government taxes.

Figure 4.2: Aggregates supply by type in Britain, 1960-2018

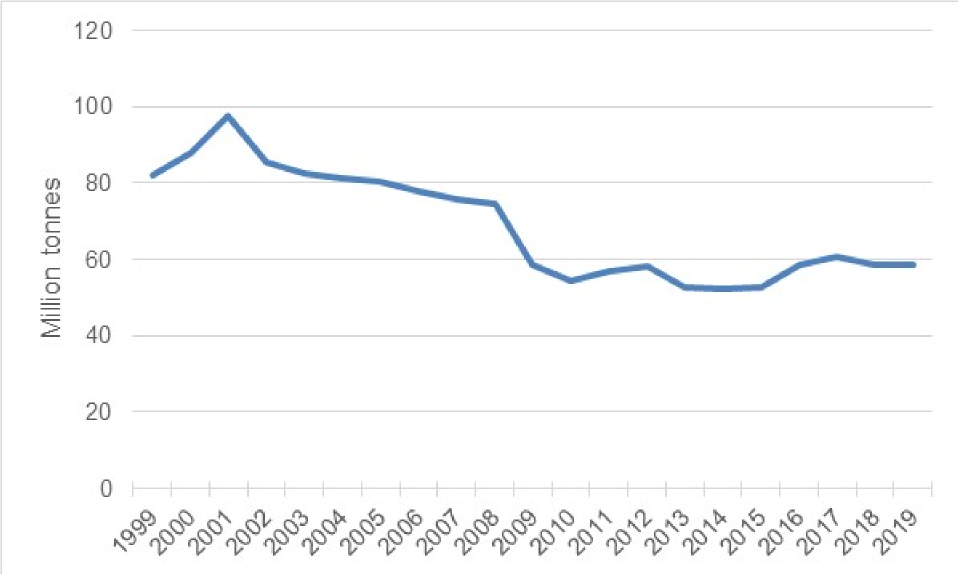


Source: Mineral Products Association, 2021.

Figure 4.3 shows sand and gravel sales in Britain over the last 20 years. The reduction in sand and gravel sales over the 20-year period (from approximately 100 million tonnes in 2001 to 60 million tonnes in 2019) is due to several factors including reductions in road building projects, economic recession and the existence of fiscal charges (the Landfill Tax and the Aggregates Levy[1] – see **section 4.5** for further details) which encourage the reuse of waste material.

[1] The Landfill Tax was introduced in the UK in 1996 to reduce the amount of construction and demolition and other waste going to landfill. The Aggregate Levy was introduced in the UK in 2002 to encourage less use of primary virgin aggregate.

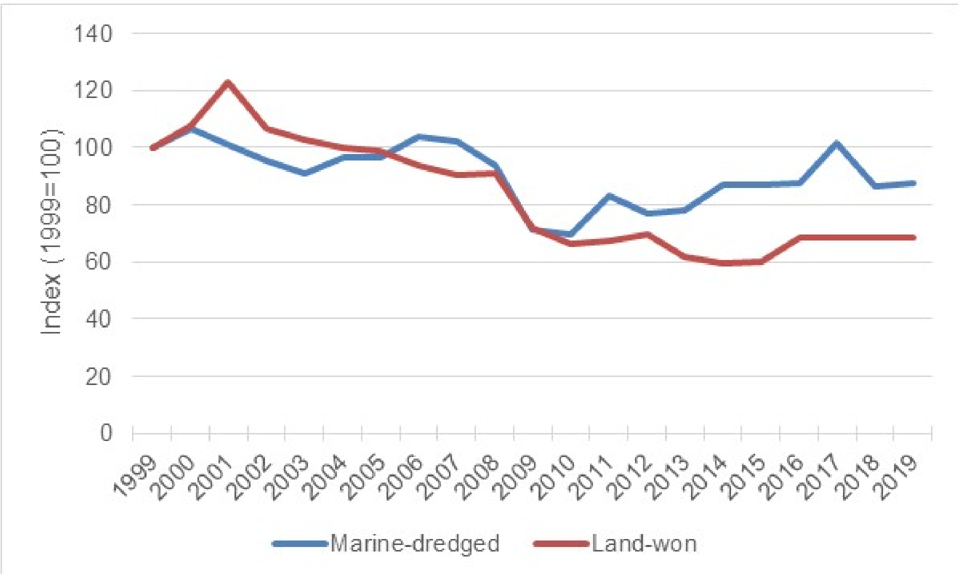
Figure 4.3: Sand and gravel sales annually in Britain, 1999-2019



Source: BEIS, 2021b.

Sand and gravel includes that which is land-won (i.e. from pits and quarries, including that derived from beaches and rivers) and marine-dredged (i.e. that which is derived from seas and estuaries). Although the quantities of both land-won and marine dredged sand and gravel sold fell between 2001 and 2010, marine-dredged material has risen since then, whereas land-won sales have remained static (see **Figure 4.4**). As a result, the proportion of all marine-dredged sand and gravel sold in Britain has increased from 16% in 1999 to 20% in 2019 (BEIS, 2021b).

Figure 4.4: Sales of land-won and marine dredged sand and gravel in Britain, 1999-2019 (index: 1999=100)



Source: calculated from data in BEIS, 2021b.

Table 4.4 shows sand and gravel sales in Britain by region of the country. This reflects the concentration of construction activity in London and the South East, which accounted for 28% of sand and gravel sales in 2019.

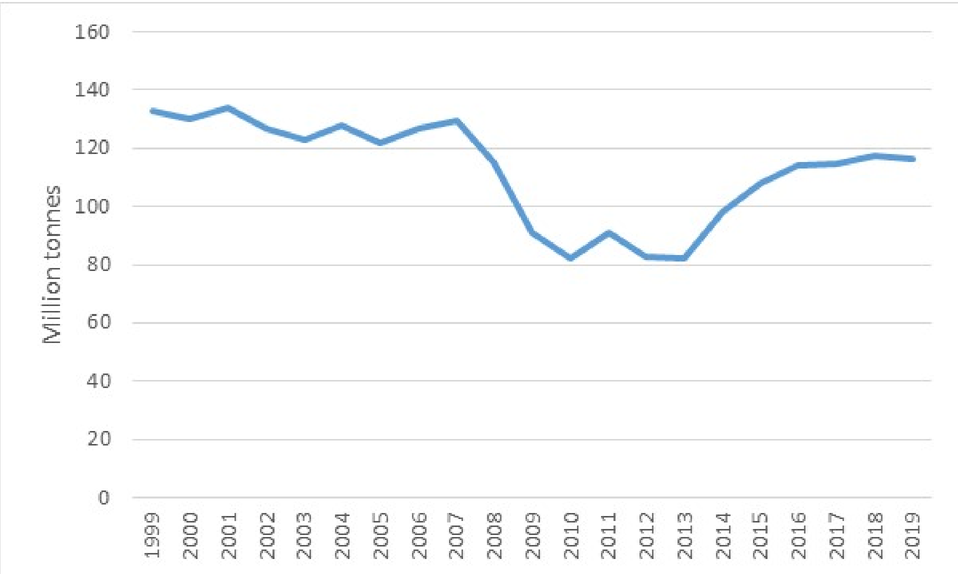
Table 4.4: Sand sales in Britain in 2019 by region of country

Region	Million tonnes	% of total
North East	2.2	4%
Yorkshire & Humber	1.9	3%
North West	2.4	4%
West Midlands	7.4	13%
East Midlands	6.0	10%
East of England	10.6	18%
South East	16.6	28%
South West	4.8	8%
Wales	1.3	2%
Scotland	5.4	9%
TOTAL	**58.5**	**100%**

Source: BEIS, 2021b.

Figure 4.5 shows crushed rock sales in Britain over the last twenty years, falling markedly in the economic recession from 2008, before increasing again since 2014.

Figure 4.5: Crushed rock sales annually in Britain, 1999-2019

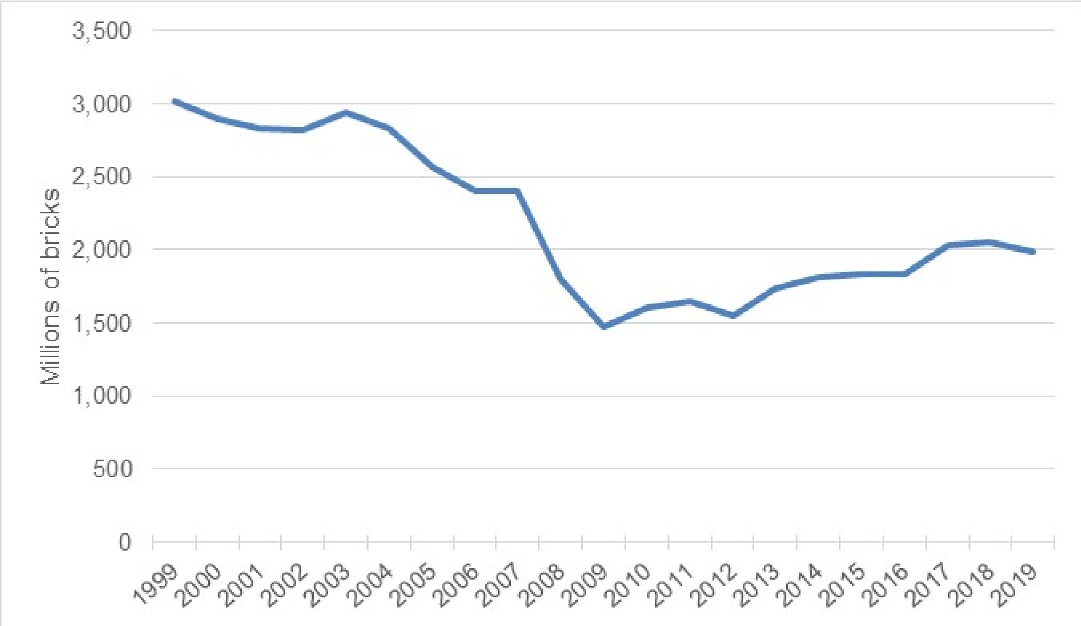


Source: Mineral Products Association, 2021.

It is estimated that 26 to 30 billion tonnes of aggregates were used in construction worldwide in 2012 (United Nations Environment Programme, 2019).

Figure 4.6 shows brick production and delivery in Britain over the last 20 years. The decline in brick use between 1999 and 2019 is a product of a reducing use of bricks in construction (as concrete has become increasingly popular), the effects of the economic recession and fiscal charges that aim to reduce construction waste and the excavation of minerals.

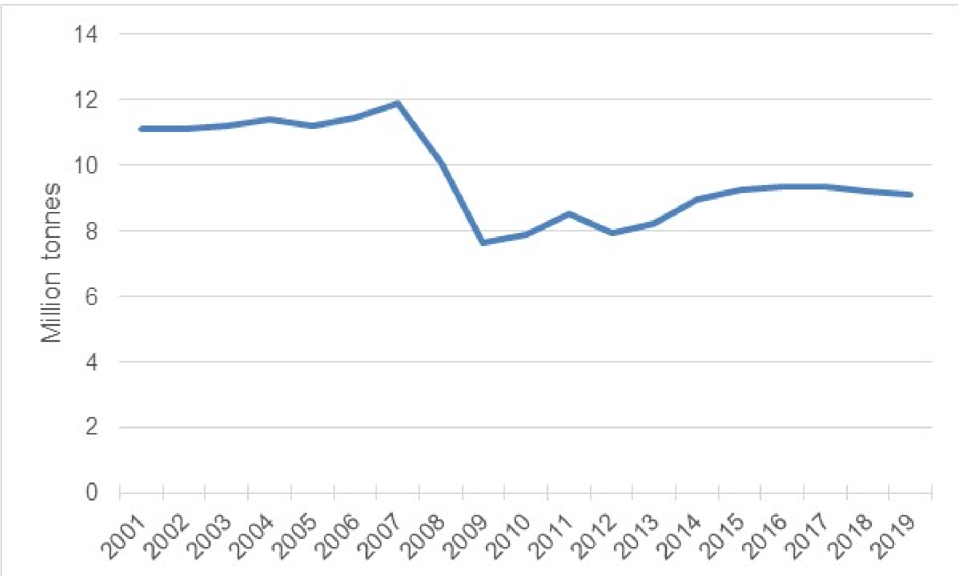
Figure 4.6: Bricks produced and delivered annually in Britain, 1999-2019



Source: BEIS, 2021b.

Figure 4.7 shows the quantity of cement produced and delivered in Britain over the last 20 years. The reduction of British cement production and deliveries from 2008 reflects the onset of the economic recession that took place, the effects of which lasted for several years, with cement production and deliveries still not returning to pre-2008 levels by 2019. It is also partly due to cement imports from outside the country. Cement imports have been rising over the last 20 years. In 2001, imports were 14% of the total cement produced in Britain, this had risen to 28% by 2019 (calculated from data in BEIS, 2021b). This is likely to be at least partially due to the exemption of imported material from the Aggregates Levy.

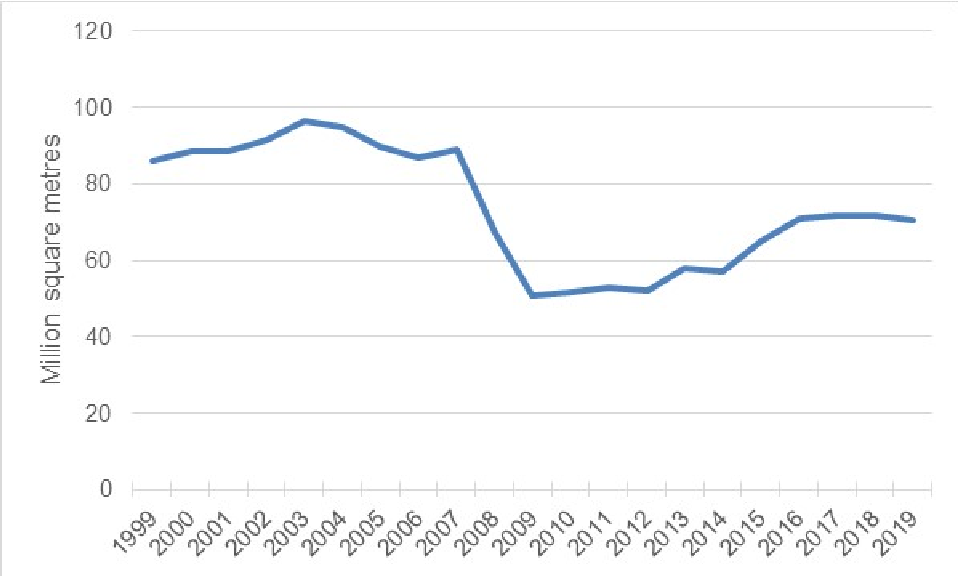
Figure 4.7: Cement produced and delivered annually in Britain, 2001-2019



Source: BEIS, 2021b.

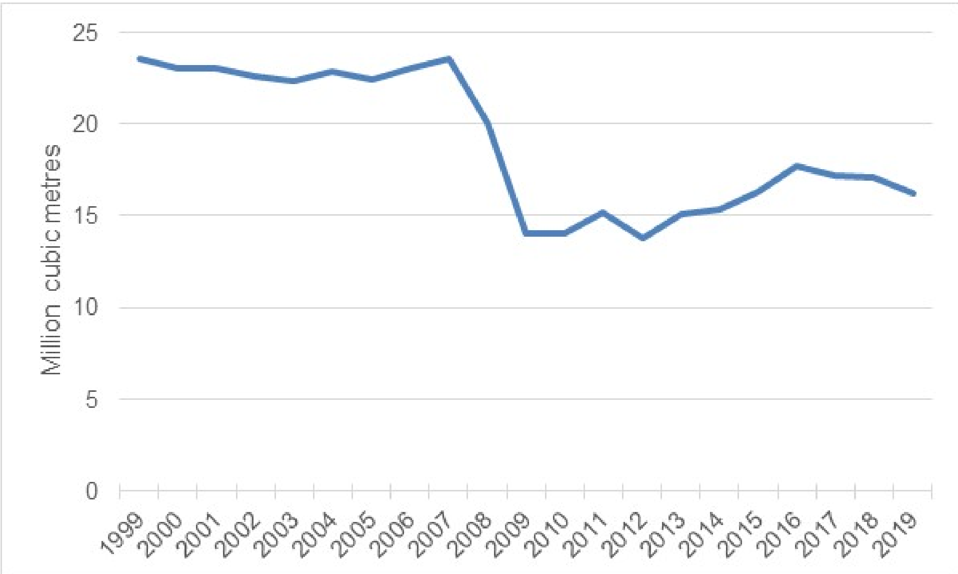
Figures 4.8 and **4.9** show the quantity of concrete blocks and ready-mixed concrete produced and delivered in Britain over the last 20 years. Again, the effects of the 2008 economic recession are evident.

Figure 4.8: Concrete blocks produced and delivered annually in Britain, 1999-2019



Source: BEIS, 2021b.

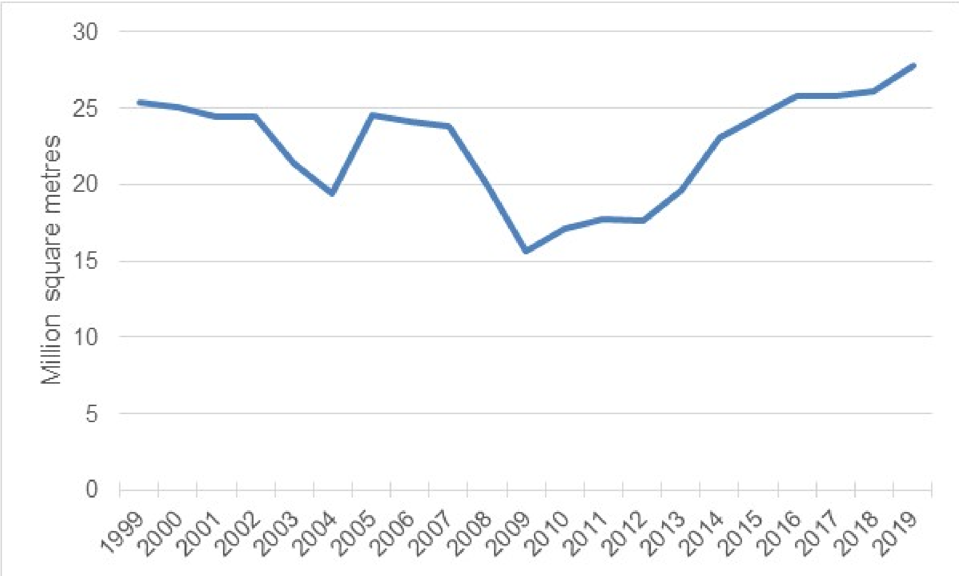
Figure 4.9: Ready mix concrete produced and delivered annually in the UK, 1999-2019



Source: BEIS, 2021b.

Figure 4.10 show the quantity of concrete roofing tiles produced and delivered in Britain over the last 20 years. The data indicates the growing use of concrete roofing tiles in preference to those made from other traditional materials.

Figure 4.10: Concrete roofing tiles produced and delivered annually in Britain, 1999-2019



Source: BEIS, 2021b.

Annual cement production in 2017 in the 150 countries in which it was reported was 4.1 billion tonnes in 2017. Approximately 60% of this was produced in China. The aggregates used in making cement varies by country, with 6-10 tonnes used for each tonne of cement produced (United Nations Environment Programme, 2019).

4.3 Construction products and components

The construction products industry is responsible for the manufacture of many products and components. The construction products industry has been estimated to generate a UK GVA of £61 billion (11% of total UK manufacturing turnover and 36% of total construction output), and to comprise of 24,000 companies and 373,000 jobs (Construction Products Association, 2021a). These products and components range from those that are standard items made to uniform specifications decided on by the producer (i.e. off-the-shelf products), through to those that are made to order for a specific construction project/client. Some are stand-alone products, while others are components that are assembled together with others either on the construction site, or pre-assembled prior to delivery to the construction site.

Table 4.5 provides estimated sales values in 2019 by UK manufacturers of selected construction products and components. It indicated the substantial value of these selected products. This data is taken from the PRODCOM (PRODucts of the European COMmunity) survey carried out by the ONS. Data are collected from a sample of 21,500 businesses, covering 240 industry subsectors and 3,800 products.

Table 4.5: Estimated sales and volumes of selected construction products in the UK, 2019

Construction product	Sales value (£ million)	Sales volume
Steel sheet and structures used in building	5,191	2.6 million tonnes
Metal doors, window frames and thresholds	2,022	3.2 million items
Radiators and boilers	1,277	1,700 tonnes
Prefabricated metal buildings	1,151	n/a
Flat glass and insulating glass	750	117.9 million sq metres
Plastic doors, window frames and thresholds	2,036	10.6 million items
Plastic baths, showers, sanitary ware and tanks	482	106 million items
Plastic shutters, blinds, fittings and mountings	426	0.6 million tonnes
Other plastic builders' wares	400	0.1 million tonnes
Plastic floor coverings	283	38.0 million sq metres
Wooden joinery products	1,470	0.7 million tonnes
Wooden doors, windows and thresholds	966	11.0 million items
Sawn wood	806	3.5 million cubic metres
Veneer sheets, wood-based panels	716	2.8 million cubic metres
Medium density fibreboard	204	40.7 million sq metres
Softwood	120	0.3 million tonnes

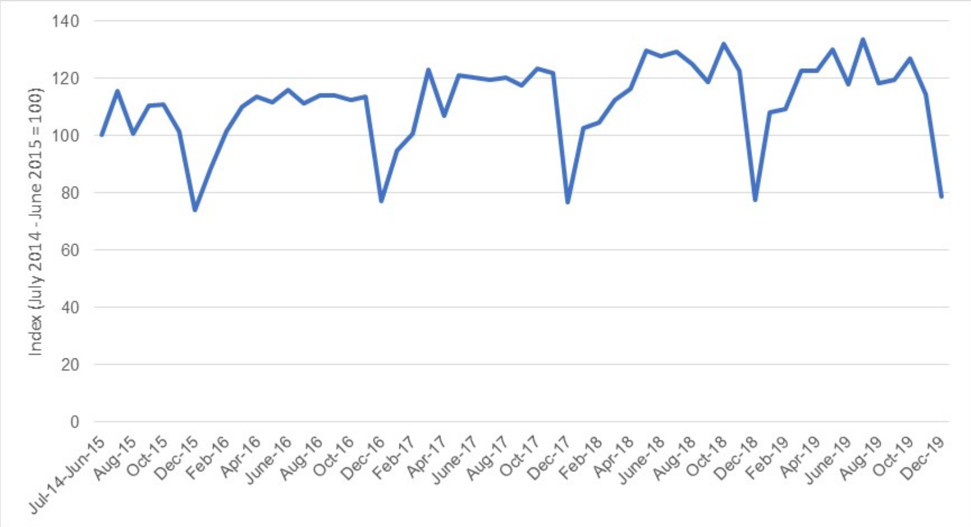
Note: n/a – not available
Source: ONS, 2021f.

Construction contractors either order these products direct from manufacturers, from stockists who specialise in specific types of construction products, or from builders' merchants who acts as wholesalers stocking many different construction materials and products. Some large contractors have sufficient scale and procurement capabilities to purchase key items direct from manufacturers and specialist stockists and may in some cases have their own material producing divisions. Smaller contractors will purchase many products from builders' merchants (intermediaries between the manufacturer and the contractor).

Builders' merchants supply a substantial proportion of all construction products and components used in the UK. The trade association that represents these merchants is the Builders' Merchants Federation, which has 751 member companies, made up of 397 builders' merchants, 249 product manufacturing companies stocked by merchants, and another 105 service companies that support merchants. Between them, these members had a combined turnover of £38 billion in 2019, employed 180,000 people and operated 5,700 branches from which goods were stocked and sold (Builders' Merchants Federation, 2020). In 2019, the top 20 builders' merchants in the UK had combined sales of £14.6 billion (Professional Builders' Merchant, 2020), which is equivalent to approximately one quarter of the estimated value of the construction products and components industry in the UK. Builders' merchants also provide credit to their customers, helping them avoid having to pay for products immediately.

Figure 4.11 provides an index of monthly sales data of all products by builders' merchants in the UK from 2015 to 2019. This index uses data from approximately 80% of generalist builders' merchants in Britain (including builders' merchants, plumbers' merchants, timber merchants and other specialist merchants, who supply products and materials to construction companies, tradespeople and the general public). It therefore provides an insight into spending patterns on construction products. The data includes the combined sales of timber and joinery products, building materials, ironmongery, plumbing, heating and electrical supplies, decorating materials, kitchens and bathrooms, tools and workwear. Total sales via builders' merchants increased between 2015 and 2019. Sales dip each year in December and January, due to the lack of demand from customers for building, repair, maintenance, and improvement work at this time.

Figure 4.11: Builders' Merchants Sales in Britain (exc. VAT), 2015-2019

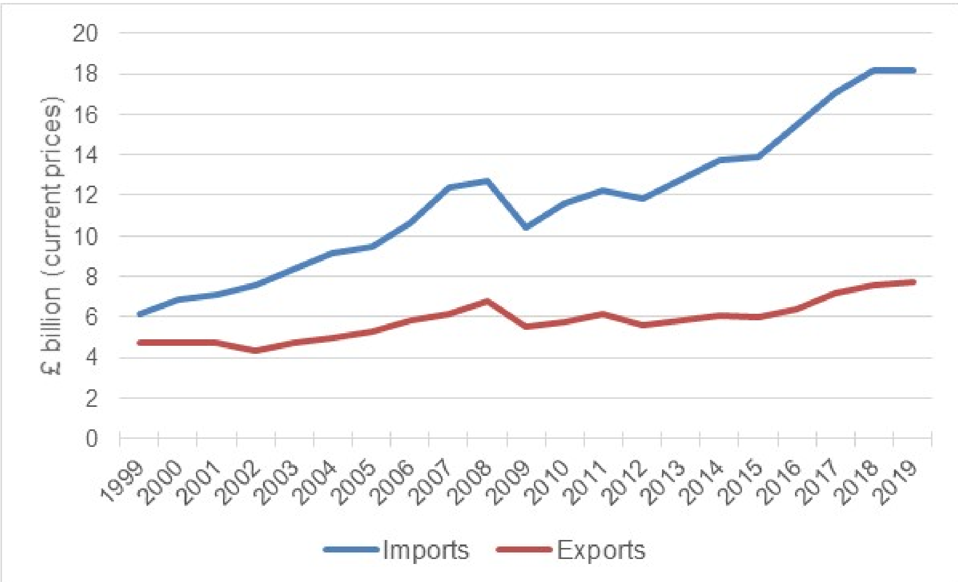


Source: GfK, 2021.

4.4 The import and export of construction materials and products

Although the majority of construction materials and products are manufactured nationally, there is also a sizeable oversea trade in these products. The UK has a sizeable and growing overseas trade in these materials and products, with the total value of imports and exports increased from £10.9 billion in 1999 to £25.9 billion in 2019 (in current prices). The UK also has a growing deficit in the overseas trade of these products, which has increased from £1.5 billion in 1999 to £10.4 billion in 2019 (see **Figure 4.12** – BEIS, 2021b).

Figure 4.12: Value of UK Overseas Trade in Construction Materials, 1999-2019



Source: BEIS, 2021b.

Given the respective weight and value of construction materials and products, and hence transportation costs, only a very small proportion of this overseas trade is in raw materials (only 1% of all UK overseas trade in construction materials and products in 2019). Semi-manufactures, which are also typically large and heavy with relatively low values, comprised 11% of this UK overseas trade in 2019. The vast majority of this UK overseas trade is in finished products and components, which accounted for 87% of this trade in 2019 (see **Table 4.6** – BEIS, 2020c). By weight, approximately 18 million tonnes of non-metallic minerals (i.e. raw materials) were imported to the UK in 2015, which is equivalent to approximately, 8% of the total used in the UK (DEFRA, 2018). However, such imports are only viable for higher-grade, higher-value materials; this is reflected by only 1.4% of the total quantity of aggregates used in the UK in 2010 being imported (Competition Commission, 2014a).

Table 4.6: Value of UK Overseas Trade in Construction Materials by type in 2019 (£ billion and %)

	Imports	**Exports**	**Balance**
All Raw Materials	0.3 (2%)	0.1 (1%)	-0.2 (2%)
All Semi-Manufactures	2.4 (13%)	0.5 (7%)	-1.9 (18%)
All Products & Components	15.5 (85%)	7.1 (92%)	-8.3 (80%)
TOTAL	**18.1 (100%)**	**7.7 (100%)**	**-10.4 (100%)**

Source: BEIS, 2020c.

Trade with the EU accounted for approximately 60% of this overseas trade and deficit in construction materials and products in 2019, while non-EU countries accounted for approximately 40% (see **Table 4.7** – BEIS, 2020a).

Table 4.7: Value of UK Overseas Trade in Construction Materials, EU and non-EU in 2019 (£ billion and %)

Region	**Imports**	**Exports**	**Balance**
EU	10.8 (59%)	4.4 (56%)	-6.4 (62%)
Non-EU	7.4 (41%)	3.4 (44%)	-4.0 (38%)
TOTAL	**18.1 (100%)**	**7.7 (100%)**	**-10.4 (100%)**

Source: BEIS, 2020c.

Table 4.8 shows the top 5 five countries for these imports and exports. China is the greatest in terms of import, followed by Germany and Italy. The greatest export market is the Republic of Ireland.

Table 4.8: Top 5 UK Export and Import Markets for Construction Materials in 2019

Top-5 Exported Markets	**£ million**		**Top-5 Import Markets**	**£ million**
Republic of Ireland	1,219		China	3,190
Germany	763		Germany	2,412
USA	705		Italy	1,003
France	646		Spain	932
Netherlands	571		Netherlands	857

Source: BEIS, 2020d.

Table 4.9 shows the top 20 construction materials and products to and from the UK in 2019 in terms of their import and export value. Electrical wires were by far the greatest import by value, followed by lamps and fitting, and sawn wood. Similarly, electrical wires were the top export (but with far lower value than imports), followed by paints and varnishes, and plugs and sockets.

Table 4.9: Value of UK Overseas Trade in Top 20 Construction Materials by value in 2019

Top-20 Exported Materials	£ million		Top-20 Imported Materials	£ million
Electrical Wires	879		Electrical Wires	1,936
Paints & Varnishes	752		Lamps & Fittings	983
Plugs & Sockets	476		Sawn Wood> 6mm thick	799
Air Conditioning equipment	403		Air Conditioning equipment	666
Lamps & Fittings	385		Central Heating Boilers	622
Linoleum Floor Coverings	317		Plugs & Sockets	602
Air Purifying Equipment	284		Linoleum Floor Coverings	545
Builders Ironmongery	264		Builders Ironmongery	529
Fire & Security Alarms	250		Paints & Varnishes	522
Structural Units (steel)	247		Structural Units (aluminium)	506
Mineral Insulating Materials	211		Aluminium for Fabrication	489
Plastic Pipes	208		Structural Units (steel)	468
Other Plastic Products	184		Taps & Valves	443
Aluminium for Fabrication	182		Steel for Fabrication	414
Steel for Fabrication	180		Unglazed Ceramic Tiles	365
Central Heating Boilers	171		Laminated wood	356
Fan systems	141		Copper Pipes	329
Copper Pipes	103		Fire & Security Alarms	308
Steel Tubes & Hollow Sections	102		Other Plastic Products	293
Wallpaper	85		Building Stone : processed	239
Top 20 total	**5,824**		**Top 20 total**	**11,414**
Top 20 as % of all construction exports	**75%**		**Top 20 as % of all construction imports**	**63%**

Source: BEIS, 2021b.

4.5 Construction waste

The various materials used in the construction industry are reflected in the waste that it generates which include excavated soil, concrete, bricks, glass, wood, metals, gypsum, plastic, solvents, as well as hazardous substances such as asbestos. In the EU-27 it was estimated that construction and demolition accounted for 36% of all waste arising by tonnage in 2018, followed by mining and quarrying waste (26%), so together these two types of construction related waste accounted for 62% of total waste (Eurostat, 2020).

It has been estimated that in the UK, 137.8 million tonnes of construction and demolition waste was generated in 2018 (including 11.3 million tonnes of spoils from off-shore dredging). This represented 62% of all waste generated in the UK (DEFRA, 2021a). About 47% of this was from mineral waste, 42% was excavated soil, 8% was dredging spoils, about 2% were metallic wastes, and the remainder comprised glass, packaging, household and hazardous wastes.

In addition, there were 14.8 million tonnes of mining and quarrying waste in the UK in 2018, which represented 7% of all waste generated in the UK (DEFRA, 2021a). Both construction and demolition waste and mining and quarrying waste are associated with the construction industry. If these waste streams are added together, they represented 152.6 million tonnes, 69% of all waste generated in the UK in 2018. Eighty three percent of this waste arose from construction activities, 10% from mining and quarrying excavations, and 7% from off-shore dredging (calculated from data in DEFRA, 2021a). **Table 4.10** shows the main types of this construction-related waste in 2018 and whether it arose from constructions sites, quarrying or off-shore dredging. Only 0.2% of all construction-related waste arising is not accounted for by those types shown in **Table 4.10**.

Table 4.10: Main types and sources of construction-related waste in the UK in 2018

Type of waste and source	Tonnes	% of all construction-related waste
Mineral waste from construction	65,135,530	42.8%
Soils from construction	58,105,809	38.1%
Mineral waste from quarrying	14,643,393	9.6%
Off-shore dredging spoils	11,318,836	7.4%
Metallic waste from construction	2,174,139	1.4%
Wood waste from construction	641,501	0.4%
Glass waste from construction	104,198	0.1%
Plastic waste from construction	98,284	0.1%
Household & food waste from construction	89,507	0.1%
Paper & cardboard waste from construction	20,762	0.0%
TOTAL OF THE ABOVE	**152,331,959**	**99.8%**

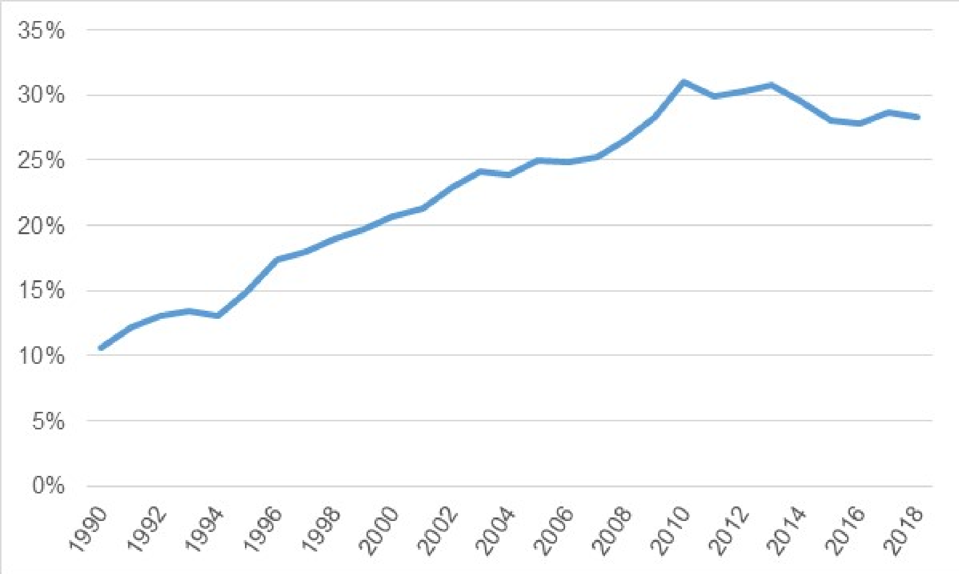
Source: calculated from data in DEFRA, 2021a.

The so-called Landfill Tax was introduced in the in the UK in 1996 to reduce the amount of construction and demolition and other waste going to landfill by incentivising its diversion to other less harmful methods of waste management including recycling and incineration. The Landfill Tax is paid by landfill operators on the disposal of material at a landfill site. These operators pass the tax onto businesses and local authorities by charging a fee for disposing of waste at a landfill. The tax is charged by weight, with the lower rate (which includes construction waste) currently set at £96.70 per tonne for standard waste including soil and rock excavated on the construction site) and £3.10 per tonne for inert and inactive waste that contains no biodegradable material (typically including materials such as rocks, concrete, ceramics from demolition). Landfill Tax receipts in 2019/20 were £641 million (HM Revenue and Customs, 2020).

Landfill Tax exemptions exist for dredging, mining and quarrying waste, and material from the reclamation of contaminated land, and filling of quarries. As a result of this exemption for quarrying waste, the so-called Aggregate Levy was introduced by the UK Government in 2002. It is an environmental tax on primary virgin aggregates (rock, sand and gravel used as bulk fill in construction). Its introduction was intended to encourage a shift in demand to alternative materials including recycled and secondary material. Construction and demolition waste is recycled material and arises both on construction sites and in recycling depots. It can be processed and blended with other aggregates for use in products such as concrete. Road planings are often used for creating paths and is recycled for use in road construction. Aggregates that are returned, unmixed, to the land at the construction site from which they were originally removed are exempt from the Levy, as is spoil, waste and other by-products of industrial combustion processes, and from the smelting or refining of metal (and which are known as secondary aggregates). Blast furnace ash from the steel industry and pulverised fly ash from electricity generating plants are used in cement formulations or directly in concrete manufacture for their cementitious properties. The Aggregate Levy has been charged at £2 per tonne since 2009 and has bought in annual revenue of approximately £250 million to £400 million since its inception (HM Treasury, 2020). In 2018, the revenue generated by the Aggregate Levy was equivalent to 31% of the gross value added by the aggregates sector (Mineral Products Association, 2021).

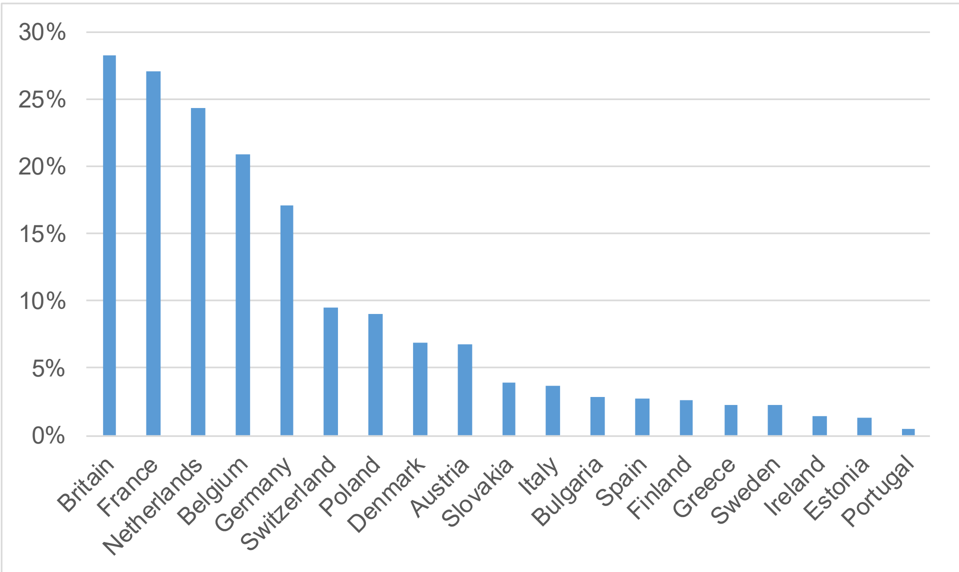
As a result of these taxes, recycled and secondary aggregates comprised 29% of total aggregate supply in the UK in 2017 (26% from recycled aggregate and 3% from secondary aggregates – see **Figure 4.13**), which is higher than any other country in Europe (Mineral Products Association, 2012 – see **Figure 4.14**).

Figure 4.13: Recycled and secondary materials in total aggregates sales in Britain, 1990-2019



Source: Mineral Products Association, 2021.

Figure 4.14: Recycled and secondary materials in total aggregates sales in European countries, 2018

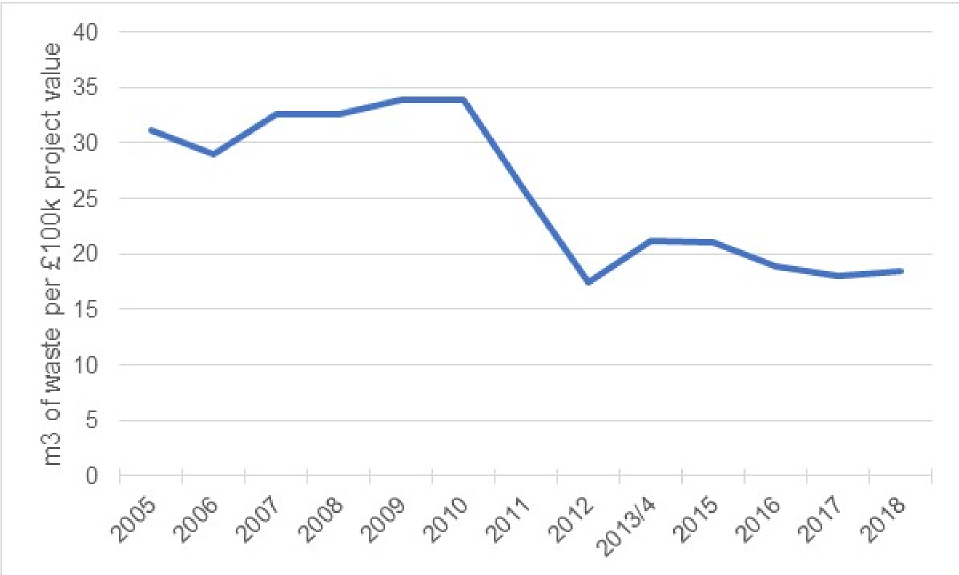


Source: Mineral Products Association, 2021.

These taxes contributed to 92% of non-hazardous construction and demolition waste being recovered in the UK in 2018, which far exceeds the UK Government's target of 70% recovery (DEFRA, 2021b). Much of this recovered material is concrete, brick and asphalt which is recycled for use as aggregate. However, the remaining 8% (approximately 5 million tonnes) of non-hazardous construction and demolition waste was sent to landfill sites in 2016 (Green Construction Board, 2020).

Data collected by the UK government and industry bodies from UK construction projects provides a key performance indicator (KPI) related to waste levels removed from construction sites. This KPI indicates that in 2018, on average, 18.4 cubic metres of waste were removed from construction sites per £100,000 of project value over the entire project (at 2016 constant prices). This represented a reduction of 41% compared with 2005 (see **Figure 4.15** – Glenigan, 2019).

Figure 4.15: Waste removed from construction sites per £100,000 project value (at 2016 constant prices)



Source: Glenigan, 2019.

The types and quantities of construction waste depend on the construction techniques used and the management of the construction project. Some construction waste is useful and therefore readily reused and recycled (such as concrete, masonry, bricks, tiles, pipes, asphalt and soli), some is not able to be directly recycled but can be recycled elsewhere (such as timber, glass, paper, plastic, oils and metal), and some is not recycled and/or may present disposal issues due to its hazardous nature (such as paint, solvents, plaster and asbestos).

However, rather than construction waste arising and then having to be dealt with, it would be preferable if such waste did not arise in the first place. The industry is working with the UK Government to better understand what current waste arising in construction is avoidable to develop a route map of how 'zero avoidable waste' (i.e. materials, products or components that can be prevented from becoming waste) might be achieved (Green Construction Board, 2020). Research has indicated that much waste arises due to design and construction phases problems. These include insufficient information being provided on drawings and in plans, design changes during the construction phase of projects, errors and damage by contractors, and inappropriate materials handling and storage facilities at the construction site (Osmani et al., 2005).

Possible methods for achieving zero avoidable construction waste include designing new buildings for better resource efficiency and for deconstruction and disassembly, efficient manufacturing processes, extending the life of buildings, and disassembly for reuse and reducing surplus materials, all of which design out waste. If waste cannot be prevented, then the next best is to aim for (in order of preference): preparing for reuse (e.g. repair or remanufacture), closed-loop recycling (where waste is used as a feedstock in the same process) and open-loop recycling (where waste is used as a feedstock for a different purpose) (Green Construction Board, 2020).

5. Freight transport and logistics in the construction supply chain

This chapter discusses the freight transport and logistics management of materials and products in the construction industry.

Where these materials and products arise depends on the location of quarries, processing facilities, factories, and sea ports in the case of imported goods. The point of extraction from the ground varies by mineral type, depending on the geology of the country and the provision of planning permission to allow workings (quarries and mines) to exist.

Planning permission for mineral workings are governed by mineral planning authorities which are either the county council, the unitary authority, or the national park authority. In deciding whether to grant permission for a mineral working, the planning authority will take into account various environmental impacts including noise, dust, air quality, lighting, visual impact, landscape character, traffic, risk of contamination to land, soil resources, geological structure, blast vibration, flood risk, land stability/subsidence, wildlife, and water abstraction (Ministry of Housing, Communities & Local Government, 2014).

Many materials used in construction such as sand, gravel, cement, concrete, bricks and metal products have relatively high bulk densities (i.e. high mass per unit of volume – measured in kg per cubic metre). Many of these products are transported in bulk without the need for packaging, with product shapes that mean that there is little, if any, space between the load carried. Therefore the freight density (also called cargo density) of these products varies little from their bulk density. Products with very high bulk densities typically have low freight transport costs per shipment given the quantity that can be carried on each vehicle and the handling requirements that can be involved. Meanwhile, some construction products such as plastic pipes, have far lower cargo densities, due to the bulk density of plastic being lower that bulk construction materials such as gravel and stone, and the shape and packaging requirements of pipes meaning that there is much space both within and between the pipes transported.

