CONSTRUCTION LOGISTICS

Briefing Report – Summary Slide Set

Technical Report ENG-TR.019

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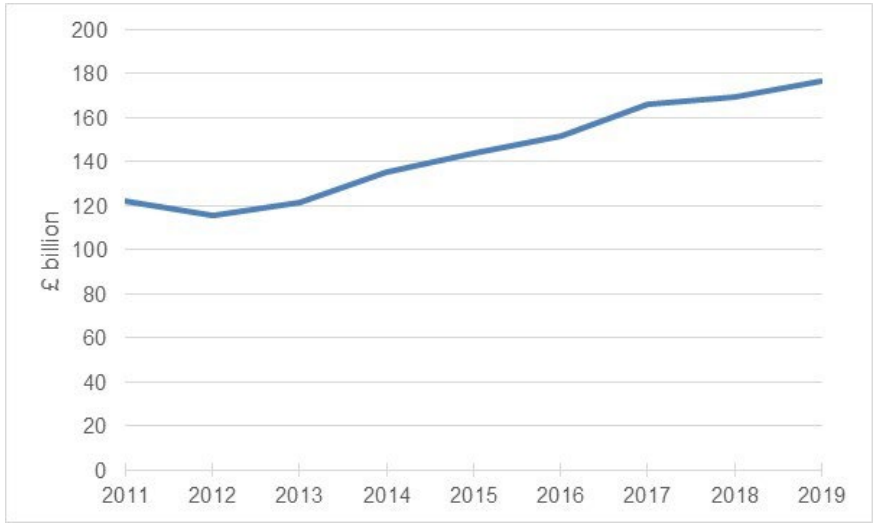
Importance of construction industry and construction logistics

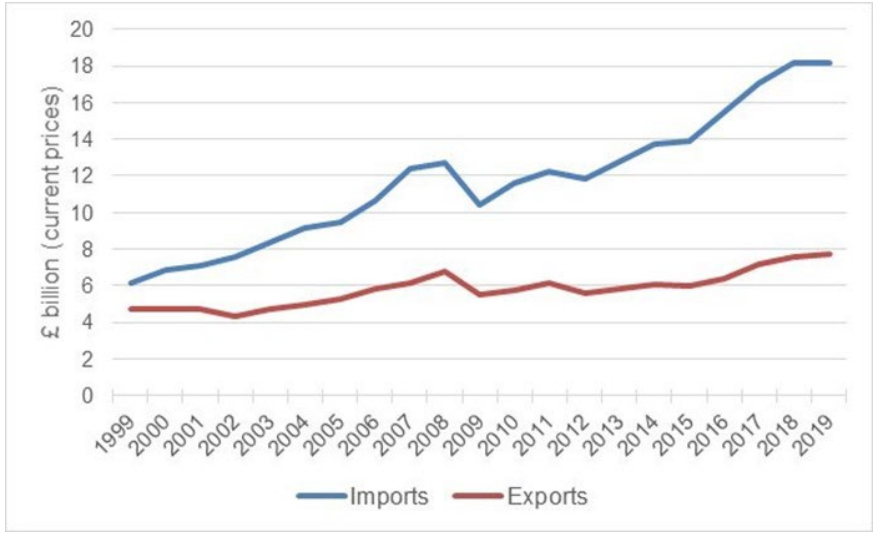
- New construction work contributed £119 billion to UK economy in 2019
- Repair, refurbishment and maintenance work contributed £57 billion to UK economy in 2019
- 2.3 million people work in construction (7% of total workforce)
- 290,000 construction companies
- But UK trade deficit in construction products:
  - UK imports more than it exports
  - Large and increasing deficit (£10.4 billion in 2019)

Output value of UK construction industry, 2011-2019



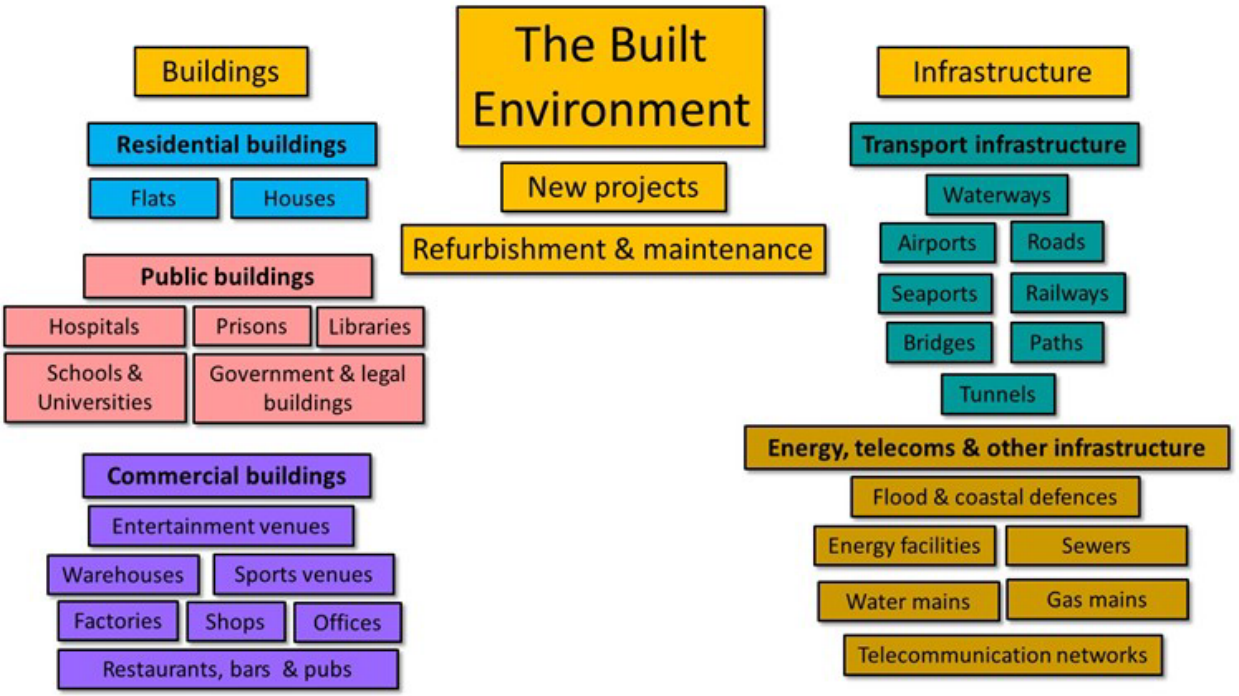
Source: ONS, 2021

Value of UK Overseas Trade in Construction Products, 1999-2019



Source: BEIS, 2021

Built environment provided by the construction industry

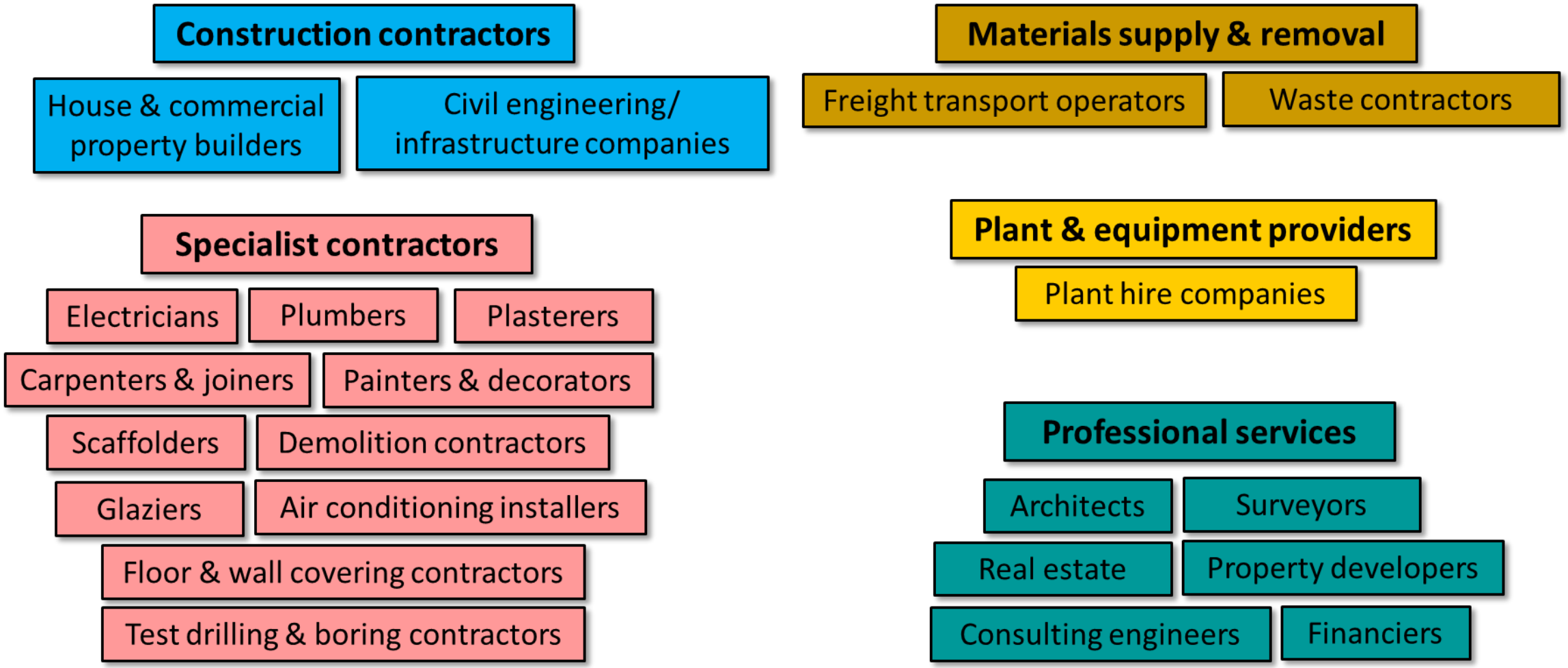


Construction output value in the UK in 2019 by type of construction (% of total construction industry value)

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, 2021

Companies carrying out many different activities in the construction supply chain



UK construction industry – economic importance and structure

- Construction industry contributed £176 billion to the UK economy in 2019 (new work plus refurbishment & maintenance)
- Equivalent to 9% of UK economy
- 2.1 million people work in construction (6.5% of total UK workforce)
- 290,000 construction companies
  - Many small as well as large companies
  - Very high level of self-employment (36% v 13% in economy as whole)
  - Micro-businesses (less than 10 employees) accounted for almost one-third of construction industry value in 2019

Source: https://commons.wikimedia.org/wiki/File:Canada_Line_False_Creek_tunnel_construction.jpg

Source: https://upload.wikimedia.org/wikipedia/commons/5/58/GRUA_TORRE_21LC550.jpg

Types of construction work in UK construction industry by output value in 2019

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 ONS, 2021

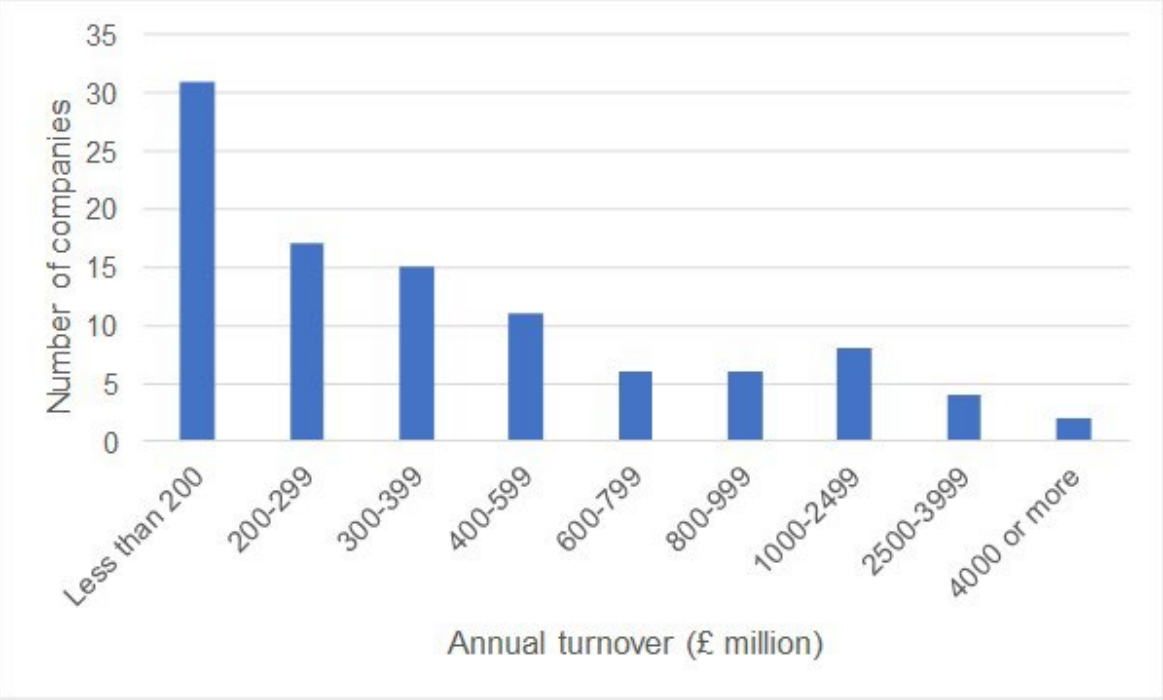
Top twenty UK construction companies by annual turnover in 2018

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

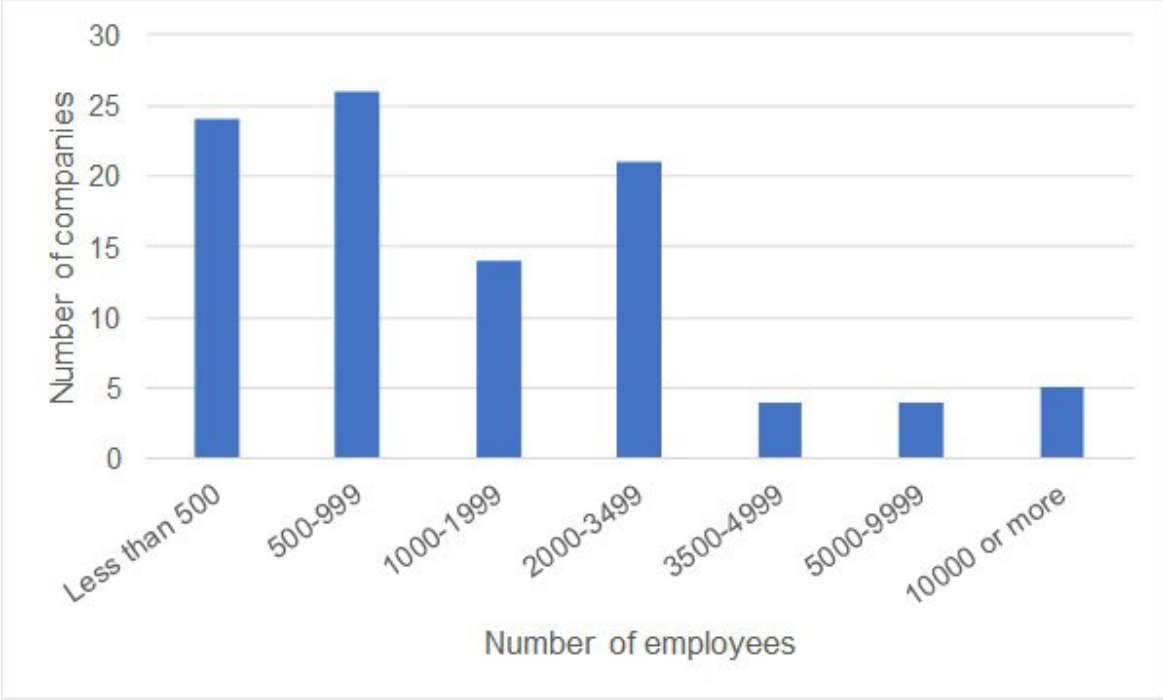
Source: Construction News, 2019

A small number of very large construction companies in the UK

Annual turnover of the top 100 UK construction companies in 2018



Number of employees of the top 100 UK construction companies in 2018



Source: calculated from data in Construction News, 2019.