Some of these construction materials also have relatively low value densities (i.e. low values per unit of weight, area or volume). If a product has both a high bulk density and a low value density (such as sand and gravel) then freight transport costs will account for a substantial proportion of the total product cost and price. As well as transport costs being substantial, so will material handling costs in many cases, with specialist equipment and vehicles equipped with tipping mechanisms, grabs and hoists required to load and unload the product. Specialist equipment such as cranes and other plant can be required to move materials and products around the construction site, together with the use of substantial labour time. For such materials efforts will be made to control costs/prices by transporting the product over as little distance as possible to provide it to the construction site. Those suppliers with local sources will be able sell their products at more competitive prices than those sourcing goods over longer distances. However, locations where materials exist and products are manufactured are not always close to centres of demand. Therefore, substantial transport distances of even the lowest value construction materials can be necessary.

Table 5.1 shows the bulk density and values density of materials and products used in construction.

Table 5.1: Bulk density and values density of selected materials and products used in construction

Material or product	Bulk density (kg/cubic metre)	Product value in 2019 (from manufacturers' sales data)
Sand	1500-2000	Construction sand: £13 per tonne
Gravel	2400	Construction gravel: £13 per tonne
Stone chips and ballast	1600-2000	Stone chips and ballast for construction: £12 per tonne
Asphalt	2200	Bituminous material: £60 per tonne Coated roadstone: £68 per tonne
Granite	2400-2500	Crude/rough cut: £5 per tonne
Limestone	2400	Bulk: £7 per tonne Crushed: £13 per tonne
Chalk	1200-2500	£12 per tonne
Building stone	2700-3000	£1060 per tonne
Cement	1280-1440	Portland cement: £86 per tonne
Mortar	1750-2100	£107 per tonne
Concrete components, blocks and tiles	2000-2500	Concrete construction blocks: £37 per tonne Concrete roofing tiles: £94 per tonne Prefabricated concrete components: £158 per tonne
Ready mix concrete	1300	£67 per tonne
Clay shale	1900	Construction clay and shale: £5 per tonne
Bricks	1500-2000	Clay building bricks: £330 per cubic metre
Timber	600-1100	Sawn wood: £230 per cubic metre Veneers and panels: £260 per cubic metre MDF: £5 per square metre
Steel	7500-8000	Cold formed steel: £1100 per tonne
Aluminium	2750	Unwrought aluminium: £1500 per tonne
Glass	2500-2600	Flat glass: £1.50 per square metre Insulating glass: £32 per square metre
Plastic	1000-2000*	Plastic fittings and other builders' wares: £2.95 per kg
Soil	1400-2000	Not applicable
Water	1000	Not applicable

Note: * - despite the bulk density of plastic, the freight density of plastic products such as pipes is far lower given their shapes with hollow interiors and the effect their shape and packaging requirements have on their transport they require.
Source: product value data from ONS, 2021g; bulk density data from Civil Lead, 2021; Bureau of Indian Standards, 1987.

5.1 Transport of aggregate: sand, gravel and rock

It has been estimated that constructing a typical residential home requires 200 tonnes of aggregate, while a mile of road building requires 45,000 tonnes. In addition, aggregate comprises two-thirds of the ingredients of cement (the other third of which is water) (Di Lorenzo and Racionero Gomez, 2019).

Crushed rock aggregate is produced from hard, strong rock formations including igneous (andesite, basalt, diorite, gabbro, granite, rhyolite, tuff), metamorphic (hornfels, gneiss, quartzite, schist) and sedimentary (sandstone, limestone) rock. The strength of igneous rock makes it suitable for road building and as railway ballast. Most limestone is also sufficiently strong for general aggregate use, whereas some sandstone is less strong and therefore used for building British Geological Survey, 2019). Aggregates are also used in cement, mortar and concrete production. In the UK sand comprises approximately 25% and crushed rock approximately 45% of cement by volume (United Nations Environment Programme, 2019).

Given the relatively low value of aggregates, ideally they are extracted and processed close to where they are required. However, geology and planning permissions for quarries, pits and dredging does not always make this possible. Sand, gravel and rock quarries exist widely across the country. In 2019, there were 583 sand and gravel workings in the UK, 118 sand-only workings, 224 igneous and metamorphic rock workings, 304 limestone /dolomite workings, and 260 sandstone workings (Bide et al., 2020).

Overall, there are approximately 1400 aggregates quarries in the UK, about 45% of which are sand and gravel workings and 55% of which are crushed rock workings. The annual outputs of these quarries vary widely, with sand and gravel quarries producing between 10,000 tonnes and one million tonnes per annum (with the majority producing 100,000 to 300 000 tonnes per annum). For crushed rock quarries in the UK, their annual output can range from 100,000 tonnes to five million tonnes (British Geological Survey, 2019).

These quarries are operated by companies of very differing sizes. In 2018, five companies accounted for approximately 70% of total UK output, namely Aggregate Industries (owned by Lafarge Holcim), Breedon, CEMEX, Hanson (owned by the Heidelberg Cement Group), and Tarmac (owned by CRH) (British Geological Survey, 2019). At the other end of the industry are many companies that own a single, small quarry, often family-owned. Approximately 75% of UK aggregates are supplied to fixed sites (which use it as a raw material in another production process such as making concrete or pre-cast concrete building products), and 25% are supplied to the general market (which range from single deliveries for small works at a residential home to many thousands of tonnes for a large construction project (Woodcock, 2015).

Crushed rock aggregate production and supply includes several activities at the quarry that can include blasting, drilling, transfer and conveying (either by mechanical conveying system or by on-site dump truck), several stages of crushing (to remove soft particles and produce the required particle size) and screening to sort particles by size, washing (if required), and storage.

Sand and gravel from land-based open pits do not require blasting and drilling. First, the overburden (typically soil, peat and clay) has to be removed before sand and gravel can be excavated. Marine aggregate, which is dredged or pumped from sea beds and rivers and brought to shore, often requires the pumping of water prior to excavation. Initial screening can take place on the dredging vessel with the main processing taking place after it is discharged from the dredger at the wharf.

Sand and gravel that is to be used for cement, concrete and asphalt production requires washing and scrubbing to remove clay. Then the sand and gravel are separated, the gravel is graded into different sizes and larger pieces of gravel are crushed to produce smaller particles. Sand is screened and classified into different grain sizes and water is removed. These materials are then transported either direct to construction sites (in the case of large projects), or to intermediate wholesalers and retailers (i.e. builders' merchants for the trade and DIY stores for private individuals).

Table 5.2 shows the production and consumption of aggregates by region, together with sales as a proportion of consumption and net exports/imports by region in England Wales in 2014.

The greatest regions of imbalance in terms net imports relative to consumption were the East of England, North West, the South East and London. While the areas of greatest exports relative to sales were North Wales, the East Midlands and the South West.

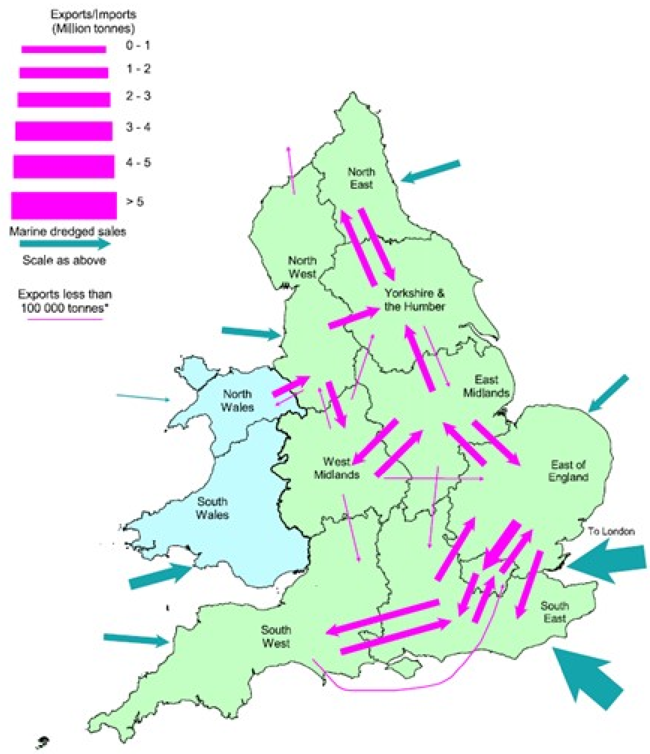
Table 5.2: Tonnages of all primary aggregates (sand, gravel and crushed rock) sold and consumed and imports/exports by region in 2014

Region	Total sales (million tonnes)	Total consumption (million tonnes)	Total sales as % of consumption	Net imports as % of consumption	Net exports of % of sales
South West	25.4	19.0	134%	n/a	25%
South East	14.3	19.2	74%	26%	n/a
East of England	5.1	9.6	53%	47%	n/a
London	12.6	16.1	78%	22%	n/a
East Midlands	30.4	17.8	171%	n/a	42%
West Midlands	9.7	12.0	80%	20%	n/a
North West	8.4	15.4	55%	45%	n/a
Yorkshire & the Humber	11.5	12.3	94%	6%	n/a
North East	5.6	6.1	91%	9%	n/a
England	***122.9***	***127.5***	***96%***	***4%***	***n/a***
South Wales	9.0	7.2	126%	n/a	21%
North Wales	5.1	2.8	182%	n/a	44%
Wales	***14.1***	***9.9***	***142%***	***n/a***	***29%***
England and Wales	**137.0**	**137.4**	**100%**	**n/a**	**n/a**

Note: n/a – not applicable.
Source: Mankelow et al., 2016.

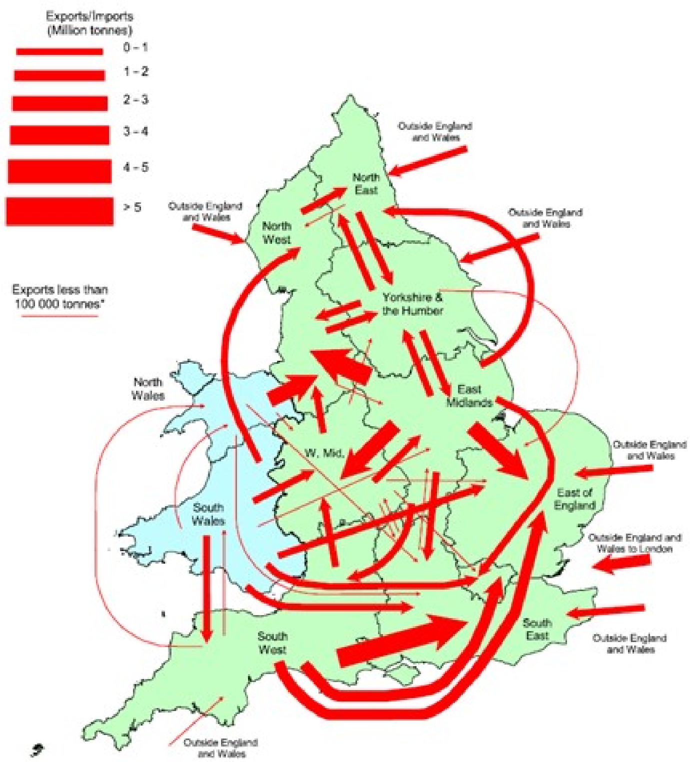
Figure 5.1 shows the inter-regional flows of sand and gravel required in 2014, and **Figure 5.2** shows these flows for crushed rock.

Figure 5.1: Sand and gravel inter-regional flows in England and Wales, 2014



Note: Exports less than 25,000 tonnes are not shown.
Source: Mankelow et al., 2016.

Figure 5.2: Crushed rock inter-regional flows in England and Wales, 2014



Note: Exports less than 25,000 tonnes are not shown.
Source: Mankelow et al., 2016.

While locally supplied aggregate will be transported by road, longer distance movement may make use of rail or water given the lower costs of these modes for products such as these given their high bulk densities. **Table 5.3** shows the principal transport mode used for aggregates in England and Wales in 2014. Road was used as the principal transport mode for 90% of all aggregates lifted in England and Wales in 2014 (Mankelow et al., 2016). This data understates the importance of water transport for dredged material as this was not typically the principal mode of transport in their onward supply.

Table 5.3: Tonnages of primary aggregates sold by principal transport method in England and Wales in 2014 (million tonnes)

	Road	Rail	Water	TOTAL
Sand & gravel	52.9 (97.0%)	1.3 (2.5%)	0.3 (0.5%)	54.5 (100%)
Crushed rock	73.5 (85.6%)	12.2 (14.2%)	0.2 (0.2%)	85.8 (100%)
All aggregates	126.3 (90.0%)	13.5 (9.6%)	0.5 (0.3%)	140.4 (100%)

Source: Mankelow et al., 2016.

Tables 5.4, **5.5** and **5.6** show the principal transport mode used for sand and gravel, crushed rock, and all aggregates (i.e. both combined) lifted in England and Wales in 2014. Variations reflect the availability of transport modes in relation to the various locations and mode choice by shipper. While this data provides helpful insight into the use of road and rail as principal mode, as mentioned above, it understates the importance of water transport for dredged material as this was not typically the principal mode of transport in their onward supply.

Table 5.4: Tonnages of sand and gravel sold by principal transport method and region in 2014 (percentage)

Region	Road	Rail	Water	TOTAL
South West	98%	2%	0%	100%
South East	93%	4%	2%	100%
London	90%	10%	0%	100%
East of England	98%	2%	0%	100%
East Midlands	100%	0%	0%	100%
West Midlands	100%	0%	0%	100%
North West	100%	0%	0%	100%
Yorkshire & the Humber	100%	0%	0%	100%
North East	100%	0%	0%	100%
England	***97%***	***3%***	***1%***	***100%***
South Wales	100%	0%	0%	100%
North Wales	100%	0%	0%	100%
Wales	***100%***	***0%***	***0%***	***100%***
England and Wales	**97%**	**2%**	**1%**	**100%**

Source: calculated from data in Mankelow et al., 2016.

Table 5.5: Tonnages of crushed rock sold by principal transport method and region in 2014 (percentage)

Region	Road	Rail	Water	TOTAL
South West	74%	26%	1%	100%
South East	89%	10%	1%	100%
London	100%	0%	0%	100%
East of England	100%	0%	0%	100%

East Midlands	78%	22%	0%	100%
West Midlands	100%	0%	0%	100%
North West	n/a	n/a	n/a	n/a
Yorkshire & the Humber	n/a	n/a	n/a	n/a
North East	99%	0%	1%	100%
England	***84%***	***16%***	***0%***	***100%***
South Wales	96%	4%	0%	100%
North Wales	100%	0%	0%	100%
Wales	***98%***	***2%***	***0%***	***100%***
England and Wales	**86%**	**14%**	**0%**	**100%**

Note: n/a – not available.
Source: calculated from data in Mankelow et al., 2016.

Table 5.6: Tonnages of all primary aggregates sold by principal transport method and region in 2014 (percentage)

Region	Road	Rail	Water	TOTAL
South West	77%	22%	0%	100%
South East	92%	6%	2%	100%
London	91%	9%	0%	100%
East of England	98%	2%	0%	100%
East Midlands	83%	17%	0%	100%
West Midlands	100%	0%	0%	100%
North West	n/a	n/a	n/a	n/a
Yorkshire & the Humber	n/a	n/a	n/a	n/a
North East	99%	0%	1%	100%
England	***89%***	***10%***	***0%***	***100%***
South Wales	97%	3%	0%	100%
North Wales	100%	0%	0%	100%
Wales	***98%***	***2%***	***0%***	***100%***
England and Wales	**90%**	**10%**	**0%**	**100%**

Note: n/a – not available.
Source: calculated from data in Mankelow et al., 2016.

Aggregates can be transported either loose in bulk, or in bagged form. Bulk aggregates can be moved by road, rail or water, while bagged material is typically moved by road. It has been calculated that in Britain in 2017 approximately 11% of aggregates were lifted by rail and 6% by water for part of their journey (final deliveries for these loads from rail terminals and are still made by road other than in the case of a very small number of major rail-connected construction sites) (British Geological Society, 2019).

Aggregates sold to customers by the major producers are both delivered by and collected from the producer depots, with the former being the more common. More specialist, higher-value aggregates are more likely to be collected by the customer than standard aggregates.

The major producers tend to make use of third-party hauliers to carry out the final delivery leg to customers, as well as in some cases having an in-house fleet. This arrangement reflects the sub-contracting that is prevalent in the construction industry. Many of these third-party hauliers come from small companies or are owner drivers (Browne et al., 2002). Some third-party operators work exclusively for the producers, and are referred to as franchised, even using vehicles that display the producer's livery (WSP, 2018a).

Producers of aggregates have reported that markets for their product were typically local, extending to about 30 miles or more around quarries (Competition Commission, 2014a). Analysis has shown considerable variation in catchment areas across major producers and product types, as several factors influence the distances over which aggregates are delivered to customers. Analysis of the major producers has shown that 80% of sales volumes of primary aggregates were transported up to around 19 miles (straight-line distance) in urban areas and up to around 28 miles in non-urban areas on average on the final leg of delivery. Catchment areas for higher-grade, higher value aggregate products tended to be significantly larger than for lower-grade products (on average, 36 miles for urban sites and 68 miles for non-urban sites). Also, catchment areas for internal sales (i.e. within divisions of large, vertically integrated producers) were larger than for these companies' external sales (Competition Commission, 2014b).

Data from the Mineral Products Association indicates that, on average, the one-way road transport distance for the final leg of delivery for aggregates is 23 miles, and for asphalt is 29 miles (Mineral Products Association, 2020a). The sales catchment areas for rail- and sea-linked quarries are far larger than those of quarries that are only road-connected, with the lower transport costs of these modes permitting the materials to be moved further.

Only the larger quarries operated by the five major aggregates suppliers tend to be rail-connected. In 2013, each of the four major producers had at least two rail-connected quarries and in one case had five. Collectively, together with their rail-linked wharves, these quarries accounted for around a quarter of the total production of primary (i.e. non-recycled) aggregates in the country in 2011. In addition, the largest rail-connected quarry of the five major producers, collectively accounted for 14% of the country's total aggregates production in 2011 (Competition Commission, 2014b).

Rail distances from quarries to depots for these major producers are greater than 100 miles in some cases, far greater than the catchment area for non-rail connected quarries. Submissions provided by the major producers indicate that their rail costs per tonne-mile were comparable with road over relatively short distances, and lower than road over longer distances (Competition Commission, 2014b).

Rail is primarily used for the transport of crushed rock aggregates, and higher-grade material including rail ballast and high polished stone value (PSV) crushed rock that is used in constructing skid resistant roads, to regions with a lack of indigenous supply, including London and the South East. These rail transport movements take place within the vertically integrated supply chains of the major producers (i.e. from their quarries and wharves to their own depots) from where for onward distribution takes place either to external customers or are used in the producers' own downstream businesses for use (such as asphalt and cement plants). Research indicates that for some of the major producers approximately 70-80% of these crushed rock products transport by rail into London are consumed by them internally in their own businesses (Competition Commission, 2014b).

Sand and gravel that is marine-dredged can be taken by sea to wharves in locations with substantial demand. A small quantity of crushed rock is also transported by sea from a few quarries located near the coast, mostly to London and the South East, such as the coastal quarry at Glensanda in western Scotland (British Geographical Survey, 2019).

By weight, approximately 2.3 million tonnes of aggregates were imported to the UK in 2010, which was equivalent to approximately 1.4% of the total used in the UK (Competition Commission, 2014a). This reflects that higher transport costs can make a high bulk density, low value density product uncompetitive compared to locally sourced material, so importation, like longer-distance domestic transport is only viable for higher-grade aggregates. These imports mostly come to the UK from the rest of Europe, transported by sea, primarily to ports in the South East.

Recycled aggregates typically travel shorter distances than virgin material as it arises on construction sites, and in some cases is reused on the same site on which it arises. Analysis indicates that recycled aggregates, on average, have catchment areas of 17 miles for urban sites and 22 miles for non-urban sites) (Competition Commission, 2014b).

Asphalt, the greatest use of which is for road and driveway surfacing, comprises different sizes of aggregate heated and mixed with an asphaltic binder, typically bitumen a tar-like substance produced from crude oil. Asphalt plants are often located at quarries or at railheads to reduce the double handling of the raw materials by road transport vehicles. It can either be produced according to demand or, less frequently where demand is more constant, can be produced in advance and stored in hot silos. It is then typically transported to its point of use in rigid (or less often articulated) tipper vehicles which require insulated bodies to retain its temperature (Woodcock, 2015).

In 2014, 31,700 people worked in quarries and mines in the British mineral extraction industry (excluding coal). Of these 11,600 (37%) were directly employed by the quarry/mine proprietor, 6,600 (21%) were contractors (carrying out activities including drilling, blasting, and plant installation), and 14,500 (46%) were goods vehicle drivers (of both own-account and third-party freight transport operators) (Department for Communities and Local Government, 2016).

5.2 Transport of cement and concrete

Cement is produced from a mixture of finely ground limestone, dolomite, chalk (limestone is by the far the most commonly used of these materials), with clay or mudstone (or other sources of silica and alumina). This mixture is heated to a very high temperature (approximately 1400-1500ºC) in a large rotating kiln. This creates an intermediate product, called cement clinker or just ‘clinker’. This clinker is then ground with a small proportion of additives (typically gypsum and/or anhydrite), which delays its setting time, to produce a fine powdered finished cement. Overall, limestone and chalk account for about 80-90% of the ingredients by weight, clay/mudstone for about 10-15%, and other additives for about 5% (British Geological Society, 2014). Over time, a growing proportion of cement is being produced from alternative and recycled materials including fly ash, slag from industrial processes and other waste products to replace the clay/mudstone which also helps reduce the carbon content of cement. Cement is supplied either in bulk (to concrete batching plants owned by the cement producers) or in bagged form (for construction companies and the wholesale trade). Mixing the cement with water causes it to set. The cement industry is subject to the Climate Change Levy and the European Emissions Trading Scheme which have resulted in efforts to make the industry more energy efficient and reduce carbon emissions associated with it.

Cement mixed with fine aggregate and water produces mortar, which is used to bind together various building products. Cement is mixed with aggregates, other additives and water to produce concrete, which is also widely used in building and infrastructure projects. Concrete can either be used to produce moulded construction components (blocks, tiles etc.) or can be used as ready-mix concrete (RMX) on construction sites.

The cement and concrete markets in the UK are even more concentrated than the aggregates industry. The five major vertically integrated UK producers (Aggregate Industries (operating as Lafarge Cement), Breedon Cement, CEMEX, Hanson and Tarmac) accounted for 78% of the UK cement market in 2018 (MPA Cement, 2019). There are approximately 300 limestone and dolomite quarries in Britain, with concentrations in the East Midlands, Yorkshire and the South West. Derbyshire and the Peak District National Park in the East Midlands are particularly important sources (Bide et al., 2020). Clay or mudstone are far more widely available and are usually sourced from quarries adjacent to cement manufacturing plants. Processing of limestone includes: crushing, grinding, sizing and then storage prior to transportation. Four limestone quarries are rail-linked, while others are served by road transport (British Geological Society, 2014).

There are currently 11 cement kiln plants in Britain, nine blending sites, one grinding site and one grinding and blending plant (kiln plants are where clinker is made, while grinding and/or blending plants only carry out these activities take place) (MPA Cement, 2019). These are operated by the five major producers. Hanson (owned by the Heidelberg Cement Group) operates six of these, Tarmac (owned by CRH) operates four, CEMEX operates two, Aggregate Industries (owned by Lafarge Holcim) and Breedon both operate one. In addition, one is operated by Francis Flower (CemNet, 2021). Five of the manufacturing plants are rail-connected, as are two of the grinding and blending plants. One manufacturing plant has a pipeline providing liquid chalk. In the case of the other plants, limestone/chalk is provided by road transport (British Geological Society, 2014). The remainder of the UK market is accounted for by imports of clinker and cement. In 2011, there were approximately twenty importing terminals, again mostly controlled by the major companies (Office of Fair Trading, 2011). The small number of cement plants results in relatively long transport distances from them to their delivery locations, commonly over 100 miles. Road transport usually involves the use of tankers, with the product moved in bulk form as a loose powder. Given the transport distances involved these are often articulated tankers, to maximise the load carried. Rail is also used to move bulk cement from plants to terminals, often using dedicated tank wagons, or sometimes, demountable ISO container tanks. Bulk cement transported by road or rail is usually destined for RMX plants or production sites where concrete products are produced. Bagged cement, usually destined for builders' merchants and DIY stores, is usually palletised and transported in curtainsided articulated HGVs (Woodcock, 2015).

RMX is concrete that is produced in a freshly mixed and unhardened state. RMX depots (also called batching plants) are situated in urban locations and serve construction sites. They are supplied with cement from cement manufacturing plants mostly by road, but some are rail-connected. This RMX concrete can either produced for construction sites in three different ways:

- the cement is mixed with aggregate, additives and water at a fixed location concrete batching plant run by a cement producer and then delivered to the construction site by a concrete mixer lorry (at which it can be tipped or pumped depending on the vehicle equipment),

- a volumetric concrete lorry carries the ingredients (sand, gravel and cement) in three separate compartments from the batching plant/depot and then, on arrival at the construction site, blends them together to provide exactly the quantity of concrete required (and which is also capable of providing different types of concrete mix if needed,

- at a batching plant located on the construction site (also referred to as a 'site batching plant' and typically only used for large construction sites given set-up costs).

In the UK, most RMX is mixed at a fixed location batching plant then delivered to the customer's site. On the construction site, the driver has to manoeuvre the vehicle into the required location and the concrete is usually either poured or pumped. The concrete may then also require consolidating or compacting, using roller machinery. The driver has to clean their mixer lorry with a hose to prevent concrete spillage onto the road before returning empty to the batching plant to collect another load for delivery (Department for Transport, 2008). Rigid vehicles are far more commonly used to transport concrete than articulated ones due to the space and turning circles available at urban concrete batching plants and construction sites

(WSP, 2018a). Major and medium-sized suppliers of RMX operate approximately 800 concrete plants in the UK, with smaller companies also operating such plants (Woodcock, 2015).

Concrete prices charged by the producers to their construction customers depend factors including: the delivery distance, size of order, type of product required, and the customer's bargaining power (Competition Commission, 2014). Given that RMX has to be used within 1 to 2 hours of being produced, catchment areas around RMX batching plants are relatively local. These catchment areas typically extend about to 8 to 10 miles from the RMX batching plant. However, volumetric trucks can deliver over greater distances than conventional concrete mixer trucks as their product can be mixed on the construction site (Competition Commission, 2014). A similar distance for the delivery from batching plant to construction site for RMX is given by the Mineral Products Association: an average one-way trip distance of 10 miles with an average load of 6 tonnes, with this all being carried out by road (Mineral Products Association, 2020a).

For the road transportation of cement and concrete, as for aggregates producers tend to make use of third-party hauliers, as well as in some cases having an in-house fleet. This includes for the distribution of bagged cement to construction customers and wholesalers, as well as for the delivery of ready-mixed concrete. Some of these operations are referred to as franchised, in these cases they are carried out by a third-party for the producer but the freight transport operator is pretty much dedicated to working for the producer and may well use a vehicles liveried with the producer's company name (WSP, 2018a).

5.3 Transport of products and components

As discussed in **section 4.3**, a very wide range of manufactured products are used in the construction industry. Steel and iron are made iron ore in steel mills and then used in manufacturing many different structures and products. Glass is made from sand and other minerals and then used to produce windows, other glazing and in other building products including glass fibre, optical fibre cables, and lamp and light bulb manufacture. Timber is harvested from forests that are processed at sawmills and then used for building and in many construction products. Plaster and plasterboard are made from gypsum in plaster plants often located close to gypsum mines. Bricks, pipes and tiles are made from clay and shale at brickworks and factories often located relatively close to supplies of these materials. Ceramics are made from clay materials such as kaolin and aluminium oxide and the material is used to manufacture a wide range of products used in construction including tiles and sanitary ware. Paints are made from resin, additives, solvent and pigment in factories.

In addition to domestic manufacture, many products and components used in the UK construction industry are imported from overseas. All of these products used in construction have extensive supply chains from the extraction of raw materials, through processing and manufacture to the construction site.

Product manufacturers and builders' merchants (who acts as wholesalers stocking many different construction materials and products) will deliver these products to construction sites. Large construction contractors may purchase commonly used products direct from manufacturers. However, they and smaller contractors, especially those working on refurbishment and maintenance projects on individual residential buildings, will purchase many items from builders' merchants, who can fulfil their multiple needs in a single order. For smaller contractors purchasing large, heavy orders from builders' merchants, the latter will provide delivery. However, for smaller items, the small contractor may collect them in person from the merchant using their own transport, typically a van.

5.4 Transport of waste

Waste materials arising at construction sites have several possible destinations depending on their type. All construction wastes have to be managed in ways that comply with legal requirements. This requires that the waste management hierarchy (i.e. reduce, reuse, recycle, dispose) has been followed and applied and that considerations has been given to which waste materials are reusable and recyclable.

Aggregates are either processed on site and used as recycled aggregates or are transported to a waste depot/reprocessing facility or another construction site for such use. Concrete and stone can be crushed on site and reused or transported for reprocessing – whilst on-site crushing creates dust and noise it does reduce freight transport.

Some excavated soil may be able to be used on a construction site to raise ground level away from the buildings. However, there is often a surplus that needs to be transported off site. Its destination and use will depend on whether it is from a greenfield site and is therefore inert, or from a brownfield / previously developed site and may therefore be contaminated, which will affect its end-use options. Inert soil is often used in landscaping and environmental restoration schemes

Waste metals, glass and wood are transported to recycling depots for reprocessing and reuse or landfilled. Hazardous construction materials are transported off-site for appropriate treatment. All waste materials removed from a construction site must be transported by a company with a valid waste carrier licence. Given the location of most construction sites and their lack of rail and water connectivity, road transport is the most common mode used for the removal of waste materials.

5.5 Road freight transport in construction

5.5.1 Freight transport vehicles used in construction and their activity

Road transport is the most commonly used transport mode in the construction industry, in all supply chain stages for construction materials and products. Road is most dominant at construction sites given the lack of non-road connections at all but a few, very large sites.

Heavy goods vehicles (HGVs) are widely used in these construction supply chains with a variety of body types. Light goods vehicles (LGVs) are also commonly used by small building contractors and sub-contractors including plumbers, electricians, roofers, plasterers and decorators. **Table 5.7** summarises the types of goods vehicle that are regularly used in the construction industry.

Table 5.7: Types of road goods vehicle commonly used in the construction industry and their uses

Vehicle body type	Vehicle classification *(HGV or LGV)*	Used at construction sites?	Construction facilities other than construction sites at which used	Vehicle uses
Tipper (with or without grabs/cranes)	HGV	Yes	Quarries, mines	Aggregates (sand, gravel, stone etc.) and removing soil and muck
Flatbed /dropside (with or without grabs/cranes)	HGV	Yes	Products from processing facilities and to/from builders' merchants and storage facilities	Delivering products, machinery, storage units and ancillary equipment such as toilets to site
Curtainsider	HGV	Yes	Products from processing facilities and to/from builders' merchants and storage facilities	Delivering palletised and other products to site
Box / Luton	HGV	Yes	N/A	Wide range of unitised / palletised products and components
Low-loader	HGV	Yes	N/A	Delivering/collecting abnormal loads of products, machinery and portacabins
Volumetric concrete lorry	HGV	Yes	N/A	Delivering the components that are mixed into concrete in the vehicle on site
Concrete mixer / pump	HGV	Yes	N/A	Delivering ready-mix concrete to site
Tanker	HGV	Yes	Quarries, mines	Liquid chalk and powered gypsum, concrete
Skip vehicle	HGV	Yes	N/A	Delivering and collecting waste skips
Refuse vehicle	HGV	Yes	Waste collections from processing facilities and builders' merchants	Collecting waste products from site
Sweeper vehicle	HGV	Yes	Site cleaning at processing facilities, builders' merchants and other facilities	Site cleaning
Van	LGV	Yes	Products purchased from builders' merchant and other outlets. Engineers and professionals working at all sites	Small building companies, tradespeople (electricians, plumbers etc.), and professional services (architects, surveyors etc.)

Note: N/A – not applicable.

Road goods vehicles used at construction sites and especially at quarries must be capable of operating on unmade surfaces and dirt roads off the public road network and carrying heavy vehicle loads of products with high bulk densities. This poses a vehicle engineering challenge in terms of their required robustness for these operations while having at the same time to be as energy efficient and produce as little noise and other environmental impacts as possible. Given the low-profitability nature of the industry, they also need to have as low capital and running costs (including maintenance requirements) (Brighton and Richards, 2010).

The most commonly used type of vehicle for moving aggregates (sand, gravel, crushed rock, and limestone) from quarries, rail terminals and wharves to construction sites by road have tipper bodies. The loose nature of these materials and the ease with which the vehicles have to be loaded and unloaded mean tipper bodies are the most suitable. Tippers are also widely used in the delivery of such aggregates to construction sites, asphalt used in road construction projects, and the collection of waste materials and soil. Although articulated tippers are used, the most commonly operated tippers are rigid vehicles capable of carrying between 16 and 21 tonnes of materials. These vehicles offer greater flexibility and manoeuvrability than articulated tippers (with carrying capacities of approximately 30 tonnes) and are therefore preferred for deliveries and collections from urban construction sites. Tipper vehicles are also used for transporting waste materials and spoil (WSP, 2018a). Asphalt transport requires the use of an insulted tipper vehicle (Woodcock, 2015).

In 2019, there were a total of 40,200 rigid tippers licensed in Britain, which represented 15% of all rigid HGVs and 10% of all HGVs including articulated vehicles (Department for Transport, 2020a). Rigid HGVs lifted 63% of all stone, sand, gravel, clay, peat and other quarrying products transported by road in Britain in 2019 (while articulated vehicles lifted 37% of these materials). This represented 18% of all the freight lifted by rigid HGVs in 2019 and 6% of all the freight lifted by articulated HGVs. Articulated vehicles are used for longer, non-urban journeys when transporting these materials. In 2019, they were responsible for 59% of total tonne-kilometres by road for these materials, while rigid vehicles carried out 41% of tonne-kilometres. The average length of haul for articulated vehicles carrying these materials in 2019 was 113 km, while it was 46 km for rigid vehicles (Department for Transport 2020b). There has however, been a marked shift away from rigid HGVs and towards articulated vehicles for transporting aggregates and other quarrying products, especially upstream in the supply chain for these products in Britain, as in 2001 rigid HGVs lifted three times as many of these materials as articulated vehicles and performed half of all the tonne-kilometres (Browne et al., 2002).

Concrete mixers and pumps are also most frequently rigid HGVs, although articulated versions of these vehicles are also available. These rigid ready-mix concrete vehicles can typically carry 6-8 m^3 of concrete, while rigid volumetric concrete lorries can hold up to 10 m^3 of concrete. There were 4,900 rigid concrete mixers licensed in Britain in 2019, which represented 2% of all rigid HGVs and 1% of all HGVs including articulated vehicles (Department for Transport, 2020a).

The time that HGVs spend at construction sites making deliveries or collections varies depending on the type of load carried and the ease of loading/unloading. For instance, it may take two minutes to unload a tipper truck but may take 15-20 minutes to load it using a grabber. It may take 5-10 minutes to unload a concrete mixer and another 5-10 minutes to wash it clean, It may take 20-60 minutes to unload a flatbed or curtainsider truck depending on the products involved, and it may take 5-15 minute to deliver or collect a skip depending on site layout and accessibility. Manoeuvring vehicles into and out of difficult to access sites can add to the time taken. In addition, it can be necessary for a vehicle to waiting at a busy, large construction site before being able to deliver or collect if other vehicles are already on site.

5.5.2 Length of haul

As discussed previously (see sections 5.1 and 5.2), the distances over which aggregates and concrete are transported by road in the UK are kept as short as possible given their high bulk density and low value density. More than 80% of sales of aggregates are reported to involve transport distances of no more than 30 miles from the quarry where it is extracted (with slightly higher distances for high value aggregates - Competition Commission, 2014b). Another data source indicates average one-way road transport distances for the final leg of delivery for aggregates and asphalt of 23 miles and 29 miles respectively (Mineral Products Association, 2020a). The catchment areas for ready-mix concrete extend about to 8 to 10 miles from the batching plant, with an average one-way road distance of 10 miles (Competition Commission, 2014; Mineral Products Association, 2020a).

Data from the Department for Transport's domestic Continuing Survey of Road Goods Transport (CSRGT) provides further insight into the length of haul by road for various materials and products used in construction within all the journeys made in their supply chains (see **Table 5.8**). This data reflects that manufactured products of wood and metal are, on average, transported over greater distances than aggregates, cement and other mineral products and waste.

Table 5.8: Goods lifted by commodity group and length of haul in Britain in 2019 (% of tonnes lifted by length of haul)

Commodity group	Up to 25km	Over 25km to 50km	Over 50km to 100km	Over 100km to 150km	Over 150km	TOTAL
Stone, sand, gravel, clay, peat and other quarrying products	25%	26%	31%	10%	10%	100%
Glass, cement and other non-metallic mineral products	32%	20%	21%	11%	15%	100%
Products of wood	13%	13%	21%	17%	38%	100%
Products of metal	18%	14%	21%	14%	36%	100%
Commercial waste products	27%	28%	25%	9%	11%	100%
ALL COMMODITIES CARRIED BY HGV	19%	18%	24%	14%	26%	100%

Notes:
Not all the products in these commodity groups are associated with the construction industry (e.g. products of glass, wood and metal are also used in other industries, and waste also arises from other sources).
'All commodities carried by HGV' includes other commodities in addition to those listed above that are related to the construction industry. These include products of agriculture and forestry, food and drink products, petroleum products, chemical products, commercial and medical machinery and equipment, domestic appliances, transport equipment, textiles and leather products, printed matter, pulp and paper products, furniture, mail and parcels, groupage, and household and municipal waste.
Source: calculated from data in Department for Transport, 2020b.

5.5.3 Tonnes lifted and moved

Table 5.9 indicates the substantial use of rigid HGVs in relation to high bulk density, low value commodities, as previously discussed in relation to aggregates and concrete. As can be seen from the data, articulated vehicles are also used for aggregates movement. Whereas rigid HGVs are more commonly used for deliveries to construction sites which often have restricted space and turning circles, in busy urban areas, articulated vehicles are often used upstream in the aggregates supply chain between quarries and processing facilities – this is reflected in the relatively greater importance of articulated vehicles in terms of tonne-kilometres than tonnes lifted, indicating their greater average length of haul.

Table 5.9: Goods lifted and moved by commodity group and vehicle type in Britain in 2019 (% of tonnes lifted and tonne-kilometres moved)

Commodity group	Goods lifted			Goods moved		
	Rigid HGV	Artic HGV	TOTAL	Rigid HGV	Artic HGV	TOTAL
Stone, sand, gravel, clay, peat and other quarrying products	63%	37%	100%	41%	59%	100%
Glass, cement and other non-metallic mineral products	55%	45%	100%	29%	71%	100%
Products of wood	19%	81%	100%	11%	89%	100%
Products of metal	32%	68%	100%	20%	80%	100%
Commercial waste products	62%	38%	100%	41%	59%	100%
ALL COMMODITIES CARRIED BY HGV	38%	62%	100%	21%	79%	100%

Note: see explanation beneath Table 5.8 about these commodity groups and 'All commodities carried by HGV'.
Source: calculated from data in Department for Transport, 2020b.

5.5.4 Own-account and public haulage

Table 5.10 indicates the relative importance of own-account (in-house) road freight transport operations compared with public haulage (third-party) operations provided by a specialist freight transport company in these commodity groups. This indicates the lower levels of outsourcing of road freight transport operations in the waste industry, with the majority of waste companies operating their own transport (which would be expected given that collecting and transporting the waste is an intrinsic part of waste operations, unlike for suppliers or materials and products).

Table 5.10: Goods lifted by commodity group and mode of working in Britain in 2019 (% of tonnes lifted)

Commodity group	Mainly public haulage	Mainly own account	TOTAL
Stone, sand, gravel, clay, peat and other quarrying products	65%	35%	100%
Glass, cement and other non-metallic mineral products	58%	42%	100%
Products of wood	77%	23%	100%
Products of metal	61%	39%	100%
Commercial waste products	34%	66%	100%
ALL COMMODITIES CARRIED BY HGV	59%	41%	100%

Note: see explanation beneath Table 5.8 about these commodity groups and 'All commodities carried by HGV'.
Source: calculated from data in Department for Transport, 2020b.

5.5.5 Empty running

Table 5.11 shows the proportion of mileage travelled empty by goods vehicles in the construction industry in 2019. This empty running rate can be seen to be higher in construction than for total HGV operations in the country for both rigid and articulated vehicles. Empty running is a key measure of the efficiency of road freight transport operations.

Table 5.11: Empty running by industry and vehicle type in Britain in 2019 (% of vehicle kilometres travelled empty)

Industry category	Rigid HGV	Artic HGV	All HGVs
Construction	38.3	40.8	38.5
ALL INDUSTRIES	30.6	29.6	30.0

Source: Department for Transport, 2020b.

5.5.6 Loading factors

A special disaggregation of vehicle loading factor data from the CSRGT survey was requested from the Department for Transport. This is shown in **Table 5.12**, sub-divided into rigid and articulated HGVs. This indicates that in 2019 the loading factor was substantially greater for aggregates than for any other construction-related commodity category, and far higher than loading factors for all goods carried by HGVs. For aggregates, rigid HGVs had a higher loading factor than articulated HGVs, the only commodity category for which this was the case. The loading factor of 1.00 for rigid HGVs carrying aggregates (the highest loading factor possible) indicates that some of these vehicle journeys are likely to have been overloaded.

Table 5.12: Vehicle loading factors by commodity group and HGV type in Britain in 2019

Commodity group	Rigid HGVs	Artic HGVS	TOTAL
Stone, sand, gravel, clay, peat and other quarrying products	1.00	0.85	0.90
Glass, cement and other non-metallic mineral products	0.43	0.61	0.58
Products of wood	0.68	0.79	0.76
Products of metal	0.38	0.58	0.53
Commercial waste products	0.68	0.74	0.72
ALL COMMODITIES CARRIED BY HGV	0.55	0.62	0.61

Notes:
See explanation beneath Table 5.8 about these commodity groups and 'All commodities carried by HGV'.
The loading factor is defined as, "the amount of goods that were moved, as a proportion of the total amount of goods that could have been moved, if when HGVs were loaded they were always fully laden."
Source: calculated from data in Department for Transport, 2020c.

5.5.7 Vehicle kilometres travelled

A special disaggregation of vehicle kilometre activity data from the CSRGT survey was requested from the Department for Transport. This is shown in **Table 5.13**, sub-divided into rigid and articulated HGVs. This shows how empty running and vehicle lading factors transform tonne-kilometres performed by HGVs into vehicle kilometres travelled. This indicates that rigid HGVs carrying all the categories of products listed (with the exception of glass, cement and other non-metallic mineral products) perform more vehicle kilometres than articulated HGVs. This is in contract to vehicle kilometres performed for all commodities carried by HGV, 57% of which are carried out by articulated HGVs.

Table 5.13: Vehicle kilometres by commodity group and HGV type in Britain in 2019 (% of vehicle kilometres)

Commodity group	**Rigid HGVs**	**Artic HGVS**	**TOTAL**
Stone, sand, gravel, clay, peat and other quarrying products	54%	46%	100%
Glass, cement and other non-metallic mineral products	35%	65%	100%
Products of wood	55%	45%	100%
Products of metal	54%	46%	100%
Commercial waste products	68%	32%	100%
ALL COMMODITIES CARRIED BY HGV	43%	57%	100%

Note: see explanation beneath Table 5.8 about these commodity groups and 'All commodities carried by HGV'.
Source: calculated from data in Department for Transport, 2020c.

5.5.8 Road freight transport activity by HGVs in the construction industry

An estimate has been made of the total road freight activity by HGVs in the construction industry in Britain in 2019. This has been conducted using Department of Transport data from the domestic Continuing Survey of Road Goods Transport (CSRGT) which provide data about the quantity of goods lifted (in tonnes) and moved (in tonne-kilometres) by commodity group. The commodity groups associated with the construction industry have been identified – these include materials, products and components, together with plant and machinery and waste arising. The road freight data for these commodity groups in CSRGT refer to total activity levels, so it has been necessary to make assumptions about the proportion of each commodity group that construction accounts for. This has been done by referring to ProdCom data (ONS, 2021h) which provides a breakdown of domestically manufactured goods by weight or volume – using the available data it has been possible to identify those goods associated with construction and then calculate the weight of these goods as a proportion of the commodity category total. In the case of waste products, DEFRA waste statistics have been used to determine the proportion of all commercial waste that construction, demolition and excavation waste accounts for (DEFRA, 2020). These assumptions are shown in **Table 5.14**.

Table 5.14: Assumed proportion of products transported by road in each commodity group accounted for by the construction industry

Commodity group	**Assumed proportion of the commodity group accounted for by construction**
Stone, sand, gravel, clay, peat and other mining/quarrying products	100%
Cement, lime and plaster	100%
Other construction materials	100%
Commercial waste	75%
Plant equipment and scaffolding	100%
Wood and cork products (except furniture)	50%
Rubber and plastic products	20%
Glass and glass products, ceramic and porcelain products	50%
Metal products	50%

These assumptions have then been applied to CSRGT freight lifted and moved data to estimate total HGV activity levels related to the construction industry in 2019 (see **Table 5.15**).