And many small companies: employee size of companies in the UK construction industry, 2019

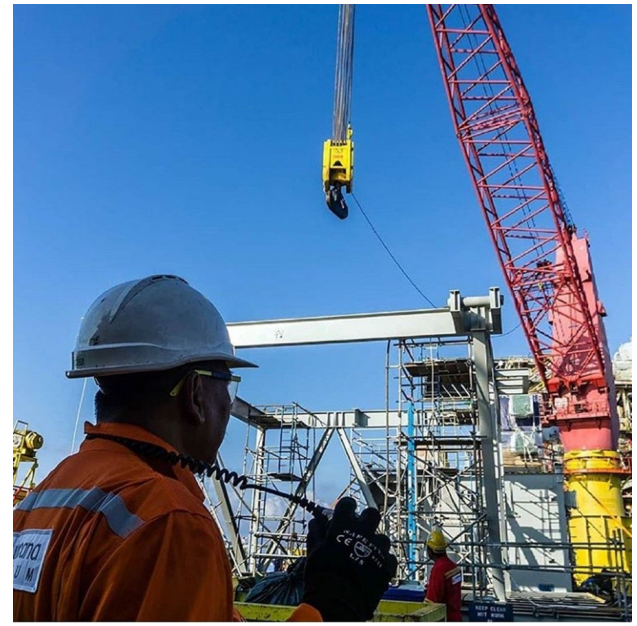
Size of Company (number of people employed)	Companies (%)	Employees (%)
0 (sole proprietors)	12%	-
1	40%	9%
2-3	28%	14%
4-7	11%	13%
8-13	4%	9%
14-24	2%	8%
25-34	1%	4%
35-59	1%	7%
60-79	0.18%	3%
80-114	0.16%	3%
115-299	0.17%	8%
300-599	0.05%	5%
600-1,199	0.02%	4%
1,200 and over	0.02%	13%
TOTAL	**100%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

Source: calculated from data in ONS, 2021

Key issues facing the construction industry

- Unique, one-off nature of construction projects (and separation of design and construction phases and parties)
- Many small companies and very high level of self-employment (36% v 13% in economy as whole)
- Fragmented nature of the industry (many parties with differing interests and motivations – trust issues)
- Training and worker skills deficits
- Poor industry image
- Ageing workforce and worker shortages
- Lack of collaboration and innovation
- Environmental sustainability and road traffic impacts

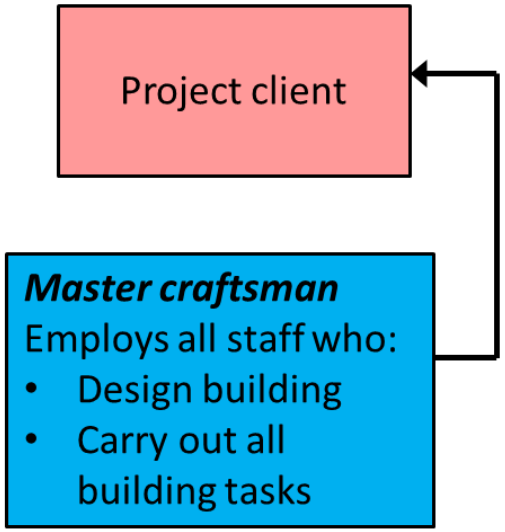
Source: https://commons.wikimedia.org/wiki/File:Europa_Building_(EU_Brussels)_18.jpg



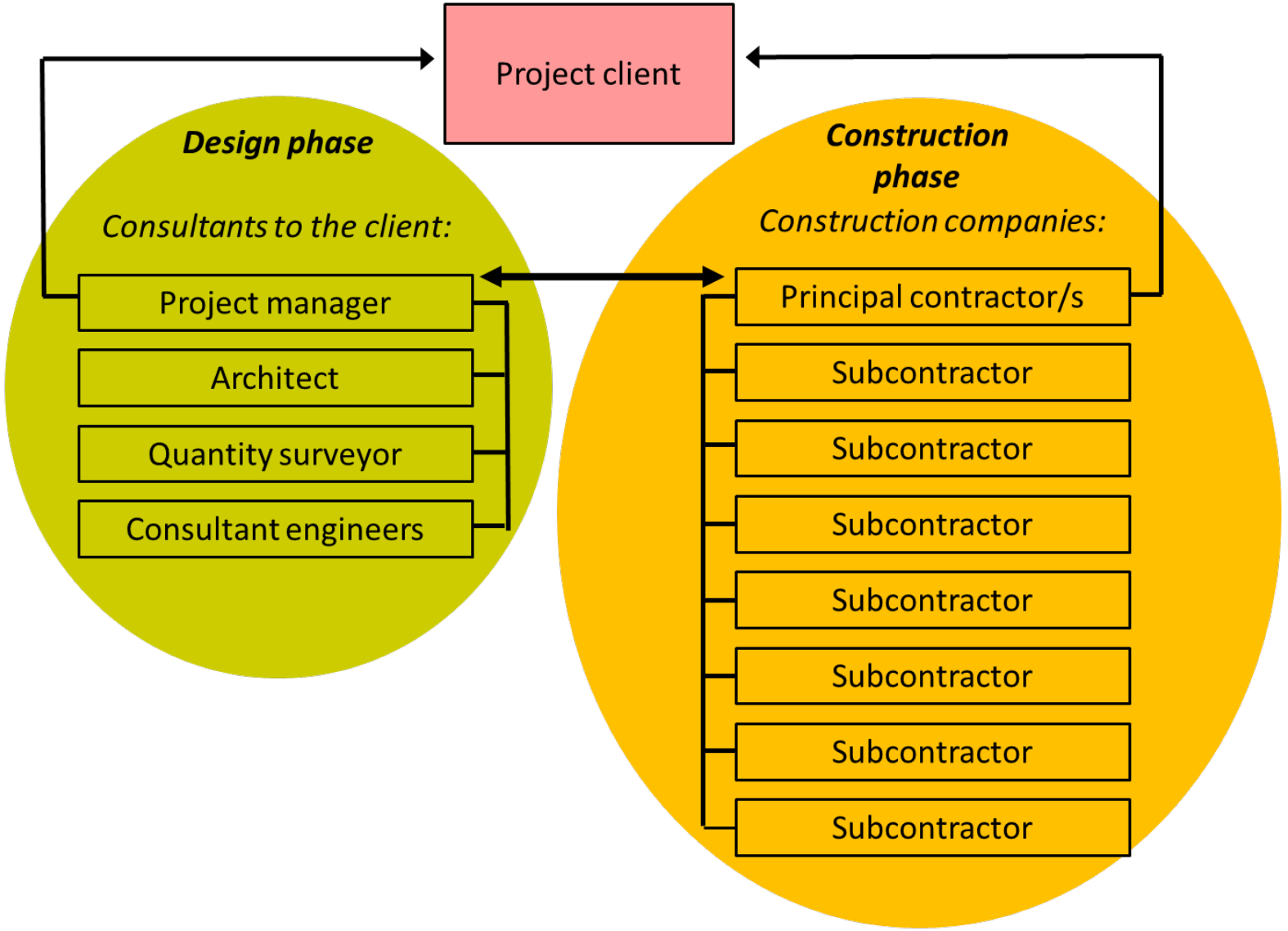
Source: https://upload.wikimedia.org/wikipedia/commons/4/43/.IMG.34.jpg

Changes in the construction industry over time

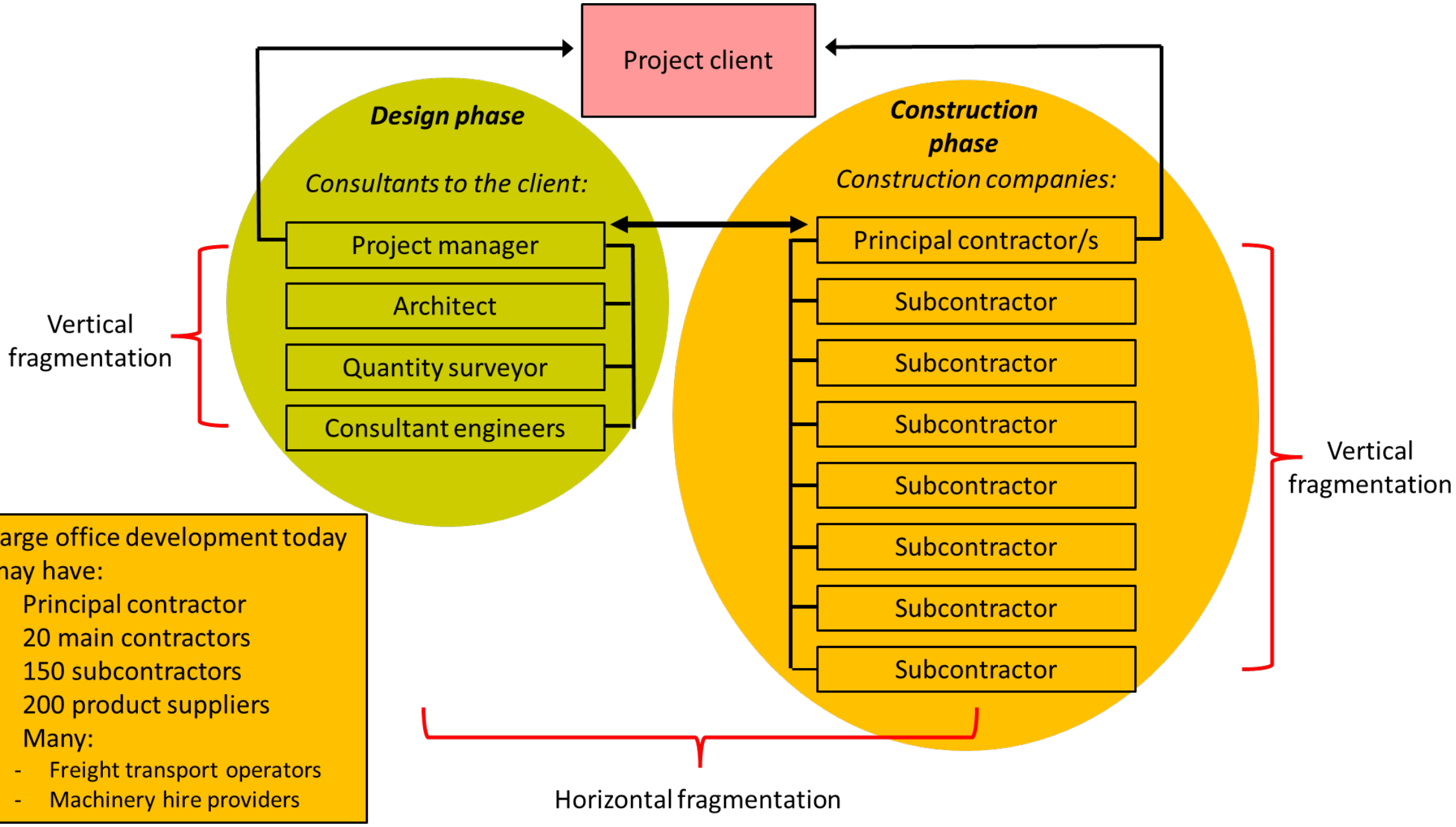
Pre-20th century



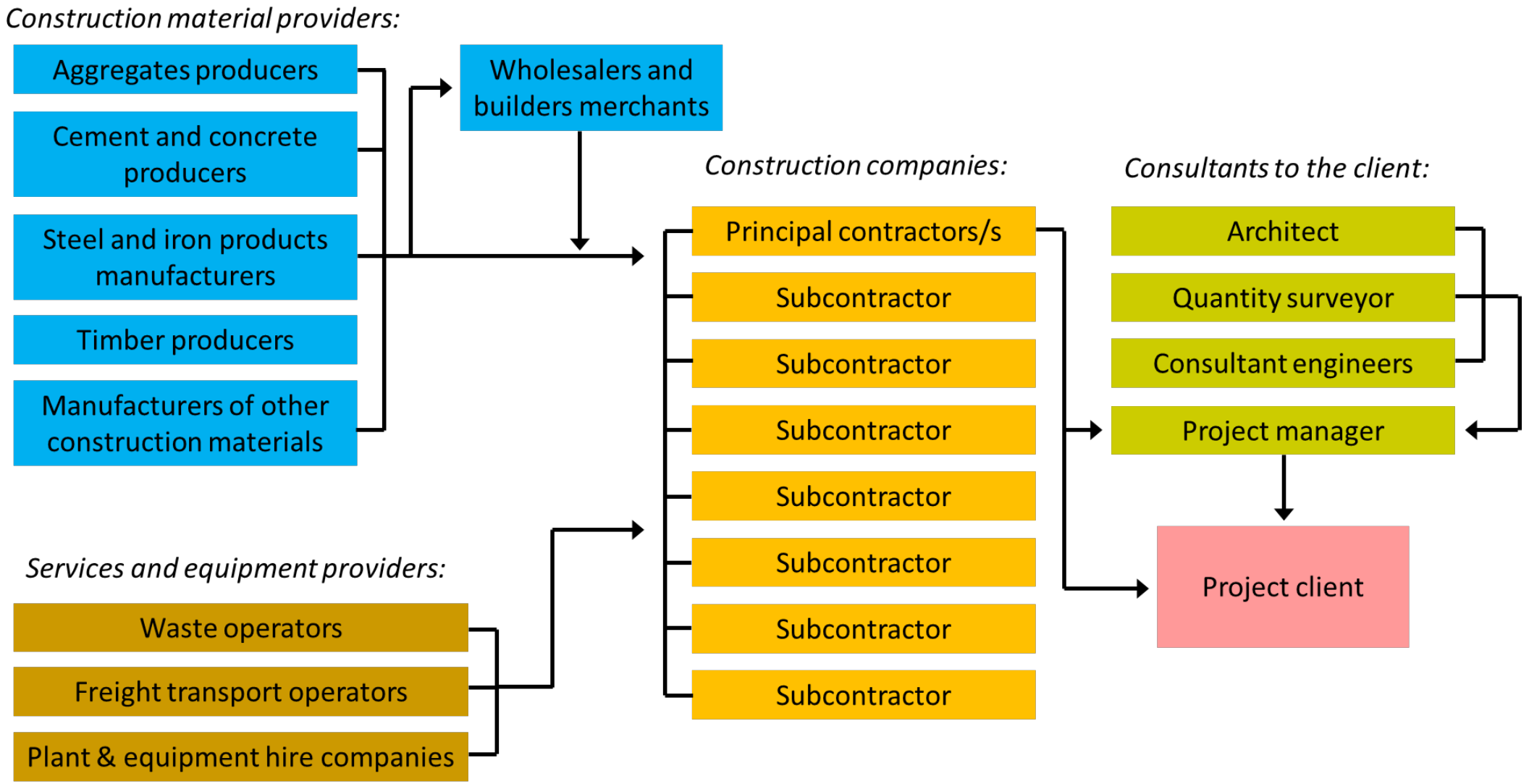
Late 20th century to present day



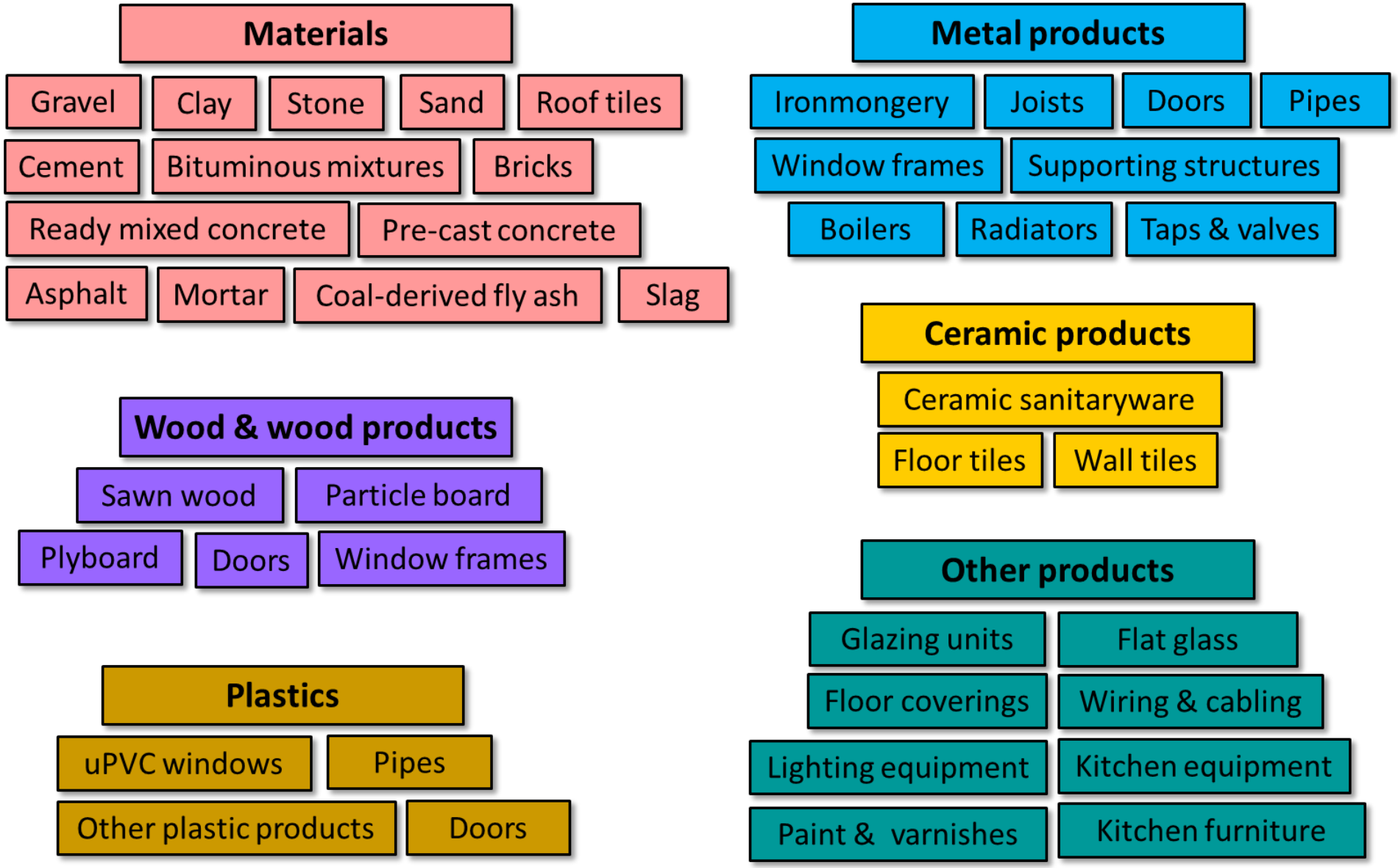
Fragmentation in late 20th century construction industry



The parties involved in wider construction supply chain for a specific project today



Materials and products used by the construction industry



Materials consumed and waste arising in UK construction

Major consumer of materials and products

Material or product	Quantity (2019)
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