Based on this estimate, construction-related freight transport accounted for 29% of the goods lifted by HGVs in Britain in 2019, and 20% of the goods moved (i.e. tonne-kilometres).

Table 5.15: Estimated goods lifted and moved related to the construction industry by HGVs in Britain in 2019

Commodity group	Goods lifted		Goods moved	
	Tonnes (million)	**% of all goods lifted by HGV in Britain**	**Tonne-kilometres (million)**	**% of all goods moved by HGV in Britain**
Stone, sand, gravel, clay, peat and other mining/quarrying products	147	10.2%	10,010	6.5%
Cement, lime and plaster	23	1.6%	2,183	1.4%
Other construction materials	96	6.7%	5,740	3.7%
Commercial waste	77	5.4%	5,873	3.8%
Plant equipment and scaffolding	38	2.6%	2,491	1.6%
Wood and cork products (except furniture)	12	0.8%	1,359	0.9%
Rubber and plastic products	2	0.1%	259	0.2%
Glass and glass products, ceramic and porcelain products	13	0.9%	1,634	1.1%
Metal products	14	1.0%	1,800	1.2%
TOTAL	**421**	**29.2%**	**31,348**	**20.4%**

Source: calculated from data in Department for Transport, 2020b.

In London, goods vehicles working in the construction industry have been estimated to account for 35% of all HGV traffic and 38% of HGV traffic in the morning peak (OPDC, 2018; CLOCS, 2019).

It is also possible to estimate road freight activity by HGVs in the construction industry in terms of vehicle kilometres travelled using these same assumptions that have been applied to tonnes lifted and moved. In order to do this, a special disaggregation of vehicle kilometre activity data from the CSRGT survey was requested from the Department for Transport. The results are shown in **Table 5.16**. Based on this estimate, construction-related freight transport accounted for 14% of the vehicle kilometres travelled by HGVs in Britain in 2019.

Table 5.16: Estimated vehicle kilometres related to the construction industry by HGVs in Britain in 2019

Commodity group	Vehicle kilometres (million)	% of all vehicle kilometres by HGV in Britain
Stone, sand, gravel, clay, peat and other mining/quarrying products	620	3.2%
Cement, lime and plaster	92	0.5%
Other construction materials	493	2.6%
Commercial waste	548	2.9%
Plant equipment and scaffolding	336	1.8%
Wood and cork products (except furniture)	121	0.6%
Rubber and plastic products	47%	0.2%
Glass and glass products, ceramic and porcelain products	121	0.6%
Metal products	220	1.1%
TOTAL	**2,957**	**13.6%**

Source: calculated from data in Department for Transport, 2020c.

It should be noted that the data presented in this section refers only to construction materials and products lifted and moved by HGVs. Considerable road freight construction activity is also carried out by LGVs (i.e. light goods vehicles, more commonly referred to as vans). However, lack of data availability about the goods carried by LGVs prevents analysis of their construction-related freight activity. However, as discussed in **section 5.5.10**, there may have been at least one million LGVs used in the construction industry in 2016.

5.5.9 HGV freight transport intensity and efficiency in the construction industry

Using the disaggregated Department for Transport road freight transport activity data from the CSRGT survey analysed in **section 5.5.8** it was possible to calculate the average distance that one tonne of each construction commodity group was transported by HGVs in Britain in 2019. The results (see **Table 5.17**) take account of the total quantity of goods lifted, the number of times they are lifted and moved, extent of vehicle empty running, and vehicle loading factors. This therefore reflects the overall road freight transport intensity and efficiency of road freight transport for each construction commodity category.

Table 5.17: Average kms travelled per tonne lifted by HGVs in Britain in 2019

Commodity group	2019
Stone, sand, gravel, clay, peat and other mining/quarrying products	4.2
Cement, lime and plaster	4.0
Other construction materials	5.1
Commercial waste	7.1
Plant equipment and scaffolding	8.8
Wood and cork products (except furniture)	10.5
Rubber and plastic products	26.2
Glass and glass products, ceramic and porcelain products	9.7
Metal products	15.7
ALL COMMODITIES CARRIED BY HGV	**7.0**

Source: calculated from data in Department for Transport, 2020b, 2020c.

The results indicate that, as would be expected, bulk construction materials (including sand, gravel, stone, and cement) are moved less distance per tonne lifted than construction products (such as wood, metal and plastic products). This is due to the bulk and cargo density and relatively low value of the former, which results in their supply from quarries and facilities that are relatively local to where they are used, as well as the high loading factors achieved when carrying these materials. By contrast, construction products are made and supplied in locations that are more remote from construction sites, can have lower cargo densities and often have lower vehicle loading factors. By comparison, all commodities carried by HGV in 2019 (i.e. not just those related to the construction industry) are carried 7 km per tonne lifted, a figure that is greater than bulk construction materials but less that construction products.

5.5.10 The use of vans in the construction industry

As well as the importance of the construction industry in HGV activity in the UK, the industry is also a major user of vans (i.e. light goods vehicles up to and including 3.5 tonnes gross weight). In 2016 there were 3.9 million vans in the UK, of which 47% (1.8 million) were registered to companies. It has been estimated that 32% (approximately 600,000) of these company-registered vans were used in the construction industry (for new construction projects, maintenance and refurbishment work). In addition, the number of vans used per unit of economic value were calculated to be higher in construction than in any other industry. The construction industry was estimated to use 5.5 vans per £1m of GVA (gross value added). This compared with 3.6 and 1.9 vans per £1m of GVA in the two next most van-intensive industries (namely transport and storage, and water supply and sewerage, respectively) (Freight Transport Association, 2018).

The use of vans registered to private individuals is likely to be similarly significant in the construction industry given that over one third of all those working in construction are self-employed. Given that there were 1.9 million vans registered to private individuals in the UK in 2016, this suggests that the total van fleet in the construction industry may have been in excess of one million vehicles in 2016 (Department for Transport, 2020a).

In terms of van activity levels, survey work by the UK government has shown that vans are more commonly used for carrying equipment, tools and materials than for the delivery/collection of goods (i.e. using the van primarily for goods transport). A 2019-20 survey indicated that 48% of van mileage was primarily for carrying equipment, tools and materials, whereas only 23% was primarily for goods delivery/collection (Department for Transport, 2020b). In 2019, all vans travelled a total distance of 89.4 billion kilometres in Britain (Department for Transport, 2020d). Based on the survey findings about the purpose of van usage, this suggests that those vans used primarily for carrying equipment, tools and materials covered a total distance of approximately 40 billion kilometres in 2019. Given the estimated van fleet used in the construction industry, it is likely to account for a substantial proportion of this van mileage for the purpose of carrying equipment, tools and materials.

5.5.11 Fleet sizes of major construction companies and suppliers of materials

Table 5.18 provides details of road vehicle fleet sizes and company turnover for selected major UK construction companies. It is important to note that as well as any HGV and van fleet operated in-house, construction companies are also provided with materials and products at construction sites by vehicles operated by many suppliers and freight transport companies. In addition, other construction sub-contractors working on projects for these major companies will also operate their own vehicle and/or receive deliveries from suppliers and freight transport companies. Therefore, the vehicle fleet data provided in the table only represents a small proportion of the total goods vehicles associated with projects carried out by major construction companies.

Table 5.18: Vehicle fleet size and turnover of selected UK construction companies

Company name	Turnover (2018)	Ranking by turnover	Vehicle fleet size in 2019		
			Number of HGVs	Number of vans	Number of cars
Balfour Beatty	£7,802 m	1	750	2,000	3,500
Kier	£4,513 m	2	509	724	687
Morgan Sindell	£2,972 m	5	80*	438	978
Amey	£2,668 m	6	2,500	3,000	2,000
Skanska	£1,935 m	11	389	752	1,874
Costain	£1,489 m	13	23	749	1,059
Eurovia**	£501 m	35	418	517	180
FM Conway	£329 m	47	403	564	82
Clancy Group	£268 m	58	158	1,432	477
Colas	£240 m	65	311	718	247

Notes:
* HGV fleet data for 2015
** Fleet size is for Eurovia's Ringway subsidiary.
Vehicle fleet details compiled as part of case studies carried out by Driving for Better Business, 2019.
Source: Construction News, 2019; Amey, 2019; Balfour Beatty, 2019, Clancy Group, 2019; Colas, 2019; Costain, 2019; Fleet News, 2015; FM Conway, 2019; Kier, 2019a; Morgan Sindell, 2019; Ringway, 2019, Skanska UK, 2019a.

Table 5.19 provides the road vehicle fleet size, sites, staff and turnover data for the five major producers and suppliers of aggregates and cement in the UK. In 2018, these five companies accounted for approximately 70% of total UK aggregates output and 78% of UK cement output (British Geological Survey, 2019 (MPA Cement, 2019). Some of these companies operate in-house fleets, while others used franchised contractors or a mix of both.

Table 5.19: Vehicle fleet size, sites, staff and turnover of major UK aggregates and cement suppliers

Company	Turnover	Number of goods vehicles in UK*	UK sites and staff
Aggregate Industries	£1.3 bn in UK in 2019 (parent LafargeHolcim - CHF 23.1 bn in 2020)	1,250 HGVs and 450 vans in 2019	200 sites, 3,700 staff
Breedon	£930 m in UK (2019)	Utilised a fleet of 1,500 goods vehicles in 2018	350 sites, 3,500 staff
CEMEX UK	£775 m in UK (parent CEMEX - $13 bn in 2020)	800 goods vehicles in 2019	22 quarries, 2,200 staff
Hanson UK	€17.6 bn (parent Heidelberg in 2020)	Currently utilises a fleet of 1,200 HGVs	300 sites, 3,500 staff
Tarmac	$27.6 bn (parent CRH in 2020)	2,000 HGVs and 1,100 vans in 2019	400 sites, 7,000 staff

Notes:
* - either operated by company or franchised contractors

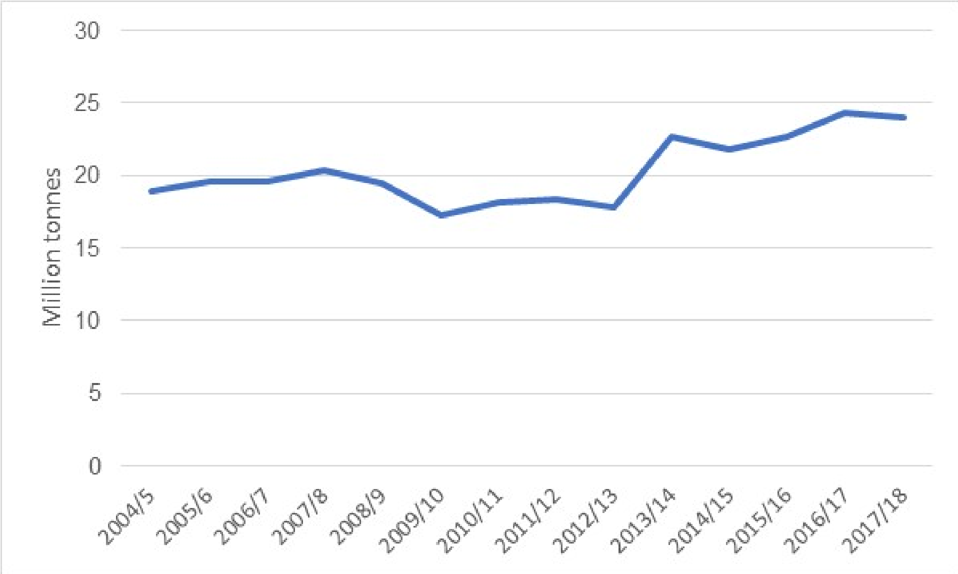
Source: Aggregate Industries, 2021a; Breedon, 2019; Breedon, 2020; CEMEX, 2021a; CEMEX, 2021b; CRH, 2021; Fleetpoint, 2019; Hanson, 2021a; Hanson, 2021b; Heidelberg Cement, 2021; LafargeHolcim, 2021; London Road Safety Council, 2019; Robinson, 2019; Tarmac, 2019; Tarmac, 2021a.

5.6 Rail freight transport in construction

Although road-based goods vehicles are the most commonly used mode for the transportation of construction materials and products, rail (and water) is also used. Rail is used for movements of bulk materials upstream in the supply chain. Rail-connected facilities include major quarries and processing facilities. For instance, it has been estimated that approximately 80% of bulk construction materials are transported into London by rail (WSP, 2018b). Rail is mostly used to transport aggregates and mineral products, making use of its advantages over road for moving these high bulk densities materials. The aggregates and mineral products most commonly transported by rail are limestone, hardstones (including basalt, granite and gritstone), cement, sand, and marine-dredged materials (Rail Freight Group and Mineral Products Association, 2019).

Figure 5.3 shows the change in construction traffic lifted by rail between 2004/5 and 2017/18. The quantity of construction materials lifted by rail in 2017/18 was 27% greater than in 2004/5. In 2017/18, 24 million tonnes of aggregates, cement and other construction materials were lifted by rail, which was equivalent to 29% of all rail freight (MDS, Transmodal, 2019).

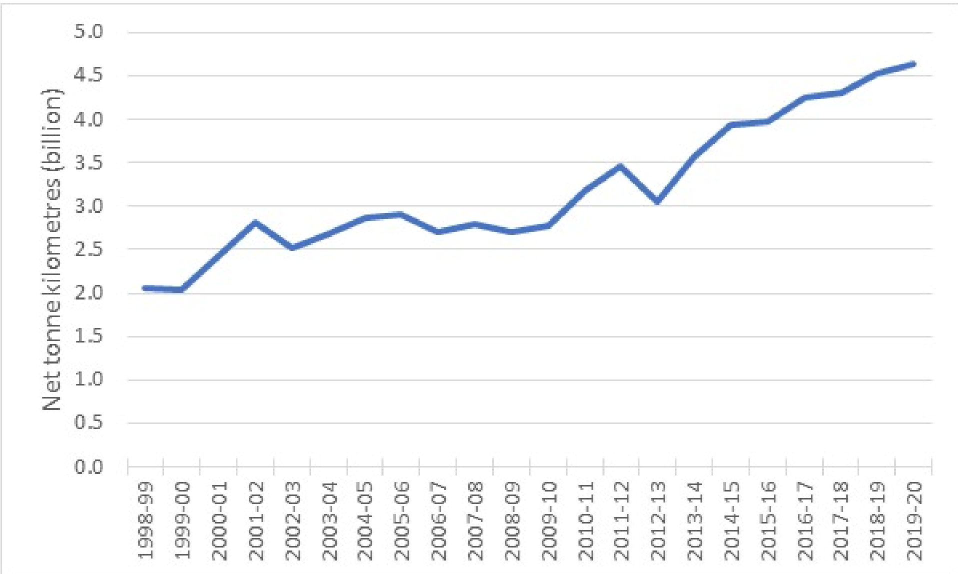
Figure 5.3: Construction traffic lifted rail freight in Britain, 2004/5 to 2017/8



Source: MDS Transmodal, 2019.

Official statistics indicate that construction rail freight activity measured in tonne-kilometres has increased rapidly over the last two decades (from 2.1 million tonne-kilometres in 1998/99 to 4.6 million tonne-kilometres in 2019/20 - see **Figure 5.4**).

Figure 5.4: Construction traffic moved by rail freight in Britain, 1998-99 to 2019-2020



Note: includes aggregates for road construction and general building works, as well as concrete and cement products, timber traffic and High Speed 2 (HS2) construction traffic (ORR, 2021).

Source: ORR, 2020a.

The construction share of the total rail freight market in terms of tonne-kilometres moved more than doubled from 12% in 1998/99, the first year for which construction-specific data were published, to 28% in 2019/20 (ORR, 2020a). This represented a 126% increase in tonne kilometres over the same period. Construction materials moved by rail freight grew faster than for other commodity types over this period, most of which, with the exception of domestic intermodal, fell (see **Table 5.20**).

Table 5.20: Commodities moved by rail freight in Britain, 1998-99 to 2019-2020

Commodity type	Percentage change in net tonne-kilometres
Construction	126%
Domestic intermodal (incl. maritime)	92%
Other	-22%
Metals	-34%
Oil and petroleum	-37%
International	-56%
Coal	-92%
TOTAL	**-4%**

Source: calculated from data in ORR, 2020a.

Given that growth in tonne-kilometres outstripped growth in tonnes lifted in Britain between 2004/5 and 2017/18, this indicates that the average distance over which construction materials was increasing. In addition to 27% more construction materials being lifted by rail in 2017/18 compared to 2004/5, the average length of haul is calculated to have 19% greater (179 km in 2017/18 compared to 151 km in 2004/5), resulting in construction tonne-kilometres by rail being 51% greater in 2017/18 than in 2004/5 (calculated from data in MDS Transmodal, 2019 and ORR, 2020a).

Between 2013-2018 the quantity of construction materials transport by rail in Britain increased by 21%, tonne-kilometres increased by 25%, and train movements increased by 12% (Rail Freight Group and Mineral Products Association, 2019).

In addition, 'infrastructure' materials (which are 'non-chargeable traffic moved for Network Rail') are moved by rail for engineering work on the rail network (ORR, 2021). These include rail ballast including aggregates and other construction materials. The quantity of infrastructure materials moved by rail was 1.3 million tonne-kilometres in 2019/20 and has also been increasing over time (this was 70% greater than in 1998/99) (ORR, 2020a).

Table 5.21 shows the quantities of materials transported by rail each year in the UK by the five leading suppliers who accounted for approximately 70% of total UK aggregates output and 78% of UK cement output (British Geological Survey, 2019 (MPA Cement, 2019). In total these five suppliers transport approximately 19 million tonnes of construction materials by rail annually in the UK, which is equivalent to approximately 80% of total construction rail freight.

Table 5.21: Rail freight tonnes lifted in the UK by major suppliers of aggregates and cement

Company	Tonnes lifted
Aggregate Industries	4.8 million (2018)
Breedon	1.0 million (2020)
CEMEX UK	2.0 million (2020)
Hanson UK	2.5 million (2020)
Tarmac	9.0 million (2020)

Source: Aggregate Industries, 2021; Breedon, 2021b; CEMEX, 2020; Hanson, 2021b; Tarmac, 2020.

There are approximately 100 rail-connected loading and handling depots, cement processing plants and concrete batching plants, and 20 rail-connected quarries in the UK that handle aggregates used in construction (Network Rail, 2013). These rail freight terminals are operated by a range of large organisations including quarrying, construction and building material companies (such as Tarmac, Lafarge, Aggregate Industries, Cemex and Hanson) and rail freight and freight transport companies (Such as DB Schenker, Freightliner, and Potter Group). For instance, the aggregates producer Hanson, uses rail to transport crushed limestone from the Mendips and hardstone from South Wales to its terminal in Dagenham in Essex, where these materials are used to produce asphalt for road surfacing. At the Dagenham site there is also a concrete batching plant, a bagging facility for supplying builders' merchants, and a recycling. Sand, gravel and crushed rock are transport from Dagenham by rail to Hanson depots at Acton, Brentford, Theale and Bow, from where it is transferred to road and supplied to Hanson's other ready-mix concrete batching plants that serve London (Port of London Authority, 2020). Brett Aggregates opened a new rail-connected concrete batching plant opened in Wembley in 2018 (Agg-Net, 2019). Some major construction infrastructure projects have made use of rail to deliver materials and remove waste, such as the London 2012 Olympics site, Heathrow Terminal 5, Crossrail and HS2, with this requirement being specified in the project agreement in some cases, thereby reducing the freight transport impacts of the project.

The transport of cement and aggregates by rail has become increasingly efficient in terms of payload carried per train in recent years. This has been achieved by designing and investing in new higher payload wagons as well as increasing the length of trains These measures have resulted in an 8% increase in loads per train in the last five years. There is scope to increase train length even further if rail network improvements are implemented (Rail Freight Group and Mineral Products Association, 2019).

The use of rail rather than road for the transport of construction materials can result in traffic and environmental benefits. A single rail wagon typically carries between 66-80 tonnes of construction material, with a train typically hauling 1000-1800 tonnes (Freightliner, 2021; Breedon, 2021a; Woodcock, 2015). An aggregates train carrying 1,500 tonnes is equivalent to 75 lorry loads, thereby reducing vehicle and CO_2 kilometres by approximately 75%, as well as reducing local air pollution in urban areas (Rail Freight Group and Mineral Products Association, 2019). Some so-called 'jumbo' trains, operating as many as 44 wagons long, can carry approximately 3,300 tonnes of aggregates (Clinnick, 2016).

5.7 Water freight transport in construction

The use of water transport, be it coastal shipping, canal or navigable river, requires sites to be adjacent to water-connected at both ends (e.g. quarry, material processing facility, construction site). Approximately 12 million tonnes of aggregates were transported on the River Thames in 2019, the vast majority of which was marine-dredged sand and gravel (Port of London Authority, 2020). The Thames is the most heavily used inland waterway in the UK for carrying construction material. This has largely come about as a result of major public sector construction projects that require the use of non-road modes, together with planning requirements imposed on other major projects, and the extent of road traffic in London. The use of water, as with rail, helps reduce the quantity of construction traffic moved on busy, urban roads. Aggregates are also transported by barge on the Rivers Trent and Severn.

Sand and gravel that is marine-dredged is brought ashore to wharves by dredgers in locations with substantial demand for these materials. Brett Aggregates land more than one million tonnes of sea-dredged aggregates from around the southern coast of England and the North Sea at its Alpha Jetty terminal at Cliffe in Kent. After processing, approximately 50% of this material is transported onwards by rail and river (Port of London Authority, 2020). Spoil arriving by river and rail from construction projects in London is also handled at this site, where a bird reserve is being developed. Brett Aggregates also operates several other terminals in the south east which supply materials to construction projects. In 2017 Brett Aggregates opened a new terminal and concrete batching plant at Peruvian Wharf in Silvertown, east London, which it ships materials to from its Kent terminal at Cliffe and produces ready-mix concrete for the central London market (Brett Aggregates, 2019). The concrete operation at Peruvian Wharf has been estimated to replace 100,000 lorry journeys by road per annum (Port of London Authority, 2020).

CEMEX, the aggregates, cement and ready-mixed concrete producer, operates four terminals on the river Thames which supply major construction projects in the southeast of England. These receive marine aggregates from the CEMEX dredging fleet, with the terminal at Dagenham in Kent, the closest to London, producing 500,000 tonnes a year. The CEMEX concrete products factory at the terminal in Northfleet in Kent produces concrete paving and blocks, while CEMEX's cement grinding and blending plant at Tilbury is the only such plant in the southeast and has an annual production of more than one million tonnes. From here, cement is distributed by water, rail and road to other London wharves and depots. Several concrete batching plants, including its own one in Fulham, are supplied with aggregates by its river barge fleet (Port of London Authority, 2020).

Hanson operates three water-connected facilities on the Thames: an asphalt plant and rail depot at Dagenham which receives about 600,000 tonnes of marine-dredged aggregates per annum, and two ready-mixed concrete batching plants, one in Wandsworth and another at Greenwich (Port of London Authority, 2020). The concrete plants are supplied with materials by barge from Dagenham.

Tarmac entered into a 25-year partnership with the Port of Tilbury in 2021 to build the UK's largest construction materials aggregates terminal, which is both water- and rail-connected. It will be capable of handling large deep-sea vessels and, via its rail link, supplying construction materials into central London.

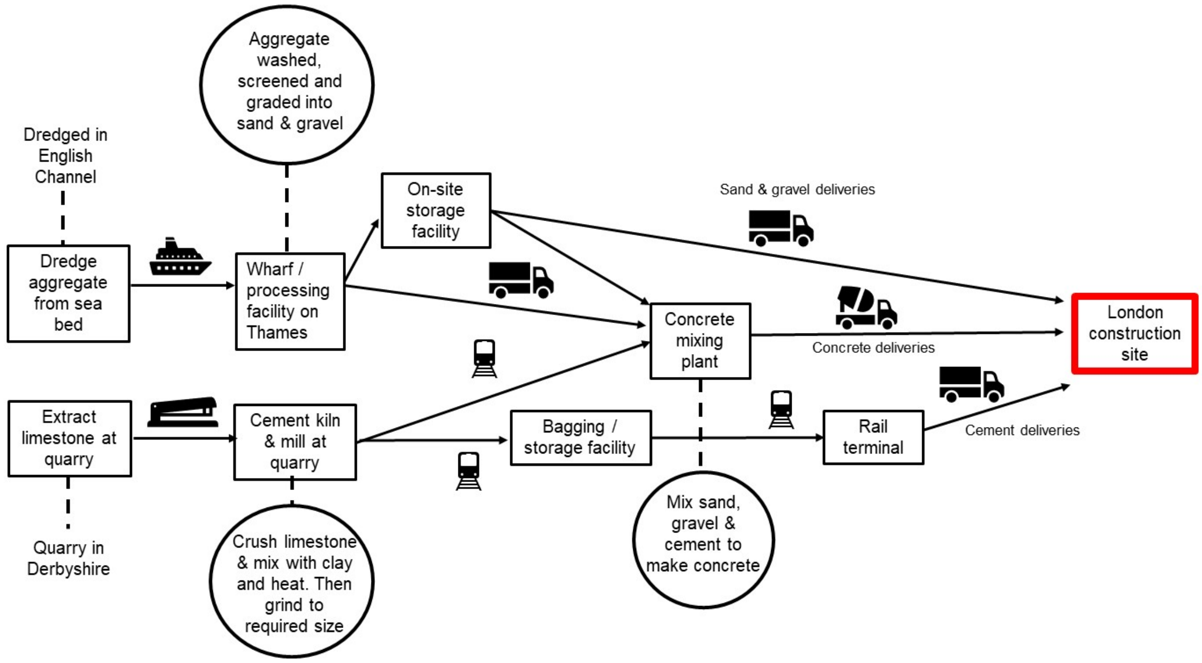
A small quantity of crushed rock is also transported by sea from a few quarries located near the coast, mostly to London and the South East. The large coastal quarry at Glensanda in western Scotland is not road- connected, so all of its output is transported by sea. Approximately one-quarter of its output in transported by sea to the Isle of Grain in Kent in South East England, with some of this material transhipped onto barges that take it up the River Thames to Tilbury for use in London (British Geographical Survey, 2019).

The river Thames has played an important role in the removal of spoil from the Thames Tideway, Northern Line extension and Crossrail projects (see **section 7.3.7** for further details).

5.8 Freight transport activity in construction by all modes

This section provides an estimate of domestic freight transport activity by mode in the UK construction industry (i.e. road, rail and water). **Figure 5.5** provides an illustration of how road, rail and water can all be used in the supply of aggregates, cement and concrete to construction sites where the geographical location permits use of all three modes.

Figure 5.5: Illustration of supply chain for aggregate, cement and concrete for use at a London construction site



Note: Compiled from information provided for a London construction site provided in Department for Transport, 2008.

Construction materials carried by rail that have been included in this analysis are the ORR rail freight commodity categories ‘construction’ and ‘infrastructure’ (which refers to Network Rail infrastructure traffic moved by rail to carry out construction and engineering work on the national rail system). In the case of water transport, the commodity categories ‘sand and gravel from the sea bed’ and ‘ores’ from Department for Transport data have been included.

An estimate of the importance of road, rail and water in the transportation of major construction materials (i.e. aggregates, cement and concrete) in Britain in 2018 is presented in **Table 5.22**. The commodity categories ‘stone, sand, gravel, clay, peat and other mining/quarrying products’ and ‘cement, lime and plaster’ have been included from Department for Transport road freight data (**see section 5.5.8** for further details). Construction materials carried by rail that have been included in this analysis are the ORR rail freight commodity categories ‘construction’ and ‘infrastructure’ (which refers to Network Rail infrastructure traffic moved by rail to carry out construction and engineering work on the national rail system). In the case of water transport, the commodity categories ‘sand and gravel from the sea bed’ and ‘ores’ from Department for Transport data have been included. The most recent year for which data is available to make this modal comparison is 2018 in the case of road and water, and 2018/19 for rail. It has been assumed that the round-trip distance for marine-dredged sand and gravel from extraction site to wharf is 50 km.

Table 5.22: Estimated construction materials (aggregate, cement and concrete products) lifted and moved in Britain in 2018 by transport mode

Commodity group	Goods lifted			Goods moved		
	Tonnes (million)	% share by mode	% of all goods lifted by mode	Tonne-kilometres (billion)	% share by mode	% of all goods moved by mode
Road	197.0	82%	14%	13.5	67%	9%
Rail	28.7	12%	34%	5.7	28%	31%
Water	13.7	6%	14%	0.9	5%	4%
TOTAL	**239.4**	**100%**	**15%**	**20.1**	**100%**	**10%**

Source: calculated from data in Department for Transport, 2020e, 2020f; MDS Transmodal, 2019; ORR, 2020a.

The estimates in **Table 5.22** indicate that road, rail and water accounted for 82%, 12% and 6% of all aggregate, cement and concrete lifted, respectively. The estimated 12% of aggregate, cement and concrete lifted by rail, and 6% by water in Britain in 2018, corresponds closely to the 2017 estimate of the British Geological Society (of 11% of aggregates lifted by rail and 6% by water - British Geological Society, 2019).

In terms of goods moved (i.e. tonne-kilometres) the estimates indicate a greater share for rail, given the longer average distance over which these goods are moved compared to road. Road, rail and water are estimated to have accounted for 67%, 28% and 5% of all commodities moved in 2018, respectively. The transportation of these commodities by all three modes is estimated to have accounted for 15% of all goods lifted and 10% of all goods moved in Britain in 2018.

Taking the analysis of all the construction products and materials transported by road in addition to aggregate, concrete and cement presented in **section 5.5.8**, it is possible to consider the effect of this wider definition of road freight construction activity (which includes steel, wood, glass and plastic construction materials and products, construction waste, and plant and scaffolding transport) on the contribution of these three modes to total domestic construction transport in Britain. Assumptions concerning the construction materials and products carried by road freight are provided in **section 5.5.8**. Although a proportion of 'steel' and 'forestry' products carried by water, and 'steel' carried by rail may be associated with construction, these have been omitted from the analysis due to lack of information about the proportion of these used in construction.

The estimates for all construction-related transport are shown in **Table 5.22** and indicate that road, rail and water account for 91%, 6% and 3% of all construction materials lifted, respectively. In terms of goods moved (i.e. tonne-kilometres) road, rail and water are estimated to account for 82%, 15% and 2% of all construction materials moved in 2018, respectively. The total construction-related transport activity by all three modes is estimated to have accounted for approximately 29% of all goods lifted and 19% of all goods moved in Britain in 2018.

Table 5.22: Estimated goods lifted and moved related to the construction industry in Britain in 2018 by transport mode

Commodity group	Goods lifted			Goods moved		
	Tonnes (million)	% share by mode	% of all goods lifted by mode	Tonne-kilometres (billion)	% share by mode	% of all goods moved by mode
Road	429.8	91%	31%	31.0	82%	20%
Rail	28.7	6%	34%	5.7	15%	31%
Water	13.7	3%	14%	0.9	2%	4%
TOTAL	**471.8**	**100%**	**29%**	**37.6**	**100%**	**19%**

Source: calculated from data in Department for Transport, 2020e, 2020f; MDS Transmodal, 2019; ORR, 2020a.

Using the official road and rail freight data used in these estimates presented above, it is possible to compare the average length of haul of commodities moved by both modes. The results indicate the longer average distance over which bulk construction materials are moved by rail compared to road. Construction materials moved by rail had an average length of haul of 198 km in Britain in 2018. By comparison, the average length of haul for sand, stone and gravel moved by road was 65 km, cement, lime and plaster was 101km, construction waste was 73 km and plant equipment and scaffolding was 63 km. Construction products moved by road had longer average lengths of haul these denser, cheaper bulk materials (e.g. for metal products it was 119 km, and for glass and ceramic products 127 km). This indicates that rail is best suited to longer distance bulk construction transport and can outperform road in such circumstances, given the payload per train. It also indicates the relatively low distances involved when delivering goods to construction sites, an operation for which only road transport is suited in all but the largest construction projects (a few of which may have non-road connections available).

5.9 Worker and business travel to construction sites

In the case of large construction projects, workers commute to the site, either by public or private transport, depending on its location and parking facilities.

Business travel is also made by tradespeople (e.g. electricians, plumbers, plasterers etc.) as and when their skills are required on-site. In the case of small construction sites, these tradespeople typically make these journeys by van due to the tools and equipment they require and their need to move between sites during the working day. For those working on larger sites in dense, urban areas they may leave tools on-site overnight and travel by public transport.

Business journeys to construction site are also made by providers of professional services (e.g. architects, surveyors and engineers) both during the planning and design phase and during the construction phase. These journeys are made by van, car or public transport, depending on location.

Small builders carrying out small-scale construction projects (often extensions of residential properties) make daily commuting journeys to the site. These journeys are typically made by vans which the builder uses to transport personnel, tools and minor building materials.

5.10 Plant and equipment used on construction sites

Many different types of wheeled machinery are used on construction sites for a variety of purposes including materials handling, digging and excavating trenches, moving soil, dredging, tree cutting, demolition, levelling surfaces, making bore holes for precast piles, and pile driving. The use of such machinery depends on the size of the construction project and the tasks required. Such wheeled on-site equipment used on construction sites includes:

- Loaders
- Telehandlers
- Fork lifts
- Dump Trucks
- Tower Cranes
- Excavators
- Backhoe
- Bulldozers
- Graders
- Wheel Tractor Scraper
- Trenchers
- Pavers
- Compactors
- Feller Bunchers
- Pile Boring and Driving Machines

Other types of non-wheeled equipment and tools are also commonly used.

Plant and machinery used on construction sites can be sub-divided into five categories (Climate Neutral Group et al., 2019):

- Earth moving – including excavators and loaders
- Material handling – including cranes, telehandlers and fork lifts
- Power – including generators
- Access – including boom lifts and electric scissors
- Tools – including breakers and drills

The wheeled and heavier equipment is typically diesel-powered (with the exception of tower cranes which use electricity), while lighter access equipment and hand tools are usually powered by electricity. Larger on-site machinery is usually delivered to construction sites on flatbed and low-loader HGVs.

The vast majority of those working in the construction industry purchase their own tools outright. In terms of larger, more expensive equipment some construction companies with the necessary scale of operation purchase their own plant and equipment outright, while other smaller companies hire this equipment for specific projects.

In 2018 this rental market for construction equipment was estimated to have a total rental turnover in the EU-28 and EFTA countries of EUR 26 billion, of which rentals in the UK accounted for approximately 25% of this turnover, and with UK rental equipment having a value of £9.1 billion. The rental market for this equipment was estimated to account for 2.7% of the total value of the construction industry in the UK in 2018, which is almost double that across the entire EU-28 and EFTA countries (1.4%). This reflects the greater penetration of equipment rental in the UK (European Rental Association, 2019).

5.11 Construction logistics and its management

5.11.1 The importance of construction logistics

As discussed in **section 2.2** and **chapter 4**, many different building materials and products are required in construction, each of which has its own supply chain, from raw material extraction and processing, through to its use in a construction project. These materials and products pass through various facilities and are subject to various transportation legs before they arrive at a construction site. However, the focus of project designers and contractors is often on the construction project and the parties directly involved in building and working on it on its construction. As a result, insufficient attention is often given to the logistics management of these materials and products both along their supply chains and also their supply, storage and use at the construction site.

This is an important oversight from a construction project cost and efficiency perspective. The materials and products used in construction are often stated to account for 30-50% of the total construction costs (Caldas et al., Guerlain et al., 2019; Sveriges byggindustrier, 2015 quoted in Ekeskär, 2016a). This varies by type of project; it may be even higher in the case of large new-build projects with sophisticated engineering requirements, but will be less in the case of repairs and maintenance projects.

In addition, freight transport costs account for a substantial proportion of the total cost of many of these construction materials and products, and hence represent an important part of total construction costs. This is due to the relatively low values and the high bulk density of many of the materials used. One estimate suggested that freight transport may account for as much as 10-20% of total construction costs (Building Research Establishment, 2003), while American data indicates that despite construction-related products such as stone, clay and glass having shorter transport distances than any other product category (less than 100 km) their freight transport costs account for the highest proportion of total product cost (27%) of all product categories. Timber also has high transport costs relative to total cost (approximately 17.5%). By comparison, despite being transported far longer distances, clothing and electronic products (approximately 5%), and food (approximately 12.5%) have far lower transport costs as a proportion of total cost. As do primary and fabricated metals, which despite their bulk density have transport costs of approximately 7.5% of total costs, due to their value density (data from US Department of Commerce adapted by and quoted in Rodrigue, 2020).

To provide a worked example from the UK construction industry, if a rigid tipper delivered 20 tonnes of sand to a construction site 20 miles from the quarry (and then returns empty – a round trip distance of 40 miles) and has an operating cost (taking into account fixed and variable costs) of £2.50 per mile, then this transport operation would cost £100. If the sand is manufactured at a cost of £15 per tonne and retailed at a delivered cost of £40 per tonne, then the transport costs would represent approximately 30% of total delivered cost and 12.5% of the product price.

In another example, if a rigid concrete mixer delivers 6 cubic metres (approximately 14 tonnes) of material to a construction site 10 miles from the batching plant (and then returns empty – a round trip distance of 20 miles) and has an operating cost (taking into account fixed and variable costs) of £2.50 per mile, then this transport operation would cost £50. If the concrete has a manufactured cost of £35 per cubic metre and is sold at a price of £80 per cubic metre, then the transport costs would represent approximately 20% of the total delivered cost and 10% of the product price. This proportion does not include the transport costs upstream of the batching plant.

However, construction materials and products are typically sold with a ‘delivered’ price in which the cost of logistics and transportation are hidden within the price of the product, providing little scope to readily identify these costs, and hence the logistics efficiency.

Sullivan et al. (2010) provides a helpful example of the scale and complexity of the materials management and procurement challenges involved with a large construction site. An office development may well involve 30 contractor companies and 150 subcontractors, some of whom have sublet work to other companies. So, in total there may be 200 companies working on such a site, and there may be 200 or more suppliers providing products to such a project. The principal contractor and their main contractors may purchase some of these products directly from manufacturers, but many will likely be purchased by subcontractors using wholesalers and merchants who purchase from manufacturers. A single contractor, such as whoever is responsible for cladding the building, may purchase the product they require from several different sources (including steel frames, glass cladding panels, gaskets, brackets and may be having some of these assembled off-site by another supplier). Even the principal contractor will have no insight into the full range of suppliers being used by all contractors and subcontractors working on the site and will have no direct contractual relationship with the contractors lower down the project tiers.

Paying greater attention to the freight transport and logistics management of construction products along their supply chain, their provision to the construction site and their use on the site has the potential to yield substantial benefits in terms of project cost and productivity. This could be achieved through improved product purchasing (especially in the case of large principal contractors working on many projects at once), stock control and inventory management (both on-site and off-site), better management of product deliveries to and collections from construction sites (including the consolidation of loads onto vehicles which deliver them to site as and when they are required), decision-making concerning what should be assembled off- and on-site, and greater standardisation of project designs and products. In addition to reducing costs and improving productivity, such logistics management can also reduce the intensity and environmental and social impacts of the freight transport activity involved in construction.

5.11.2 Construction Logistics Management

The efficiency, productivity and environmental sustainability of a construction project depends on the logistics management of all the necessary activities: i) in the supply chain upstream of the construction site, ii) on the construction site, and iii) between the wider supply chain and the construction site. This requires planning, co-ordination and collaboration both within and between companies. Logistics management in construction involves a range of activities including:

- Resource assessment
- Lead time assessment
- Supply and demand planning
- Sourcing and procurement
- Production planning and scheduling
- Packaging and assembly
- Inventory management and order fulfilment
- Inbound and outbound transport management
- Warehousing
- Vehicle loading/unloading and vehicle design
- Materials handling
- On-site vehicle and plant management

- Customer services
- Waste management

As well as dealing with day-to-day issues as they arise, construction logistics management is dependent on putting in place advance planning before construction site work commences. This planning involves defining project stages and identifying the materials, products, plant, equipment and tools requirements associated with them.

In addition to being required between facilities in the construction supply chain, logistics management is also required on the construction site itself as this is a dangerous location with a constrained physical size, and within it materials need to be received, stored and allocated as required to avoid delays in construction activities (with them having to be moved around the site so that they are available in the correct location and quantity when needed in order that work can continue seamlessly); expensive plant, machinery and tools need to be maintained and secured overnight; and worker wellbeing needs to be managed to avoid workplace injuries occurring.

Traditionally, whilst the principal contractor has been nominally responsible for on-site supply chain and logistics management, they and the numerous sub-contractors working on a construction project have taken day-to-day responsibility for their own materials requirements and supplies, and for their on-site logistics activities. In this approach there is no nominated logistics organisation, and the site workers take responsibility for goods receipt, storage and materials handling as part of their job, deviating from construction activities to carry out these tasks. This frequently leads to inconsistencies, duplication and gaps in the provision of logistics activities on-site. A lack of strategic planning both on-site and in the wider supply chain for the site, leads to operational confusion on-site and logistics inefficiency which manifest. Given that many contractors and subcontractors only work on a project for part of its duration, this results in further lack of continuity in responsibility for on-site logistics activities, such as site layout, keeping working areas clear and waste management.

Often no budget has been set aside in construction projects for logistics activities and management, making it extremely difficult to implement logistics management practices and/or appoint a specialist logistics contractor to co-ordinate these. However, effective logistics management can help to reduce total construction project costs, keep projects to timescale and reduce the social and environmental impacts for which they are responsible. Cost reductions can be achieved via logistics management through:

- ensuring products and personnel are available on the construction site as and when required to prevent delays,

- reducing waste levels (through preventing over-ordering and the placement of incorrect orders),

- dealing with material and products deliveries to site promptly and efficiently,

- identifying incorrect deliveries as soon as they arrive on-site prior to unloading,

- planning appropriate storage locations for materials and products (either on- or off-site) to safeguard their quality and reduce the potential for damage and theft, and to maintain construction site cleanliness, ease of movement and safety

- and thereby reducing project overruns which can result in expensive contractual penalty clauses.

5.12 Vehicle delivery and collection operations at construction sites

Many construction sites, especially those in urban areas, have limited space availability for freight vehicles servicing the site (in terms of loading bays, materials handling equipment and vehicle manoeuvring). Sites are also typically constrained by the hours in which they can operate and receive vehicle arrivals due to planning constraints. On larger sites involving many contractors, without a contractor responsible for logistics management, vehicle arrivals can occur in an unplanned and chaotic fashion, with deliveries bunched into the morning hours and vehicles queuing on-street to make deliveries. In addition, contractors may arrange to have deliveries made in advance of when they are needed to ensure that products are on-site when required to prevent disruption to the work, but this takes up valuable storage space and requires the products to be handled and moved on- site more than is necessary. Depending on the site specifics, deliveries have to take place on-street if the site is too small to accommodate vehicles. Even when vehicle booking systems are in place at a construction site, urban traffic conditions may result in late running, creating further difficulties at the site.

Given the types of materials and products involved, some vehicle loads transported in the construction industry can be difficult and time-consuming the get onto and off of the vehicle, requiring material handling equipment. In addition, some loads required sheeting and securing with straps. Depending on the type of load, the unloading of materials from vehicles can make use of various types of material handling equipment including forklift trucks and cranes. Some vehicles are equipped with their own materials handling equipment or are able to mechanically tip their load, but for others without the necessary equipment this will need to be available on-site.

Relatively few studies have been carried out of freight transport operations at construction sites, presumably due to the lack of attention often given to the importance of transport and logistics to many in the construction industry. The findings of those studies that have been identified are provided below.

Data collection and analysis in a project that surveyed large eight construction sites in London for the vehicle deliveries and collections made at them (AECOM, 2017). A total of approximately 40,000 vehicle arrivals were collated. These eight sites received an average of 9-74 vehicle arrivals per day over the period they were surveyed. The data indicates that the peak period for vehicle arrivals at site is between 08:00 to 10:00. The proportion of unsuccessful deliveries at these sites ranged from 0-14% depending on site. These delivery failures were due to a variety of reasons including the vehicle not having been booked in prior to arrival (at sites where this was necessary), inappropriate or defective vehicles, drivers/vehicles being turned away due to lack of compliance with site requirements (such as the Fleet Operator Recognition Scheme – FORS, or not having the required Personal Protective Equipment) and vehicle drivers queueing to access the site who decided not to wait (AECOM, 2017).

These construction sites surveyed were at various stages of completion from site set-up and demolition, through to excavation and piling, as well as fit-out and completion. The extent of completion of the project will be reflected in the type of vehicles arriving at site. **Table 5.25** provides a breakdown of vehicle arrivals by type across all eight sites.

Table 5.26 shows the vehicle breakdown by construction site together with the phase of the site and vehicle activity. This indicates the prevalence of tipper vehicles, except during fit-out and commissioning phase (as are concrete mixers). Flatbeds are also commonly used, except during the set-up and demolition phase (AECOM, 2017).

Table 5.25: Vehicle types arriving at the construction sites

Type of goods vehicle	Proportion of all vehicle arrivals at the sites surveyed
Tipper	7-83%
Flatbed	1-54%
Concrete Mixer	0-43%
Box	0-27%
Tanker	0-23%
Curtainsider	0-8%
Refuse / skip	0-6%
Steel	0-4%
Low loader	0-3%
Dropside	0-3%
Truck with grabber/crane	0-2%
Other/ unclassified	0-11%

Source: AECOM, 2017.