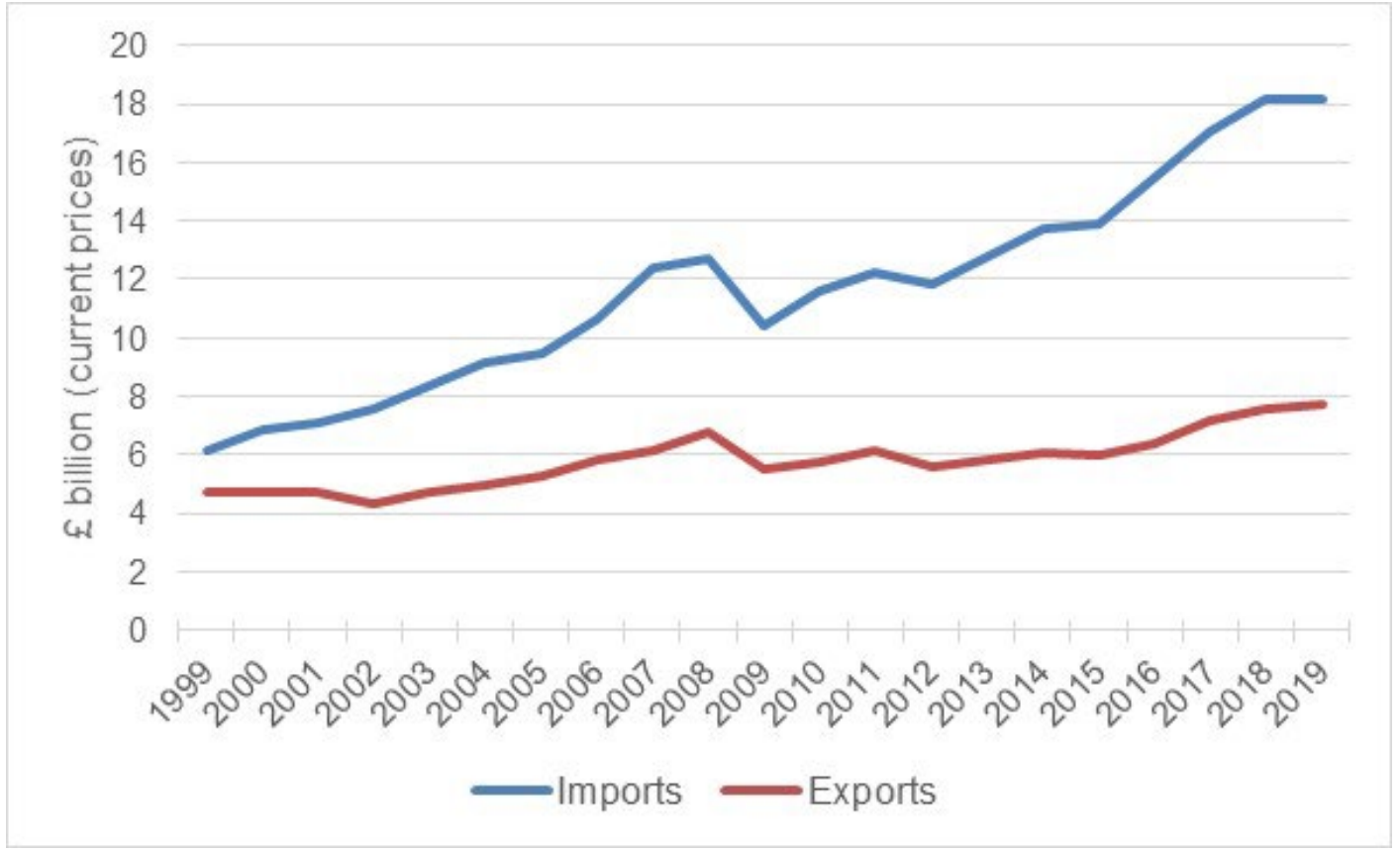
Sources: BEIS, 2021b; Bide, 2021

Major generator of waste materials

Type of waste and source	Tonnes (2018)
Mineral waste from construction	65.1 million
Soils from construction	58.1 million
Mineral waste from quarrying	14.6 million
Off-shore dredging spoils	11.3 million
Metallic waste from construction	2.2 million
Wood waste from construction	0.6 million
Glass waste from construction	0.1 million
Household & food waste from construction	0.1 million
Plastic waste from construction	0.1 million
Paper & cardboard waste from construction	0.02 million
TOTAL	**152.6 million**

Sources: calculated from data in DEFRA, 2021.

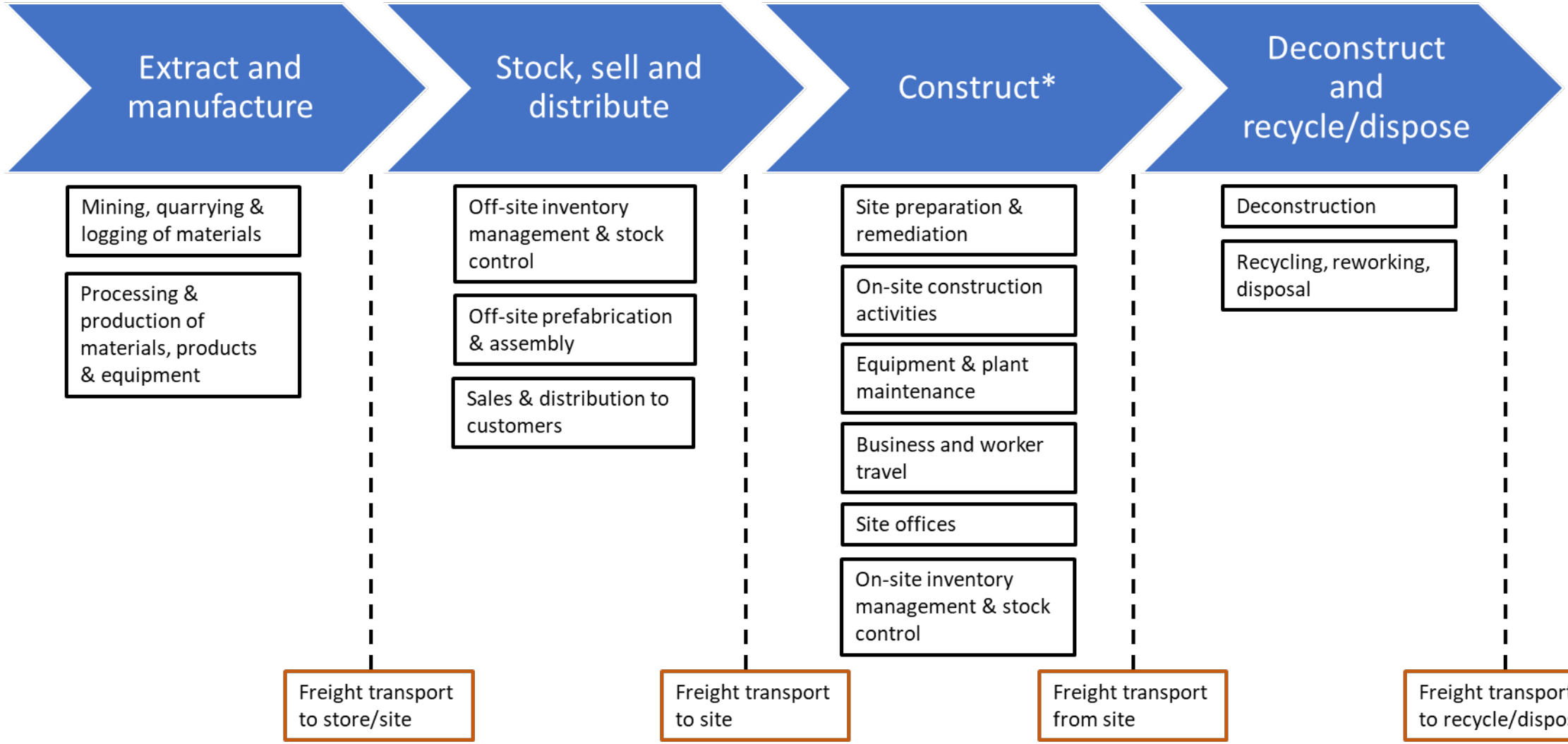
Value of UK Overseas Trade in Construction Materials, 1999-2019



Source: BEIS, 2021

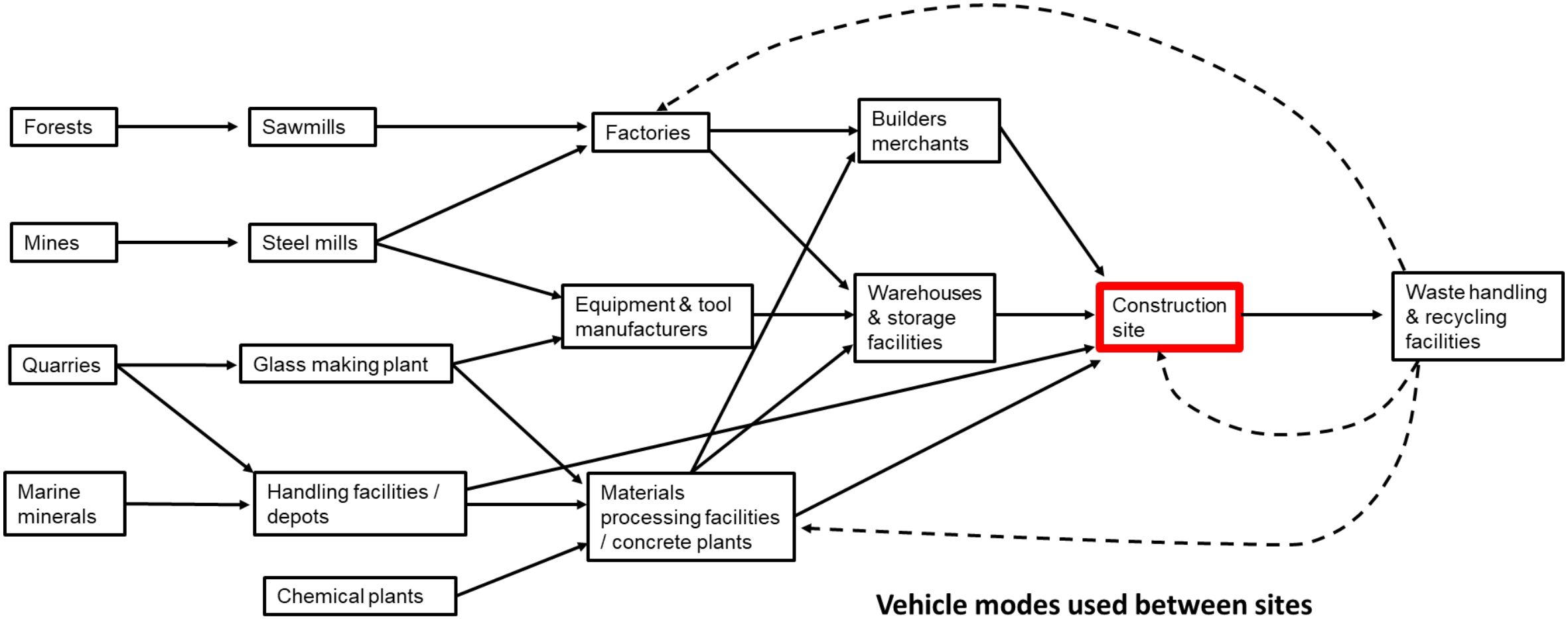
- Although majority of construction materials and products are manufactured nationally, there is also a sizeable overseas trade in these products
- UK overseas trade in these materials and products is growing, with the total value of imports and exports increased from £10.9 billion in 1999 to £25.9 billion in 2019 (in current prices)
- UK also has growing deficit in this overseas trade, which increased from £1.5 billion in 1999 to £10.4 billion in 2019