Table 5.26: Vehicle types arriving at the construction sites, by site and phase

	Construction sites -number of site and construction phase							
Site number	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 6**	**Site 7**	**Site 8**	**Site 9**
Construction phase at site when surveyed	Excavation & piling	Excavation & piling	Sub-structure	Set-up & demolition	Fit-out & commissioning	Set-up & demolition	Fit-out & commissioning	Excavation & piling
Vehicle arrivals per day	38	74	53	51	11	9	21	50
Type of goods vehicle arriving								
Tipper	83%	35%	64%	41%	8%	17%	7%	28%
Flatbed	5%	20%	15%	8%	54%	1%	48%	5%
Concrete Mixer	3%	20%	0%	26%	0%	43%	6%	43%
Box	0%	4%	9%	20%	13%	20%	27%	7%
Tanker	1%	1%	0%	2%	23%	1%	2%	1%
Curtainsider	3%	4%	0%	1%	2%	5%	3%	8%
Refuse / skip	1%	6%	0%	1%	0%	3%	2%	4%
Steel	0%	0%	0%	0%	0%	0%	1%	4%
Low loader	0%	0%	0%	0%	0%	1%	3%	1%
Dropside	3%	2%	0%	0%	0%	0%	0%	0%
Truck with grabber/crane	0%	2%	0%	1%	0%	2%	0%	0%
Other/ unclassified	3%	7%	11%	1%	0%	7%	0%	0%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: AECOM, 2017.

Ten small construction sites, each with five or fewer vehicle arrivals per day were also surveyed in this research. This showed that across all ten sites, the importance of different types of goods vehicle were as follows: flatbeds: 22% of vehicle arrivals, box trucks – 22%, tippers – 14%, flatbeds, - 14%, tankers – 14%, concrete mixers – 7% and vehicles with grabbers / cranes – 7% (AECOM, 2017).

Interviews with logistics and freight transport companies who make deliveries to major construction sites sought their rankings on how well deliveries were typically managed at these sites. The answers provided by respondents contained variability. However, despite respondents reporting that deliveries were typically successful (i.e. delivered), half reported that waiting arrangements and waiting time before entry to the construction site was granted were poorly managed. Some reported a lack of provision of vehicle holding areas and poor management of dwell times when the vehicle had gained access to the site. The overwhelming majority of respondents also noted the difficulty of manoeuvring vehicles on the construction site. Half the respondents also reported having been turned away from construction sites when trying to make deliveries, reasons for this included the site not being ready to receive the delivery and too many vehicles already waiting to make deliveries (AECOM, 2017).

A study took place of vehicles delivering to and collecting from a major construction project at a university in central Auckland, New Zealand which involved the building of 13 storey tower block with lecture theatre and integrating several existing buildings on campus (Ying et al., 2014). The construction comprised three phases: ground works, structure, and fit-out. A total of 6,300 vehicle arrivals at the site were recorded over the 58-week duration of the project, with these vehicles despatched by 257 different companies. However, one of these companies (delivering ready-mix concrete accounted for 15% of all vehicle arrivals at the site, and they and four other companies accounted for approximately 35% of all vehicle arrivals (Ying et al., 2018). Two-thirds of these vehicle arrival took place before midday, and 08:00-11:00 being the busiest period. The vast majority of these vehicles (87%) were delivering materials or equipment to the site rather than collecting (waste or other products), and approximately 70% of these vehicles were running empty when they left the site. The split between vehicles delivering materials and collecting materials (i.e. not including plant and equipment) the ratio was 4:1. Only 7% of vehicles visiting the site both unloaded and loaded during their visit. During the ground works and structure phases, three quarters of the vehicles were classified as heavy (with more than three axles) and one-quarter light vehicles. During the fit-out stage, the proportion of light vehicles rose to 40% of the total, corresponding with the smaller delivery loads received during that phase. Very large vehicles (more than 11.5m long with three to six axles) accounted for 1% of vehicle arrivals over the entire project. The work found that the principal contractor and sub-contractors working on the project paid little attention to logistics management and vehicle movements (Ying et al., 2014). Analysis of the origin of the vehicle journeys from depot locations indicated that 10% of vehicles had journeys of up to 10 km to the site, 55% of vehicles had journeys of 11–20 km, 9% had journeys of 21-30 km, and 9% had journeys of more than 30 km to the site. The total vehicle journeys to the site over the course of the project were estimated to have generated 220,000 km (Ying et al., 2018).

A questionnaire among 30 managers and directors in five principal contractors investigated transport and logistics management practices on the construction projects they were currently working on (the vast majority of which were in France) (Dakhli and Lafhaj, 2018). Almost half of the respondents reported that delivery delays to construction sites were common, and these were most frequently experienced in Paris where traffic levels are greatest. In addition, the vast majority of respondents reported constrained site sizes in Paris, making vehicle deliveries difficult to deal with. Approximately 65% of respondents noted storage problems on site due to space constraints, with 60% reporting that storage problems were dealt with as they arose rather than planned for in advance. Twenty five percent of respondents estimated that up to 5% of construction products were damaged or stolen on site, while approximately 40% of respondents estimated this to be 6-10% of products, and another 35% of respondents providing an estimate above 10%. Half of respondents graded the storage management of subcontractors as bad or very bad. Almost half of the respondents were not familiar with the concept of consolidated deliveries in which related but separate products and components are delivered to site as a single unit (Dakhli and Lafhaj, 2018).

5.13 Vehicle delivery and collection operations at quarries

One UK project carried out in 2010 has investigated the types of road transport vehicles used at quarries and their operations. Survey work was carried out with thirteen quarry operators in the UK. Four types of quarries were included: (i) sand and gravel, (ii) sandstone and gritstone, (iii) igneous and metamorphic rock, and (iv) limestone (Brighton and Richards, 2010).

This research found that material transport systems used were either mechanical conveyors or dump trucks (with capacities from 20 to 90 tonnes). The type of on-site transport system used depended on the material being quarried. All of the respondents operated their own in-quarry equipment. Approximately 70% of quarry operators surveyed operated their own road transport fleet, while the other 30% used third-party hauliers to transport their materials. Road transport was carried out by both rigid and articulated vehicles with tipper bodies. Across all respondents, rigid vehicles were responsible for transporting approximately 70% of the aggregates transported and articulated vehicles for 30%. The rigid vehicles had carrying capacities of 7 to 20 tonnes. The articulated vehicles had capacities of 20 to 30 tonnes. The rigid vehicles travelled 20,000 to 80,000 km per year with a mean annual distance of 47,000 km, while the articulated vehicle travelled 46,000 to 100,000 km per year, with a mean annual distance of 68,000 km (Brighton and Richards, 2010).

6. Negative impacts of construction and construction logistics

6.1 Introduction

The construction industry is responsible for a variety of negative environmental and social impacts. These arise at various points along the construction supply chain from quarries, to product processing plants and factories, to construction sites, and at waste disposal and reprocessing facilities, as well as during the various stages of transport that link these locations together and move products between them.

These negative impacts that arise in production processes and at sites in the construction supply chain include:

- CO_2 emissions and resource depletion from the production of construction materials and the use of on-site machinery and tools
- Workplace injuries and deaths
- Local air pollution and dust arising from these activities at quarries, factories, waste plants and construction sites
- Other local impacts at these locations including noise disturbance and vibration, visual intrusion, soil and water contamination, water use, land use change and habitat loss at the construction site

The freight transport activity required to provide the flow of materials between these locations imposes a range of impacts that include:

- Contribution to road traffic levels which is linked to several impacts
- CO_2 emissions from the use of fossil-fuelled freight transport operations
- Exhaust emissions and braking from road goods vehicles resulting in local air pollution and health impacts
- Injuries and deaths to other road users especially cyclists and pedestrians
- Additional health and safety risks for other road users, especially cyclists and pedestrians, together with travel disruption
- Airborne dust emanating from the load being transported and vehicle body during loading and travel and debris (including mud and dust) being deposited on the highway and increasing road risk for other users
- Noise and vibration from the vehicle engine and from the vehicle body/chassis
- Damage to public highways and footways, and the repairs and disruption this results in
- Road closures, one-way systems, temporary traffic lights at/near construction sites and the displaced traffic resulting from construction site operations

While the contribution of construction transport to road traffic levels in the list above is not in itself an impact it is related to all the other transport impacts listed, with the distance travelled by goods vehicles, all other things being equal, leading to increases in the occurrence of them.

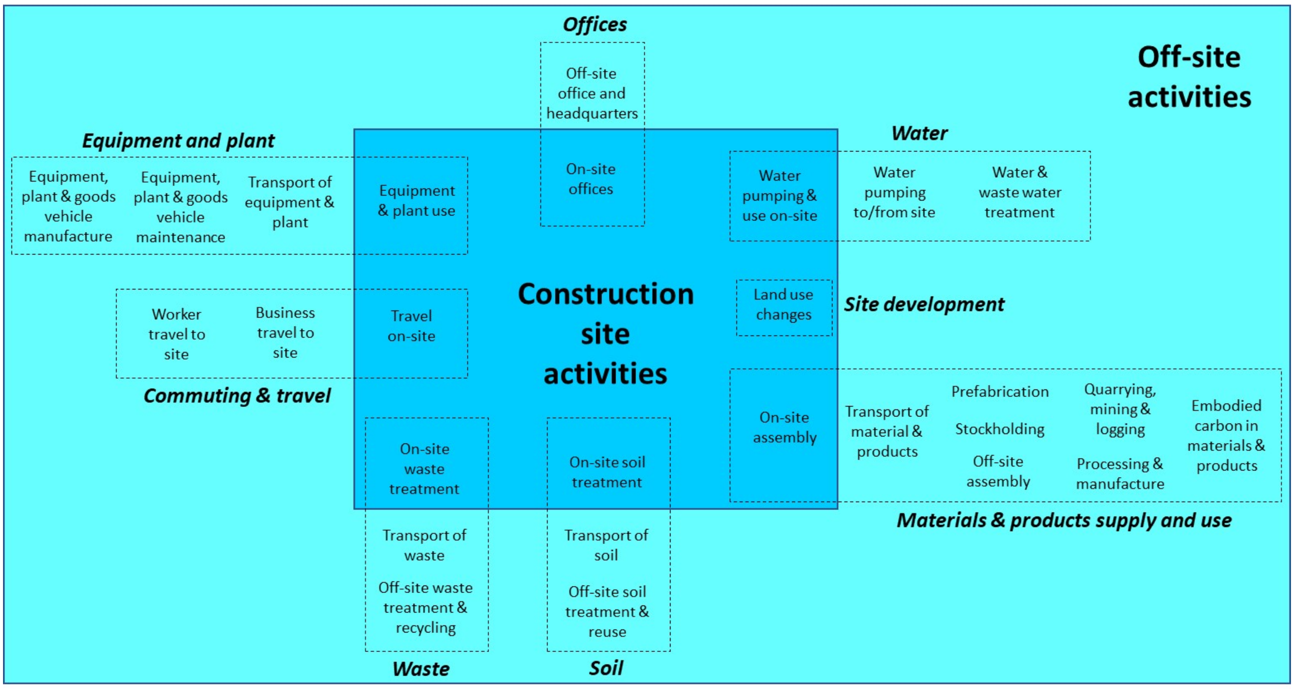
Given that road transport is by far the most commonly used mode for the movement of construction materials, it is road-based goods vehicles that are the predominant source of these transport-related impacts. In all but a handful of cases, the only transport mode available at construction sites is road.

These transport-related impacts occur: (i) on the road network as vehicles travel between sites, (ii) at the interface point between the road network and the construction site (as vehicles enter and leave the site, or unload from the kerbside on the public highway, and (iii) on-site when vehicles enter quarries and construction sites to collect and deliver loads.

Although these impacts imposed by the construction industry arise at all stages in the construction supply chain from quarry to construction site, the effect of local impacts are greatest at construction sites as these are commonly located in busy, urban areas with large numbers of people living and working nearby and which are passed by many people travelling around towns and cities in the course of their daily lives.

Figure 6.1 indicates the activities associated with construction sites both on- and off-site that impose these negative impacts, including the commuting and travel that takes place by construction site workers commuting to site and others traveling there for business such as architects, engineers and planners.

Figure 6.1: Processes related to construction projects that result in impacts



Source: adapted from Ove Arup, 2010b.

6.2 Greenhouse Gas Emissions from the Construction Industry

This section discusses the Greenhouse Gas (GHG) emissions associated with the construction industry taking account of the various activities including transport that are responsible for these emissions.

The UK construction industry accounted for 6.5% of UK economic output in 2019 but is estimated to be responsible for 10-11% of the UK's greenhouse gas (GHG) emissions (ONS, 2021a; Low Carbon Construction Innovation & Growth Team, 2010; National Engineering Policy Centre, 2021). In total, the built environment account for approximately 40% of UK energy consumption and 19% of UK GHG emissions (HM Government, 2018b). The UK government and the construction industry, via the Construction Leadership Council, set a target in 2013 of a 50% reduction in GHG emissions in the built environment by 2025, and reiterated this pledge in 2018 (HM Government, 2013; HM Government, 2018b).

Greenhouse gas emissions arise from several aspects of construction, including the processing and production of the building materials and products used, the activities carried out at the construction site during the building phase, the freight transport and logistics operations required to move these materials and products in the construction supply chain and deliver them to site as well as removing and transporting waste, and the personal travel associated with the site.

In addition to the greenhouse gas emissions from the various products and activities associated with construction, the building or infrastructure will also use energy during its operational life which has further GHG implications. The GHG emissions associated with building use are influenced by the materials and products used, the building design and its construction methods. So, construction is also an extremely important factor in the lifetime GHG emissions of a building.

This chapter considers the various materials and products used and their processing, the plant and machinery used on construction sites and the goods vehicles that transport materials in the construction supply chain that together result in GHG emissions in the construction industry.

6.2.1 Construction materials and products

The construction industry is a major consumer of raw materials and manufactured products. It has been estimated that, globally construction is responsible for more resources and raw materials than any other activity, annually using approximately three billion tonnes of raw materials to construct buildings and other infrastructure (World Economic Forum and the Boston Consulting Group, 2016). The quantity of construction materials used annually in the UK has been reviewed in **chapter 3**.

The production of construction materials results in GHG emissions. These emissions arise from the equipment used to excavate, dredge, and, in the case of plant-based products, harvest them; from the processes involved in their preparation, especially the use of heat, and from their transportation.

A key source of carbon emissions in the production of construction materials arises from the combustion of fossil fuels used in the heating processes required. For instance, bricks are usually made from clay or shale mixed with water that is fired in a kiln; cement is typically made by heating limestone with other materials to very high temperatures in a kiln and then mixing this with a small quantity of gypsum; steel is made by heating iron ore using coke and coal and melting it at very high temperatures in a furnace, obtaining the correct carbon content and removing the impurities; glass is made from a combination of sand and other minerals that are melted together in a furnace and then shaped and cooled. The heating processes used in all the construction products typically use fossil fuels given the very high temperatures required.

Even many naturally occurring materials used in construction require some preparation or treatment before their use in a structural application. For instance, trees require felling, debarking, sawing and treating, while stone requires quarrying, cutting into slabs, calibrating and polishing.

An analysis of CO_2 emissions associated with construction in the UK that also took account of project design, construction site activities, and the transportation of products and waste estimated, that the manufacture of materials and products used in construction accounted for 86% of CO_2 emissions in the construction supply chain (BIS, 2010).

The following sub-sectors discuss the energy use and CO_2 emissions of the key sectors in construction materials and products.

Cement, concrete and aggregates

Cement and concrete are used in construction to bind other materials together. Concrete is made by mixing cement with aggregates such as sand and crushed stone with water. Concrete is the most widely used construction material in the world, with over 10 billion tonnes used each year (Timperley, 2018). Almost all concrete used today is produced from so-called Portland cement, also called Portland clinker, of which 4 billion tonnes are produced each year (Lehne and Preston, 2018). In order to produce this clinker, pulverised limestone is heated at high temperatures (about 1450 degrees centigrade) to produce lime which then reacts with the other constituents from the raw material to form new minerals, collectively called clinker (WSP et al., 2015a). This process results in the release of waste carbon dioxide. Whereas the heat used in producing cement (and metal and glass products) can potentially be provided by electricity from renewable sources, the carbon dioxide released when limescale is heated cannot be eliminated by changing the source of the heating fuel. The clinker is then ground with gypsum to a fine powder which forms cement. It can be stored dry in silos for long periods and has a higher value than aggregates such as sand and gravel, allowing it to be profitably traded internationally and shipped over longer distances (Office of Fair Trading, 2011).

In the case of cement (and therefore concrete), the ratio of carbon emitted from process arising from this chemical reaction, compared to carbon emissions from burning fossil fuels to heat kilns to the high temperatures required is approximately 55:45 (Timperley, 2018). The combination of these chemical and heating processes involved in the production of cement have been estimated to account for approximately 8% of annual global CO_2 emissions (Olivier et al., 2016). Globally, the average CO_2 intensity of cement production reduced by 18% between 1990 and 2014 through energy efficiency, fuel and product substitution. However, these reductions were more than offset by increases in cement production and demand, resulting in approximately a 50% in global cement production carbon over the same period (Lehne and Preston, 2018).

It has been noted that cement and concrete have smaller CO_2 and other environmental impacts per kilogramme than metals. However, the volume of concreate used is far larger and therefore its total environmental consequences are also substantial (OECD, 2020).

In the UK, in 2013 a production of 11.6 million tonnes of cement resulted in 6 million tonnes of CO_2 emissions (WSP et al., 2015a). There were 702 kg of direct CO_2 emissions per tonne of cement produced in the UK in 2019 (Mineral Products Association, 2020a), 70% of which arose from the calcination process, 25% from the combustion of fossil fuels and 5% from electricity use (Mineral Products Association, 2020b). Direct emissions of CO_2 per tonne of Portland Cement from the UK cement industry were 25% lower in 2018 than in 1998 (Mineral Products Association, 2020c).

Several studies have considered the contribution that transportation operations in the production of cement and concrete make to the total carbon emissions. These transport operations include the provision of raw materials including limestone to cement plants, the distribution of cement to the wholesale market and to concrete batching plants, and the final delivery of ready-mix (RMX) concrete to construction sites. One study of cement estimated that about 10% of the product's total carbon emissions come from the diesel-powered machinery used to mine and transport the materials (Timperley, 2018). Another study indicates that UK concrete production resulted in 72.1 kg CO_2 per tonne in 2018, while all transport activities produced 8.9 kg CO_2 per tonne, a ratio of 89%:11% (Sustainable Concrete Forum, 2020).

A study of the emissions from concrete production in China, which takes account of all transport stages as well as the disposal of concrete from end-of-life buildings, which involves breaking it into smaller pieces using crushing equipment before transporting it for either reuse, recycling or landfill, estimated that in total, transport accounted for 12.5% of the CO_2 emissions (Cao, et al., 2021).

Cement production is expected to increase, with the worldwide building floor forecast to double over the next 40 years, which is equivalent to adding the total building floor area of Japan to the planet every year to 2060 (UN Environment and IEA, 2017).

In addition to the CO_2 emissions associated with cement/concrete, other construction materials that require excavation and processing/crushing (such as crushed rock, gravel and sand, asphalt, and stone) also result in CO_2 emissions. These excavation and processing activities include (Hill et al., 2012):

- Blasting and drilling (to loosen rock into a form where it can be handled, and to break it into
- appropriately sized particle)

- On-site loading and movement (moving the blasted rock from the face to the crushing plant, using a loader to place it in a truck or conveyor by which it can be moved to the crushing and screening facility. Conveyors are more energy efficient, but less flexible).

- Crushing and screening (to produce products of various standard particle size)

CO_2 emissions from selected materials produced in the UK in 2019 that were used in the construction industry are shown in **Table 6.1**. This includes all the activities involved in which emissions arise including drilling, blasting, heating, crushing, transfer and conveying at quarries, screening and loading and storing. With the exception of cement, the emissions for these materials are mostly associated with the machinery used in excavation and processing. Unlike cement, the other materials do not require heating at high temperatures and do not themselves release CO_2 during processing. Therefore, their CO_2 emissions are far lower than for cement.

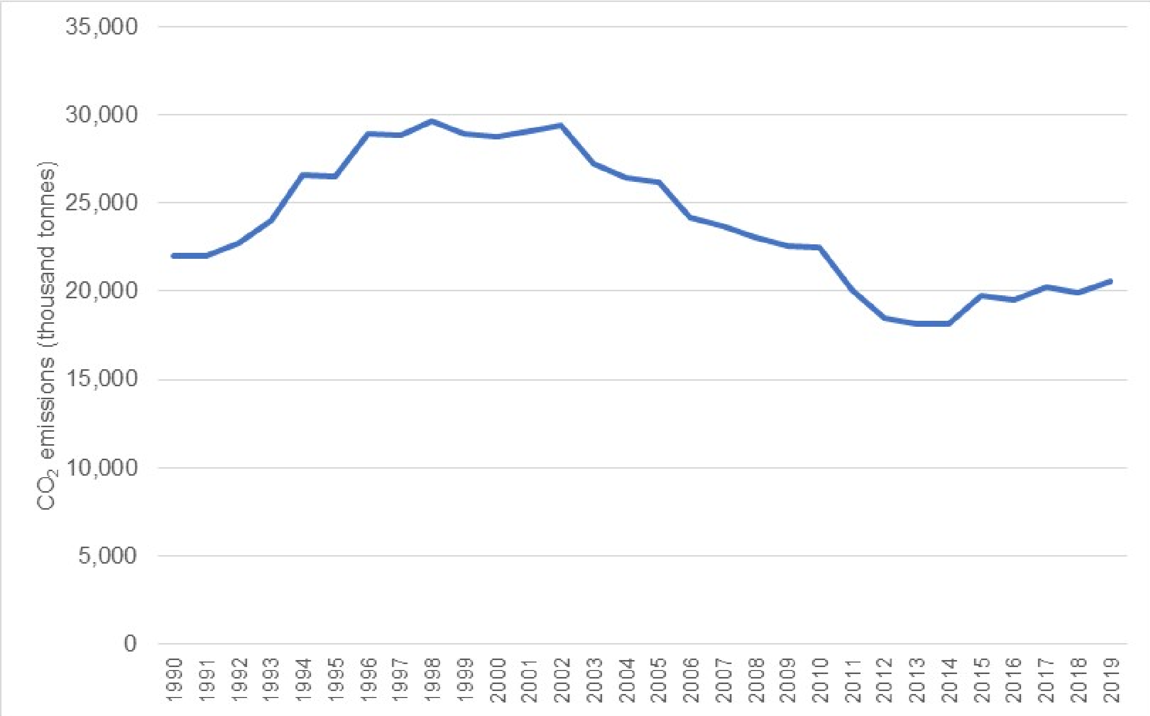
Table 6.1: CO_2 emissions from excavated materials produced in the UK in 2019

Material	CO_2 emissions (kg/tonne)
Cement	702
Crushed rock production	3.3
Sand and gravel- land won	2.3
Asphalt production	2.2

Source: Mineral Products Association, 2020a.

Figure 6.2 shows the total CO_2 emissions from mining and quarrying in the UK since 1990 (this includes extraction and processing activities). This illustrates the extent of reductions in CO_2 emissions between 1990 and 2013 (of approximately 20%) since when it has stabilised. This is mostly due to the reduction in emissions related to cement production discussed above.

Figure 6.2: CO_2 emissions from UK mining and quarrying, 1990-2019



Source: BEIS, 2020e.

Far less work has been carried out into the relative importance of freight transport in the supply of aggregates, which do not involve the industrial heating processes required for cement and concrete production. However, one study estimated that in the case of aggregates supplied for use in concrete production in China, the transportation of limestone and other inputs accounted for 8.0% of total concrete CO_2 emissions, while aggregates production accounted for only 1.7%, indicating that four times as much carbon was emitted from limestone and other aggregates transport than from its extraction and preparation prior to transport to a cement plant (Cao, et al., 2021).

Data provided by the Mineral Products Association in **Table 6.1** for CO_2 emissions from aggregates production in the UK, together with UK data previously cited from the Sustainable Concrete Forum for transport CO_2 emissions in concrete supply, both indicate that, in the case of aggregates, freight transport emissions are likely to exceed production-related emissions.

Iron and steel products

Steel and iron products are used in many applications in construction, automotive, heavy machinery, packaging and appliances, mechanical engineering, and energy industries. However, the construction industry is a key user, it has been estimated that, globally, construction is responsible for approximately 50% of steel production (World Steel Association, 2020a).

Steel production accounts for 7-9% of global carbon dioxide emissions (World Steel Association, 2020b). While the energy intensity of steel has gradually reduced since 2009, increased steel production has resulted in increased energy demand and CO_2 emissions (IEA, 2020). The iron and steel industry is one of the biggest industrial emitters of CO_2 in the UK, accounting for 23 million tonnes of CO_2 emissions in 2013 for a production of 12 million tonnes of steel (WSP et al., 2015b). These emissions come from the process-related emissions from coal combustion, the direct emissions from on-site combustion of fossil fuels and the indirect emissions from electricity consumed during the production process (WSP et al., 2015b).

Traditionally, steel is produced using a blast furnace using iron ore and requiring coal as a reductant. This remains the most widespread method for making steel. Temperatures of up to 1700 degrees centigrade are required (WSP et al., 2015b). The equipment used in steel production has a long replacement cycle. Some of the traditional blast furnaces in the UK have been in operation for 60 to 70 years (WSP et al., 2015b).

Glass

Glass is made from sand and other minerals melted together at very high temperatures (approximately 1500 degrees centigrade). It is used to for a wide range of applications including container glass (bottles and jars), flat glass (windows for the construction and automotive industries), domestic glass (tumblers, wine glasses and decorative glass), glass fibre (used for building insulation, glass wool, textiles, and the reinforcement of plastics), optical fibre (used for optic cables for telecommunication), glass tubing (used for scientific instruments and lighting), and lamp and light bulb manufacture (WSP et al., 2015c). Container glass accounts for the greatest consumption (about 60%) followed by flat glass (about 30%) and fibre glass (about 10%) (BEIS and British Glass, 2017).

Three million tonne of glass production in the UK resulted in 2.2 million tonnes of CO_2 emissions in 2012 (British Glass, 2014). These emissions come from fossil fuel combustion and the decomposition of carbonate raw material in the furnace (i.e. process emissions from sodium carbonate, limestone and dolomite) and from electricity use. The melting furnace accounts for about three quarters of total energy consumption in a typical UK glass plant. Natural gas account for 81% of this energy use in 2013, followed by electricity use (13%) and other fossil fuels (6%) (British Glass, 2014). Between 1979 and 2008, furnace energy efficiency improved by 54%, however improvements after 1996 were far less than those before (WSP et al., 2015c). The melting furnace accounts for about 75-85% of these CO_2 emissions and the decomposition of carbonates for the remaining 15-25% of CO_2 emissions (Glass Alliance Europe, 2019). Glass furnaces have replacement cycles of approximately 10-20 years (WSP et al., 2015c). Glass is a recyclable product and recycling rates in the UK have risen in recent years, especially in the glass container sector. However, most glass waste arising from buildings currently either ends up in landfill sites or is used as aggregate.

Ceramics

The ceramics sector manufactures a wide range of products used in construction including bricks, roof tiles, wall tiles, drainage pipes and sanitary ware, as well as other products purchased by households including tableware and giftware.

Ceramics production is energy intensive, with gas accounting for approximately 80% of the overall energy use. Total CO_2 emissions in 2012 were 1.2 million tonnes (BEIS and British Ceramic Confederation, 2017).

Imported construction products

It should be noted that many products used in the UK construction industry are manufactured overseas and then imported (see **section 4.4**). In the case of such products, the CO2 emissions associated with their production are not included in UK Government data for the UK manufacturing industries. If the CO_2 emissions related to the production and supply of these products was included it would result in the CO_2 emissions of the UK construction industry being calculated to be even greater than it otherwise is.

6.2.2 Plant and machinery used on construction sites

Construction also involves the use of much plant and machinery both on-site where the construction activity is taking place and also to transport the building materials, machinery and waste products to and from construction sites. The range of plant and machinery used on construction sites has been discussed in **section 5.10**. The vast majority of heavy, wheeled plant and machinery used in construction for digging, loading, moulding, sheet piling and transportation on-site are diesel-powered, while hand tools, tower cranes and some access equipment such as boom lifts use electricity (Bellona, 2018; Climate Neutral Group, 2019).

The CO_2 emissions of using heavy plant and machinery in construction depends on several key factors: (i) its utilisation (i.e. how much it is used during its life), (ii) its energy consumption per hour, (iii) the efficiency with which and distance over which it is transported between construction sites, and (iv) the disposal method at the end of its life (i.e. the extent to which it is recycled or not) (Climate Neutral Group, 2019).

A study has shown that inefficient use of such equipment (in terms of its utilisation, transport between sites, and lack of recycling) results in substantial increases in CO_2 emissions. In the case of a mini-excavator and telehandler, this research estimated that inefficient use resulted in approximately 90-100% more CO_2 emissions per hour over the life, while for a generator and a mast boom lift inefficient use was estimated to resulted approximately 25% and 200% more CO2 emissions respectively (Climate Neutral Group, 2019).

In Oslo it has been estimated that machinery (including road vehicles) associated with construction sites account for 7% of the city's GHG emissions, and 30% of the city's transport GHG emissions (DNV GL Energy, 2019; City of Oslo, 2021).

An analysis of CO_2 emissions associated with construction in the UK that also took account of the production of materials, project design, and the transportation of products and waste, estimated that the operations taking place on construction sites accounted for 6% of CO_2 emissions in the construction supply chain (BIS, 2010).

Another UK study that analysed construction CO_2 emissions, but which did not take account of the production of materials, estimated that the plant and machinery used on construction sites together with energy use by on-site offices accounted for 41% of CO_2 emissions in the construction supply chain (Ove Arup, 2010a).

The Climate Change Committee has estimated that approximately 6 million tonnes of CO_2e were emitted in the UK in 2018 by plant and machinery used on construction sites for buildings and infrastructure projects and on mining and quarrying sites, which was equivalent to approximately 1-1.5% of total UK GHG emissions. Plant and machinery used on construction sites accounted for approximately 85% of these GHG emissions with those used in quarrying and mining responsible for the remainder (Climate Change Committee, 2020a).

6.2.3 Emissions from freight transport construction operations

Road, rail and water transport are used to distribute construction materials and products between all the facilities in the construction supply chain, as well as to dispose of waste products arising from construction sites, with road being the most commonly used mode. A wide range of different types of goods vehicles are used to transport these goods (see **section 5.5.1** for further details).

It has been estimated that the transport of primary minerals is responsible for approximately 40% of the energy consumed by the minerals industry and that this figure is likely to be even higher for aggregates (Mankelow et al., 2010). Modelling work has indicated that the use of rail rather than road to distribute 15 million tonnes of aggregates from UK quarries to rail depots would result in an 85% reduction in transport-related CO_2 emissions, equivalent to 263,337 tonnes of CO_2 per annum as well as reduced damage to local roads (Mankelow et al., 2010).

An analysis of CO_2 emissions associated with construction in the UK that also took account of the production of materials, project design and construction site activities, estimated that the transport of materials and products accounted for 6% of CO_2 emissions in the construction supply chain. In addition, waste, demolition and refurbishment activities which are heavily transport-intensive, accounted for 2% of CO_2 emissions (BIS, 2010).

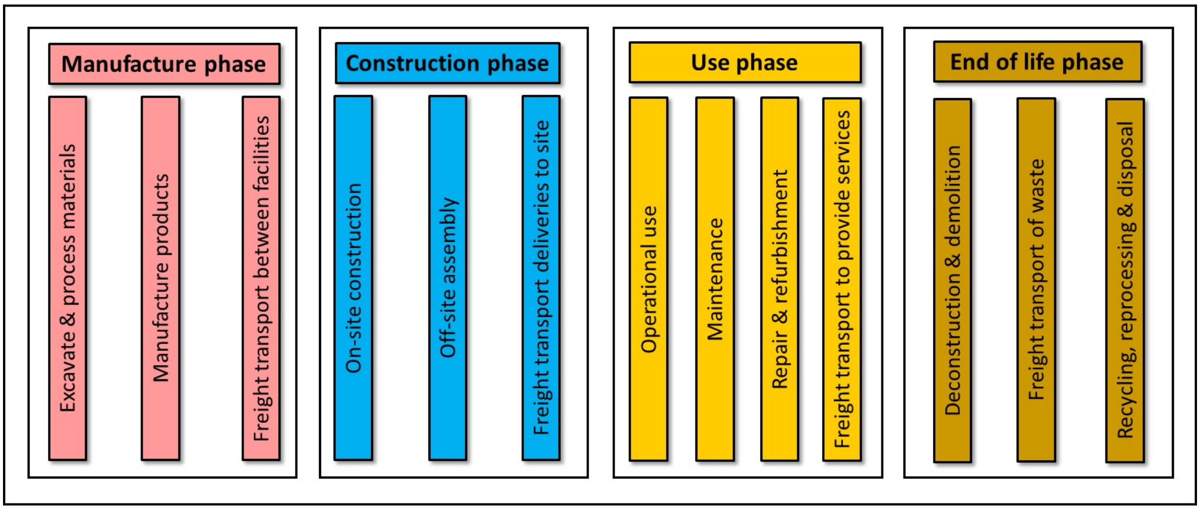
Another UK study that analysed construction CO2 emissions, but which did not take account of the production of materials, estimated that freight transport of building materials from factory or point of extraction to construction sites accounted for 37% of CO_2 emissions in the construction supply chain, while waste removals from sites by freight transport accounted for 12% (Ove Arup, 2010a).

6.2.4 Embodied and whole of life energy use and GHG emissions

The energy use and associated GHG emissions discussed in the previous sub-sections of **section 6.2**, that arise from the manufacture of construction products, the activities that take place on construction sites, and the freight transport used to deliver these products and remove waste from construction sites, are often not taken account of when policy makers assess the energy efficiency and carbon emissions of buildings and set targets associated with carbon emission reduction. Instead, such targets often only address the energy used during the operational life of the building. Even then, such assessments often omit the energy and emissions associated with the maintenance and refurbishment required during the life of the building.

Proper consideration of the energy efficiency and carbon emissions of buildings and infrastructure involves taking account of the energy used to construct it, as well as to dispose of it at the end of its operational life. This is referred to as ‘embodied’ energy and emissions. **Figure 6.3** shows all the phases and activities in the life of a building or other infrastructure that affect the total energy use and carbon emissions of a building or other infrastructure.

Figure 6.3: Phases in the life of a building or infrastructure that generate energy use and carbon emissions



The manufacture, construction and end of life phases (i.e. those associated with embodied energy and emissions) are likely to be more difficult to decarbonise than the operational use of buildings and other infrastructure due to the fossil- fuels used in blast furnaces, the carbon release from the production of cement, and the use of diesel-fuelled vehicles and machinery to transport these materials and carry out on-site activities. These are more difficult to provide alternative clean technologies for that are financially viable than is the case for the heating, cooling and lighting of buildings and other infrastructure.

Given the demand for new buildings and infrastructure globally, together with efforts to reduce energy use and emissions during their operational life, it is estimated that carbon emissions in the manufacture and construction phases will be responsible for half of the entire carbon emissions of new construction up to 2050 (World Green Building Council, 2019).

However, assessing the embodied carbon emissions of the construction is not required by current UK Government policy (Environmental Audit Committee, 2021).

As well as considering the embodied energy in building materials and the activities involved in construction, it is also important to consider how these materials and processes will affect the energy requirements of the building when it is operational. It is therefore necessary to consider both how to increase the use of low-carbon building materials in terms of their embodied emissions and their contribution to energy requirements during the operational life new buildings. Lower-carbon building can be achieved by various means including the use of low-carbon resources such as wood and other natural materials rather than steel and concrete as well as designing building so as to require as few resources as possible.

It was estimated that in 2008 operational use accounted for 83% of the CO_2 emissions associated with buildings in the UK, compared with 17% being associated with embodied CO_2 emissions (BIS, 2010). However, decisions made in the construction design phase about which materials to use and the layout of the building have a crucial bearing on the operational energy use.

In 2019, while the buildings construction industry accounted for approximately 10% of total global energy-related CO_2 emissions, the operation of residential and commercial buildings (i.e. after building has been completed and these buildings are used) is estimated to have accounted for 28% of total global energy-related CO_2 emissions (United Nations Environment Programme, 2020). It is estimated that in the UK in 2019, direct GHG emissions from buildings (i.e. not taking account of electricity use) accounted for 87 million tonnes of CO2e, 17% of UK GHG emissions, with these emissions mainly arising from fossil fuels used for heating and three-quarters of this need being met by natural gas. Homes were responsible for 77% of these emissions, commercial buildings for 14%, and public buildings for 9%. Buildings were responsible for 59% of UK electricity consumption in 2019, which was equivalent to a further 31 million tonnes of CO_2e of indirect emissions (with this electricity mostly used for powering appliances and lighting in residential buildings, and for cooling, catering and ICT equipment in non-residential buildings (Climate Change Committee, 2020b).

6.2.5 Total CO_2 emissions from the construction industry

Estimates suggest that the construction industry currently accounts for approximately 10-11% of total global energy-related CO_2 emissions (National Engineering Policy Centre (2021; United Nations Environment Programme, 2020; World Green Building Council, 2019).

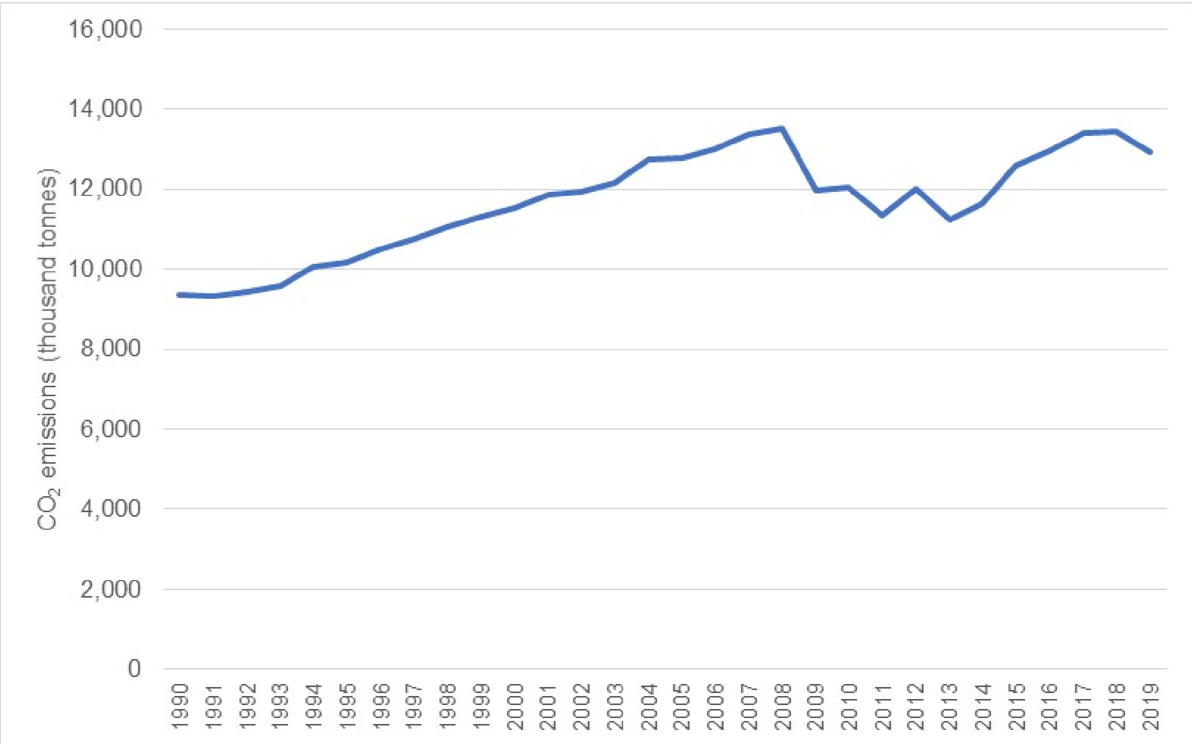
In the EU-27 the construction products and associated construction works are estimated to have accounted for 699 kg CO_2 per capita in 2018 which was equivalent to 11% of all CO_2 emissions, the second highest product type (after electricity, gas, steam and air conditioning which accounted for 11%) (Eurostat, 2020).

The GHG emissions of construction companies based in the UK were 41% higher in 2019 than they were in 1990. Of other industrial sectors that are important emitters of GHG emissions, only transport, and wholesaling and retailing rose at similar rates, rising by 28% and 41% respectively over this period. All other industrial sectors that are major emitters saw falls in GHGs over this period. However, the rate of increase in GHG emissions from these construction company has slowed in recent years, increasing by 2% between 2015 and 2019 (ONS, 2020b).

In the UK, a 2010 report estimated that construction accounted for 10% of the UK's CO_2 emissions, 8% of which was due to the manufacturing of construction materials and 2% of which was due to other construction-related activities (namely on-site operations, transport of materials, design and the removal of construction waste) (Low Carbon Construction Innovation & Growth Team, 2010).

Figure 6.4 shows the total estimated CO_2 emissions from construction in the UK since 1990 (this is based on the activities of construction companies so does not include the manufacture of materials and products used in construction). UK construction CO_2 emissions were approximately 40% higher in 2019 than in 1990. These emissions can be seen to be linked to the scale of construction activity, falling with the onset of the economic downturn in 2008, and then beginning to rise again from 2014.

Figure 6.4: CO_2 emissions from UK construction, 1990-2019



Source: BEIS, 2020e.

In 2010, it was also estimated by the UK government that the construction industry accounted for 10% of UK carbon emissions (8% of which was due to manufacturing construction materials and 2% of which was due to other construction-related activities (namely on-site operations, transport of materials, design and the removal of construction waste) (Low Carbon Construction Innovation and Growth Team, 2010).

Further work in the UK at this time using official data and data provided by major construction companies provided an estimated breakdown of CO_2 emissions between sources of energy use in construction. The analysis subdivided activities associated with construction sites into: on-site activities (the use of plant and ancillary equipment and powering site accommodation), freight transport of building materials (from factory or point of extraction to construction sites), waste removals by freight transport (of construction, demolition and excavation waste from the construction site to waste treatment centre), off-site assembly (assembling building components off-site) and off-site offices (including corporate headquarters). The results are shown in **Table 6.2**. In total, this study estimated that construction activities (not including the manufacture of materials and products) resulted in 5 million tonnes of CO_2 emissions in the UK in 2008 (Ove Arup, 2010a).

Table 6.2: CO_2 emissions from construction activities in Great Britain in 2008

Activity	CO2 emissions (% of total)
Construction sites (plant, machinery and offices)	41%
Freight transport of building materials to site	37%
Waste removals from site by freight transport	12%
Off-site assembly	5%
Off-site construction company offices	5%
TOTAL	**100%**

Source: Ove Arup, 2010a.

Another analysis of CO_2 emissions in construction in the UK also carried out in 2010 subdivided activities associated with construction sites into: design (energy and transport used by architects, planners and engineers during the project design phase), manufacture (the domestic production of construction materials and embodied in imported materials), transport (freight transport of materials to and from construction site together with business and worker travel), on-site operations (machinery and equipment used on the construction site), and waste, demolition and refurbishment (energy use in demolition and waste removal, as well as the process of refurbishment). This study made use of data in **Table 6.2** together with other official data. In total, this study estimated that construction (including the manufacture of materials and products, construction site activities and freight transport) resulted in 52 million tonnes of CO2 emissions in the UK in 2008. The results are shown in **Table 6.3**.

Table 6.3: CO_2 emissions from construction activities in Great Britain in 2008 (including manufacture of construction materials and project design energy use)

Activity	CO2 emissions (% of total)
Project design (travel and energy use)	3%
Manufacture of construction materials	86%
Construction sites (plant, machinery and offices)	4%
Freight transport of building materials to site	4%
Waste removals from site by freight transport	1%
Off-site assembly	0.5%
Off-site construction company offices	0.5%
TOTAL	**100%**

Source: calculated from BIS, 2010.

Data collected by the UK government and industry bodies from UK construction projects indicates that in 2018 approximately 370 kg CO_2 was emitted on site by construction projects per £100,000 of project value (Glenigan, 2019).

The major construction company Skanska UK commissioned a report in 2019 into the CO_2 emissions associated with its entire operations, broken down by activity (Skanska UK, 2019b). The analysis took account of both direct and indirect emissions (i.e. carbon emissions from activities Skanska carried out itself as well as those produced by other companies in its supply chain when working on Skanska projects). It also included construction and maintenance activities and took account of embodied carbon in the materials Skanska uses in its projects. It excluded emissions that arise from a construction once Skanska has completed work on it and handed it over to the client (i.e. operational emissions from a building or infrastructure asset constructed were not included). This work provides a recent and helpful insight into the source of CO_2 emissions from the perspective of a major construction company. The direct and indirect emissions for the following eleven categories were included and calculated in the analysis (Skanska UK, 2019b):

- Fuel (used on the construction project in all commercial vehicles and site plant and equipment either leased or owned by Skanska) – direct and indirect emissions
- Fuel (used in all Skanska premises) – direct and indirect emissions
- Process and fugitive emissions (from Skanska's industrial activities such as fuel processing and leaks from air conditioning not related to construction) – direct emissions
- Electricity (used by Skanska at its construction sites and project offices) – direct and indirect emissions
- Electricity (used in Skanska permanent premises) – direct and indirect emissions
- Imported heat – direct and indirect emissions
- Vehicle fuel (used in vehicles operated by Skanska staff) – direct and indirect emissions
- Public transport (for Skanska staff work-related travel by rail, taxi and air) – indirect emissions
- Subcontractors (who provide construction, transport and maintenance activities on the project – taking into account fuel used in subcontractor goods vehicles and their plant and equipment used on Skanska construction sites) – indirect emissions
- Waste (from the generation and disposal of waste across Skanska operations including premises and construction sites and the waste of subcontractors working on Skanska projects) - indirect emissions
- Materials (from the 56 most commonly used materials across all Skanska operations, projects and premises and also their transportation) – indirect emissions

The European Network of Construction Companies for Research and Development (ENCORD) protocol was used for calculating these CO_2 emissions. Wherever possible actual emissions were calculated. In cases in which this was not possible emissions were estimated using carbon factors from DEFRA (the Department for Business, Energy & Industrial Strategy) and Bath University's Inventory of Carbon and Energy.