The processes and activities across the lifecycle of a construction project



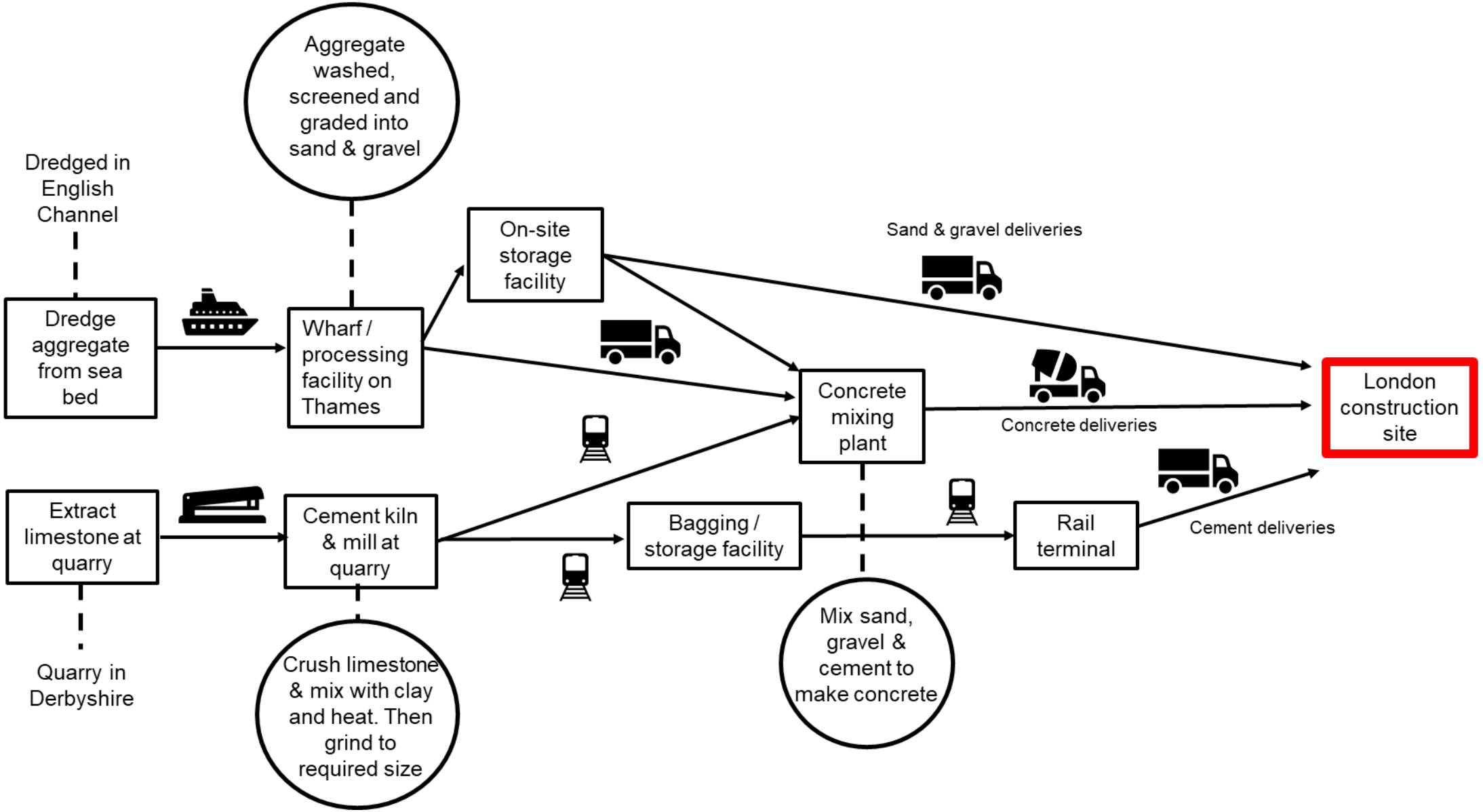
Note: * - could also involve repairs, maintenance, major refurbishment and renovation of existing building/infrastructure

The sites and freight transport activity involved in the construction supply chain



(Freight facilities inc. road-based depots, rail freight terminals and seaports)

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



Source: Compiled from information provided for a London construction site provided in DfT, 2008.

The complexity of the UK construction industry

Extremely diverse range of construction projects

The Built Environment

- New projects
- Refurbishment & maintenance

Buildings

Residential buildings
- Flats
- Houses

Public buildings
- Hospitals
- Prisons
- Libraries
- Schools & Universities
- Government & legal buildings

Commercial buildings
- Entertainment venues
- Warehouses
- Sports venues
- Factories
- Shops
- Offices
- Restaurants, bars & pubs

Infrastructure

Transport infrastructure
- Waterways
- Airports
- Roads
- Seaports
- Railways
- Bridges
- Paths
- Tunnels

Energy, telecoms & other infrastructure
- Flood & coastal defences
- Energy facilities
- Sewers
- Water mains
- Gas mains
- Telecommunication networks

Very wide range of materials & products delivered to construction sites

Aggregates
- Gravel
- Clay
- Stone
- Sand
- Cement
- Bituminous mixtures
- Bricks
- Ready mixed concrete
- Pre-cast concrete

Wood & wood products
- Sawn wood
- Particle board
- Plyboard
- Doors
- Window frames

Ceramic products
- Ceramic sanitaryware
- Floor tiles
- Wall tiles

Metal products
- Window frames
- Joists
- Taps & valves
- Ironmongery
- Supporting structures

Plastics
- uPVC windows
- Pipes
- Other plastic products

Other products
- Boilers
- Floor coverings
- Glazing units
- Wiring & cabling
- Lighting equipment
- Heating equipment
- Paint
- Kitchen furniture

Many different contractors & service providers

Construction contractors
- House & commercial property builders
- Civil engineering/ infrastructure companies

Materials supply & removal
- Freight transport operators
- Waste contractors

Specialist contractors
- Electricians
- Plumbers
- Plasterers
- Carpenters & joiners
- Painters & decorators
- Scaffolders
- Demolition contractors
- Glaziers
- Air conditioning installers
- Floor & wall covering contractors
- Test drilling & boring contractors

Plant & equipment providers
- Plant hire companies

Professional services
- Architects
- Surveyors
- Real estate
- Property developers
- Consulting engineers
- Financiers

Source: https://commons.wikimedia.org/wiki/File:Helsinki_Music_Centre_construction_from_air.jpg

Attributes of construction materials

- Many construction materials have:
  - High bulk and transport density
  - Low value density
- So, freight transport costs are high per value of unit moved
- Leading to desire to minimise transport distance where possible
- But some materials are not locally available due to:
  - Geology
  - Processing requirements
  - Manufacturing locations
  - Where construction takes place

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
Limestone	2400	Bulk: £7 per tonne Crushed: £13 per tonne
Cement	1280-1440	Portland cement: £86 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

Construction-related transport by road goods vehicles

- Wide range of vehicle types used in construction-related transport (mostly large, heavy goods vehicles):
  - Tippers (with or without grabs/cranes)
  - Flatbeds /dropside (with or without grabs/cranes)
  - Curtainsiders
  - Box / Lutons
  - Low-loaders
  - Volumetric concrete lorries
  - Concrete mixers / pumps
  - Tankers
  - Skip vehicles
  - Refuse vehicles
  - Sweeper vehicles
  - Vans
- Estimated approx. 30% of tonnes lifted and 20% of tonne-kms by road freight transport in Britain in 2019 related to construction supply chain

Source: https://commons.wikimedia.org/wiki/File:Cement_mixer_trucks,_Kirtling_Street,_London_SW8.jpg

Source: https://upload.wikimedia.org/wikipedia/commons/2/20/Volvo_FH12_and_Wacker_Neuson_14504_%283%29.jpg

Goods lifted by HGV 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%
Commercial waste products	27%	28%	25%	9%	11%	100%
ALL COMMODITIES CARRIED BY HGV	19%	18%	24%	14%	26%	100%