The contribution of these eleven categories to CO2e emissions in Skanska's entire supply chain are shown in **Table 6.4**.

Table 6.4: Estimated CO_2e emissions from Skanska operations in 2018

Category	Proportion of CO_2e emissions
Fuel (project)	6.1%
Fuel (premises)	0.2%
Process and fugitive	0.01%
Electricity (project)	0.6%
Electricity (premises)	0.1%
Imported heat	0.0%
Vehicle fuel	1.5%
Public transport	0.2%
Subcontractors	13.8%
Waste	1.5%
Materials	75.9%
TOTAL	**100%**

Source: Skanska UK, 2019b.

Table 6.4 indicates that the most important categories in terms of CO_2e emissions in Skanska's operations were materials and their transport (76%), subcontractors (14%) and fuel used by Skanska in their vehicles, plant and equipment (6%). Together these three categories were estimated to account for 96% of CO_2e emissions (Skanska UK, 2019b).

In the 'fuel' category, diesel accounted for approximately 52% of CO_2e emissions, red diesel for 48% and petrol for less than 1%. In the 'subcontractors' category, red diesel used in plant and equipment accounted for approximately 85% of CO_2e emissions and diesel used in goods vehicles for 15%. In the 'waste' category, waste transport accounted for approximately 60% of CO_2e emissions, disposal to landfill about 20% and recycling and reuse about 20%. In the 'materials' category, steel was estimated to account for approximately 40% of CO_2e emissions, concrete and cement for about 17.5%, plastics for about 10%, other materials for about 25%, and the transport of materials for about 5% (Skanska UK, 2019b).

Overall, freight transport operations by Skanska, its subcontractors, waste operators, and freight companies and suppliers delivering materials were estimated to account for about 10% of total CO_2e emissions in the Skanska operation in 2018. Plant and equipment used on construction sites by Skanska staff and subcontractors accounted for about 15% of total CO_2e emissions. While personal travel by Skanska employees accounted for about 1.5% of total CO_2e emissions (Skanska UK, 2019b).

In total, Skanska's emissions in 2018 were estimated to be 413,000 tonnes of CO_2e. Of this, direct emissions by Skanska comprised about 8% and indirect emissions from materials and subcontractors in the Skanska supply chain about 92% (Skanska UK, 2019c).

6.3 Transport and traffic impacts to other road users and the general public

Road transport in the construction industry imposes several impacts on other road users and the general public. These include:

- The scale of construction traffic on the roads, especially in urban areas, travelling to and from construction sites (see **section 6.3.1**)
- Collisions on the road network with other road users that result in injuries and deaths (see **section 6.3.2**)

- Additional health and safety risks for vulnerable (i.e. cyclists and pedestrians) and other road users especially at the entrance to construction sites and their immediate surroundings, together with the disruption caused to their journeys from associated hazards (see **section 6.3.3**)

- Fly-tipping of construction-related waste (see **section 6.3.4**)

6.3.1 Construction road traffic levels

The construction industry generates substantial goods vehicle activity for the delivery and collection of materials, as well as the journeys associated with the work carried out by contractors and tradespeople using vans. As discussed in **section 5.6**, it is estimated that construction-related freight transport accounted for 28% of the goods lifted by HGVs in Britain in 2019, and 20% of the goods moved (i.e. tonne-kilometres). Much of this HGV activity involves large rigid and articulated HGVs at the upper end of vehicle weight classes. As estimated in section 5.7, there are also likely to be in excess of one million vans used by those working in all the trades associated with the UK construction industry, travelling tens of billions of vehicle kilometres.

To provide some insight into the HGV journeys associated with major construction developments in the UK are summarised below.

HS2, the high-speed rail link currently being constructed from London to Birmingham is estimated to generate a peak daily flow during busy periods of up to approximately 900 two-way HGV journeys to the delivery and collections site around Euston Station (where the London terminus is located) during the eleven years of the construction work (HS2, 2013).

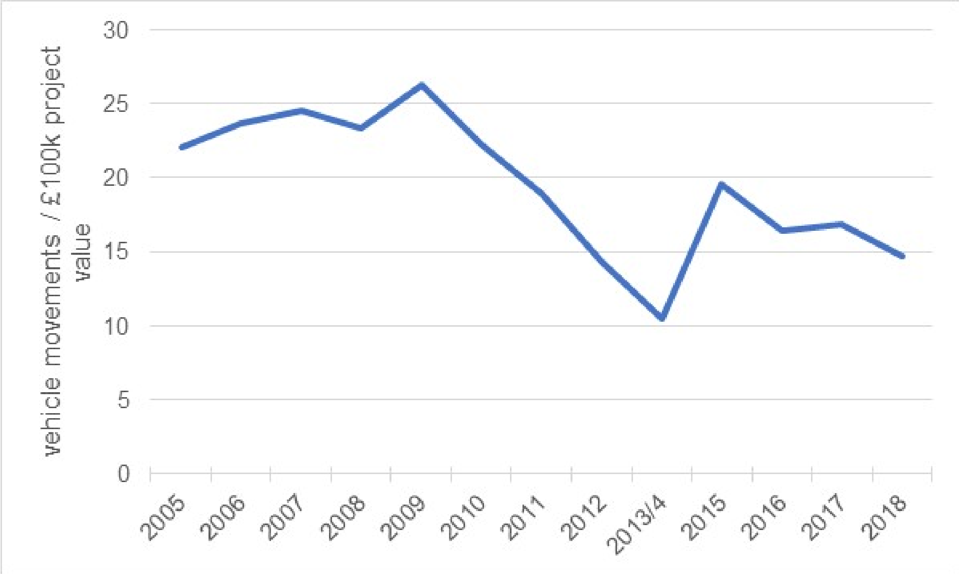
The Thames Tideway Sewer project in London is estimated to result in approximately 11 million road vehicle kilometres by construction HGVs over the entire project, with a total of approximately 530,000 two-way construction HGV journeys to the 24 construction sites. In the peak construction periods the project will generate approximately 475 HGV movements per day. In addition, it is estimated to generate approximately 11,000 two-way barge movements by river (Thames Tideway, 2013).

Over the five-year period from August 2012 to July 2017, the main constructions sites for the Crossrail project in London generated 925,000 HGV arrivals (Crossrail, 2018).

It has been forecast that the redevelopment of Old Oak and Park Royal for residential properties accommodating 25,000 people and business premises that will support 65,000 jobs will generate 1.5 million loaded one-way HGV movements (and the same number of empty return trips) across its various construction sites over the life of the construction work, which would run over several years. In addition, it is estimated that this development would generate 200,000-300,000 van journeys. Peak monthly construction activity is estimated to result in 9,000 loaded HGV journeys, which is equivalent to 407 HGV loaded movements per weekday. It is envisaged that concrete lorry journeys would make up approximately 50% of all the 1.5 million HGV journeys. It is therefore planned that as for other major public-led projects in London (such as the Olympics, Thames Tideway, Crossrail, and HS2) a concrete batching plant would be located either close to the development area or within it (OPDC, 2018).

Data collected by the UK government and industry bodies from UK construction projects provides a key performance indicator (KPI) related to goods vehicle activity levels at construction sites. This KPI indicates that in 2018 there were, on average approximately 15 goods vehicle arrivals at construction sites per £100,000 of project value over the entire project. This represented a reduction of 33% compared with 2005 (see **Figure 6.5** – Glenigan, 2019).

Figure 6.5: Goods vehicle arrivals at construction sites per £100,000 project value (at 2016 constant prices)



Source: Glenigan, 2019.

Using this 2018 KPI indicates that a £50 million commercial development may generate approximately 7500 HGV arrivals at the construction site. If work is spread over an 18-month period, this would equate to an average of approximately 20 vehicle arrivals per day, with possibly more than 50 arrivals per day during peak vehicle periods in the project.

Quarries also generate substantial HGV activity, with journey rates related to the size of the facility. Large quarries can generate as many as 1,000 HGV movements per day.

Street works and road works carried out on public highways result in substantial impacts on road traffic speeds and journey time delays and unreliability, as well as increasing risks for vulnerable road users. In 2016, the Department for Transport (DfT) calculated that approximately 2.5 million road works are carried out in England each year, with an estimated cost to the economy of around £4 billion per year (Department for Transport, 2017a).

There are many utility companies that carry out works to access facilities located under the road system, leading to this traffic disruption, road risk, and environmental impacts. Better management of road works and utility companies' ability to dig up roads, together with new technology-based approaches to road works could help reduce the traffic delays, road risks and productivity impacts associated with them (Institution of Civil Engineers, 2018).

6.3.2 Road safety: deaths and injuries involving construction vehicles

As well as being among the most dangerous industries to work in (see **section 6.4**), construction vehicles operating on the public road network also pose a substantial danger to other road users, especially the most vulnerable, namely pedestrians and cyclists.

Due to extensive media coverage of cyclist fatalities in London from 2010 onwards, with 26 such fatalities occurring in London in 2010 and 2011, research was carried out that showed one-third of these involved a goods vehicle being used in the construction industry. This led to Transport for London commissioning the first-ever UK research project into the involvement of road freight vehicles working in the construction industry in cyclist casualties. This research identified that construction vehicles were over-represented in collisions leading to fatalities with cyclists in London over the period 2008 to 2011 (Delmonte et al., 2012). This analysis also found that of the 104 HGVs and vans with known body types that were involved in collisions in which cyclists were either killed or seriously injured in London between 2008 and 2011, 29 of these vehicles were tippers, 9 were concrete mixers and 5 were skip loaders, and 80% of these vehicles had four or more axles. Therefore, over 40% of the rigid HGVs involved had body types closely associated with construction work. Approximately 45% of these collisions with cyclists took place at crossroads, 37% at staggered T-Junctions and 10% on roundabouts. The most commonly recorded contributory factor in these collisions for these vehicles was 'vehicle blind spot' (recorded in approximately 40% of these collisions), followed by the vehicle driver 'failed to look properly' (recorded in approximately 30% of these collisions), and 'passing too close to cyclist, horse rider or pedestrian' (recorded in approximately 15% of these collisions) (Delmonte et al., 2012). Another study analysing cyclist fatalities in London between 2009 and 2014 that involved goods vehicles of 7.5 tonnes gross weight or greater found that 59% of these vehicles were working in the construction or waste sector (Robinson et al., 2016).

In another study of all collisions resulting in fatalities and serious injuries to cyclists in London (i.e. not just those in which construction vehicles were involved) between 2007 and 2011 found that the most common manoeuvres were the other vehicle turning left across the path of the cyclist (accounting for a third of all these collisions), the other vehicle running into the back of the cyclist pedal cycle (approximately 15% of these collisions) and the cyclist and other vehicle travelling alongside each other (approximately 10% of these collisions). This study found that HGVs were involved in a quarter of all these 53 collisions, and that HGVs highly associated with construction-related work (namely tippers, concrete mixers, refuse vehicles, skip carriers, flatbeds and dropside vehicles) comprised approximately three-quarters of these HGVs (Talbot et al, 2014).

Driver visibility from construction vehicle cabs, which traditionally are high-up, was found to be poor in the London study, making it especially difficult for the drivers to properly see cyclists to the left and in front of the vehicle, even when the vehicle was fitted with mirrors that complied with legal requirements (Delmonte et al., 2012). Interviews carried out with principal contractors and sub-contractors at three construction sites in this same study also found that road risk was viewed as less important than construction site health and safety risk by these companies, and that there was a lack of ownership of this road risk by both clients and contractors in the construction industry. Respondents stated that vehicle incidents driving on road to or from the site would not be reported to other supply chain parties working on site. The research also indicated that self-employed owner-drivers are not necessarily subject to the same rigorous health and safety policies and procedures as drivers employed by companies. The site interviews also indicated that, in the view of some of the contractors interviewed, vehicle delivery booking systems operated at large construction sites to co-ordinate and manage vehicle arrivals can have the unintended consequence of placing pressure on the driver to not arrive late as vehicles arriving outside of the allotted time may well be turned away (Delmonte et al., 2012).

Analysis of collisions involving cyclists and goods vehicles of 7.5 tonnes gross weight or more between 2005 and 2014 showed that 45% of cyclist fatalities were killed in collision with the nearside of the vehicle when it makes a left turn. Another 16% were killed when the goods vehicle moves off from rest, 8% were killed when in collision with the nearside and 4% in collision with the front of the goods vehicle. In terms of pedestrian fatalities in London over the same period, 25% of all pedestrian fatalities from collisions with a large truck took place with the front of the vehicle as it moved off from rest (compared with 6% for Britain as a whole). Pedestrian fatalities in London in collision with the front of a vehicle 'going ahead other' were equally frequent, while 12% of pedestrian fatalities involved the truck turning left (Robinson et al., 2016).

These cyclist and pedestrian fatalities in London all had the potential to be influenced by blind spots in the goods vehicle driver's vision. The study reported that, "the area of greatest risk extends across the full width of the front of the vehicle and 5 metres back down the nearside of the vehicle. Within this area of greatest risk, the nearside zone is considered relevant to a larger number of London pedestrian and pedal cyclist casualties than the front zone (this is reversed if GB is considered as a whole where the front zone is more relevant). Two manoeuvres are responsible for these crashes, the vehicle moving off from rest and the vehicle turning left" (Robinson et al., 2016).

Further research to understand the variability of blind spots in direct vision through windows and indirect vision through mirrors for HGVs used in the UK, especially those used in the construction industry. Th.is work showed that all nineteen standard HGVs studied had blind spots which can hide cyclists and pedestrians from the driver's direct vision, with the height of the drivers' cab above the ground being the key vehicle factor which affects the size of direct vision and indirect vision blind spots. The construction HGVs that were assessed were found to be, on average, 32% higher than the same cab design for other HGVs, and that this resulted in the distance away from the vehicle that a pedestrian in front of the vehicle can be hidden from the driver's view to be approximately three times greater than for the other HGVs, and for the distance away that a cyclist to the passenger side of construction HGVs can be hidden to be approximately two times greater than for other HGVs (Summerskill et al., 2015)

Most tipper goods vehicles used in the construction industry are capable of operating off-road, as they have to be able to operate within construction sites, waste facilities and quarries where they may encounter rough, uneven terrain without proper road surfaces, having to cope with rapid changes in gradient, unstable surfaces and standing water. The off-road characteristics of these vehicles that make this possible do not allow provision for certain safety features, such as under-run protection, while their increased axle height and elevated cabs creates greater blind spot areas around the vehicle (AECOM, 2016).

Due to the temporary nature of construction sites, drivers making vehicle journeys to and from them may be less familiar with these journeys and routes than drivers working in other industries where locations are fixed. These sites are also more likely to be in busy urban areas than in industries than in other industries using large, heavy goods vehicles in which these vehicles will often deviate little from major roads. The construction site itself is often more difficult to manoeuvre a vehicle into and out of than delivery and collection points in other industries.

A Norwegian study similarly found that clients and contractors in the construction industry paid little attention to off-site transportation and that issues concerning these freight journeys was largely left to freight transport companies and drivers. The vehicle drivers interviewed (who delivered building materials and concrete and collected waste) often received little advance warning of the deliveries they need to make to construction sites and receive little information beyond the material requirements and the address. This provides them little opportunity to plan suitable routes and they are often not provided with telephone or other details of the relevant construction site personnel to contact should they encounter any problems (Hannasvik, 2018). Drivers also reported that urban construction sites were often difficult to reach due to narrow streets not designed for their large, heavy goods vehicles and they typically had to find out about vehicle weight and/or height limitations on roads themselves, sometimes by checking themselves but more often by encountering them during the journey (Hannasvik, 2018)

The extensive media coverage of cyclist fatalities involving construction vehicles in London from 2010 onwards, together with pressure from cycling groups and friends and family of the deceased, resulted in the Mayor of London devising and implementing measures intended to reduce and ultimately eliminate this risk, including the introduction of Construction Logistics Plans as part of the planning application process, working with the industry to assist it in establishing the CLOCS scheme, and the introduction of the Safer Lorry and Direct Vision Standard (see **section 7.3.14**).

6.3.3 Other health and safety issues and disruption to journeys

The entrance to construction sites and their immediate surroundings, which are most often in urban areas, impose safety and mobility risks for other road and pavement users, especially cyclists and pedestrians. These arise from several sources: (i) the risk of collisions and casualties related to vehicles making deliveries to and collections from the site (see **section 6.3.2**), and (ii) hazards resulting from the construction site and its related vehicle activity that deters and causes inconvenience to vulnerable road users. Research has shown that some people are put off walking due to concerns about road danger, so it is important to mitigate such risks arising from construction work (Transport for London, 2018a).

Transport for London, which manages 5% of London's roads, expects these works on its streets it to meet the following requirements in order not to discourage pedestrians and cyclists (Transport for London, 2018b):

- Safe - minimising collision risk with a sensible balance between practicality and risk mitigation, and feeling comfortable to use at all times of day
- Inclusive - allowing comfortable passage for people of all abilities and prioritising those for whom a barrier or diversion could compel them to take uncomfortable, risky or significantly more physically demanding alternatives
- Practical - providing realistic ways of enabling movement that minimise disruption for people
- Legible - being easily understood and unambiguous for all users

The entrance to the construction site may be physically constrained making the ingress and egress of vehicles onto the site from the public highway a complex manoeuvre for the driver. Visibility from the driver's cab together with the driver's focus on the complicated manoeuvre (which may involve reversing) makes other road users, particularly pedestrians and cyclists, especially vulnerable during such vehicle activity.

Where footways are affected by construction activity in the UK, it is the responsibility of the site operator to make sure that pedestrians passing the works are safe, both in terms of protecting them from both the works and other passing road traffic. Account has to be taken of the needs of children, older people and disabled people. The same is the case for cyclists passing the site. Safe routes must be provided for pedestrians and suitable provisions must be made for the safety cyclists (Department for Transport, 2013).

Sometimes when vehicles arrive at construction sites, especially those generating substantial vehicle journeys, the site and site personnel may already be busy with another vehicle delivery or collection. In such circumstances the driver will typically either: (i) park at the kerbside to wait (resulting in an additional hazard and limiting available road space for other users – this increases road risk especially for vulnerable road users such as cyclists and pedestrians who need to cross the road), or (ii) be told by construction site staff to drive around the local area before returning at an agreed time (thereby adding to local HGV road traffic levels) (Barratt, 2021a).

In addition, there are a range of other risks and disruption that can be posed to other road users, especially pedestrians and cyclists, near construction sites (Barratt, 2021a, Transport for London, 2018b):

- Narrow temporary traffic lanes are installed outside some construction sites that endanger cyclists.

- Signage that should be used to warn and direct road traffic near construction sites is often not used (such as telling drivers of motorised vehicles not to overtake cyclists in dangerous spots such as narrow temporary lanes).

- Signage that is used is often inappropriately positioned, becoming a trip hazard or obstacle for pedestrians and cyclists.

- Some signage is inappropriately used (such as “cyclists dismount” signs given that some disabled cyclists cannot dismount and push their bicycles – in such cases all other possible actions should have been investigated by the contractor before making us of such a sign but this is often not the case).

- Temporary signage used near construction sites needs to take into account hidden disabilities when it is being designed such as dyslexia, dyspraxia, colour blindness, and autism (in terms of colours used, clarity of message and avoided overloading people with multiple signs).

- Unlevel surfaces are common near construction sites that are unsuitable for pedestrians and cyclists.

- Temporary ramps for cyclists and pedestrians near the entrance to construction sites to get up and down kerbs are often of an inappropriate design for the situation. They need to have suitable gradients for cyclists and wheelchair users, as well as suitable turning circles at top/bottom of ramp and cyclists.

- Temporary road crossing points near construction sites regularly have push button that are facing the wrong way and are not accessible for disabled people.

- In the case of footway closures, diverted routes are not always accessible and may force disabled pedestrians and wheelchair users into the road.

- Temporary hoardings can make some feel very uncomfortable, claustrophobic, and raise public fear of crime. The colours that they are painted and their design needs to be considered – avoiding painting them black and using hidden corners and recesses wherever possible. Hoardings can encourage pedestrians to walk in the road instead or not go out at all.

- Temporary bus stops (that have been relocated as the usual bus stop is very close to the site entrance) need to be accessible and fully open from both sides. A temporary bus stop should be as near to the closed one as possible as the next regular one will be at least 400 metres away.

- Lorries parked on street outside construction sites waiting to make deliveries or making deliveries from the public street over the pavement present major risks to pedestrians and cyclists in terms of protruding wing mirrors and obstruction when pedestrians need to cross the road.

- Vehicle idling by drivers waiting on-street to deliver adds to air pollution and health impacts.

- Lorries making deliveries to small, residential construction sites often cause permanent damage to the pavement and kerbstones, presenting a trip risk to pedestrians.

- Some construction vehicles park on the pavement, forcing pedestrians to walk in the road to pass around them.

- Site access mats may protect public footways but some are a trip hazard presenting a risk to pedestrians.

- Cable covers are also trip hazards.

- Standing water, mud and dust from a construction site that has escaped onto a footpath or road presents a hazard to all road users.

- Traffic cones are often inappropriately positioned by those working on construction sites increasing danger to road users, especially vulnerable ones.

- Skip placement is sometimes inappropriate, blocking pavements for pedestrians.

Air pollution from vehicles operating at construction sites, together with that from on-site plant and equipment also imposes health impacts on those living near and travelling past these locations.

As noted in **section 6.1**, road freight traffic serving construction sites can lead to damage to public highways and footways in the vicinity, which leads to the needs for repairs and further traffic disruption. In addition, some construction projects require alterations and improvements to the public highway (such as new or altered turnings, roundabouts, signal junctions, and crossings close to the development site – referred to as section 278 agreements) that cause further disruption to highways and footways and the users of them during the works.

Construction projects can also necessitate road closures, one-way traffic systems, and the implementation of temporary traffic lights during part or all the works. As well as leading to traffic disruption for other road users, this can also result in traffic displacement as these road users seek alternative, sometimes unsuitable routes to avoid the disruption.

Construction sites that stipulate the need for specific types of HGVs in their planning consent (such as those that meet Direct Vision Standards (DVS) or specific Euro engine standards) can encounter problems when receiving deliveries from overseas suppliers made by non-complaint vehicles. This requires the management of the transfer of the goods/trailer to a compliant vehicle tractor, which can add to vehicle activity and driver requirements.

In the UK, the major utilities, gas, electricity, water, sewerage and telecommunications are usually routed under the road and footpath network. Therefore, when upgrades, maintenance and repair of this infrastructure is required it tends to require digging up and closing part of the road and footpath network. The same is true of road works which involve repairs and upgrades to the road itself. These types of construction work therefore have an even greater impact on traffic flow than off-street construction sites, as the latter typically only causes major delays to other motorised road vehicles during the ingress and egress of goods vehicles from such sites. These street and road works also present greater health and safety risks both to the public given the area of road and footpath they can involve and to those working on them due to their workplace being in the road itself. In London there were 355,000 road and street works in 2017/18 (Transport for London, 2018b).

Despite their often more rural locations, quarries also pose health and safety risks to those living near them. Survey work was carried out in 2010 with thirteen quarry operators in the UK. Four types of quarries were included: (i) sand and gravel, (ii) sandstone and gritstone, (iii) igneous and metamorphic rock, and (iv) limestone (Brighton and Richards, 2010). The road transport vehicles used comprised both rigid and articulated tippers.

The vast majority of these road goods vehicle used to collect materials from the quarries (85%) had to travel off-road within the quarry in order to do so. The potential for a vehicle to collect debris when operating within the quarry was found to be dependent on the type of material quarried, the material used to construct the unsealed roadways within the quarry (usually sand and/or crushed rock) and the weather conditions. Wheel and cleaning systems used to reduce the risk of material from the quarry being transferred to the public roads ranged from none (in the case of one quarry) to fully automatic drive through wheel and chassis wash machines ((in the case of eight quarries). Loads transported on the public roads were covered prior to transport at all the quarries surveyed (Brighton and Richards, 2010).

In terms of the environmental impacts imposed by these road vehicle operations, respondents viewed debris on the road as most important, closely followed by vehicle exhaust smoke and noise, and CO_2 as least important. When asked to justify their views on the importance of CO_2 emissions, respondents stated that this was set by vehicle manufacturers and therefore outside of their control (Brighton and Richards, 2010).

Survey work was also carried in this 2010 project among residents living in properties close to the road in three villages in close proximity to sand and gravel quarries in the UK. This type of quarry was chosen as they tend to produce less in-quarry noise than hard rock quarries due to their lack of blasting and rock crushing requirements. The researchers felt that this would result in the respondents being more focused on the noise of the transport vehicles if they were the predominant source of quarry-related noise. In addition, due to the light, fine nature of the material, sand and gravel quarries also have the potential to cause greater contamination of the public roads.

Thirty-five respondents were asked to rate the significance, in their view, of different impacts from the vehicles used for transport to and from the quarries namely vehicle emissions (CO_2 and local air pollutants), engine noise, banging and rattling from truck bodies, mud dust and debris deposited on the road, road traffic flow, and road safety. Overall, respondents viewed debris on the road, and noise from engines and bodies as the worst impacts, followed closely by exhaust emissions, and road safety. Traffic congestion impacts were viewed as least important (Brighton and Richards, 2010).

6.3.4 Fly-tipping and illegal waste sites

There were 976,000 fly-tipping incidents in England in 2019/20, of which 5% (51,000 incidents) were construction, demolition and excavation waste. In terms of the size of all fly-tipping loads, 33% were small van size loads, 11% were transit van size loads and 2% were tipper lorry size loads (DEFRA, 2021c). In 2019 there were 79 serious incidents involving illegal waste activities with just over half of these related to illegal waste sites in the UK (i.e. waste sites operating without the appropriate permit that are handling multiple loads of waste in an organised manner and usually run as a business) (Environment Agency, 2021). Approximately 17% of waste arising on illegal waste sites in the UK by weight has been estimated to be inert construction and demolition waste, and 6% to be non-inert construction and demolition waste. The Landfill Tax is an important factor in fly-tipping and the operation of illegal waste sites. The Environment Agency closes several hundred illegal waste sites each year (Environment Agency, 2017).

6.4 Safety in the construction industry: worker deaths and injuries

The construction industry has a hazardous working environment at the quarries, waste facilities and construction sites associated with it. The activities involved and the equipment, machinery and vehicles used make it one of the most dangerous of all industries.

Construction ranks second only to agriculture and forestry in annual fatality rates per 100,000 workers (HSE, 2020a). There were, on average, 37 fatal injuries per year to construction industry workers in Britain between 2015/16 and 2019/20. This represented 27% of all workplace fatalities in Britain over the five-year period (HSE, 2020a). The main causes of these fatalities are shown in **Table 6.5**. The most common cause of death was a fall from height (45%), while being struck by a moving vehicle resulted in 9% of deaths (HSE, 2020a). In addition, there were an average of five construction industry related fatalities to members of the public each year over this same period (HSE, 2020b).

Table 6.5: Cause of construction worker fatality in Britain, 2015/16-2019/20

Cause of fatality	Proportion of all fatalities
Fall from height	45%
Trapped by something collapsing	15%
Struck by object	12%
Struck by moving vehicle	9%
Contact with machinery	2%
Exposed to explosion	2%
Contact with electricity	2%
Other	13%
TOTAL	**100%**

Source: calculated from data in HSE, 2020a

Once inside a large construction site, the goods vehicle driver is typically confronted with an environment that is far less obvious and demarcated than the public road network, without any road markings or traffic lights, or defined stopping points. Internal road surfaces and loading bays may not be installed on large sites before work begins which adds to the complexity of driving and unloading vehicles on uneven surfaces. On smaller sites, such infrastructure will never be added, and in the case of refurbishment work at a single residential property, deliveries will typically have to take place from the public road, adding to the difficulty and loading and unloading and the use of handling equipment. Even on larger sites, the handling equipment available may be inadequate as contractors may not have provided it. On sites that have no logistics or traffic specialist, each contractor becomes responsible for their own deliveries and collections. All of these factors increase the risk posed to those working on construction sites by goods vehicle deliveries and collections.

There were, on average, 61,000 non-fatal injuries to construction workers each year in Britain from 2017/18-2019/20. This is 2.8% of workers in the construction industry. Twenty seven percent of these non-fatal injuries resulted in an absence from work of over seven days (HSE, 2020b).

Between 2017/18 and 2019/20, 0.5 million working days (full-day equivalent) were lost each year due to workplace injury. Workplace injuries impose both financial costs (such as lost output and healthcare costs) and non-financial costs (the monetary valuation of the human cost of injury and illness in terms of loss of quality of life). In 2018/19, the total economic cost of workplace injury in the construction industry was estimated to be £0.7 billion, and accounted for 12% of the cost of all workplaces injuries in Britain (HES, 2020b).

HSE inspectors issued 2,031 notices (comprising 944 improvement notices and 1086 prohibition notices) in the construction industry in 2019/20 (HSE, 2020b). An improvement notice is served when an inspector is of the opinion that there is a breach of the law which needs to be remedied within a certain period of time. A prohibition notice is served when an inspector is of the opinion that there is a risk of serious personal injury associated with a particular work activity or process or, if a serious deficiency in measures is identified, to prevent or mitigate the effects of major hazards. A prohibition notice can take immediate effect or be deferred for safety reasons (HSE, 2015). Improvement and prohibition notices issued in the construction industry between 2015/16 and 2019/20 accounted for 17% and 49% of the total notices issued in total in Britain, respectively (HSE, 2020c).

In the waste industry, which has a close relationship to construction, of the nine workers who died on average each year between 2015/16 and 2019/20, 32% of these fatalities resulted from being struck by a vehicle (HSE, 2020a). Of the 4,000 waste industry workers who sustained a non-fatal injury between 2015/16 and 2019/20, a substantial proportion of these were logistics related – with 9% resulting from being struck by a moving vehicle, 8% from handling, lifting and carrying, 5% resulting from contacts with moving machinery, and 15% resulting from falls from height (HSE, 2020d).

At quarries and other mineral workings, 94% of workplace fatalities are accounted for by six occurrences (in order of the fatalities they result in): (i) being struck by moving or falling objects, (ii) contact with moving machinery including conveyors and crushing machines, (iii) collisions between pedestrians and mobile plant and vehicles on-site, (iv) working at height and associated falls (v) road traffic collision and casualties on public roads, and (vi) workplace respirable crystalline silica (Safequarry.com, 2021a). Between 2015-16 and 2019/20 there were 11 fatalities at quarries and mines in the UK, with three of these due to being struck by moving vehicles. Although the absolute number of fatalities occurring at quarries and mines in the UK are less than those at construction sites, they have very similar rates of fatal injury per 100,000 workers (HSE, 2020a).

There were 43 fatalities at waste collection, treatment and processing facilities in the UK between 2015-16 and 2019/20, giving them a rate of fatal injury per 100,000 workers that was approximately five times greater than construction sites and quarries (HSE, 2020a).

There were three fatalities involving rail infrastructure workers in 2019/20, two on the mainline network and one on London Underground (ORR, 2020b).

In addition to direct, instantaneous events of death in the construction industry, research has indicated that construction sites are the UK workplace most associated with cases of cancer among men. An HSE study found that in 2005, 56% of cancer registrations in men were attributable to work in the construction industry. As noted in the study, construction sites involve worker exposure to ten or more carcinogens including asbestos, DEE, silica and solar radiation. In 2005, 2,717 construction workers died of cancer as a result of exposure to asbestos, 234 from cancer related to diesel engine exhaust (Rushton et al., 2010).

It has been reported that in 2016/17 approximately 3,000 construction workers in the UK were suffering with breathing and lung problems that they believed were caused or made worse by their work, where they were exposed to equipment and activities that produce pollution (CLEC, 2021). A 2014 survey of those working in construction, the majority of whom were health and safety advisors, found that only 3% of respondents thought that those working in construction were fully aware of the risks of dust, and 15% thought that workers were not at all aware of its health risks. Thirty percent of respondents believed that poor management arrangements on construction sites create a situation where the dust controls provided fail to work properly either most or all of the time (IOSH, 2014).

6.5 Other environmental and social impacts of construction

The construction of buildings and infrastructure, together with the provision of building material from quarries and other sites, result in a number of other local environmental impacts. These include:

- the consumption of resources (both renewable and non-renewable),
- energy use,
- permanent changes to the natural environment (both at the construction site and at quarries where building materials are extracted),
- the loss of open space and agricultural land and wildlife habitat, with consequences for animals, plants and trees and biodiversity,
- air pollution with dust, particulate matter and toxic substances from extraction, transport and machinery use,
- sediment runoff and toxic spills from construction sites resulting in the pollution and contamination of surface water bodies including rivers and lakes, and underground water sources,
- soil and ground loss and contamination,
- noise and vibration from work at construction sites and vehicles making deliveries and collections to/from them,
- visual intrusion (both during the construction work and subsequently once the work is completed),
- waste generation,
- water consumption to produce building materials,
- damage to archaeological remains.

The 2016 London Atmospheric Emissions Inventory estimated that the construction industry accounted for 34% of the PM10, 15% of PM2.5, and 7% of NOX emissions in London (Greater London Authority, 2019). Recent on-road light duty diesel vehicle emission tests have shown significant differences between real-world NOX emissions compared with results from laboratory based regulatory tests.

Research has shown that the non-road mobile machinery used on construction sites in London tends to have a relatively long life compared with that of road goods vehicles, with 31% of it in 2016 being older machinery. In addition, the introduction of EU emission standards for these off-road vehicles lag behind those of on-road goods vehicles, and there is a leniency in the limit values for these off-road machines. Research carried out on construction sites in London of generators and other construction site equipment has been carried out. Telemetry data indicated that, on average, wheeled machines spend 45% of the time idling. Results showed that of the equipment tested, many emitted more than the EU emission NOX limit values. Particle tests, which were only carried out on generators, found that those tested were all within their emission PM limit values (Desouza et al., 2020).

Data collected by the UK government and industry bodies from UK construction projects indicates that in 2018 approximately 18 cubic metres of mains water was use on site by construction projects per £100,000 of project value (Glenigan, 2019).

Construction sites and the areas surrounding them are also frequently subject to crime. Table 6.6 shows the type and number of criminal offences committed at construction sites in the Metropolitan Police Service (i.e. Greater London) area. This indicates that burglary, robbery and theft (of materials, tools and equipment) accounted for 80% of all offences at construction sites in London in 2018. In 2016, each of these crimes cost, on average, £20,000 (Barratt, 2019a).

Table 6.6: Criminal offences with construction site recorded as location in MPS area in 2018

Offence	Number of offences	% of offences
Violence against the person	177	7.1%
Sexual offences	7	0.3%
Robbery	16	0.6%
Burglary	1190	47.5%
Vehicle offences	109	4.3%
Theft	791	31.6%
Arson and criminal damage	135	5.4%
Drug offences	10	0.4%
Possession of weapons	10	0.4%
Public order offences	45	1.8%
Miscellaneous crimes against society	16	0.6%
TOTAL	**2506**	**100.0%**

Source: Metropolitan Police, 2019.

Whilst hoardings placed around the boundary of construction sites can help to prevent thefts and robberies from construction sites, they can also obscure footpaths and create blind-spots, which can foster crime outside the construction site, as well as graffiti, rough sleeping and drug use, and often lead to fear among using those having to use them as part of their journey.

6.6 External costs of road freight transport operations

Transport for London (TfL) has estimated the marginal costs of HGV operations in the construction industry in London. This estimate is based on a 32 tonne grow weight, eight-wheeled rigid vehicle with a Euro 6 engine standard that drives at 30 km per hour. The estimate incorporates vehicle driving time and idling/stationary time at a construction site. The algorithm used to estimate these costs takes account of HGV vehicle operating and time-based costs, as well as the external economic costs (value of time to other road users including bus delays and revenues), social costs (risk of collisions), and environmental costs (health costs of air pollution). The total marginal cost of this construction vehicle is estimated to be £3.98 per km, of which just over half is accounted for by vehicle operating costs borne by the HGV operator, approximately one-third is accounted for by vehicle operating costs and value of time of other road users, and approximately 15% of which is accounted for by health costs of air pollution, collision risks, and lost bus revenues. **Table 6.7** shows the overall importance of each of the marginal costs in these estimates. TfL uses this marginal cost in its estimates of the inefficiencies of logistics operations serving construction sites, and how changing these logistics practices could potentially benefit both society and the construction industry (Barratt, 2021b).

Table 6.7: TfL's estimated marginal costs of construction HGV operations in London

Cost component	**Cost (£ per HGV vehicle km)**	**%**
HGV standing costs	£0.53	13.3%
Vehicle running costs (HGV and other road users)	£0.86	21.6%
Time-based costs (HGV and other road users)	£2.06	51.8%
Air pollution	£0.28	7.0%
Risk of collision	£0.04	1.0%
Lost bus revenues	£0.20	5.0%
TOTAL	**£3.98**	**100%**

Source: TfL, 2020 quoted in Barratt, 2021b.

7. Measures the public and private sector can take to mitigate impacts of construction

7.1 Introduction

This chapter provides a review of research, pilot schemes, guidance, policy and company actions that have the potential to mitigate social and environmental impacts arising from the construction supply chain and its associated logistics and transport activities. It is divided into two sections: **section 7.2** presents measures related to construction materials and non-transport activities, while **section 7.3** presents measures related to freight transport.

7.2 Potential actions related to construction materials and supply chain / logistics activities

7.2.1 Building materials technology to reduce CO_2 emissions

In 2020, several major UK construction companies established 'Contractors UK Declare' in which they declared a state of Climate and Biodiversity emergency. These companies include: BAM Construct UK, BAM Nuttall, Canary Wharf Contractors, Morgan Sindall Group plc, Multiplex Europe, Sir Robert McAlpine, Skanska UK, and Willmott Dixon. In signing up to the Declaration, these companies committed to eleven principles governing the manner in which they will work with their employees, their clients, design teams and supply chains to move towards net zero carbon construction. The principles in the Declaration include: openly sharing knowledge and research to assist in reducing CO_2, evaluating all new projects against their CO_2 impacts, extending the life of existing assets rather than demolition and new build, working together with supply chain partners, engineers, designers and clients to achieve greater reductions in construction waste and to accelerate the uptake of construction materials with low embodied carbon. The intention is to achieve means by which to align with the 1.5-degree climate change scenario. These founders have invited other construction companies to join them in working towards net zero carbon and to sign up to the declaration. Their approach was prompted by the "UK Architects Declare" campaign (UK Contractors Declare, 2020). By June 2021, 46 construction organisations had signed up to the Declaration.

<u>*Cement*</u>

Carbon emissions from cement and concrete can be reduced in four ways: (i) energy efficiency (i.e. using better, newer equipment to produce cement - cement kilns in the UK have operational lifespans of 30-40 years – WSP, 2015a), (ii) fuel switching (i.e. using non-fossil fuels to heat limestone), (iii) clinker substitution (i.e. replacing a proportion of the clinker content in cement with other materials), and innovative technologies (including carbon capture and storage (CCS)) (Lehne and Preston, 2018).

Along with other major suppliers, Aggregate Industries has recently introduced lower carbon content cement alternatives across as much of its product range as possible in the UK market. These are: (i) ECOPact 30-50% CO_2 reduction which comprises blended cement compared to a standard concrete (CEMI) mix, (ii) ECOPact Prime 50-70% CO_2 reduction - an engineered low carbon concrete utilising higher blends of cements using GGBS, and (iii) ECOPact Max Above 70% CO_2 Reduction, the lowest carbon concrete range using cement alternative technology such as geopolymers and alkaline activators. Alongside these products, the company has also introduced a carbon calculator tool. The calculator, which includes over 100 different cement mixes and which draws on the company's research and development, is intended to assist product selection by customers. A technical team is also available to help customers make sustainable material choices (Aggregate Industries, 2020a).

Cemex has been implementing a new fuel system at its Rugby Cement plant which uses green hydrogen and will be able to run entirely from alternative fuels. Its implementation has cost

$25 million (£18 million). This new fuel system is scheduled to be operational in June 2021. In total CEMEX has committed $100 million of investment in the UK to reducing CO_2 emissions. The company has reduced CO_2 emissions from its European operations by 35% compared to 1990 levels and is aiming to reduce these by at least 55% by 2030 (Builders Merchants News, 2021).

UK concrete and cement currently account for approximately 1.5% of UK CO_2 emissions, five times lower than the global average. This is due to action taken by the UK cement industry which has led to CO_2 emissions being 53% lower in 2018 than in 1990 (compared with a 15-20% reduction since 1990 at the rest of the European level and internationally) (Mineral Products Association, 2020b; European Cement Association, 2020; Global Cement and Concrete Association, 2021). Fossil fuels used in the heating process have been substituted with waste-derived alternatives. In 2018, 1.4 million tonnes of waste and by-products from other industries were co-processed in UK cement production. In 2019, 45% of the energy used by the UK cement sector was from waste and waste derived fuels, with waste biomass fuels accounting for 18% of the energy input to the cement manufacturing process (Mineral Products Association, 2020a). The UK cement and concrete industry has also reduced the amount of clinker used in cement produced, using an average of 29% clinker substitute materials in 2015 (BEIS and MPA, 2017). This resulted in a recycled content of cement of approximately 10% (Mineral Products Association, 2020c).

The European Cement Association has developed a route map for carbon neutrality for 2050 in which it foresees CO_2 reductions from: (i) using decarbonated materials in place of only limestone, (ii) using alternative fuels including recycled minerals and biomass to power furnaces rather than fossil fuels, (iii) using new types of cement clinkers that are being developed that are chemically different from conventional Portland cement clinker (however these have different properties and can currently only be used for specific purposes), (iv) making cement kilns even more efficient than their current operating levels of 70-80% efficiency, and (v) Carbon Capture, Utilisation and Storage (CCUS) which is currently in a developmental stage. The targets that have been outlined in this route maps include (European Cement Association, 2020):

- up to a 3.5% reduction of process CO_2 emissions by replacing some limestone with decarbonated materials by 2030 and up to 8% reduction by 2050, and a 2% reduction in process CO_2 emissions by 2030 and 5% by 2050 by using new types of cement clinker.

- increasing the 2017 level of alternative fuel use (which represented 46% of the total fuel needs of kilns across Europe) to reach 60% alternative fuels containing 30% biomass in 2030, and 90% alternative fuels with 50% biomass by 2050.

- a 4% improvement in thermal efficiency by 2030, and 14% by 2050.

- a 42% reduction in CO_2 emissions through various carbon capture techniques by 2050

The UK cement and concrete industry has also drawn up a route map to achieving net zero emissions by 2050. It foresees the following potential reductions in CO_2 emissions in cement production between 2020 and 2050 (MPA UK Concrete, 2020):

- Indirect emissions from decarbonised electricity - 4% CO_2 reduction
- Use of low carbon cements and concretes - 12% CO_2 reduction
- Fuel switching to recycled minerals and biomass - 16% CO_2 reduction
- Carbon capture, usage and storage (CCUS) - 61% CO_2 reduction
- Carbonation (the process by which concrete absorbs CO_2 from the atmosphere throughout its lifetime) - 12% CO_2 reduction

- Thermal mass (the property of concrete and masonry whereby heat is absorbed, stored and released, reducing the energy needed to heat and cool buildings) - 44% CO_2 reduction

It also foresees that freight transport can provide a further 7% CO_2 reduction by 2050 through using non-fossil fuels for road transport and further increases in use of rail (MPA UK Concrete, 2020).

Iron and steel products

Carbon emissions can be reduced for the manufacture of iron and steel products through improving energy efficiency, reducing production losses, and using biomass as an alternative reductant or fuel. In the longer term, CCS could also be applied (Hoffmann et al., 2020). Newer electric arc furnaces can be powered by renewable electricity and scrap steel is used as the main ferrous feed in them, and they are thereby associated with lower carbon emissions (IEA, 2020). As steel can be continually recycled without loss of properties or performance, scrap steel can also be used in either of these production processes. Additionally, reducing the amount of scrap generated when steel products are transformed into final consumer goods (which accounts for up to 50% of the scrap generated) can also have an important impact on CO_2 reduction (World Steel Association, 2020b).

Glass

The key source of CO_2 emissions in glass manufacturing is the high-temperature heat from fossil fuel combustion in the furnace for melting, which accounts for 75-85% of the total CO_2 emissions, with the remaining 15-25% of CO_2 emissions due to process emissions from the decomposition of carbonates used. CO_2 improvements using this technology are reaching their theoretical maximum but greater use of recycled glass in place of virgin carbonates, waste heat recovery, and furnace design and construction are still leading to small improvements. To achieve further substantial reductions in CO_2 emissions requires the adoption of carbon neutral energy sources (such as biogas) or switching to electric melting using decarbonised electricity (a technology not currently available for large furnaces), together with research and development in process emissions and in carbon capture and storage (CCS) (Glass Alliance Europe, 2019).

Embodied energy – operational energy use

A report by the Green Construction Board has considered the feasibility of achieving a 50% or greater reduction in energy use of new buildings by 2030. Case studies of residential buildings, schools and offices carried out as part of this work indicate that achieving at least a 50% reduction in the energy use of new buildings is technically and financially feasible. This was found to be best achieved through designing a building with a compact form, selecting an appropriate building fabric to achieve the airtightness of walls and windows, suitable building ventilation using openable windows and vents, and considering all energy uses that will take place in the building (Green Construction Board, 2019).

The Climate Change Committee has recommended to UK Government that the 29 million existing homes in the UK must be made low-energy and low-energy, using low-carbon sources of heating such as heat pumps, and an increase in loft and wall insulation, together with passive cooling measures for shading and ventilation and measures to reduce indoor moisture. Meanwhile new homes, of which the UK Government plans 300,000 need to be built per year, must be built to be low-carbon, energy and water efficient and climate resilient. Where possible, these new homes should be timber-framed, and from 2025 should not be connected to the gas grid (Climate Change Committee, 2019).

The UK Government is planning to future-proof new buildings and avoid the need for costly retrofit, by implementing a so-called 'Future Home Standard' and also consulting on increased standards for non-domestic buildings so that new buildings are energy efficient and use low carbon heating. This will include the phasing out of gas boilers and the installation of heat pumps, powered by either electricity or hydrogen. The Future Home Standard is expected to result in homes with 75–80% lower CO_2 emissions than those built to current standards. The UK Government has put in place several initial schemes providing grants and funding in pursuit of these reductions. The Green Homes Grant is intended to improve the energy efficiency of private homes and replace fossil fuel heating, the Homes Upgrade Grant is targeted at upgrading the heating systems of those living in homes off the gas grid, especially in rural areas, the Social Housing Decarbonisation Fund is targeted at upgrading the least efficient social housing, and the Public Sector Decarbonisation Scheme is meant to reduce emissions in schools, hospitals and public buildings (HM Government, 2020). However, the £1.5 billion Green Homes Grant scheme was withdrawn by the UK Government only six months after its launch, with accusations from the building industry and consumers that the scheme was hard to access, bureaucratic, poorly administered, and that few grants had been approved (Harvey, 2021).

A body comprising 43 of the UK's professional engineering organisations led by the Royal Academy of Engineering has called for whole-life CO_2 assessment to be applied to construction projects procured by the public sector, ensuring that that these projects are first appraised in terms of their contribution to the UK's net zero target. In addition, this body has also called for construction design and performance standards to be updated to support and enable more environmentally-efficient design and reuse of materials (National Engineering Policy Centre, 2021).

Various accreditation schemes exist in relation to the sustainability of new buildings and infrastructure such as BREEAM, LEED, CEEQUAL and Green Star (Tien Doan et al., 2016). While including consideration of the CO_2 emissions of buildings and infrastructure, they also take account of a range of other sustainability factors and consider the operational as well as the construction phases. BREEAM (The Building Research Establishment Environmental Assessment Method) was established by the Building Research Establishment (BRE) in 1990. Various environmental, social and economic aspects of a building including its design, materials used, land use and ecology, waste management, construction and operational transport, and operational energy efficiency are assessed as part of BREEAM, and it is awarded a grading from outstanding to unclassified. The intention is to encourage more sustainable constructions that enhance the well-being of the people who live and work in them, help protect natural resources and make for more attractive property investments. Project clients may specify the BREEAM status a building must achieve at the commissioning. Since its inception, 2.3 million buildings have been BREEAM-registered (BRE, 2021a). CEEQUAL (The Civil Engineering Environmental Quality Assessment and Award scheme) was also developed by BRE. It is targeted at infrastructure projects, also rating their sustainability from unclassified to outstanding (BRE, 2021b). LEED (Leadership in Energy and Environmental Design) is another similar rating scheme providing a framework for assessing the sustainability of new and existing buildings including their energy efficiency and ways in which they support the health of those using and living in them. It was developed by the US Green Building Council (US Green Building Council, 2021).

7.2.2 Off-site manufacturing

Off-site manufacturing (also referred to as pre-manufacturing, pre-fabrication and modular construction) involves the production, preparation and assembly of building products in factories upstream of the construction site that are then delivered to the site and are simply assembled. This removes the need to carry out complicated building processes on site that require many different building contractor specialists and complicated sequencing of tasks in an often small and non-optimal working environment.

Off-site manufacture can therefore both reduce construction project waste levels, time taken and costs (it can potentially lead to a 20–60% reduction in the construction programme time and a 20–40% reduction in construction costs), as well as helping to prevent on-site project delays and defect rates. It can also help improve on-site worker safety, overcome the shortage of construction workers (with a potential reduction of 70% or more in on-site labour), reduce noise and air pollution at construction sites as well as goods deliveries and other travel to site. Off-site manufacture can be can up to 30% lighter than traditional masonry products (Housing, Communities and Local Government Committee, 2019; House of Lords Science and Technology Select Committee, 2018). Products that that be manufactured off-site include factory-made concrete, steel and cross-laminated timber components through to precast wall panels and modules, and facade units complete with windows and balconies.

In 2005, the National Audit Office published a report on modern methods of construction to build housing more rapidly and efficiently, in which off-site manufacturing was promoted. In 2017, in an effort to increase the relatively low use of off-site manufacturing, the UK Government announced that off-site manufacturing would be favoured by five government departments for its future public sector construction projects from 2019 where it represents best value for money (HM Government, 2019). Criticism of off-site manufacturing by the Building Alliance has suggested that it results in greater reliance on imported building products and represents government interference that detrimentally affects the British masonry industry (Building Alliance, 2018).

The UK Government contributed £22 million of funding to Laing O'Rourke's offsite manufacturing facility in Nottinghamshire in order to help promote, showcase and research this approach in the construction industry. This is a 23,000 square metre factory from which the main output is precast wall panels and modules for home-building. The facility site contains a prototype two-storey house made entirely from factory-manufactured components (Jensen, 2015).

The use of off-site manufacturing has been proposed for the construction of a new third runway at Heathrow Airport. This would take place at so-called logistics hubs, which would be responsible for both manufacturing products and consolidating product flow destined for the project. Other examples include The Ocean Academy, a school for 340 pupils in Poole which opened in September 2015. The construction made use of modular design with 90% of the building being manufactured off-site. Off-site manufacturing has also been used for some components for the Crossrail project. In the case of Heathrow Terminal 5 off-site manufacturing was also made use of for various mechanical and electric modules, car park floor slabs, and drywalls. These products were delivered to the Colnbrook Logistics Centre, where they were consolidated and then delivered in bulk to the construction site by both road and rail. It was estimated that the off-site construction of fourteen risers for the project resulted in time savings of four months per riser compared to traditional on-site construction (Oakley, 2018).

Work is on-going to provide evidence-based research that quantifies the benefits of off-site manufacturing in a transparent and consistent manner. A guide has been produced that provides a methodology for assessing how construction project performance and outcomes may be influenced by the use of off-site manufacturing (Jansen van Vuuren and Middleton, 2020).

7.2.3 Supply chain working practices

Supply chain operations and collaboration

Paying greater attention to the freight transport and logistics management of construction products along their supply chain, their provision to the construction site and their use on the site has the potential to yield substantial benefits in terms of project cost and productivity (Ying et al, 2014). A study has identified the poor procurement and supply-chain management performance of the construction industry, with companies overpaying by up to 15 percent for materials and services, and poor supply chain management accounting for 10 to 30 percent of cost and time overruns (McKinsey and Company, 2017). Improved product purchasing (especially in the case of large principal contractors working on many projects at once), stock control and inventory management (both on-site and off-site), better management of product deliveries to and collections from construction sites (including the consolidation of loads onto vehicles which deliver them to site as and when they are required), decision-making concerning what should be assembled off- and on-site, and greater standardisation of project designs and products. In addition to reducing costs and improving productivity, such logistics management can also reduce the intensity and environmental and social impacts of the freight transport activity involved in construction.

Research into the problems that arise on construction sites has attempted to identify and trace these problems to their origin either in the construction site project process, in the wider supply chain or in the intersection between these two. As part of this work, the problems identified were categorised into four groups: (i) material flow, (ii) internal communication within a single company, (iii) external communication between companies, and (iv) complexity issues (such as changes made by the client, lack of standardisation and weather) (Thunberg et al., 2014; 2017). Collaboration in the construction industry is traditionally limited to the relationship between the client and principal contractor, so much scope exists for greater collaboration across the organisations involved in a construction project (Ekeskär, 2016b). However, due to the multi-stakeholder, fragmented and temporary nature of supply chains for construction projects this represents a sizeable challenge (Robbins, 2015).

Research suggests that linking supply chain considerations and logistics practices in the construction industry (including tasks such as design specifications, product procurement and the transport and delivery of products to the construction site) with the logistics practices on the construction site (including the planning of construction tasks, product flows and site layout) is extremely important to achieving supply chain integration in the construction industry and productivity and efficiency in the industry (Dubois et al., 2019). However, achieving such supply chain integration involves addressing and overcoming various long-term weaknesses in the construction industry such as the large number of organisations involved in each construction project each with its own motivations and objectives, supply chain fragmentation (with high numbers of small companies and high levels of self-employment) and the temporary nature of construction projects (see **chapter 3** for further details of these issues).

Qualitative case study work carried out with construction companies in Sweden has identified much potential for innovation both within the individual companies, between the companies that work together on a construction site, and in the various supply chains used by these companies (Bengtsson, 2019). Based on research carried out, the CIVIC project developed in conjunction with urban authorities and construction companies the so-called ‘Smart Governance Concept’ which consists of seven steps including stakeholder involvement tools, logistics solutions concepts, traffic optimisation models, cost calculations and KPIs to improve construction supply chain and logistical efficiency and thereby also reduce negative traffic and social impacts. The concept is based on strong collaboration both between construction companies and also with urban authorities to jointly define problems, work together on developing and implementing potential solutions (CIVIC, 2018; Morel, 2020).

Unlike many others in the construction industry, Mace, a major construction company established in 1990, has long focused of the importance of logistics performance as well as seeking to develop long-term relationships with the subcontractors in its supply chain. In the 1990s it produced a web-based real time system to monitor the performance of deliveries and other logistics activities and shared this with its subcontractors. In 2006, Mace established its own in-house business school to train its own staff and those of subcontractors in supply chain management. This was the first of its kind in the industry. The intention of this training was to improve the performance of its construction companies in its supply chain through learning and knowledge sharing. Rather than source new contractors with greater logistics knowledge, Mace sought to build on its long-term relationship with its subcontractors by sharing its expertise with them (Moone, 2015).

In 2012, seven major construction and materials companies (namely Skanska, Kier, Lend Lease, Morgan Sindall, Sir Robert McAlpine, Willmott Dixon and Aggregate Industries) established the ‘Supply Chain Sustainability School’ in Britain. Freely available to construction clients, contractors and their supply chain partners, it is intended as a knowledge and experience sharing centre to increases the skills, knowhow and collaboration of those working in the industry in relation to sustainability, focusing on working practices that can support this and at the same time enhance efficiency including off-site manufacturing, ‘lean’ construction and management, and use of BIM. Online training resources available from the school include: online learning modules, talks, videos, presentations, workshops and webinars. The school is therefore an industry-led initiative which is part funded by the Construction Industry Training Board. It currently has 125 partner companies and 50,000 individual members from approximately 15,000 companies (Skanska UK, 2013; Supply Chain Sustainability School, 2021).

Focus needs to be placed on logistics performance in the bulk materials supply chain (i.e. aggregates, cement and concrete) as well as on the construction site, as the former has been equally if not even slower in embracing efficient logistics practices and supply chain thinking. Due to the geographical availability and local focus of bulk materials, major suppliers of these products have tended to organise their businesses by individual product with local planning and management, which has limited the introduction of new ideas and practices (Woodcock, 2015). This is reflected in the frequent outsourcing of delivery operations to many owner-drivers, each with only one or a few vehicles, stifling opportunities for rapid innovation. The peaky, ad-hoc nature of demand for materials such as concrete and asphalt leads to substantial peaks and troughs in demand (by day of week and time of day – with a preference for morning deliveries on Tuesdays, Wednesdays and Thursdays - as well as over economic cycles) makes advance supply chain planning, and this has led to little implementation of logistics management principles, software and tools. There is substantial scope for bulk materials suppliers to move away from a reactive business model, that is based on siloed goals of individuals business units to one focused on cross-functional decision making within these companies and collaborative working with their supply chain customers and suppliers. The extent of vertical integration that already exists within the major bulk material companies should help facilitate the adoption of more integrated, collaborative practices (Woodcock, 2015).

Business Information modelling (BIM)

BIM is modelling software that allows the creation of a virtual 3D building or infrastructure, the virtual testing of that building and the processes to be used for its production and the management of that production process, including the data associated with this (Beaumont and Underwood, 2015). By virtually generating such processes through 3D modelling it is possible for all the stakeholders in the construction supply chain (including architects, engineers and construction contractors) to gain the required insight and information to plan, design, construct, and manage the sequence of activities required in building and infrastructure construction more efficiently before physical construction commences, thereby improving productivity and quality, and reducing waste, time taken and project costs. Studies have indicated that BIM can reduce time taken and costs in both the design and construction phase (World Economic Forum and Boston Consulting Group, 2018). BIM is intended to ensure that appropriate information is created and stored in a suitable, accessible format at the right time so that better decisions can be made throughout the design and building of construction projects.

For BIM to be used requires collaborative working and data sharing between the construction supply chain parties in a way that has not traditionally occurred. The benefits of BIM are that it facilitates, "essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them" (BIM Task Group, 2016). BIM works well in tandem with the premanufacturing of products.

A study of two UK public sector construction projects designed and built using BIM (one an office building and the other a flood barrier upgrade) has estimated that the gross total quantified benefits were 1.5% and 3.0% of whole of life expenditure, respectively. As not all benefits could be quantified, this are likely to be lowest case estimates. Across the design, build and commission, and handover phases, the benefits were 0.7% and 1.4% of capital expenditure, respectively. The largest benefits were calculated to arise during the operation phase of both assets: 73% of total benefits in the case of the office block, and 61% in the case of the flood barrier upgrade. The largest source of benefit in both cases is in maintenance planning and execution. Time savings in design was the second largest benefit for the flood barrier (estimated as 5% of total design cost), followed by time savings in build and commission, and cost savings in clash detection based on inputs obtained from stakeholders. For the office block, time savings in build and commission was estimated as 15% of total BIM-related savings, time savings in handover as 12.5%, and time savings in design as 6% (pwc, 2018).

Other estimates of the benefits of BIM suggest that in the ten years from 2016 (when the research was carried out), full-scale digitalization in non-residential construction would result in cost savings of 13% to 21% in the engineering and construction phases and 10% to 17% in the operations phase (Boston Consulting Group, 2016).

As well as reducing design, construction and operational maintenance costs of building projects, through both time savings and reduced wastage, BIM also thereby leads to reductions in CO_2 emissions during construction activities through reductions in wasted effort and reworking.

In terms of construction logistics, BIM can be used to produce three-dimensional site layouts including site access points, the positioning of plant such as hoists and tower cranes, loading bays and material storage areas, helping to allow efficient utilisation of the area available. Time-related data can be used in BIM to predict the programme of works including the deployment and removal of plant and machinery, loading bays and storage facilities at various stages. These features of BIM in relation to site logistics can lead to improved site safety, less clashes between tasks, and better procurement and logistics planning (Whitlock et al., 2018).

In a survey carried out among 398 contractors, consultants and assets owners in the construction industry in August 2020, 95% of respondents agreed with the statement that "digital innovation will be increasingly important after the Covid-19 crisis" in the construction sector (with 56% of respondents strongly agreeing with the statement) (Savanta ComRes, 2020).

The UK Government has made the use of BIM a prerequisite for all centrally procured government construction projects (Infrastructure and Projects Authority, 2016).

7.2.4 Site layout and logistics management

Site layout considerations and logistics management are required on the construction site itself as this is a dangerous location with a constrained physical size, and within it materials need to be received, stored and allocated as required to avoid delays in construction activities. These materials have to be moved around the site to ensure they are available in the correct location and quantity when needed in order that work can continue without disruption.

The traditional approach involves numerous sub-contractors working on a construction project each take their own responsibility for their materials requirements and supplies, and for their on-site logistics activities, with site layout and logistics nominally overseen by the principal contractor but in which there is no overall logistics planning or co-ordination for the project or on-site (Dubois et al., 2019). This often leads to the unavailability of materials, tools and machinery where and when they are required on site which affects worker productivity and project costs (Linden and Josephson, 2013). These on-site logistics costs can be divided into four categories: (i) direct costs including worker hours, and the management of on-site logistics and machinery; (ii) indirect costs including costs for handling equipment used (often hired) to move materials around the site such as pallet trucks, hand trucks, and hoists and the need for storage facilities; (iii) material waste costs, related to worker damage, unused materials and theft; (iv) other logistics costs including those related to weather conditions, which can affect the use of tower cranes to move materials and can damage materials being handled and stored on-site, and packaging which can affect handling time when deliveries are made (Linden and Josephson, 2013).

Research has shown that on-site logistics constitutes an important project cost and has an important impact on project productivity. For instance, a study has estimated that craftsmen in Scandinavia spend as much as 14% of their working time moving materials and equipment to the assembly area (Strandberg and Josephson, 2005). Another study indicated that Swedish construction workers spend, on average, over 50% of their time waiting and handling materials (Josephson and Saukkoriipi, 2007). Another study of has shown that in the case of gypsum boards, outsourcing the on-site handling of these rather than doing so with existing on-site resources can reduce the handling costs of these materials by approximately 20% through being able to position these where they are required after regular working hours on-site (Linden and Josephson, 2013).

<u>*Use of a specialist construction logistics provider*</u>

Logistics expertise for construction projects can be provided in various ways. This includes by the principal contractor employing a construction logistics manager and staff who perform this role, or by engaging the services of a specialist construction logistics company or a third-party logistics services provider with expertise in construction as a sub-contractor. Principal contractors working on large construction projects may employ these logistics staff directly, but this is not always the case (Brown, 2015).

It is possible to enlist a specialist construction logistics company to take control of the on-site logistics planning and management to help avoid the inconsistencies, duplication and gaps in the provision of logistics activities on-site that this traditional approach often results in (Ekeskär and Rudberg, 2020; Janné and Rudberg, 2020; Sundquist et al, 2018). This can help to eliminate operational confusion on-site and logistics inefficiency due to a lack of strategic planning both on-site and in the wider supply chain for the site, which can result in substantial product damage and loss, and downtime in construction tasks. This specialist construction logistics contractor can provide 'on-site coordinated configuration' coordinating on-site logistics activities as well as the interface of the site with the flow of products to it from numerous supply chains that manifest as vehicle deliveries and collections. Their tasks will involve: planning of the construction site layout (for deliveries, storage and equipment), delivery and collection arrangements and operations (including booking systems and vehicle marshalling on arrival), on-site storage systems, and on-site materials handling activities.

An even more integrated approach to logistics, the so-called ‘supply network coordinated configuration’ can also be applied in which, in addition to all the previously mentioned tasks, the specialist logistics contractor is also responsible for coordinating activities beyond the construction site to include the product supply chains as well. This approach involves consolidating the flows of products upstream of the site to reduce the number of deliveries to site and the quantity of products that need to be stored on site, with deliveries being made as and when required by workers (Dubois et al., 2019). This latter is less commonly used, and when it has been used its application has often been related to a requirement to manage vehicle activity and its impacts rather than solely to improve logistics efficiency and project costs (Fredriksson et al., 2021).

The services provided by specialist construction logistics companies can take three forms (Hedlund and Telese, 2019):

- On-site coordination, storage and handling of the construction materials on the site only.
- In addition to the above, the coordination and management of all deliveries of materials and other goods to the construction site to avoid traffic impacts at site entry points and a smooth flow of materials on-site as and when required.
- In addition to the above, the management of an off-site Consolidation Centre (CC) where materials are delivered to by suppliers and freight companies rather than direct to the site (with co-ordinated, well-loaded onward deliveries to the construction site operated by the appointed logistics company (see **section 7.3.5** for further details of CCs).

Effective construction logistics management can help to reduce total construction project costs, keep projects to timescale and reduce the social and environmental impacts for which they are responsible. Research into construction sites in Sweden has indicated that standardisation in the management and coordination of transport and logistics activities provides opportunities for improving site efficiency in construction (Dubois et al., 2019).

Specialist construction logistics companies that can provide more efficient logistics management are typically appointed by the principal contractor to perform this role. Nowadays, for larger construction projects, computer-based software is often also used to help manage the complexity of the supply chain process, and the required interactions of many activities and companies (see **section 7.2.3**). A survey carried out among respondents working in various roles in the construction industry including site-managers, foremen and buyers who had experience of using a specialist logistics provider found that the most commonly cited benefit was that it allows construction companies to focus on their core activities. This was followed in importance by the ability it allows to utilise external logistical competence, and the way in which hiring such a specialist logistic provider offers the opportunity to reorganise the wider construction supply chain in a beneficial way. The vast majority of respondents it is possible to notice that the most common operative benefits, as highlighted by the respondents were of the opinion that specialist logistics providers increase operational efficiency on the construction site and reduce the level of materials held on site (Hedlund and Telese, 2019).

The potential advantages of a specialist logistics contractor can be provided through an example. On a £50 million commercial development with a 100-week work programme, there may be 30 contractor companies on site at any time, each employing two labourers to carry out materials handling and movement tasks. If these 60 labourers can be replaced with a dedicated logistics team of 20 employed by a specialist logistics contractor, who streamlines and co-ordinates the delivery of materials to site and on-site, then site productivity can be improved. If these productivity gains amount to an hour per contractor per working day, this could save 150 hours per week, reducing total project time by several weeks and total project costs. Such changes in logistics management arrangements can result in overall project cost savings of 2-4% (Sullivan et al., 2010). Some large construction sites have a traffic manager in addition to a logistics manager who focuses specifically on transport-related issues.

It has been noted by a manager from a third-party logistics service provider, that making use of such a logistics specialist requires a large-scale project that will run for a sufficiently long period of time (typically five years or more) for the provider to be able to make a return on their capital investment in assets such as vehicles and distribution centres. They also point out that where use has been made of logistics specialist on such construction projects, the scope has often been limited to 'last-mile logistics' rather than to the entire construction supply chain. This emerges from the logistics specialist typically working as a sub-contractor to a principal contractor who bids with others to be appointed to the project, rather than being appointed by and working with the developer and their project design team (which would permit involvement in the entire supply chain design for the project and potentially far greater logistics -related benefits). Logistics specialists could be engaged to work in this way by large home builders who have repeatable projects that provide greater opportunity to develop longer-term relationships than one-off infrastructure projects.

Increasing uptake of BIM (see **section 7.2.3**) in the construction industry has the potential to provide greater opportunity for the engagement of construction logistics specialists by developers at the design stage and for their involvement in all aspects of supply chain planning and management in the wider construction supply chain for a project.

Third-party logistics specialists already work with many major construction products manufacturers. They could use these skills and resources to also provide centralised planning, inventory management and delivery services to builders' merchants who often currently operate at a branch level, thereby providing greater logistics efficiency to this part of the construction industry.

Site layout and logistics

Many urban construction sites are confined in terms of the space available, leaving little room for activities such as plant and material movement, storage of materials and other facilities such as temporary offices and facilities. Research has suggested that the five most important issues in the management of materials on a confined construction site are: (i) contractor's material spatial requirements exceed the available space, (ii) difficult to coordinate the storage of materials in line with the programme, (iii) location of the site entrance makes delivery of materials particularly difficult, (iv) difficult to store materials on site due to the lack of space, and (v) difficult to coordinate the storage requirements of the various sub-contractors (Spillane et al., 2011). Further research has indicated that, in terms of personnel management, the top five issues on a confined construction site are: (i) accidents due to an untidy site, (ii) one contractor holding up another because of the lack of space, (iii) a risk to personnel because of vehicular traffic on-site, (iv) difficult to facilitate several contractors at one work location, and (v) numerous personnel working within the one space (Spillane et al., 2013).

Such confined sites require far greater activity and resource than larger sites in order to be able to operate efficiently and safely, and this requires planning and management, especially between the various contractors working on site, that goes well beyond that usually required. In addition to normal space-scheduling, this requires analysis and planning of dynamic workforce and equipment movements taking account of time and location (Kooragamage, 2015).

Agent-based modelling has been applied to construction site layout and logistics planning. This has the advantage over other modelling tools of taking into account spatial as well as temporal factors. It was applied to the planning of earthmoving activities for the London Gateway Port project in 2011 in an effort to improve their efficiency given that these constituted a substantial activity. Observational research using video carried out on site showed that dumper trucks were subject to problems that included: (i) irregular travel routes and hence varying distances between the excavation and dumping areas, (ii) other on-site logistics activities affecting the progress of the earthmoving vehicles – there was found to be a 75% probability that a dumper truck would encounter spatial time clashes with these other logistics activities which would delay its movement, and (iii) on reaching the discharge location on site, the dumper trucks sometimes had to queue, parking nearby in ‘holding areas’ while they waited in an effort to avoid on-site traffic congestion – as these ‘holding areas’ were often unmarked, they were often used by other subcontractors to execute their tasks, causing further delays and confusion. Agent-based modelling was used to estimate the delay of the earthmoving vehicles due to these factors including other logistics activities. The work also highlighted the lack of productivity of the on-site concrete batching due to a lack of consideration of the logistical operation for the concrete pour. It was identified that the efficiency of this operation could be optimised through the use of agent-based simulation in its planning, thereby reducing vehicle emissions due to engine idling and queuing, as well as reducing total vehicle requirements (Kooragamage et al., 2009).

7.2.5 Plant & equipment fuel used on site

Start-stop technology automatically shuts down construction site machinery and goods vehicles’ engine when they are stationary and then restarts them when they are engaged to move. This reduces the amount of time the equipment is idling, and hence its fuel consumption and emissions. Energy savings are approximately 30% from start-stop technology. Companies, including Bosch Rexroth and Ryder, are supplying the construction industry with vehicles and machines installed with start-stop technology (CCS Best Practice Hub Administrator, 2019).

The CAT 730 C2 EJ diesel dump truck is being used on a road construction project on the M20. Its fuel-saving operating mode, together with other fuel saving features result in a 19% improvement in fuel efficiency compared to earlier models. It is also fitted with cab-mounted mirrors that improve all-round visibility for the operator and has a rear-view camera. The cab design reduces noise levels in the cab (Vinci, 2019).

In one scheme, plant operators on a construction site were issued with a personalised smart card that stored data regarding their use of the equipment. Through this information it was possible to understand the efficiency with which they used the equipment. This data and system can be used to determine which workers should be allowed to use machinery and worker training requirements. It can help to reduce the fuel consumption and safety of plant use on site (Barratt, 2018a).

In the longer term, plant and machinery powered by electricity or hydrogen has the potential to remove carbon emissions and local air pollution, as well as reducing noise from pumps, generators, compressors, and engines (Bellona, 2018). A database of manufacturers of zero emission construction machinery together with details of prototypes that they have developed has been compiled as part of a Norwegian project (Bellona, 2021).

Equipment powered by electricity provided by from overhead catenaries is being developed and tested for use in quarries and mines. The CAT trolley assist system can be retrofitted to the CAT 795F AC wheeled loader mining truck and will also be made available for other CAT electric drive trucks. In the case of the CAT 795F, which has a payload of 313 tonnes, when connected to the trolley system, the truck's propulsion system becomes powered only by electricity from the overhead power grid, thereby minimising the use of the vehicle's diesel engine. CAT has estimated that diesel consumption is reduced by 90% or more through the use of this system (CAT, 2021). Liebherr has also developed an overhead electric catenary system to use with its T236 100 tonne diesel mining truck. This was tested on a 500-metre test track at a mine in Austria in 2020. A 5 km track is now being developed for testing (Wordsworth, 2020).

Various hydrogen fuel cell and battery electric machinery is currently being tested. For instance, Ballard has provided hydrogen fuel cells for piloting in several construction site machines. These include a heavy-duty mining truck that Anglo American is using in its operation at one of its South African mines, a hydrogen fuel cell powered 20 tonne excavator that is being tested by JCB in the UK, and a 200-tonne mining truck using 800kW of hydrogen fuel cells provided by Weichai and Ballard will begin work in a trial in late 2021 (Pocard, 2021).

As well as testing this hydrogen fuel cell excavator at its UK quarry, JCB also went into full production in 2019 of the construction industry's first fully electric mini excavator, the 19C-1E, and has since extended electric technology to its Teletruk telescopic forklift range, launching the JCB 30-19E (JCB, 2020).

Plant manufacturer Komatsu has established what it refers to as "a power agnostic truck concept" that can run on "a variety of power sources including diesel electric, electric, trolley (wired), battery power and even hydrogen fuel cells". Komatsu plan to unveil the vehicle at a trade show in America in September 2021. As part of this development work the company has set up the Komatsu Greenhouse Gas (GHG) Alliance with several of its mining and quarrying customers becoming founder members (including Rio Tinto, BHP, Codelco and Boliden). These companies will work together to on product planning, development, testing and deployment of this alternatively fuelled machinery (Komatsu, 2021).

Based on projects using zero emissions construction site equipment, the City of Oslo decided in 2019 to revise its procurement policies to reduce carbon emissions and air pollution from all the construction projects it is responsible for including environmental criteria, and from 2025 all of Oslo's public construction sites will have to operate zero emission machinery (and zero emission transport of materials and workers to the site) (Bellona, 2019). In 2019, the City of Oslo also implemented the world's first zero emission construction site, which is in the city centre. The company awarded the tender is using all-electric plant on site (Bellona, 2019).

The Mayor of London implemented a Low Emission Zone for Non-Road Mobile Machinery (NRMM) in February 2021 which requires that all construction site engines with a power rating between 37 kW and 560 kW meet a specified emissions standard. This standard is higher in central London and Canary Wharf than in the rest of London to begin with, but will be equalised in 2025, with the emission standard increasing in 2030, and then in 2040 only zero emission machinery will be allowed (Mayor of London, 2021). A practical guide has been produced to assist those with construction to provide guidance on the London NRMM Low Emission Zone and to help them ensure that they have complied with the processes and procedures that must be in place (Cleaner Construction for London, (2020).

7.2.6 On-site dust and pollutant management

Traditionally, water has been used to suppress dust in the construction industry, either using a sprinkler system, a hose pipe, or sprayed as a fine mist from a canon. However, this results in considerable water usage, it evaporates quickly, can result in water pollution, and its efficacy has not been well tested (Marsh et al., 2019).

Chemical dust suppressants may well be more effective at reducing the particulate matter (PM) in the air than using water. Trials of the suppressant Calcium Magnesium Acetate (CMA) on paved roads in London found that there was an observable level of improvement in 24-hour PM10 concentrations (of 10-14%). This has led the Greater London Authority to recommend using chemical dust suppressants on busy roads and roads near to and within construction and waste sites with high levels of local PM pollution. However, this is a potentially costly method of dust suppression (Marsh et al., 2019).

To avoid PM being transported onto the public road networks, constructions sites where such suppressants such as CMA are used should ideally also have vehicle wheel washing facilities. To prevent dust being transported from construction and waste sites onto the public roads by vehicles, these sites and nearby streets should be regularly swept to remove dust. Controlling vehicle speed on unmade roads on sites may also offer a straightforward method of reducing the spread of dust (Marsh et al., 2019).

A requirement for vehicle wheel washing may be identified as part of an environmental risk assessment and can be part of planning permission being granted. Wheel washing facilities should be positioned at site exits to remove dust, mud and other pollutants from vehicles and prevent them being deposited on the public road network (Kukadia et al, 2003).

7.2.7 Waste management

As explained in **chapter 4**, the Landfill Tax was introduced in the UK in 1996 to reduce the amount of construction and demolition and other waste going to landfill by incentivising its diversion to other less harmful methods of waste management including recycling and incineration. It is paid by landfill operators on the disposal of material at a landfill site. These operators pass the tax onto businesses and local authorities by charging a fee for disposing of waste at a landfill.

The Aggregate Levy was introduced by the UK Government in 2002. It is an environmental tax on primary virgin aggregates (rock, sand and gravel used as bulk fill in construction). Its introduction was intended to encourage a shift in demand to alternative materials including recycled and secondary material. Construction and demolition waste is recycled material and arises both on construction sites and in recycling depots. It can be processed and blended with other aggregates for use in products such as concrete.

As a result of these taxes, recycled and secondary aggregates comprised 29% of total aggregates supply in the UK in 2017 (26% from recycled aggregates and 3% from secondary aggregates), which is higher than any other country in Europe (Mineral Products Association, 2012).

These taxes contributed to 92% of non-hazardous construction and demolition waste being recovered in the UK in 2016, which far exceeds the UK Government's target of 70% recovery (DEFRA, 2020). Much of this recovered material is concrete, brick and asphalt which is recycled for use as aggregate. However, the remaining 8% (approximately 5 million tonnes) of non-hazardous construction and demolition waste was sent to landfill sites in 2016 (Green Construction Board, 2020). No information is available concerning the impact of these taxes on the freight transport activity associated with waste materials.

The construction industry is working with the UK Government to better understand what current waste arising in construction is avoidable to develop a route map of how 'zero avoidable waste' (i.e. materials, products or components that can be prevented from becoming waste) might be achieved (Green Construction Board, 2020). Research has indicated that much waste arises due to design and construction phases problems. Possible methods for achieving zero avoidable construction waste include designing new buildings for better resource efficiency and for deconstruction and disassembly, efficient manufacturing processes, extending the life of buildings, and disassembly for reuse and reducing surplus materials, all of which design out waste. If waste cannot be prevented, then the next best is to aim for (in order of preference): preparing for reuse (e.g. repair or remanufacture), closed-loop recycling (where waste is used as a feedstock in the same process) and open-loop recycling (where waste is used as a feedstock for a different purpose) (Green Construction Board, 2020).

Opportunities exist to reuse demolition material that arises on site (such as aggregate, soil and crushed concrete) rather than transporting it elsewhere. Such actions help to increase waste recycling rates and also reduces road freight transport. TfL is keen to support such action and to work with those involved to mitigate any impacts that may otherwise arise from associated dust and noise, especially in the case of crushing concrete on site (Barratt, 2018b). At one construction site in central London, 7000 cubic metres (approximately 15,000 tonnes) of concrete was crushed and used on site for piling mats. It was estimated that this resulted in the prevention of approximately 33,000 km of HGV activity to remove it and an associated 87 tonnes of CO_2 emissions from diesel use (Barratt, 2016; Barratt, 2017a).

In terms of fly-tipping, local authorities in England carried out 474,000 enforcement actions in 2019/20 and issued 75,400 fixed penalty notices. There were also 2,671 court fines issued (DEFRA, 2021c). In addition, the Environment Agency, which is responsible for waste loads of greater than 20 tonnes that have been illegally dumped, closes several hundred illegal waste sites each year (Environment Agency, 2017).

Recent examples of court fines issued to construction companies include London Engineering and Construction Ltd being charged fines and costs of almost £5,000 in 2018 for waste from a construction site that it was responsible for being fly-tipped in Denham, Buckinghamshire (Peracha, 2018). In 2018, John Jones Civil Engineering & Groundworks Ltd was fined £50,000 and ordered to pay prosecution costs of £50,000 for illegally dumping 5,000 tonnes of soil, stone, brick and concrete waste at a farm in Herefordshire, and in so doing, destroying a habitat for protected great-crested newts (Prior, 2018). In 2019, two Essex-based companies, waste and demolition company Walsh & Sons Ltd and Calahans Cleaning Services Ltd, received fines and charges with a combined total of £45,000 for sub-contracting waste clearance work to an unknown carrier who went on to fly-tip the material in Colchester. They had failed in their duty of care to check if the unknown carrier was registered to carry waste, ask to where the waste would be taken, or completed any transfer of waste papers (Environment Agency, 2019). In 2018, Gloucester-based construction company Morgan Barnfield was charged fines and costs of almost £10,000 for dumping a lorry-load of construction waste including rubble, insulation material, bricks and pallets from a residential project it was working on in Cheltenham (Calderbank, 2018). In 2017, RM City Construction was charged fines and costs of £3,710 for waste fly-tipped in Sheffield that was traced to a construction site it had worked on. The company said it had paid a private individual to dispose of the waste but had failed to carry out any checks as to where the rubbish might end up of it the person was registered to carry waste (The Star, 2017).

The National Fly-Tipping Prevention Group has been established to share experience and best practice for the prevention, reporting, investigation and clearance of fly-tipping at the local level (The National Fly-Tipping Prevention Group, 2014). Their advice to help prevent fly-tipping include: the use of physical barriers to prevent access to private land, improving the visibility of areas make fly-tipping activity more noticeable, the use of lighting and CCTV as deterrents, and the rapid removal of waste to discourage others from adding to it.

7.2.8 Crime prevention

Actions can be taken to prevent thefts and burglaries and other criminal offences from taking place on construction sites. These include improving site access controls and management to identify who should be on site and to challenge those who should not be, minimising site access points, erecting secure gating and hoarding around the site perimeter, the securing and identification of equipment and construction materials, and refraining from holding more equipment and materials at site than necessary. Hoarding and fencing needs to be of a suitable construction and height (at least 2.4 metres) to prevent attack and climbing (Barratt, 2019a; National Business Crime Centre and Considerate Constructors, 2019).

The Equipment Register (TER) is Europe's largest database of plant and equipment. Owners can register equipment with TER who then assist police and law enforcement agencies with the identification and recovery of stolen plant and equipment (TER, 2021). The Construction Equipment Security and Registration Scheme (CESAR) marking scheme helps protect plant and equipment from theft and increases the chances of recovery (CESAR, 2021).

Hoardings can obscure footpaths and create blind-spots, that encourage crime and provoke fear in those using the rights of way that run alongside them. Construction contractors McLaughlin & Harvey Ltd and Keltbray worked with the project developer, TfL and the Metropolitan Police to carry out a crime impact assessment at a site in East London. This involved perimeter surveys (both day and night) of the hoardings which look at positioning, security and lighting, access arrangements and an area-wide study of existing crimes. This assessment identified anti-social behaviour, rough sleeping, drug use and fear-provoking environments for the public in rights of way alongside hoardings (Barratt, 2019a).

Following this assessment measures have been implemented to help reduce the opportunity for crime which included the installation of trixi mirrors (to improve visibility around corners), the use of chamfered hoarding base (to reduce ease of climbing), changing the colour of the hoarding from black to white (to improve lighting and appearance), increased use of CCTV, the removal of recesses for rough sleeping, and frequent litter sweeps (Barratt, 2019a; Barratt, 2019b; National Business Crime Centre and Considerate Constructors, 2019).

7.3 Potential actions related to freight transport

7.3.1 Vehicle fuel source / engine standards

Several electric HGVs for use in construction transport have recently begun trials. In 2020, Volvo Trucks provided two HGVs, a fully electric Volvo FMX truck fitted with a hooklift and an all-electric mixer truck, to the Swedish construction materials supplier Swerock which it will trial in Gothenburg over a two-year period. As well as producing zero tail pipe emissions, these vehicles will also provide quieter vehicle operations. This pilot project will also assess the use of electric power in the heavy-duty construction sector in relation to vehicle workload and recharging requirements. Both stationary charging stations and portable ones will be tested (Volvo Trucks, 2020).

The Swiss vehicle manufacturer Liebherr also began providing all-electric articulated ready mix cement mixer HGVs in 2020, which are being used in trials in Switzerland by the cement companies Holcim and KIBAG. Both the vehicle and the cement mixer body are powered jointly by the traction battery. The drum has a capacity of up to 12 cubic metres. Whereas battery technology is currently unsuitable for many longer-distance HGV operations, it can potentially be deployed in these operations given the relatively short distances from concrete plants to construction sites. The vehicle is based on the 670 HP all-electric Volvo FM (Liebherr, 2020; Randall, 2020).

In 2020, Chinese construction machinery and vehicle manufacturer SANY unveiled two prototype construction 31 tonne HGVs that run on hydrogen fuel cells, a dump truck and a mixer truck. The latter is the world's first hydrogen-powered mixer truck and both vehicles have a range of more than 500 kilometres (REFIRE, 2020; SANY, 2021).

Major construction projects have the potential to require the use of goods vehicles that are cleaner than most vehicles on the road. For example, as part of the high-speed rail HS2 project it is required that all HGVs and light duty vehicles making collections or deliveries have Euro VI emissions standards. In addition, targets have been set by HS2 that 25% of HGVs used in Clean Air Zones and 10% of HGVs used on all other routes should be cleaner than EURO VI, and that 75% of vans and 100% of cars used on all routes should be ultra-low emission vehicles (i.e. these vehicles should have emissions lower than 75g CO_2/km and zero-emission range of greater than 10 miles or, for an all-electric vehicle, a range greater than 60 miles) (HS2, 2020a).

The construction materials supplier Tarmac and rail freight operator DB Cargo UK plan to commence freight train operations powered by 100% renewable fuel (hydro-treated vegetable oil - HVO) between Tarmac's Mountsorrel site in Leicestershire and its asphalt plant in the centre of Birmingham. All the trains carrying these products will be fuelled in this way. Previous trials by DB Cargo UK have estimated that using HVO reduce freight trains' CO_2 emissions by approximately 90% compared to traditional diesel operations (Tarmac, 2021b).

7.3.2 Vehicle design

Due to concerns about the involvement of HGVs (and especially those used in the construction industry) in collisions in which cyclists and pedestrians were seriously injured and killed (see **section 6.3.2**), the 'Safer Lorry Scheme' was introduced in London in 2015. It requires that that only HGVs (over 3.5 tonnes gross weight) with basic safety equipment fitted would be allowed to operate on London's roads. HGVs need to be fitted with: (i) Class V and Class VI mirrors giving the driver a better view of cyclists and pedestrians around their vehicles, and (ii) side guards to protect cyclists from being dragged under the wheels in the event of a collision. The scheme is in operation across the whole of London at all times. Drivers without a compliant vehicle may be issued with a Fixed Penalty Notice. As part of this scheme, even construction vehicles that were exempt from national legislation for basic safety equipment had to be retrofitted (Transport for London, 2014a; 2015).

Following on from the Safer Lorries Scheme, a Direct Vision Standard (DVS) has been introduced in London, with enforcement of the scheme having commenced in March 2021. It requires operators of lorries over 12 tonnes gross vehicle weight to obtain a safety permit before entering and operating in London. DVS uses a star rating system to score these HGVs based on the driver's visibility through their cab windows. Stars awarded range from zero (the lowest level of direct vision) to five stars (the highest level). To obtain a permit, HGVs initially require a minimum of a one-star rating. Those rated as zero star will only receive a permit if they are fitted with safety measures including sensors with audible warnings and cameras to monitor to nearside of the vehicle. The star ratings required to obtain a permit will increase over time. DVS has been introduced as part of the Mayor's Vision Zero plan to eliminate all road traffic deaths and serious injuries in London (Transport for London, 2019a).

However, research has indicated that freight transport companies and drivers are far less keen on some of the changes to vehicles that are required. For instance, consultation work carried out by TfL indicated that while, overall, 82% of respondents were in favour of the need to fit clear vision panels into side passenger doors of HGVs, 81% of respondents from the freight industry were opposed to this measure (Transport for London, 2016a). Further survey work with HGV drivers has indicated that they see their traditional high-up cab position in HGVs as "comfortable", "reliable" and allowing them to do their job. Drivers generally feel that their training and current vehicle safety standards are performing well in terms of visibility of vulnerable road users (cyclists and pedestrians). When the concept of a low-entry HGV with more window area and direct visibility was explained to drivers in this survey work, they were doubtful of its benefits, feeling that their current vehicle gives them better vision over the top of other vehicles, allowing them to see dangers ahead, while the idea of lower vehicles made them feel more vulnerable with extra glass making them feel exposed, and with glass not seen as a strong material if a crash took place. They were also concerned about it operational performance in terms of height clearance on construction and waste sites. Test drives with a range of vehicles with greater direct visibility (some with low-entry cabs) led to drivers positively changing their views about the visibility they offer. But there were some concerns about cab temperature and ventilation, and it did raise operational issues on some sites with uneven surfaces and in terms of vehicle handling. However, difficulties encountered on construction and waste sites led to relatively low vehicle recommendation scores for the vehicles among the drivers taking part in the study.

This is despite the fact that research has indicated that importance of driver vision from HGV cabs. For instance, an HGV driver viewing a pedestrian directly results in driver reaction times that are approximately 0.7 seconds quicker than indirect viewing, which at vehicle speeds of 15 and 5 miles per hour would equate to 4.7 and 1.5 metres of extra travel before braking respectively. As the report states, "Any collision with an HGV, even at 5mph has the potential to be fatal, so any increased stopping distance could make the difference between a collision, and halting at a safe distance, particularly in an urban environment" (Arup, 2016). This same research also found that collision rates were reduced in low-entry HGVs compared with traditional, higher cab set-ups for all three vulnerable road user (i.e. cyclist and pedestrian) events studied: (i) a cyclist coming up the inside of the HGV on a left turn when the HGV is starting from a stopped position, (ii) a cyclist coming up the inside of the HGV on a left turn when the HGV is in motion, and (iii) a pedestrian walking in front of a stopped HGV when the HGV is about to move off. The research indicated that the event with the biggest reduction in collision rates was the pedestrian condition. "In this event, the proportion of drivers who collided with the pedestrian dropped from 27% (eight participants) to 3% (only one participant) - because the driver could view the pedestrian through their windscreen as opposed to only via their mirrors" (Arup, 2016).

A fleet of forty RMX trucks with low-entry cab and fitted with a panoramic glass cab design and 360° cameras are being used on the Thames Tideway tunnel sewer project in London. They have been designed with cyclist and pedestrian safety in mind by providing the vehicle driver with enhanced direct vision. These vehicles, operated by Hanson the construction material supplier, are also front- and rear-steer enabled to improve manoeuvrability (Hanson, 2018; Tideway, 2018).

The construction company, FM Conway, produced a video in 2016 about the low-entry cab vehicle with enhanced direct visibility that it has made use of (FM Conway, 2016).

7.3.3 Vehicle inspection and maintenance

Vehicle inspection and maintenance is an important part of ensuring vehicle safety and also optimising operational efficiency and reducing environmental impact. For all goods vehicles, not just those used in the construction industry, the driver or another responsible person must carry out a daily walkaround check, ideally before the vehicle is used, and any defects must be reported. Operators must ensure that vehicle safety inspections are carried out at the stated frequency, typically every four to eight weeks if the vehicle is heavily used for arduous and off-road work, and inspection forms completed. These inspections are required in addition to vehicle servicing which should take place in accordance with the vehicle's usage and manufacturer's recommendations (DVSA, 2020a).

Roadside checks and enforcement operations against non-compliant operators, drivers and vehicles are used to improve vehicle safety. For instance, in London, Transport for London (TfL) and the UK Department for Transport (DfT) established the Industrial HGV Task Force (IHTF) in 2013. The IHTF is staffed by officers from Driver and Vehicle Standards Agency (DVSA), the Metropolitan Police Service (MPS) and the City of London Police (CoLP). The IHTF has the aim of contributing to a reduction in fatalities and serious injuries involving vulnerable road users and HGVs through coordinated, targeted roadside enforcement operations. A particular focus of the IHTF's enforcement work is HGVs in the construction and waste industries due to their involvement rates in cyclist fatalities. The roadside checks carried out by IHTF are in addition to the usual commercial vehicle compliance activities of DVSA and the Police (Transport for London, 2014b).

7.3.4 Vehicle carrying capacity

Currently, in London and UK rigid HGV tippers and concrete mixers are far more commonly used than articulated ones for making deliveries to construction sites. A study carried out in London in 2018 investigated the potential to use articulated rather than rigid HGVs (which have greater carrying capacities) for deliveries of these materials to construction sites as a means by which to reduce total construction traffic (WSP, 2018).

The study found that the key reason for the preference for rigid tipper and mixer lorries are due to concerns about access to and within construction sites, and safety concerns about vehicles tipping over during the unloading process. While incidents do sometimes occur in which tipper vehicles tip over during unloading, such occurrences are rare. They are typically due to misuse and are generally avoidable if correct safety procedures are followed and adhered to. Research indicates that the main cause of tippers tipping over is when they tip their load on a gradient or uneven ground. Other causes of such vehicles tipping over includes tipping on soft ground which causes the trailer unit to sink and lean, tipping loads without the tractor and trailer in line with each other, the load to be tipped sticking inside the trailer or being uneven or overloaded, tipping loads too quickly or moving forwards too fast whilst the load is raised, poor vehicle maintenance and high winds (WSP, 2018).

Interviews carried out in the research indicated that suppliers and freight transport companies delivering bulk construction materials are keen to use articulated vehicles but that it is their customers who insist on them using rigid vehicles. Some suggested that planners could specify the use of articulated vehicles to improve average carrying capacities and hence journey efficiency. It is construction contractors that seem reluctant to accept the use of articulated vehicles and that prevent this change from taking place. In addition, some concrete batching plants are too small to make use of larger, articulated vehicles. There has been a small increase in the use of articulated tippers and concrete lorries in London in recent years. This has typically been achieved either: (i) by ensuring construction sites are sufficiently safe for their use and that drivers and workers are suitably trained and experienced, and/or (ii) by using alternative vehicle technology such as non-stick liners and moving floors. Using articulated tippers and concrete mixers can reduce transport costs per tonne by approximately 30% compared to rigid vehicles (or approximately 20% in the case of tippers with moving floors). The use of articulated vehicles can result in approximately 30-35% increase in vehicle loads carried, and hence a similar reduction in vehicle journeys required as well as CO_2 emissions (WSP, 2018).

Research has been carried out to identify the minimum standards required for construction site accessibility by goods vehicles and develop a framework to assess site suitability using a range of criteria. This work can be considered in conjunction with the use of articulated HGV tippers and concrete vehicles, as well as in conjunction with low-entry vehicles designed to improve the direct vision of drivers and thereby reduce the number of traffic collisions involving construction vehicles and cyclists and pedestrians (AECOM ,2016).

The Driver and Vehicle Standards Agency (DVSA) provides guidance on legal road requirements for goods carried by vehicles operating in the construction and other industries. This includes details of suitable load heights and the need to sheet bulk loads carried in rigid tipper and skip vehicles, and details of the requirements for the carriage of scaffolding and of plant and equipment (DVSA, 2020b). DVSA also provides videos containing guidance and advice on vehicle load security (Driving for Better Business, 2020).

7.3.5 Vehicle utilisation on journeys

Consolidation centres (CCs) can be implemented in the construction supply at which materials and products destined for a construction site are delivered. Such CCs are typically located in relatively close proximity to the construction site. From here, these can be delivered to the construction site as and when required using well-loaded vehicles, thereby reducing the total number of vehicle arrivals at the construction sites (and the queuing and vehicle circulating that uncoordinated deliveries result in, imposing hazards, traffic disruption and disturbance in the locality of the site). Such a CC can also help ensure that the delivery vehicles meet the site compliance requirements and arrive at the agreed time. CCs can also be used to store fast-moving and essential products and equipment and tools, to ensure that they are available as required on-site, thereby preventing disruption and delays to building work. Using a CC reduces storage space requirements at construction sites and can also reduce damage to and theft of goods on the construction site. It also provides the opportunity to use clean, modern goods vehicles over the short distances between the CC and construction sites. In these ways, CCs can reduce the transport and environmental impacts associated with deliveries to construction sites, while also improving on-site worker productivity and reducing on-site costs (Allen et al., 2012; Browne, et al., 2005; Janné, 2020; Janné and Fredriksson, 2018).

Research of CC operations has indicated their potential to reduce material waste on site as well the potential to use CC vehicles leaving the site to backload waste packaging, empty pallets, equipment and unwanted materials, thereby improving vehicle utilisation. It also provides cost and time savings to freight transport companies due to the far shorter delivery times. It has been estimated that the cost of a construction CC is 0.5-3% of the construction project value but can offer project cost savings of up to 8% depending on the specific project (WRAP and The Logistics Business, 2011).

CCs are not subject to the restricted operating hours of construction sites, so can accept deliveries at times when sites cannot (including early mornings and evenings). The use of a CC is usually implemented together with the use of construction logistics management contractor to coordinate CC and site operations, thereby improving all aspects of site logistics including coordinating procurement and delivery management across all site contractors.

CCs have been made use in various types of construction projects including residential, office, airport, sports venue and hospital developments. The use of CCs have been most widely made use of in the UK and Sweden. Such CC can either serve either a single major construction site or several. Either the client and project designer decide to make use of a CC in planning the scheme, or it can be mandated through the planning system.

A two-year pilot study involving a CC that served several commercial construction sites in the City of London took place from 2005 to 2007. It was operated from a 5,000 square metre facility located three miles from the City of London. The trial was established and supported by TfL with the intention, "to deliver in the safest and most efficient manner possible the right materials to the right site at the required time in active partnership with trade contractors and project managers". The trial provided an opportunity to study the benefits and impact reductions that such a scheme could provide. The trial also involved two major developers and a construction logistics company that operated the CC during the trial; sixteen staff (including management) and six goods vehicles were operated by the CC. Most products were delivered to construction sites shortly after their arrival at the CC, with a maximum CC storage time of ten days. During the trial, approximately a sixth of all the deliveries required by the construction sites from the CC were needed within less than 24 hours' notice, a level of service that is difficult to achieve when made directly to site by suppliers. The goods vehicle operated from the CC consolidated numerous contractors' orders onto each vehicle. As well as delivering construction materials to the sites, the CC goods vehicles also collected recyclable packaging and unused materials from the sites and brought these back to the CC. Some large and heavy materials such as aggregates, structural steel, ready-mix concrete, escalators and furniture, continued to be delivered direct to site on a full-load basis rather than via the CC. The use of the CC reduced deliveries to site by 68%, achieved an on-time and in-full delivery reliability of 97%, and resulted in journey times to sites that were approximately 120 minutes shorter than those direct from suppliers. Reductions in materials waste due to reduced damage, theft and overordering were estimated to be 15%, while increased productivity of the site workforce by up to 30 minutes per day were also estimated (Department for Transport, 2007; Transport for London, 2007). The two-year trial in London was deemed to have proved successful. Since then several logistics companies in the construction industry have offered CC services from existing warehouse locations they operate in London. TfL provides a directory of these construction CC operations available in London (Transport for London, 2016b).

A development of 86 residential apartments at a space-constrained site in central London that was completed in 2010 that made use of a CC reported a 66% reduction in vehicle arrivals in delivery vehicles at site (than would otherwise have been required), 100% on-time deliveries at site from the CC, no damaged goods occurring at the CC or on-site, and the use of CC vehicles to transport back to the CC. CCs have also been used in other construction projects in London including the expansion of Heathrow airport (Terminal 5), and the London Olympics, development (Transport for London, 2016c).

In Stockholm, a construction CC was used as part of the Hammarby residential housing development with public sector project funding the majority of the costs of the CC at the outset so that its benefits could be better understood and valued. Once these benefits became apparent, the proportion of public funding diminished over time and was replaced with private funding. The development took place between 2001 and 2010, with the vast majority of the material deliveries taking place in the first three years. The development provided 8,000 apartments as well as commercial premises and schools, with approximately 30,000 people living and working in the development area following completion. The CC provided 3,500 square metres of storage indoors and a further 4,000 square metres outside and was located near to the construction site, acting as a delivery point for all delivery vehicles coming to the site. These incoming materials were consolidated for 22 different delivery points within the site, with two vehicle trips made per day from the CC to each delivery point. A logistics contractor was appointed to run the CC and its management and delivery operations, with ten staff and five goods vehicles. If flows had not been coordinated, 400 vehicles would, on average, have made deliveries direct to the construction site each day. The CC improved vehicle load factors (from approximately 50% to 85%) and reduced vehicle dwell time at the site from approximately sixty minutes to six minutes (Ottosson, 2005; Wilson James and Mace, 2003).

As part of a European project (SUCCESS), other CCs in Europe were reviewed and an analysis of the different business models that can be applied in the case of a construction CC was carried out. Then business models for the trial CCs in the project were designed (VPF, 2017a; VPF, 2017b). The SUCCESS project considered the potential benefits of construction CCs in relation to four construction sites in Luxembourg, Paris, Valencia and Verona (VPF, 2017c), and went on to provide guidance about the replications and transferability of construction CCs (VPF, 2017d), as well as providing a road map for doing so (VPF, 2017e).

As part of the Construction Logistics programme in London, which is led by industry with support from Transport for London, guidance has been produced that explains to project developers and construction contractors the role that CCs can play in urban construction projects, the benefits, and how to go about doing so (WSP, 2018b).

Load consolidation can also be achieved without the use of a physical CC through improved planning of materials requirements at construction sites (which ensures that required materials are available on site and reduces the need for urgent deliveries of small quantities on poorly loaded vehicles), through the use of fewer suppliers in the procurement process and the greater use of wholesalers who can provide substantial product ranges, greater collaboration in procurement between contractors working on large construction sites, and less insistence.

As discussed above in relation to CCs, there is potential for less empty running by vehicles leaving construction sites. There is scope for these vehicles to carry a wide range of materials including waste packaging, empty pallets, equipment, unwanted materials, and spoil. This requires careful advance planning and coordination and the matching of vehicles and their routings to suitable loads and destinations.

7.3.6 Vehicle routeing for journey co-ordination and arrival time

Computing software companies have developed production planning and vehicle routeing and scheduling systems to help the construction industry improve their coordination and planning of the delivery of materials and vehicle operations to meet customer requirements, while at the same time improving vehicle utilisation, travel times and on-time deliveries. Some products like ready mix (RMX) concrete are especially time sensitive due to their needing to be delivered before setting and becoming unusable. It is therefore important to avoid delays at concrete batching plants, use the best vehicle routing options and travelling times, and eliminate queuing at the construction site. As well as reducing transport impacts and logistics costs, it also enhances site productivity by removing disruption and delays to the construction work. Academic research has observed real-world concrete delivery operations and then developed computing algorithms to improve them (Choi et al., 2018; Weiszer et al, 2020).

LafargeHolcim, the global cement and concrete provider, created an app for its north American operations on which customers could place their orders and then track the vehicle journeys. The vehicle routing system used, provided by HERE Routing, resulted, on average, in a reduction in customer waiting time of five minutes per journey, as well as greater transparency for drivers, managers and customers. Geofencing was used to indicate when a vehicle has arrived at the construction site, so site personnel can deal with it immediately. This has helped to reduce vehicle waiting times, vehicle idling and concrete wastage (McLoughlin, 2021).

A similar app developed in Brazil for Concrebase by Gurtam is reported to have also improved concrete delivery operations and reduced operating costs by 15-20% (Voytikhovich, 2018). In Australia, Hanson has enhanced its fleet management systems in recent years using TomTom data resulting in improved on-time vehicle arrivals and operational cost savings (Clay, 2020). A UK-based concrete supplier implemented a computer-based booking and dynamic vehicle scheduling system to replace its previously manual one, which makes use of Webfleet, Agg Smart and TomTom traffic data has improved its operational productivity by 25% Fleet Management (2018).

7.3.7 Use of non-road modes

Rail and water transport have been extensively used on some large public sector construction projects. These projects have helped to demonstrate and publicise the potential that these modes offer in construction transport when major sites are rail- or water-connected.

Rail freight was heavily used during the construction work at the Olympic Park for the London 2012 Olympics Games, which had a target to deliver 50% of materials to the site by non-road modes. The rail freight operator DB Schenker used a rail freight terminal in Stratford, east London to operate a logistics service to other rail freight providers, while also competing to provide rail services to construction site contractors. All contractors building the Olympic Park, the Olympic Village and Westfield made use of this rail freight service. Major product flows delivered by rail included aggregates, tiles for the Aquatics Centre (which came from Italy) and bathroom pods for the Media Centre (which came from Scunthorpe) (Carris et al., 2011).

Aggregate Industries, the major aggregates and cement supplier, operates a fleet of tugs and barges on the Thames through its company Bennett's Barges. These vessels transport hundreds of thousands of tonnes of aggregates products each year from the Isle of Grain depot to London customers. At work carried out on Blackfriars Bridge, Bennett's Barges moved about 80,000 tons of material to and from the site by water. Barges with gross weights of 800-1,600 tonnes (with the heaviest of these carrying as much material as approximately 100 lorries). During the Thames Tideway sewer project, Bennett's Barges will have transported approximately 800,000 tonnes of spoil by water from the tunnelling sites, equivalent to approximately 35,000 lorry journeys, thereby reducing construction-related road traffic with consequent benefits for other road users including cyclists and pedestrians. Eleven of the 24 Tideway construction sites are river-connected (Tideway, 2019, Port of London Authority, 2020).

The Thames Tideway project has been estimated to generate require and generate 8 million tonnes of materials, approximately 60% of which is excavated material. River transport is being used for cofferdam fill, excavated material from shafts, the main tunnel and other works and sand and aggregates for secondary tunnel linings. It is planned that river will transport 90% of these materials, with the other 10% transported by road. River will account for just over 50% of the total tonnage of construction materials being transported in the project (Thames Water, 2013).

Similarly, spoil from the tunnelling work for Crossrail and the Northern Line London Underground extension at Battersea have been transported by water to Tilbury in Essex, where it has been used to create a nature reserve and arable farmland. Crossrail has generated 5 million tonnes (7.3 million m³) of spoil (Crossrail, 2009). In addition, the Thames was also used to transport concrete segments for lining Crossrail tunnels into London from a factory in Chatham (Port of London Authority, 2015). Approximately 90% of all the spoil (850,000 tonnes) arising from the Northern Line extension project to Battersea has been conveyed from tunnel and construction sites to barges at the existing jetty at Battersea power station on the river Thames by a series of covered conveyor belt systems. The Battersea station construction site was used as a waste transfer station to handle spoil from the various tunnelling projects and construction sites which was transported there via a temporary construction railway before being conveyed above ground to the river barges. These barges have then transported the spoil to Tilbury. Using barge transport prevented an estimated 50,000 lorry journeys (Brinklow, 2017; Longhorn, 2021; Mayor of London, 2013; Milne, 2017). In his consideration of the Planning Inspector's public inquiry and report and in subsequently granting permission for the Northern Line Extension to proceed, the Secretary of State for Transport noted that he was, "satisfied that taking into account the proposed use of the River Thames to take excavated materials away from construction sites and the other mitigation measures including the preparation of a Traffic Management Plan for each worksite, there would be no traffic consequences that would justify refusing the Order" (Secretary of State for Transport, 2014).

During 2021, as part of the HS2 high speed rail line construction project, approximately 180 freight trains will deliver materials to the main construction compound in Buckinghamshire.

This is expected to remove about 12,500 HGV journeys that would otherwise have been needed, thereby reducing road traffic and saving an estimated 30,000 tonnes of CO_2 emissions. Over the course of the entire HS2 project, 15,000 freight trains will transport 10 million tonnes of aggregates to construction sites, removing the need for 1.5 million HGV journeys. The Calvert Railhead, a 26,200 square metre site located about halfway between London and Birmingham, will be operated by the main project contractors with more than 650 people receiving and storing these goods and organising their supply for the various works in the 80 km central section of the new rail line which will include 17 viaducts, 81 bridges and three tunnels (HS2, 2020b).

Research into the barriers that exist in preventing greater movement of construction materials and construction waste by non-road modes in London involved telephone interviews with developers, contractors, supply chain organisations, boroughs and planners (steer davis gleave, 2017). Barriers were grouped into five categories:

i) Physical (that physically prevent the use of non-road modes such as lack of transport infrastructure),
ii) Logistical (operational issues associated with the use of non-road modes),
iii) Financial (the costs of using non-road modes),
iv) Policy (barriers arising from the development planning process and general planning system), and
v) Industry Awareness (of non-road modes and their capabilities).

Findings of this research indicated that physical and logistical barriers to the use of non-road modes were of most concern to those surveyed, followed by financial barriers. Respondents also displayed uncertainty and a lack of consistency about who they perceived to be most responsible for determining non-road use for construction. The research also highlighted the lack of awareness of the potential for water and rail usage, with the lack of readily available information hindering the potential to include these options in decision-making processes. The research also indicated the importance of communicating the need for maximising the use of non-road modes early in the planning process and in tendering documents if this goal is to prove effective and be met (steer davis gleave, 2017).

As part of the Construction Logistics programme in London, which is led by industry with support from Transport for London, guidance has been produced that explains to project developers and construction contractors the role that non-road modes can play in urban construction projects, the benefits, and how to go about doing so (WSP, 2018b).

7.3.8 Use of non-motorised road vehicles

Cargo bikes are being trialled by some construction, plant hire and freight companies delivering to construction sites in London as a means by which to reduce the number of motorised road vehicles used for these deliveries (in order to meet Mayoral policy targets of reducing goods vehicle traffic, associated traffic injuries and fatalities, improve air quality and reduce CO_2 emissions. Analysis indicates that cargo bikes could replace some vans delivering to construction sites. Using cargo bikes can provide the operator with lower operating costs, more reliable delivery arrivals and less waiting times at site compared with vans. An important consideration is the types of product that they could carry which includes signage, personal protective equipment, tools, lighting, traffic cones, other site plant and consumables. Companies involved in trials have included JG McCoy, Speedy Hire, Mace, GAP, HSS, FM Conway, Morgan Sindall and O'Neil & Brennan (Barratt, 2021c).

FM Conway has been working with Transport for London to better understand whether and if so, how, cargo cycles could be applied in its operations related to a project involving bridges over the River Thames. The work began with a test ride followed by an analysis of the products that could be transported by bike. A full test was carried out to assess the capabilities of the bike, which included off-road testing of the bike's loading up to 100kg, determining safe routes from the depot to one of the bridges making use of cycle lanes wherever possible, carrying out a risk assessment of the route. FM Conway are now using two cargo bikes as part of their ongoing operation in London (Barratt, 2020a; Barratt, 202cb; Transport for London, 2020).

In cargo bikes trials with Transport for London and the London Borough of Hackney, principal contractor Morgan Sindall and logistic contractor O'Neil & Brennan have been trialling cargo bikes for deliveries of various plant and site consumables at a construction site. To overcome interactions between cargo bikes and HGVs at the site, a dedicated area was established to load and unload cargo bikes safely. In addition, bespoke signage was produced to make everyone aware of the usage of this area on the site (Barratt, 2020b).

7.3.9 Driver training and fleet management

In 2008, Balfour Beatty, the UK's largest construction company, launched its 'Zero Harm' which sets a target of, "no injury, ill health or incident caused by our work activities". As part of this, in 2009, the 'Permit to Drive' scheme was introduced which brought all aspects of driver profiling into one scheme. This requires that all vehicle drivers working for the company take part in the scheme in order to obtain a Balfour Beatty Permit to Drive card. This involves online assessment including driving qualifications, collision, history and driving habits, followed by online driving scenario assessment to assess attitude, together with periodic checking of driving licence validity and endorsements, data from complaints received and vehicle insurance incidents. Drivers are given a risk score which need to be below a threshold to be permitted to drive as part of their work. Ongoing monitoring is carried out using vehicle telematics performance data. As well as monitoring harsh braking, accelerating and cornering and vehicle speed, this is also used to monitor vehicle idling, fuel economy, CO_2 emissions, and on-board weighing providing insights into driver safety and sustainability. This Permit to Drive scheme has resulted in collisions that company drivers were responsible for falling from 24% of the vehicle fleet in 2011 to 9% in 2017. Balfour Beatty is a member of the FORS and CLOCS initiatives (see **section 7.3.14**) (Balfour Beatty, 2019).

The major construction company Skanska UK has a range of policies in place concerning work-related driving (including commercial vehicles) that includes: DVLA licence checks through a fleet management system, online driving risk assessments with e-modules, in-cab risk-assessment for HGV drivers, a management system to record all road traffic incidents, an Occupational Road Risk Policy, Driver's Handbook for commercial vehicles and cars, use of in-vehicle telematics. Staff are also provided with safety briefings and online talks. Interactive road safety awareness sessions are also made available. Working with its external partners that collect work-related data on its behalf, this is continuously analysed to produce performance measures including: vehicle speeding and harsh driving events, collision frequency, collision damage costs, and fuel consumption. This data shows that 18% of the commercial vehicle fleet was involved in collision incidents in 2018, compared with 28% in 2016 (Skanska UK 2019a).

The major construction company Kier implemented a so-called Group Fleet Compliance Management System (GFCMS). This set out the company procedures and regulations for work-related driving. The introduction of this driving policy and monitoring resulted in vehicle collisions reducing by approximately 50% between 2015 and 2018. Late in 2018, the Kier HGV and van fleet has been equipped with telematics equipment that tracks vehicle location, speed, utilisation and time spent on site. This is being used to optimise fleet utilisation and monitor vehicle emissions reduction targets. The telematics also provides monitoring of driver behaviour including braking, acceleration and cornering (Kier, 2019a).

As part of the Tideway tunnel sewer project in London, every construction HGV driver takes part in a full-day training programme which focuses on the challenges they face on London's roads. The course is accredited by the Driver and Vehicle Standards Agency and thereby counts towards HGV drivers' mandatory Driver Certificate of Professional Competence (DCPC) requirements (Tideway, 2018).

The construction company Costain ran an internal engagement campaign on road safety. This was based on more than half of company participants stating that they wanted more information about driving safely in an assessment of their wellbeing needs. The campaign took the form of a week-long series of toolbox talks during Road Safety Week, a programme of safety messages, 45-minute risk management workshops, and a 'train the trainer' session at which managers and supervisors were instructed by a forensic collision investigator on how to carry out vehicle checks at the start of shifts to ensure continued compliance with road traffic legislation. The campaign reached the entire team (Costain, 2021).

The UK Health and Safety Executive (HSE) has produced guidance on the safe use of vehicles on construction sites which includes information on planning and managing vehicle operations; selecting and maintaining vehicles; and safe driving and working practices (HSE, 2009). The Mineral Products Association has produced guidance for quarry operators about providing segregation between on-site vehicle activities and workers to ensure safe practice (Mineral Products Association, 2020e; 2020f). It has also produced handbooks for HGV drivers, and van and company car drivers involved in quarry-related driving work to help promote safe practice and raise awareness of risks and their prevention (Mineral Products Association, 2018a; 2018b). Meanwhile, CEMEX, the major cement supplier has produced an interactive training session and video to facilitate open discussion with independent hauliers about their perception and management of road risks (CEMEX, 2015).

TfL has shared the insights it has gained through its research, trials and on-going schemes with other transport authorities. For instance, staff from Brighton & Hove City Council were provided with talks and site visits to gain insights into taking the perceptions and views of all vulnerable road users in construction traffic management schemes, together with the methods developed and implemented by TfL (Barratt, 2018c).

In addition to driver and worker training, the developer Berkeley, together with cement and concrete supplier CEMEX ran day-long interactive workshops and classes for 1,000 school children in west London over the course of a week to teach them about cyclist and pedestrian safety. Sessions included practical learning about crossing roads, wearing cycling helmets and high visibility clothing and the opportunity to see a concrete mixer and discuss driver blind spots, and its indicating and reversing practices.

7.3.10 Traffic management schemes: goods vehicles

<u>On-street waiting areas</u>

If the road on which the construction site is located has sufficient capacity (i.e. more than one lane and sufficient width so as not to pose risks to other road and footway users) it can sometimes be possible to arrange with the highway authority to make use of the nearside lane for goods vehicle waiting prior to them being allowed on site during the project. This waiting area is then managed by personnel from the construction site. Such managed use of the nearside lane can help prevent vehicles circulating in the area while awaiting admission to the site, unmanaged vehicle queuing on-street, and vehicle reversing that causes traffic disruption. Such an arrangement was implemented for a major construction site in Glasgow, with the lane being incorporated into the construction site to segregate it form other road traffic. Vehicles arriving at site were able to enter this lane, wait and then be unloaded in a co-ordinated way, thereby reducing vehicle traffic from circulating vehicles, and removing the need to reverse into the site. Pedestrians needing to cross the road were controlled by a gate-person and the use of barriers and flashing beacons (BAM Construction, 2019). At a site in London Bridge, in central London, TfL worked with the developer to create two on-street vehicle waiting areas close to the site by relocating a taxi rank and parking spaces. A Memorandum of Understanding was drawn up between the parties involved to ensure smooth running of the scheme. This reduced circulation by goods vehicles goods vehicles that would have otherwise taken place while awaiting site entry. It was estimated that this saved approximately 10,000 km being driven over the course of the two-year construction project (Transport for London, 2017a).

Vehicle holding areas

Where space is available, off-street ‘holdings areas’ can be established close to construction sites which vehicles making deliveries or collections call at and wait before being requested to travel to the construction site when space is available and site staff are ready for the vehicle. The use of such holding areas helps to prevent vehicles circulating and adding to traffic while they await admission to site, or queuing on street outside construction sites on roads without sufficient capacity for this to be managed in a co-ordinated manner that does not affect road safety for pedestrians and cyclists or traffic flow for other road users. In most cases, holding areas will be at a separate location to the construction site, but in the case of large sites could be within the site itself (AECOM, 2017). A limitation on the use of holding areas is the availability of such space in busy urban areas. Therefore, where such space does exist it is best for it to be shared between several construction sites wherever possible to maximise its usage (CLOCS, 2021a). Holding areas can also be used by drivers to take rest breaks and drivers can be provided with refreshments by site welfare officers.

TfL, working with Southwark Council, managed to help construction companies Mace, Sir Robert McAlpine and Structuretone arrange the use of such a holding area for a nearby project. This holding area was already being used by construction company Wates but had some spare capacity, so discussions were held and all parties entered into a memorandum of understanding (MoU) to share the site (Barratt, 2021d). TfL worked with Keltbray during a major construction development in East London, which provided the latter with a holding area within a park during periods when major flows of vehicles were required for concrete delivery to the site (Barratt, 2018d).

Using technology to record delivery activity and incidents at sites

Those responsible for managing deliveries at Berkeley Homes’ construction sites wear body cameras to record these activities and any incidents that arise in the course of their work. This is used in conjunction with software which is loaded onto tablets and used by these staff positioned on delivery gates to plan, record and review all delivery activities taking place at the site. This information can be shared across multiple devices, thereby syncing information if the site has more than one delivery gate (Berkeley Homes, 2017).

MACE developed a similar approach involving the use of tablets and cameras to monitor and record delivery activity on a specific site in central London. It removed the need for paper-based recording of delivery activity and provided drivers with information updates about waiting times to access the site, resulting in less vehicle queueing at site and a reduction in vehicles circulating around the immediate area while waiting. The use of this system saved time in terms of recording delivery activity and gave site personnel more time to carry out the vehicle checks necessary before vehicles were allowed on site (MACE, 2017a; MACE, 2017b).

Providing site and delivery information to drivers

During the Covid-19 epidemic, Alandale Logistics provided a video with the delivery booking confirmation which provides drivers with information about the construction site and its operations. It contains information about the approach to the site and footage of the gate, as well as the processes in place for accessing the site and its unloading area. Although originally developed for one project to communicate Covid-19 site restrictions, this communication approach for drivers is now being developed for all the company's projects (Alandale Logistics, 2020).

At a construction site adjacent to the Accident and Emergency department at a hospital in Edinburgh and which lies on the emergency access route for ambulances it was necessary to ensure that delivery vehicles did not wait to make deliveries in locations that would hinder the progress of ambulances. A short video was made of the route to site from the main road together with information about the delivery process at the site, the holding points within the site, the various locations for unloading on site, and the pedestrian crossing locations and one-way route in place on the site. Suppliers are sent a link to this video in advance of the delivery, so that drivers can access and view it (Balfour Beatty, 2020).

Toureen Group, the groundworks construction contractor, has put in place a system whereby all its drivers need to participate in a site induction before being allowed to make deliveries/collection at the site. During this induction, drivers are provided with a booklet which contains information on the site rules and delivery arrangements; a diagram of the traffic management plan, information on access to site and prohibited areas on site; and information on protecting vulnerable road users. This booklet is intended to reinforce information imparted during the site induction and provide drivers with a means by which to remind themselves of this (Toureen Group, 2019).

Delivery Management Systems

A delivery management system (DMS) is used to plan and manage the vehicles making deliveries to a construction site, notifying contractors when vehicles arrive, and ensuring on-site activity of these vehicles is controlled and co-ordinated. At its most basic, DMS may involve the use of paper-based or spreadsheet management. While these may be suitable for small construction sites, they are prone to error, are not multi-user accessible, do not update themselves and do not function in real time. More typically, especially on larger construction sites, a DMS is internet-based, fully-computerised software that allows all contractors and suppliers to be able to access it remotely. It usually contains a delivery booking diary with delivery dates, times, locations and arrangements, together with vehicle tracking and tracing to and from the site as well as on-site. Such software contains both planned and historical data and can be used for multiple construction sites at the same time (Ballard and Hoare, 2015). DMS can thereby be used to prevent vehicle queuing and idling at sites, help ensure deliveries keep to time and improve delivery-related safety at the site. DMS can be used in conjunction with off-street holding areas and on-street waiting areas to prevent vehicles, which can also help to prevent vehicles circulating in local traffic while they await a delivery slot.

A study of construction sites in London using DMS found that the capability of the systems used varied substantially, with some only providing basic vehicle scheduling with little monitoring and enforcement, through to full vehicle tracking and management. DMS also varied in terms of how it was applied and used at the sites studied. It was found that DMS worked best when vehicle management is co-ordinated and managed by one contractor rather than many different contractors and sub-contractors each co-ordinating their own deliveries (AECOM, 2017).

Traffic light analysis to reduce distance travelled

As part of the traffic management for a construction site in central London vehicle had to turn left into the site and then had to turn left on leaving it. Due to on-street temporary road changes not associated with the construction site, this resulted in vehicles having to follow a diversion that added of 3.7 miles to their journeys. By turning right out the site, this additional mileage could be avoided. However, the egress point was adjacent to a main set of traffic signals with four traffic lanes, two of which were bus lanes, raising safety concerns. TfL investigated the traffic signal cycle times, traffic flows and all potential traffic conflicts. It was found that there was a 58 second window of opportunity for a vehicle to turn left which reduced conflicts with opposing flows and caused no additional delay to other traffic. Further analysis showed that HGVs were capable of undertaking the manoeuvre. A trial was carried out to ensure the safety of this approach. To ensure all parties were in agreement of how the method was to be managed, A Memorandum of Understanding was drawn up between TfL, the London Borough of Hackney, and the construction contractor JRL which included the method to be use for right turns, including the use of temporary barriers to hold pedestrians, monitoring methods to be used and the marshal training required, and this alternative right-turn was implemented for the duration of the construction project. It is estimated that the implementation of this scheme saved 286 miles of HGV travel and 31 hours of driving time in central London (Transport for London, 2020c).

Traffic marshals at construction sites

Traffic Marshals (also sometimes referred to as banksmen) are employed at large construction sites and roadworks to help ensure safety for workers and the general public. There are three types of Traffic Marshal associated with construction sites: (i) those who work at the interface between the construction site and the public road network, controlling and managing vehicles entering and leaving the site in order to ensure this happens safely both for the general public and workers (often referred to as Site Access Traffic Marshals); (ii) those who work within the construction site to ensure the safe movement of plant and vehicles (often referred to as banksmen or Vehicle and Plant Marshals); and (iii) those who manage traffic at temporary streetworks and roadworks (often referred to as Highways Traffic Management Operatives) (Davies, 2020).

The first type, Site Access Traffic Marshal, have become more commonplace since the introduction of CLOCS as they are a required as part of any CLOCS compliant site (see **section 7.3.14**). Their role includes ensuring that vehicles arriving at the site comply with the CLOCS road risk requirements, controlling site traffic levels, and directing vehicle ingress and egress to and from the site. They communicate with the general public passing the site to ensure their safety and often use temporary segregation equipment to separate the public from vehicle operations. They have to take appropriate action in the event of a road traffic incident or collision, and if they discover non-compliant vehicles (either in terms of issuing warning or refusing site access). Various companies in the UK provide training for Site Access Traffic Marshals.

Some construction companies now issue their Site Access Traffic Marshals with body cameras to record activities at the delivery gate and in (un)loading areas on site, which provides helpful information in the case of traffic incidents, acts as a deterrent for delivery drivers or others who may otherwise have ignored marshals or become abusive, and is more cost-effective than the use of CCTV (for example, see MACE, 2017b).

TfL has developed additional training for Site Access Traffic Marshals given that they are well placed to observe unsafe or inefficient activities that put the public at risk. These include poorly managed traffic management layouts, bad driver behaviours (such as speeding or aggressive driving), as well as identifying criminal activities. To train marshals in the potential outcomes of such incident and behaviours and what to look out for, TfL and the Metropolitan Police

Counter Terrorism Focus Desk have developed and run joint presentations to help improve construction standards at some major sites in London. Topics addressed in these presentations include the risks inappropriate management and behaviours raise for pedestrians and cyclists, especially those with disabilities, how poor site design can increase the potential for crime and disorder, and how to identify potential security threats (Barratt, 2017b).

Another scheme developed by TfL for Site Access Traffic Marshals involves an escorted walk around the immediate environment surrounding the site to experiences its impact from the perspective of other road users, especially pedestrians and cyclists. This includes taking account of the condition of footways and physical accessibility issues especially for those with disabilities. During this escorted walk organised with the construction contractor Multiplex, the group were joined by a wheelchair user who could demonstrate potential difficulties in dealing with changes to the footway including footway closures and the diversions involved, as well as the need for suitable ramps, and the impact of reduced footway widths and poor surfaces. Marshals are the public face of the construction site. This additional training is intended to provide them with greater knowledge and understanding, and thereby empower them to identify and report issues they observe which impacts public mobility (Barratt, 2020c).

Timing of deliveries and associated safety requirements

The UK Department for Transport has published a guidance document on carrying out deliveries to construction sites outside of typical delivery hours if these deliveries are planned and managed so as not to result in noise disturbance to local residents (Department for Transport, 2014). The intention of permitting such ‘off-hours’ deliveries is to reduce peak-time construction traffic levels and their social and environmental impacts, as well as to increase construction sector efficiency through longer site delivery windows and shorter freight transport journey times. It advocates increased community engagement with the project developer at the pre-planning stage, during the planning application process, and when the development is about to be built to ensure suitable measures are put in place in respect of noise. It also encourages improved quality monitoring to help oversee the construction site's performance in respect of noise to help address issues before they become problems. However, this Department for Transport guidance is not prescriptive and is intended to be used to aid discussions held by clients, project designers and construction companies with planning officers and the local community about construction management at any given site (Department for Transport, 2014).

A major supply of concrete to a construction site in central London delivered by HGV concrete mixers from a batching plant was required. The construction company, Multiplex Collaboration, and TfL worked together to investigate how best this should take place. This involved planning ‘holding lanes’ on-street where the HGVs could wait before being called to site (to minimise traffic disruption, noise and emissions), the implementation of a temporary cycle lane to reduce the risk to cyclists posed by the substantial flow of HGVs, the carrying out of Equality Impact Assessments to protect and maintain safe access for disabled people, the devising a site traffic marshalling strategy to manage the HGV movements and arrival at site and ensure the safety of vulnerable road users (which included 40% of the marshals attending an Elite Marshal training course), the running of events to ensure workers were aware of the potential hazards of working at and through the night, and an effort by Multiplex that as many low-entry HGVs as possible would be used. A Memorandum of Understanding was put in place between Multiplex and TfL, which documented all the aspects of the agreement. This allowed the concrete pour to take place over the course of a weekend with minimal disruption to the road network and no reported traffic incidents. A total of 533 HGVs delivered 4000 cubic metres of concrete non-stop over a 31 hour-period from 19:00 on a Friday until 02:00 on a Sunday (Barratt, 2020e).

Construction sites are typically not allowed to receive deliveries before 08:00, and drivers are often requested by construction companies to make deliveries when the site opens so materials are there for that day. However, given the unpredictability of journeys during the morning peak and that such journeys tend to take longer and use up valuable driving time, many drivers make such journeys far earlier and then arrive at site and wait on-street long before 08:00, sometimes with their vehicle engines idling. This can cause a hazard for cyclists, pedestrians and buses, possible impacts on traffic flow and pollution and disturbance for residential neighbours. set off and arrive early to avoid peak traffic. TfL receives complaints from residents and road users affected in this way. So, in another initiative associated with the timing of deliveries to construction sites, TfL has entered into some agreements with developers and construction companies which allow delivery vehicles to be driven on-site earlier in the morning than would otherwise usually be permitted (i.e. 08:00) and wait there until the delivery can be made at the site opening time (08:00) as long as it does not result in adverse consequences for those living near to the site. These are known as 'Early Doors Agreements' and involve TfL liaising with developers, local authorities and local stakeholders to investigate the amount of space the site has available for vehicle waiting, and whether allowing vehicles on site to wait will cause negative impacts. If it is found that early deliveries are possible then a Memorandum of Understanding is signed between by all the relevant parties. This document will specify the number of vehicles that are permitted on-site early and the protocol for these vehicles which typically includes turning engines off and making no noise and are subject to constant monitoring. Where this approach is possible it can reduce road traffic safety risks, impacts of traffic flow, pollution and noise, as well as provide drivers with a less pressurised working schedule (Barratt, 2017c).

Equipment-related interventions

Temporary Bollards were erected at the corners of the road providing access to one construction site with difficult accessibility due to these corners in order to encourage slow, careful driving and to prevent large, heavy vehicles from mounting the kerbs at these corners. The bollards were made from plastic pipes filled with concrete. They were low cost and easily removed when final road surfacing took place (CCS Best Practice Hub Administrator, 2015).

Motion detectors can be fitted to the rear of wheeled on-site machinery in order to cut its engine if a pedestrian is detected passing its rear (Carillion, 2014). Blind-spot sensors and cameras can also be fitted to site machinery and goods vehicles to reduce risk to pedestrians and cyclists, as can strobe beacon and voice warning that the vehicle is turning left every time the driver uses the indicator to turn left, thereby providing a visual and audible warning to those on the nearside of the vehicle (MACE, 2014).

7.3.11 Traffic management schemes: cyclists and pedestrians

Various street space management schemes are put in place in the vicinity of major construction sites in urban areas in efforts to ensure the safety of the general public, especially pedestrians and cyclists who need to pass the site. This may include the signage to warn the public about hazards and temporary alterations to the street space, ramps to assist pedestrians and cyclists pass over surfaces of different heights, the use of segregated lanes using barriers, and the erection of temporary hoardings to separate and protect the public from the works. Some of these innovative interventions are summarised below.

Keeping cycle lanes operating

TfL has developed an innovative method of traffic management assessment for construction-related schemes which involves using a five point assessment which includes understanding: the type of work, location and duration; existing road use (traffic flows, speed, and existing facilities); the footprint of the works including the safety zone required for workers; measuring remaining capacity outside the footprint of the works; and analysis of potential methods of mitigation (Barratt, 2018e).

Using this approach, the construction contractor Midgard Ltd worked with TfL and the London Borough of Tower Hamlets to keep a major cycle route operational during a construction project in central London. Due to the proximity of the development to the cycle lane, there were safety concerns about the risk of falling objects during work. Rather than close the route, to address these concerns a tunnel was designed and implemented for the duration of the construction work. Cycling groups have praised the way in which the plans and solution were handled and implemented (Barratt, 2019c). Similarly, TfL worked with Cadent Gas to overcome the need to close a busy bi-directional cycle lane in central London while works were carried out on-street. A traffic management solution was designed that maintained roadway for all traffic demands. The remaining road space was sub-divided and modified to provide a bi-directional cycle lane and three lanes for motor vehicles enforced by a 20mph zone. This helped to prevent the traffic congestion that would have arisen through the initial scheme in which only two lanes for motor vehicles was envisaged (Transport for London, 2018c).

At another major construction site in central London alongside a major cycle route which involved substantial works to the footway, TfL worked with the property developer St George to devise a scheme whereby the cycle route could be kept open by moving it. A scheme was drawn up in which a suitably wide segregated cycle lane was temporarily relocated towards the middle of the road by removing street furniture, and using ramps and in-filling to provide a level surface. Stakeholder engagement took place with cycling groups and users of bicycles and cargo bikes, who provided feedback on the plans. As a result of these responses, some changes to the scheme design were made to ensure that ramps were not too steep for all types of cycle and super elevation was included to help cargo bikes negotiate the route. The cycle route proved popular with cyclists and was shortlisted for an award (Transport for London, 2018d).

Where it is necessary to temporarily close cycle routes when substantial roadworks and streetworks are taking place due to adverse impacts on them, TfL has been working with local cycling groups to assess the viability of implementing alternative cycle routes. This includes: carrying out a desk top study of possible alternative routes with existing cycling facilities and/or roads with lower traffic flows; a visit to examine the possible routes and carry out a risk assessment by TfL, the local cycling group and the contractor where possible; a subsequent discussion between the participants of the cycling experience on the proposed route; and consultation with the relevant Highway Authority about use of the potential cycle route and signage requirements. Once this has been carried out it is written up in a report for consideration by the project team (Barratt, 2020f; Transport for London, 2019b).

When a tower crane required dismantling at a construction in London over the course of a weekend it required the closure of a two-way section of cycle lane. To facilitate cyclists still using the road it was proposed that cyclists merge with general motor traffic for the section of the works before returning to the cycle lane. However, poor motor vehicle driver behaviour and inappropriate speeds had been observed along this section of road, and this this raised concerns about cyclist safety as well as for construction site staff who would need to work close to the motor traffic. The construction company, Kier Group, worked with TfL and Nationwide Traffic Solutions to devise an approach that would cause motor vehicle drivers to reduce speeds on each approach to the shared section of road and thereby improve and make safer the cyclist and construction worker situation. ‘Road quake’ rumble strips, which are highly visible to approaching drivers, were positioned side by side on the approach sections of road. Traffic observations showed that approximately 80% of drivers reduced speed to negotiate the strips and the temporary scheme resulted in no incidents (Barratt, 2018f).

At a construction project in Hertfordshire that required the diversion of pedestrian footways, an ‘on demand’ pedestrian crossing was included in the traffic management scheme to ensure safe crossing of the road by school children and local residents (Osborne, 2017).

<u>*Equipment-related interventions*</u>

TfL, Cadent Gas and Oxford Plastics have developed a so-called ‘cycle path plate’ which allows cycle lanes to be maintained in some locations when street works or road works are taking place. This is a composite plate that can cover an excavation in the road that can be used to make the surface safe for cyclists. This plate comes in sections so that it can be used on various widths of cycle tracks. It can cover up to 4 metres of cycle track width and trench width of approximately 1 metre and is designed to withstand impact from cyclists while remaining in position and is anti-skid coated. The plate is easily manoeuvred during the course of the road works. In order to trial the prototype design, TfL gained the involvement of several cycling croups and operators (including the London Cycle Campaign, Wheels for Wellbeing, Cargobike Life and PedalMe) to ensure a range of cycle types were included. The plate is available through a range of suppliers (Barratt, 2019d).

At one construction site the hoarding and raised pedestrian walkway that was necessary meant that the vehicles egressing the neighbouring building would not have a clear view of oncoming cyclists in the cycle lane on the road, resulting in an increased for cyclists. To address this, a camera was installed to relay live images of the cycle lane to vehicles at the top of the ramp via a large screen prior to the vehicle crossing the cycle lane onto the road (Sisk, 2019).

A handheld Stop and Go board with LED lighting for use at night and with a small camera mounted on the top to record any incidents taking place, was developed for one London construction site. Traffic Marshals were also provided with helmets that were also fitted with cameras to record any incidents (CCS Best Practice Hub Administrator, 2014).

A construction project near a town centre in outer London required two bus stops outside the site to be suspended during the scheme. Work was carried out to identify alternative, temporary locations as close to the usual bus stops as possible, however this was complicated by inadequate space availability to accommodate these. The only location that was suitably located had insufficient kerb height to enable the required access arrangements. Faith Dean, the construction contractor worked with the London Borough of Redbridge to devise an alternative solution. This involved designing and installing a temporary platform that was suitable for all bus users (Barratt, 2019e).

The UK Department for Transport has produced a code of practice to ensure any construction work being carried out on or near a road is carried out safely, so that no other road users are put at risk by the works. This code provides details of the signing, lighting and guarding of street- and road works (Department for Transport, 2013). Transport for London has produced guidance for the designers of traffic management schemes associated with temporary road- and street works and construction sites about how to make these schemes safer especially in relation to pedestrians and cyclists (Transport for London 2018b). An HSE guide emphasises the importance of vehicle and pedestrian separation at and near to construction sites and provides advice (HSE, 2009).

7.3.12 Appreciating the perspectives of vulnerable road users

Various methods have been developed by public authorities in the UK, especially by Transport for London, which developers, designers and constructors can use to better reflect the needs of pedestrians and cyclists in their traffic management scheme designs for larger projects.

Transport for London and London Boroughs have established collaborative working groups in areas where there are multiple construction developments about to or currently taking place that bring together scheme developers, designers, contractors, residents, local businesses, cyclist and pedestrian groups, bus operators, the police and city authority personnel including planners, highway and traffic signal personnel, and environmental teams. These groups provide all participating with an opportunity to understand the construction work and to provide input into mitigation methods to reduce the traffic and environmental impacts, improve safety, as well as cost savings (Barratt, 2018g; Transport for London, 2018e).

TfL has also offered first-hand experience from the perspective of a cyclist in London together with presentations and discussions to senior management from companies in the construction industry so that they can obtain personal experience of how construction traffic potentially cyclists and pedestrians, and to see how safety schemes in construction can help to protect these vulnerable road users, so that they are better placed to address public health and safety in their traffic schemes (Barratt, 2018h). Those attending provide feedback of the experience and their learnings from it (Barratt, 2018i). Similarly, TfL had also used on-foot ‘walk arounds’ to allow constructors to see how their sites, others nearby sites and works are managed from the perspective of a pedestrian. This approach was developed and implemented in the central London location of Vauxhall, Nine Elms and Battersea (VNEB) and Waterloo, where many construction projects have taken place recently, with these walks taking place on a bi-monthly basis. The intention is to make participants aware of how the working practices of sites and their traffic impact the road network and pedestrians, taking account of factors including footway closures, hoarding design, on-site handling equipment, noise and dust (Transport for London, 2018f).

TfL has also TfL been trialling the use of a 360-degree camera mounted on a cyclist’s back footage from which is uploaded to YouTube to provide construction sector viewers who are not cyclists (especially aimed at those designed construction traffic management schemes) with insight into the challenges cyclists face near construction sites and roadworks. This provides all-round footage, including how other road users approach the cyclists from the rear, close passes by vehicles, and cyclists’ behaviour due to road surface conditions and traffic schemes. TfL is also considering using this approach using a 360-degree camera to provide insight from a pedestrian perspective (Barratt, 2018j).

Cyclist safety has also been considered in a scheme for a construction site in Yorkshire which had many passing cyclists and which many workers commuted to by bike. This was done by producing a Virtual Reality (VR) presentation that was made available at worker and local community sessions and online which highlighted hazard perception onsite, cyclist awareness and goods vehicle driver awareness (CCS Best Practice Hub Administrator, 2018).

TfL has also been working on how to ensure that the needs of physically disabled people and those with learning difficulties are taken into account in construction traffic management schemes, to ensure they are not substantially disadvantaged. TfL has organised workshops in which its staff can spend time with disabled people in order to learn about and understand the challenges they face from construction sites. A trial day workshop with 18 people who with learning disabilities and two construction contractors, McGee and Cadent Gas attending as guests, was organised. Participants were presented with various scenarios including construction site signage, pedestrian diversion routes, the use of ramps, noise, and dust pollution and a group discussion was held in which participants provided thoughts and experiences. This was followed by a construction site visit, where TfL staff could observe how the participants experienced and responded to the site layout and signage, and to witness how it made them feel. The day concluded back in the office reviewing the experience. TfL intends to run further such workshops and the produce a disability guidance document for constructors (Barratt, 2020g). TfL has also worked specifically with people with autism to be able to raise awareness of the challenges they face in relation to construction sites, and appropriate signage to warn them of site works and alternative routes that takes account of their needs at a site in London (CCS Best Practice Hub Administrator, 2020).

TfL is trialling an approach for construction projects in several locations to enhance the design of traffic management schemes for all cyclists and pedestrians including those with disabilities which involves three tiers of assessment: (i) the works developer, contractor and highway authority walk and cycle the local area with local community cycling and pedestrian groups before any work commences. This may include older people, people who use wheelchairs, people with walking impairments, people who are visually impaired, people who have learning disabilities, and parents with buggies. This is so that the contractor actively experiences and gets a better understanding of the barriers to access people face on a daily basis; (ii) these learnings are then incorporated by the contractor into the traffic management design and assessment process for the project (which may include adequate ramp gradients, smooth surfaces, turning space for people who use wheelchairs and buggies, signage with sufficient contrasts for visually impaired people, clear and easy to understand signage for people with learning disabilities, and protected areas for all types of cyclists); and (iii) these same groups revisit the local area again during the works to walk and cycle the traffic management areas to gain further experiences and report their experiences which may be able to be incorporated into any scheme of reasonable project duration (Transport for London, 2019c).

As part of the Tideway tunnel sewer project in London, Tideway has worked with the Corporation of London and the City of London Police to inform cyclists of the dangers of getting too close to HGVs in the City through the development of the so-called ‘Exchanging Places’ programme. This programme provides cyclists with a short briefing with a police officer in the driver’s seat of an HGV to give them the best understanding of what drivers can and cannot see when they are on the road (Tideway, 2018).

7.3.13 Planning conditions for site traffic and logistics

Several documents can be required by planning authorities as part of applications for construction projects that relate to transport and logistics arrangements for the site. These include:

- Transport Assessments (TAs) or Transport Statement which provide details of the expected transport impacts of the project during its construction and operational life (TAs are used for projects of strategic importance, while a Transport Statement is a shorter, simpler document for schemes with limited transport impacts).

- Construction Logistics Plans (CLPs) (also called Construction Traffic Management Plans - CTMPs) – required to explain the impacts on the community and vulnerable road users of projects expected to have sizeable transport and logistics impacts during their construction and how these impacts will be minimised. It typically includes: details of the levels of construction traffic that will be generated; routes these vehicles will use to avoid sensitive areas; traffic management and road safety approaches to be used; and details of the use of more sustainable, non-road modes where feasible (CLOCS and Transport for London, 2021).

- Construction Management Plans (CMPs - also called Construction Management Statements) – explains the approach to be taken to managing the construction works and how impacts will be minimised. It can include details of site access arrangements for vehicles, plant and personnel; site layout including location of on-site offices, unloading/loading areas, and access points; storage areas; screening and hoarding arrangements; dust and mud control measures; site waste management measures; site lighting and drainage arrangements; and other health and safety issues (Designing Buildings Wiki, 2020a).

- Construction Environmental Management Plans (CEMPs) – explains how a construction project will minimise or mitigate its impact on the environment and surrounding area in line with the environmental commitments made in the Environmental Statement/Policy for the project. It typically covers topics including: air quality; water quality and drainage; noise and vibration; geology and soils; landscape and visual impact; nature conservation; archaeology and cultural heritage; waste; energy; transport and materials.

The requirement for the submission of such documents as part of the planning process depends on the requirements of the Local Planning Authority (LPA) concerned, and the scale and likely impact of the proposed construction project.

TAs and CLPs typically precede CMPs and CEMPs but transport and logistics arrangements in the former may be included in these later documents. The transport and logistics elements of these documents can become planning conditions required by the LPA as part of the permission process.

Construction project developers have responsibility for the submitting these documents and the management of the development once work commences. They have to agree the planning conditions with the LPA and are also responsible for ensuring that construction contractors conform with these measures. Principal contractors may well make an input or write the detailed CLP and are responsible for the day-to-day management of the construction site. Freight transport and logistics companies providing services to the construction site have to comply with abiding by the measures outlined in these documents. As well as granting planning permission and imposing planning conditions to this permission, LPAs are also responsible for ensuring construction is carried out according to the terms of these conditions.

Both ‘outline’ and ‘detailed’ CLPs can be required by the LPA. An outline CLP accompanies the planning application and provides an overview of the expected logistics activity during the construction programme). A detailed CLP is submitted after permission has been granted and provides a far more detailed plan of the logistics activity during the construction programme and which is implemented and monitored during the project. In London, for example, construction projects that have values below £2 million and are deemed by the LPA to have lower impacts may require a TA or outline CLP, while those with values above £2 million, which comprise 10 or more residential units or 1,000 metres square or more floorspace, and which are expected to have medium or high impacts usually require both outline and detailed CLPs (CLOCS and Transport for London, 2020).

A CLP should contain details of how contractors will make goods vehicle drivers visiting the site aware of its logistics operations, and related environmental and safety measures. This includes: site opening times; site entry and exit points; changes to the highway and its management; vehicle routes be used to the site (avoiding facilities such as residential areas, schools, hospitals, community centres, sports facilities, public transport hubs and major cycle lanes wherever possible); vehicle routes and loading/parking on site; goods vehicle booking and scheduling arrangements; and any other measures to minimise anti-idling and impacts on vulnerable road users. Construction and infrastructure projects should provide details of the timing of the various phases of work and the plant and vehicles associated with them. In the case of construction projects, six phases are defined: i) site setup and demolition, ii) basement excavation and piling, iii) sub-structure, iv) super-structure, v) cladding, and vi) fit-out, testing and commissioning. For infrastructure projects, the following six phases are defined: i) site establishment, clearance and alterations, ii) excavation and foundations, iii) sub-structure, iv) super-structure, v) services and systems installation, and vi) fit-out, testing and commissioning (CLOCS, 2021c). A spreadsheet tool has been developed and made available for use in planning the vehicle movements associated with construction and instruction projects that can be used in a CLP (Transport for London, 2017b). A CLP is considered to be a 'living document' which should be updated as appropriate during the construction project to reflect any changes in circumstances (CLOCS and Transport for London, 2020). A website has been developed that provides information and guidance about CLPS (Construction Logistics, 2021).

TfL has devised several approaches to traffic management for deliveries and collection to construction sites to overcome adverse traffic, safety and environmental impacts from such operations (that have been discussed in this chapter). To ensure such approaches, where permitted, are managed and maintained to high standards, TfL has introduced a Memorandum of Understanding (MoU), which lists all the requirements of the agreed operation with key stakeholders. This takes the form of a visual task sheet which can be managed in conjunction with the Construction Logistics Plan for the site. All relevant parties sign the MoU and are expected to adhere to its agreed operation. Such MoUs are monitoring to ensure compliance. Any contraventions of the MoU lead to its suspension until improvements are made and agreed (Barratt, 2020h). TfL has made a template MoU available (Transport for London, 2021a).

In the case of several major public sector infrastructure schemes (such as the London Olympics, Crossrail, Thames Tideway, the Northern Line extension to Battersea, and HS2), the use of rail and water for the delivery of materials and/or removal of spoil and waste has been secured via the planning process. (See **section 7.3.7** for further discussion of non-road modes in construction projects).

7.3.14 Public-sector initiated private-sector led voluntary transport and logistics schemes

Given the incidence of construction goods vehicle collisions with cyclists and pedestrians in London and the media and public attention this received from 2011 on (see **section 6.3.2**) Transport for London developed the Construction Logistics and Community Safety scheme (CLOCS) to improve road safety, which it sought construction industry participation in, and tendered to be run on an administrative day-to-day basis by private organisations. It also linked its existing Fleet Operator Recognition Scheme (FORS), which had been established in 2006, to CLOCS. These, as well as other related schemes, are summarised below.

CLOCS – Construction Logistics and Community Safety

The Construction Logistics and Community Safety scheme (CLOCS) was developed by TfL to help ensure that the potential impact of construction projects on the community and vulnerable road users (pedestrians and cyclists) have been properly risk-assessed developers and contractors have, and that they have put in place suitable measures to minimise these risks. CLOCS is a voluntary scheme open to companies in the construction industry that is intended to enhance freight transport and logistics safety standards and to be used in developing, implementing, updating and monitoring Construction Logistics Plans (see **section 7.3.13**).

The so-called CLOCS Standard provides the construction industry and those designing projects with best practice guidance, policies and codes of practice to facilitate an industry standard that can be implemented by regulators, developers, principal contractors and freight operators. It has been developed through joint efforts by the public and private sector. The Standard is intended to ensure that construction companies follow safe practices in the management of their operations, vehicles, drivers and construction sites.

The CLOCS scheme encourages regulators to (CLOCS, 2019):

i) embed the requirement for construction companies to operate to the CLOCS Standard in policy and guidance documents,
ii) ensure the planning process requires submission and approval of a CLP, and
iii) require a construction project to have effective monitoring procedures and enforcement mechanisms in the case of CLOCS breaches.

Developers and principal contractors are encouraged to comply to the CLOCS Standard and ensure that the entire project team implements a CLP, together with effective monitoring of compliance with it. Freight operators are encouraged to ensure that all their construction journeys are compliant with the CLOCS Standard, which involves meeting the requirements required of Silver members of FORS for management, driving, vehicle standards and operations (CLOCS, 2019).

Those wishing to be awarded the CLOCS Standard need to comply with a range of measures documented in it. The compliance levels in the CLOCS Standard include those that are mandatory, those that are recommended as good practice, and those that are optional or an emerging practice (CLOCS, 2019). These measures are aligned with those recommended for inclusion in a CLP (CLOCS and Transport for London, 2020). Many of the goods vehicle management and construction traffic management measures recommended and suggested in the CLOCS Standard have been reviewed in chapter 7, especially in sections **7.3.10** and **7.3.11**.

CLOCS began as a London scheme, but has since become a national standard. Members of CLOCS pay an annual membership fee which is used to help ensure CLOCS is the robust national industry standard for all regulators, clients, contractors and fleet operators. They receive accreditation together with access to tools and resources to help assist their knowledge and implementation of CLOCS, webinars and forums, and CLP training. CLOCS is run administratively on behalf of TfL by private organisations appointed to do so on a tender basis.

CLOCS provides guides on: managing supply chain compliance which includes site monitoring, reporting and corrective management (CLOCS, 2020a); how CLOCS can be embedded in the procurement process for construction projects and in the planning process (CLOCS, 2020b; 2020c); and assessing construction site ground conditions for goods vehicles to ensure safe use (CLOCS, 2020d).

TfL promotes the use of CLOCS in its advice to developers and contractors about Construction Logistics Plans (CLOCS and Transport for London, 2020). A website is available that freely provides many CLOCS resources (CLOCS, 2021b).

The site requirements for goods vehicles, drivers and deliveries for the Tideway sewer tunnel construction in London that takes account of CLOCS and FORS provides a useful example of how project designers and principal contractors can implement the elements of these schemes in their operations, as does Tideway's Driver Information Pack (Tideway, 2016; 2020).

The Fleet Operator Recognition (FORS) Scheme

The Fleet Operator Recognition (FORS) Scheme was launched by Transport for London (TfL) in the UK in 2006. It was a key part of the London Freight Plan that was published in 2008. FORS is a voluntary accreditation scheme for fleet operators available to any operator of HGVs, vans, wheeled plant, passenger carrying vehicles, cars and powered two-wheelers (i.e. not only construction companies) (FORS, 2021a). FORS provides members, who pay a subscription fee, with practical advice and guidance to help reduce fuel consumption, CO_2 emissions, vehicle collisions. This is achieved through improving driver behaviour, vehicle and fleet management, and safety and efficiency in transport operations. The programme is delivered through classroom and online training, workshops and webinars, a conference, and electronic guides and tools. Three levels of FORS membership are available: bronze, silver and gold. To gain bronze membership operators need to demonstrate that they have put in place the specified FORS management systems, policies and procedures on: drivers and driver management, vehicle maintenance and fleet management, transport operations, and performance management. Silver membership requires that operators are committed to improving the safety, environmental impact and efficiency of their vehicle operations. Gold membership is awarded to exceptional operators providing evidence of yet further improvements in safety, environmental impact and efficiency (FORS, 2020).

FORS began as a scheme for those operating vehicles in London but has since become a national scheme. Administration of FORS is operated on a day-to-day basis on behalf of TfL by a private company, awarded a contract to do so (FORS, 2020). FORS currently has approximately 5,000 accredited members who operate about 100,000 vehicles. TfL promotes the use of at least Silver-accredited FORS freight operators by developers and contractors in its advice on Construction Logistics Plans (CLOCS and Transport for London, 2020). A website is available that provides further details about FORS (FORS, 2021b).

Another freight and fleet operator accreditation scheme is ECOSTARS, which was established in 2009 for the South Yorkshire Transport Plan Air Quality Steering Group in the UK as a means by which to reduce the impact of road transport emissions from goods vehicles on local air quality. ECOSTARS is intended to assist road transport operators to invest in and improve their fleet environmental performance. Scheme participants receive ECOSTARS Fleet Recognition status. The scheme was expanded through a European project which has resulted in authorities in other European countries having now established their own ECOSTARS schemes (ECOSTARS, 2021).

Considerate Constructors Scheme

The Considerate Constructors Scheme (CCS) is a national scheme established in 1996 by the Construction Industry Board (CIB) and the Chartered Institute of Building (CIOB) to raise the standards in the construction industry and to improve its image. CCS is a not-for-profit, self-financing, independent scheme which construction sites, companies and suppliers can voluntarily register with, in return for the payment of a fee, and are then obliged to practice in accordance with its Code of Considerate Practice, against which they are monitored. By 2017 more than 100,000 construction sites in the UK had been part of the scheme. As well as site and company accreditation, CCS also provides online learning material and a Best Practice Hub, which comprises an online library of best practice examples to help share and promote best this across the construction industry (CCS, 2021a).

The CCS' Code of Considerate Practice comprises five parts (CCS, 2021b):

- Care about Appearance – that sites, companies and workers are well managed and have a clean and tidy appearance.

- Respect the Community – that construction companies carefully consider the site impacts on neighbours and the general public, minimising deliveries, parking and transport issues and communicating these actions; work on the public highway.

- Protect the Environment – construction companies manage and promote environmental issues on sites, including their carbon footprint, waste, resource use, ecology and wildlife and all types of local pollution.

- Care about Safety – construction companies must have in place practices and approaches for occupational health and safety for visitors, the workforce, neighbours and the general public's interactions with the site.

- Value their Workforce – construction companies should provide a supportive and caring working environment based on respect and fairness and support, and showing courtesy and consideration to those affected by the work.

Safequarry.com

Safequarry.com is an online hub established by the Mineral Products Association (MPA), the British Aggregates Association (BAA), the Health and Safety Executive (HSE) and companies working in the quarrying and mining sector to provide health and safety information, advice and good practice for those working throughout the construction supply chain from quarries, to processing plants, to the transport of materials and products, to deliveries to construction sites. Safequarry.com provides a searchable database of best practice, online talks, videos, as well as incident alerts and new content alerts for those registered (Safequarry.com, 2021b)

7.3.15 Road- and street works management

Road works refer to the maintenance of roads by the local highway authority (such as installing cycle or bus lanes). Street works refer to works carried out by the water, gas, electricity and telecommunications utility companies to install, repair or maintain these services. Street works and road works carried out on public highways result in substantial impacts on road traffic speeds and journey time delays and unreliability, as well as increasing risks for vulnerable road users. In 2016, the Department for Transport (DfT) calculated that approximately 2.5 million road works are carried out in England each year, with an estimated cost to the economy of around £4 billion per year (Department for Transport, 2017a).

In London and Kent, since 2012 and 2013 respectively, lane rental schemes have been in operation which permits the highway authorities to charge utility companies carrying out such works for the time their works occupy the highway. Charges vary depending on the times at which the works take place and the level of traffic that uses the street (Department for Transport, 2017a).

This approach permits these highway authorities to charge up to £2,500 for each day that works take place on the highway. This charge is intended to reflect the costs of congestion caused by the works and thereby to encourage utility companies to: i) reduce the time taken to carry out the works, ii) carry out more works outside of peak times (i.e. evenings and weekends where possible), ii) improve their planning, coordination and working methods (and to collaborate with each other to carry out works on the same road at the same time), and iv) complete works to the required standard thereby reducing the need to return to carry out remedial work (Department for Transport, 2017b).

The UK Government carried out a consultation on the future for lane rental schemes in 2017. Following this, the Government decided to roll-out the opportunity to other local highway authorities in England and Wales to bid for and set up lane rental schemes as a means to reduce the impact of street works on busy roads at busy times (Department for Transport, 2017a).

Monitoring of this lane rental scheme in London has shown that between October 2013 and March 2020 approximately 11,500 days of lane rental were saved through early discussions with utility companies. Also, between 2010/11 and 2019/20 the number of collaborative street work sites per period have increased by 31%, there has been an increase in planned utility works taking place overnight from 11% in 2010/11 to 41% in 2019/20, the total number of works undertaken has decreased by 20-30%. There has also been a substantial reduction in the total number of permits for works, and road user / customer satisfaction with respect to street works taking too long has improved substantially (Transport for London, 2021b).

Surplus revenue raised from lane rental can be used by the highway authority to fund projects that 'reduce the disruption or other adverse effects caused by the works'. In both London and Kent projects have been funded that involve innovation, trialling new techniques for speeding up road works, installing ducting on busy routes that can subsequently be used by utilities, and implementing extraordinary measures to mitigate congestion caused by road works (Department for Transport, 2017a). Examples of some such projects are provided below.

For a construction site in central London, street works were required to divert utilities. Initial plans were to excavate across a major road containing a four-lane carriageway, two-way cycle lane and adjacent footways. The works were expected to take four months to complete and would have resulted in major transport disruption. TfL, the City of London, the construction project manager and a utility consultant worked together to investigate alternative ways in which the work could be carried out that would avoid these transport impacts. A method called pipe jacking was eventually planned and implemented that involved tunnelling under road between two shafts, one located in a side road and the other within the site boundary. Sections of tunnel constructed in concrete were pushed into position by a hydraulic jack. Once the tunnel was in place, the utilities could be inserted through the tunnel and into their required position. Using this approach, there was no need to excavate the main road, and all transport impacts of having done so were avoided (Barratt, 2019f).

In another scheme, a key road in central London was identified by TfL and the London Borough of Lambeth as requiring future work by many different utility companies as a result of adjacent construction developments, resulting in major disruption to all road users including cyclists and pedestrians. To avoid the road being excavated of numerous separate occasions, an accessible duct network was installed to facilitate future capacity and connections for nearby planned developments. The work to install the network duct was carried out between 2019 and 2020. The excavation of a single 400 metre trench to install the duct network cost approximately £250,000. Given that its installation will accommodate eight future developments, estimated construction savings are approximately £2 million, together with the transport benefits (Barratt, 2021e).

TfL is working with London boroughs, developers, and utility companies to identify further opportunities to future proof London’s roads by forward planning and designing-in future needs to prevent the need for utility works associated with major construction sites to result in transport disruption, especially to cycle lanes and pedestrian footways.

TfL also carries out roadwork and construction patrols by bike to observe infrastructure and operational issues at construction sites, and at street works and road works, including road, cycle track and footway conditions and widths, and goods vehicle drivers, cyclist and pedestrian behaviours. These patrols are open to all stakeholders including residents’ groups, cycling groups, the Police, developers, construction contractors, freight transport operators and utility companies. Problematic situations are noted and photographed. Afterwards, participants discuss their experiences and thoughts and a report is written up. This patrol approach facilitates collaboration between different interest groups and is being incorporated into its assessment procedures (Barratt, 2017d). An example of a roadworks patrol report is provided by a report from Southwark in 2017 (Barratt and Bernstein, 2017).

8. Sustainability targets, plans and actions of major companies in UK the construction industry

This chapter provides insight into the sustainability targets, plans and actions of major UK construction companies (**section 8.1**) and suppliers of construction materials (**section 8.2**).

8.1 Sustainability plans of major construction companies

Table 8.1 provides a summary of the sustainability targets and plans (in terms of CO_2 emissions and waste reduction) implemented by the top fifteen construction companies in the UK by turnover in 2018, together with an indication of whether these plans include explicit reference to the impacts of construction subcontractors and building materials, and freight transport operations. The companies are listed in order of the magnitude of their turnover. **Table 8.1** also shows the features of these sustainability plans in terms of whether or not they explicitly mention the greater adoption of sustainable procurement of construction materials, off-site manufacturing, and supply chain collaboration. It also indicates whether these companies currently publish detailed environmental data about the impact of their construction work. The information used in compiling **Table 8.1** has been produced by reviewing the sustainability and environmental strategies published by these Top 15 construction companies.

Table 8.1: Sustainability targets and plans of the Top 15 UK construction companies

Company	Turnover (£ billion - end Dec 2018)	CO_2 reduction target (if so, target by when)	Scope 3* CO2 emissions explicitly mentioned?	Waste included? (if so, target by when)	Freight transport mentioned?	Off-site manufacturing mentioned?	Procurement of more sustainable materials mentioned?	Supply chain collaboration mentioned?	Publishes detailed environmental performance data?
Balfour Beatty Plc	7,802	Beyond net zero by 2040	Yes	40% reduction by 2030. Net zero waste by 2040	No	Yes, reduce on-site activity by 25% by 2025	Yes	Yes	Yes
Kier Group Plc	4,512	Reduce energy use by 30% by 2030. Net zero CO_2 by 2045.	Yes	Eliminating avoidable waste by 2035	No	Yes	Yes	Yes	Yes
Interserve Plc	3,226	Intention to reduce CO_2 use but no target	No	Intention to reduce but no target	No	No	Yes	Yes	No
Galliford Try Plc	3,132	Intention to reduce energy use but no target	No	Intention to reduce but no target	No	No	Yes	Yes	No
Morgan Sindall Group Plc	2,971	Intention to reduce CO_2 use but no target	Yes	Intention to reduce but no target	Yes	No	Yes	Yes	Yes
Amey Plc	2,668	Intention to reduce CO_2 use but no target	No	Intention to reduce but no target	No	Yes	Yes	Yes	No

Mace Ltd	2,350	Reduce CO_2 by 60% and eliminate diesel use on sites by 2030	Yes	Reduce by 20% by 2030	Yes	Yes	Yes, reduce embodied carbon by 20% by 2030	Yes	Yes
ISG Plc	2,238	Operational net zero CO_2 by 2030	No	Intention to reduce but no target	No	No	Yes	Yes	No
Keller Group Plc	2,224	Intention to reduce but no target	No	Intention to reduce but no target	No	No	No	No	No
Laing O'Rourke Plc	1,986	75% reduction in own CO_2 by 2030	Yes	Intention to reduce but no target	No	Yes	Yes	Yes	No
Skanska UK Plc	1,935	50% reduction in CO_2 by 2030; net-zero by 2045	Yes	Intention to reduce but no target	No	No	Yes	Yes	Yes
Wates Group Plc	1,601	Net zero CO_2 in own operations by 2025	No	Zero waste by 2025	No	No	No	No	No
Costain Group Plc	1,489	Net zero CO_2 by 2035	Yes	Intention to reduce to zero	No	No	Yes	No	Yes
Willmott Dixon Holdings Ltd	1,323	55% reduction in CO_2 by 2030 and net zero CO_2 operations by 2040	Yes	Zero avoidable waste by 2030	No	Yes	Yes	Yes	No
Multiplex Construction Europe Ltd	1,065	Net zero CO_2 operations by 2030	Yes	Zero avoidable waste by 2030	Zero transport emissions by 2030	No	Yes, reduce embodied carbon by 50% by 2030	Yes	Yes

Notes: * - Scope 3 emissions are those that arise in these construction companies' supply chains, arising from construction materials and their transport and the operations of subcontractors.

Source: Construction Index, 2019 – for company turnover data; Amey, 2020; Balfour Beatty, 2021; Galliford Try, 2020a, 2020b, 2020c, 2021; Keller, 2021; Kier, 2019b; Kier, 2020, 2021; Interserve, 2020a, 2020b; Laing O'Rourke, 2021; MACE, 2020, 2021; Morgan Sindall, 2020; 2021; Multiplex Europe, 2021; Skanska UK, 2021; Willmott Dixon, 2020a, 2020b.

As can be seen in **Table 8.1**, all of these 15 companies have at least a stated intention to reduce their CO_2 emissions, with ten of them setting a specific reduction target and date. Nine of the 15 companies consider the CO_2 emissions arising in their supply chains from subcontractor activities and the supply of materials as part of these commitments. Six of the 15 have set specific targets and dates for waste reduction. The vast majority of these companies include mention of collaboration with supply chain partners (including with subcontractors) and the procurement of sustainable building materials as part of their CO_2 emissions reduction strategies, while six also mention off-site manufacturing. These major construction companies rarely include freight transport considerations in their sustainability plans concerning CO_2 emissions and environmental impacts, with only one company including a target to eliminate freight transport CO_2 emissions by a specified date. If goods vehicles are considered by these construction companies it is usually as part of the health and safety strategies in terms of the risks they pose to workers and the general public.

8.2 Transport sustainability plans and actions of major suppliers of building materials

Sustainability Strategies, Policies and Annual Report together with other online material published by the five major suppliers of construction materials (aggregate, asphalt, cement, and concrete) in the UK have been analysed to provide insight into their plans and actions to bring about more sustainable, efficient and safe freight transport operations. Each company plan is summarised in turn below.

Aggregate Industries

Aggregate Industries has committed in its Transport Sustainability Plan (Aggregate Industries, 2020b) to "minimise the environmental and social impact associated with the transportation of our product." The company seeks to use rail and water wherever possible rather than road transport. When road has to be used, the company has adopted a hierarchy of intent. It aims to first and foremost, minimise the pollution from that road transport; secondly, increase the volume per load to improve efficiency with like-for-like environmental impact; thirdly to reduce congestion (although volume carried is not improved, the carbon impact is reduced when traffic conditions are easier); and fourth, "to reduce incidents which in turn reduce congestion."

- Pollution reduction for road freight transport by:
  - Implementing a fleet of Euro 6 HGVs. 74% of the fleet met this in 2020, and there is a target of 95% compliance by the start of 2024.
  - Trialling hydro-treated vegetable oil (HVO) at the Battersea London Concrete site.
  - Reducing waste through fully adopting electronic Proof of Delivery (ePoD) in 2020 to reduce paper usage.
  - Ensure third-party freight operators used have aligned strategies in their contracts.

- Reducing CO_2 per Load Delivered by:
  - Introducing walking floor trailers for the delivery of aggregates and asphalt
  - Products (which offer improved vehicle stability compared to tippers. Aim to add a further 20 of these to take the total to 50 vehicles by 2024.
  - Use rear steer vehicles with improved manoeuvrability where possible for rural operations and deliveries.
  - Use vehicles with greater carrying capacity where possible (such as replacing 6m3 RMX vehicles with 8m3 ones) and incentivise contractors to do so as well.
  - The in-house and franchise vehicle fleet (tippers and concrete HGVs) are fitted with equipment to monitor driver performance on fuel economy, engine idle time and cruise control usage. Data is reviewed and used for training.

- Congestion reduction by:
  - The ongoing development of the delivery planning system (DPS) for the Midlands fleet to increase the vehicle utilisation and proportion of loaded miles travelled, included combining concrete deliveries where possible.
  - Continue to use the satellite tracking system to avoid delays on the road network, and that contractors continue to use navigation equipment to reduce distance travelled and use appropriate roads.
  - Deliver asphalt to road works during the night and double-shift these vehicles where possible.

- Incident Reduction by:
  - Ensuring new core fleet vehicles are FORS Silver and CLOCS compliant, together with all around camera systems and scanning technology for improved visibility of other road users – full fleet implementation by 2023

- All tippers have been equipped with telematics since 2018 to monitor harsh braking, cornering and acceleration events.
- Increase the use of low-entry cabs
- All drivers undertake a Vulnerable Road User training course and site induction. A Driver Foundation Approval Programme is being trialled.

Breedon

Breedon's Annual Report for 2020 explains that (Breedon, 2021c):

- In its cement operations, it continues to work to increase the proportion of the primary movement by rail (in 2020 saving approximately 100,000 road miles).

- An investment has been made in new Mercedes Econic low entry cab mixers equipped with the latest safety features – but does not provide details of the proportion of the fleet this represents.

- Rail freight volumes increased by 3% compared to the previous year despite lockdown restrictions and average rail payload increased by 170 kg per load year-on-year, which removed approximately 30,000 road miles.

- Focus on driver training supported by telematics systems has continued. Fuel efficiency monitoring software installed and trialled on in-house goods vehicles at Whitemountain demonstrated a 12% improvement in fuel economy and an 11% cent CO_2 emission reduction. This fuel monitoring system will be rolled out to another 300 goods vehicles in 2021.

- Another telematics solution trialled on the cement division's in-house fleet saved 19,000 litres of diesel consumption. This has now been rolled out to the contracted haulage fleet as well and these drivers are receiving assistance to improve their driving style and fuel economy.

CEMEX UK

In its Sustainable Logistics Strategy CEMEX UK aims maximise the use "of rail, river and short sea movements wherever possible." When using road transport CEMEX UK (CEMEX, 2021c):

- Uses a single fleet of lorries for the transportation of materials, which results in lorry movements required to service highway maintenance operations having been reduced by up to 65%.

- Requires that all UK fleet drivers are trained in the Safe and Fuel Efficient Driving (SAFED) scheme and are regularly assessed on their fuel usage and driving style. CEMEX UK also runs its own fuel training programme that addresses on all aspects of fuel usage suing a general awareness campaign, fuel saving information provided in the driver handbook.

- Has trialled the use of a 50% bio-diesel blend for six months at one site and is currently evaluating the outcomes and consider a potential rollout across the business.

- Plans its delivery operations to maximise payload and minimise empty running.

- Maximises vehicle utilisation through off-peak and night deliveries where possible to avoid peak travel times and reduce contributing to traffic levels. This assists in improving fuel economy and journey delays.

- Has its own fleet of vehicles that are, on average, under 5 years old.

Hanson

Hanson's Sustainability Policy for 2021 contains no specific actions and targets concerning its transport operations, other than a commitment to (Hanson, 2021c):

- "Have stringent targets to reduce emissions to air from all our operations."

- "Will transition our operational fleets from traditional combustion engines to alternative forms of energy and, through collaboration with suppliers, our fleets will be more efficient through new technology."

Its Sustainability Strategy notes that in 2019, road accounted for 85% of its total transport, rail for 14% and water for 1%. Total transport CO_2 emissions were 5% lower in 2019 than in 2018 but were 5% greater per tonne of product delivered. This was due to an increase in the average distance travelled per tonne of aggregates and concrete delivered (Hanson, 2021d).

Tarmac

In its Sustainability Strategy, Tarmac explains that it is continuing to seek opportunities to increase its use of rails, already having sixty rail-connected sites nationwide, and the greatest user of the rail network among the major construction material suppliers. It is supporting the rail freight industry in its net zero carbon ambitions (Tarmac, 2021c). This includes working with the rail freight operator DB Cargo UK to commence freight train operations powered by 100% renewable fuel (hydro-treated vegetable oil - HVO) between Tarmac's Mountsorrel site in Leicestershire and its asphalt plant in the centre of Birmingham (Tarmac, 2021b). Another rail freight scheme involves the implementation of major off-loading machinery at the Battersea concrete rail depot which receives sand and gravel from Greenwich Wharf and limestone from Tunstead, which will facilitate greater use of rail freight and a substantial reduction in the use (Tarmac, 2021d).

In terms of its road freight operations, Tarmac is (Tarmac, 2021e):

- Trialling and adopting new vehicle designs and technologies, being first to trial the Mercedes Benz Econic mixer design with enhanced field of vision and low entry cab.

- Using moving floor trailer which offer both improved safety and environmental performance when unloading and an increased carrying capacity compared to standard rigid HGV tippers.

- Creating a new national community safety programme as well as developing and trialling innovative new technologies to aid driver and vulnerable road user awareness of hazards.

- Continuing to provide driver training programmes, as well as playing an active role in educating local communities about safety. An ongoing community engagement programme has resulted in the provision of road safety sessions in schools, raising awareness of the importance of safety awareness of trucks involving approximately 3,000 pupils in 2019.

- Working with local police and cycling communities and is regularly involved in Exchanging Places events which provide the public the opportunity to sit in an HGV cab to appreciate the driver's perspective.

- A founding member and champion of the CLOCS Standard and member of the Fleet Operator Recognition Scheme (FORS) with all contractor hauliers working with Tarmac holding a minimum of FORS Bronze accreditation.

9. Recommendations for action

9.1 Analysis of relationship between potential actions and impacts

Using the review of available measures to reduce the negative impacts of construction activity (see **chapter 7**) it is possible to identify the relationship between these measures and the specific areas of impacts they have the potential to improve. This is shown in **Table 9.1,** together with an indication of those measures that have the scope to result in improvements in work efficiency/productivity and hence reductions in construction project costs.

Table 9.1: Categories of construction measures and their potential impacts

Categories of measures		**Impacts**						
	GHG emissions	**Road vehicle kms travelled**	**Goods vehicle journeys to/from construction sites**	**Deaths and injuries**	**Disruption and fear for road/pavement users**	**AQ & other local environmental impacts**	**Noise, disturbance and other social impacts**	**Site productivity/efficiency & construction cost**
Materials and supply chain / logistics related measures								
Building materials production technology to reduce CO_2 emissions	✓					✓		✓
Off-site manufacturing	✓	✓	✓	✓		✓	✓	✓
Supply chain working practices	✓	✓	✓	✓		✓	✓	✓
Site layout and logistics management	✓	✓	✓	✓	✓	✓	✓	✓
Plant & equipment used on site	✓			✓	✓	✓	✓	✓
On-site dust and pollutant management						✓		
Waste management	✓	✓	✓			✓		✓
Freight transport related measures								
Vehicle fuel source / engine standards	✓					✓	✓	
Vehicle design	✓			✓	✓	✓	✓	
Vehicle maintenance	✓			✓		✓	✓	
Vehicle carrying capacity	✓	✓	✓	✓	✓	✓	✓	✓
Vehicle utilisation on journeys	✓	✓	✓			✓		✓
Vehicle routeing for journey co-ordination and arrival time	✓	✓	✓	✓	✓	✓	✓	✓

Use of non-road modes	✓	✓	✓	✓	✓	✓	✓	✓
Use of non-motorised road vehicles (e.g. cargo cycles)	✓	✓	✓	✓	✓	✓	✓	✓
Driver training and fleet management	✓			✓	✓	✓	✓	✓
Appreciating others' perspectives				✓	✓			
Traffic management schemes: goods vehicles	✓	✓	✓	✓	✓	✓	✓	✓
Traffic management schemes: cyclists & pedestrians				✓	✓			
Planning conditions for site traffic & logistics	✓			✓	✓	✓	✓	✓
Voluntary transport and logistics schemes – operation accreditation schemes: CLOCS & FORS	✓			✓	✓	✓	✓	
Voluntary transport and logistics schemes- Good practice sharing: CCS and Safequarry.com	✓			✓	✓	✓	✓	
Road- and street works management	✓			✓	✓	✓	✓	✓

The potential effect of the measures listed on the UK construction industry as a whole depends on several factors including: i) the impact of each measure when implemented (with the degree of impact varying between measures and the way in which any given measure is applied), and ii) the scale of uptake of these measures across construction sites and the construction industry. There is insufficient existing research to have any certainty about the potential impact of many of the listed measures and their relative importance.

Only major construction sites and projects in the UK are likely to currently make use of many of these measures. And even within these major sites and projects, some of the freight transport-related measures, including the use the latest goods vehicles designed with safety in mind and the of non-road roads, are only likely to be implemented on a small number of public sector projects that specify the use of these as part of the project procurement process.

Smaller construction projects and sites carried out for private sector clients, either companies or private individuals are less likely to apply these measures than larger projects.

Those measures that reduce the vehicle kilometres travelled by goods vehicle will also reduce CO_2 emissions, air pollutants, road-related injuries and deaths, and disruption caused by goods vehicle operations, all other things being equal.

9.2 Actions available to stakeholders in the construction industry

Based on the review of measures carried out in **chapter 7** it is possible to consider these according to the various stakeholders in the construction supply chain that are best placed to take the lead in their implementation and requirements. By doing so, this provides further insight into the actions each stakeholder can champion. This is shown in **Table 9.2**.

Clients of construction projects may be private or public sector organisations. They can use position as project procurer to require that construction companies adhere to certain standards in their activities and materials sourcing strategies while working on the project. For instance, Transport for London requires that construction contractors and their freight transport subcontractors working on its projects are accredited to the CLOCS Standard and the FORS Standard, holding at least FORS Silver accreditation. Similarly, clients can decide that the buildings that they commission comply with environmental performance standards such as BREEAM.

Utility companies (such as power, water, sewerage and telecommunications providers) are part of the 'client / designer of construction project' when they need to carry out infrastructure projects and excavate roads in order to carry out maintenance and improvements to their services located beneath the road surface. However, they also have a more general role to play when the provision of utilities needs to be added or altered as part of other construction projects. Emergency services (i.e. police, fire and ambulance services) also have views that need to be taken account of in planning construction projects and measures to mitigate their negative impacts, as do local businesses and residents.

Table 9.2: Categories of construction measures and the lead stakeholder(s)

Categories of measures	**Stakeholders**					
	Client / designer of construction project	**Construction companies**	**Suppliers of materials/products**	**Freight and waste transport companies**	**National/international government**	**Local government / planning authority**
Materials and supply chain / logistics related measures						
Building materials production technology to reduce CO_2 emissions	✓	✓	✓		✓	✓
Off-site manufacturing	✓	✓				
Supply chain working practices	✓	✓				
Site layout and logistics management	✓	✓				
Plant & equipment used on site	✓	✓			✓	✓
On-site dust and pollutant management	✓	✓				✓
Waste management	✓	✓		✓	✓	✓
Freight transport related measures						
Vehicle fuel source / engine standards	✓	✓		✓	✓	✓

Vehicle design	✓	✓		✓		✓
Vehicle maintenance	✓	✓		✓	✓	
Vehicle carrying capacity		✓		✓		
Vehicle utilisation on journeys	✓	✓				
Vehicle routeing for journey co-ordination and arrival time		✓		✓		
Use of non-road modes	✓	✓				✓
Use of non-motorised road vehicles (e.g. cargo cycles)	✓	✓				✓
Driver training and fleet management		✓		✓		
Appreciating others' perspectives		✓		✓		✓
Traffic management schemes: goods vehicles	✓	✓				✓
Traffic management schemes: cyclists & pedestrians	✓	✓				✓
Planning conditions for site traffic & logistics					✓	✓
Voluntary transport and logistics schemes – operation accreditation schemes: CLOCS & FORS	✓	✓		✓		✓
Voluntary transport and logistics schemes- Good practice sharing: CCS and Safequarry.com	✓	✓	✓	✓	✓	✓
Road- and street works management		✓				✓

In terms of actions available to national, international and local government and planning authorities, these fall into two categories, those that are mandatory and those that are advisory. Mandatory actions would include national and international regulatory requirements concerning goods vehicle engine emissions standards, national and local vehicle construction requirements to enhance safety, and local requirements concerning transport and traffic management arrangements (such as vehicle routes and times of operation) that must be put in place for a construction site or quarry as part of planning conditions. Advisory actions would include encouraging construction companies to join CLOCS, fleet operators to join FORS, adopt driver training and use telematics and fleet management systems, and to use non-road modes where possible.

As can be seen from **Table 9.2** there are many measures available to the stakeholders that can be implemented to enhance the sustainability and safety of construction and its related logistics and transport activities. The suppliers of building materials have the least measures available as these only extend to producing sustainable materials and products, but in so doing they can make a major contribution. In addition, many of the larger material supplier, who account for much of the supply of aggregate, asphalt, cement and concrete either operate or contract transport operations for the delivery of these, so have further opportunities to influence sustainability and safety in this way.

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