Empty running by HGVs 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: calculated from data in Department for Transport, 2020

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, 2020

Construction-related freight transport estimated to account for 29% of the goods lifted by HGVs in Britain in 2019, and 20% of the goods moved (i.e. tonne-kilometres) by HGVs in 2019

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

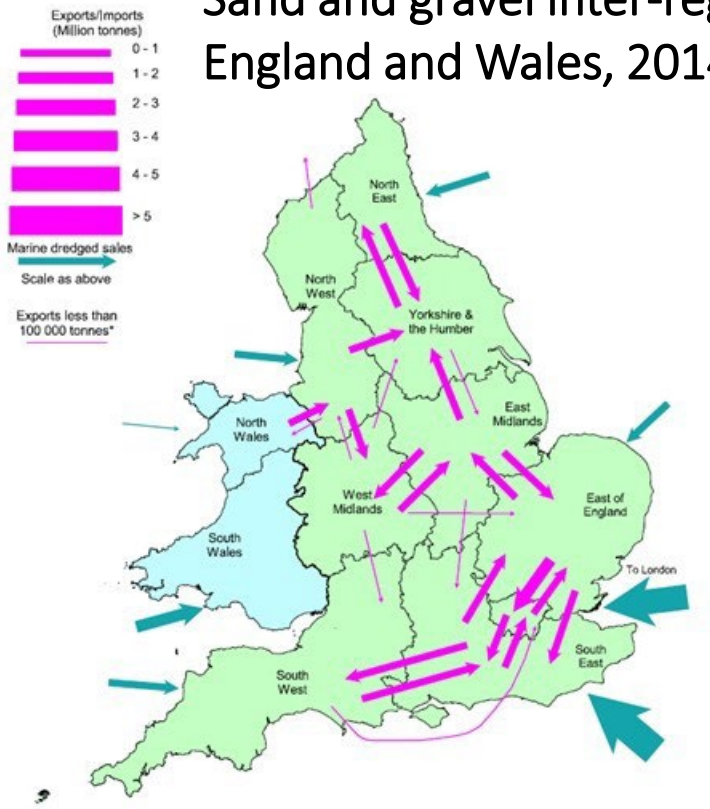
Notes:
* HGV fleet data for 2015
** Fleet size is for Eurovia's Ringway subsidiary.
Source: Construction News, 2019; Amey, 2019; Balfour Beatty, 2019, Clancy Group, 2019; Colas, 2019; Costain, 2019; Driving for Better Business, 2019; Fleet News, 2015; FM Conway, 2019; Kier, 2019; Morgan Sindell, 2019; Ringway, 2019, Skanska UK, 2019.

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

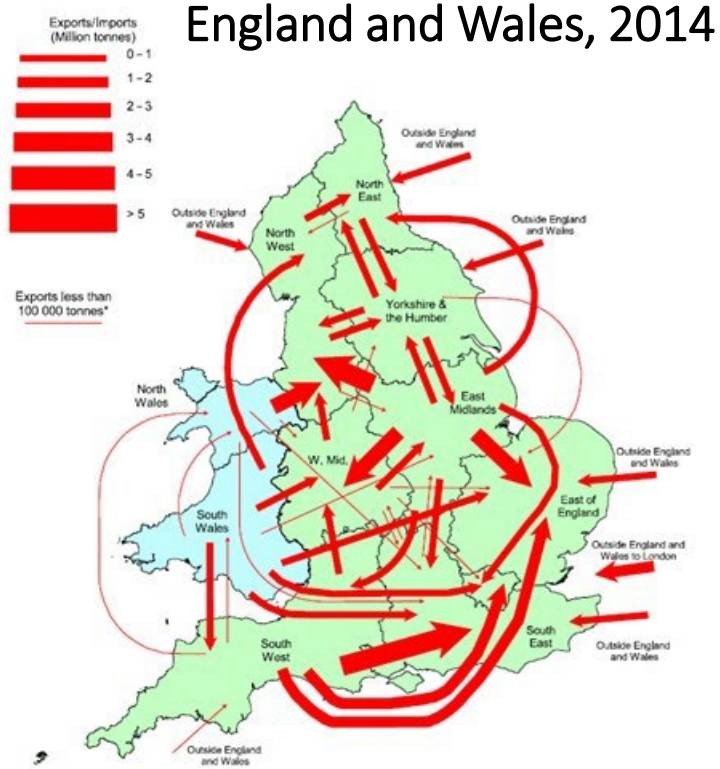
Notes:
* - either operated by company or franchised contractors
Source: Aggregate Industries, 2021; Breedon, 2019; Breedon, 2020; CEMEX, 2021; CRH, 2021; Fleetpoint, 2019; Hanson, 2021; Heidelberg Cement, 2021; LafargeHolcim, 2021; London Road Safety Council, 2019; Robinson, 2019; Tarmac, 2019; Tarmac, 2021.

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



Source: Mankelow et al., 2016

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



Source: Mankelow et al., 2016

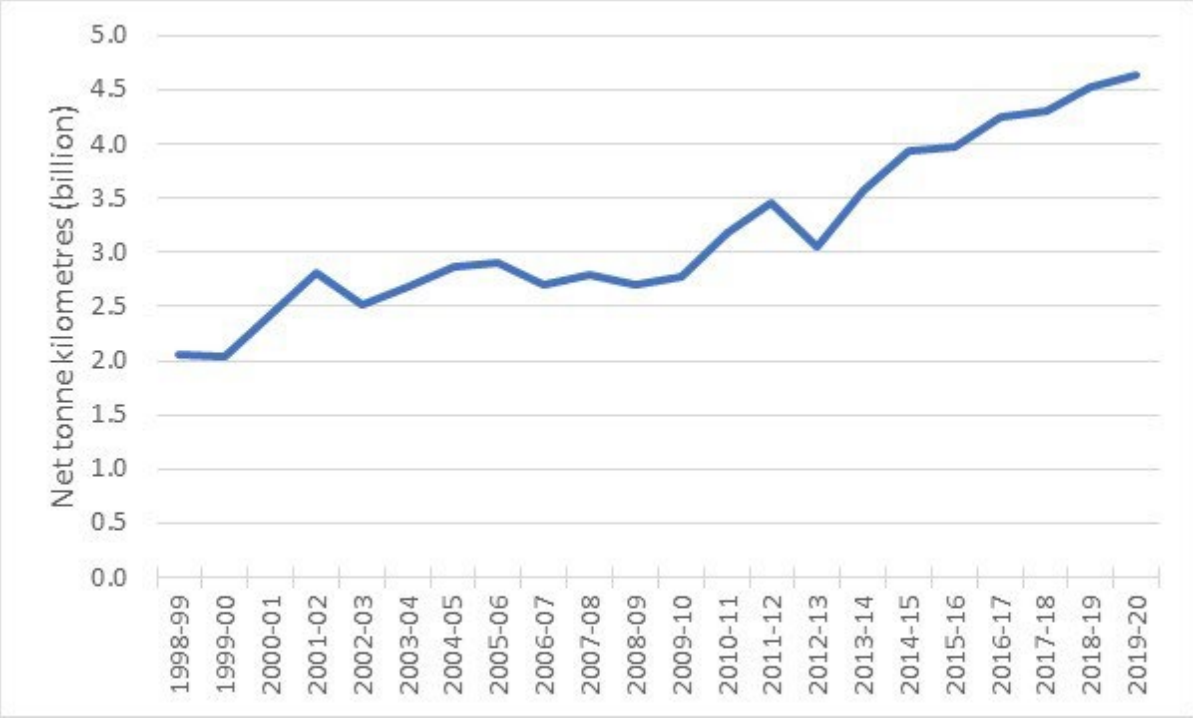
Principal transport method in England and Wales in 2014 (million tonnes)

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

Source: Mankelow et al., 2016

Growing importance of construction in rail freight transport

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



Source: ORR, 2020

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, 2020

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, 2021; CEMEX, 2020; Hanson, 2021; Tarmac, 2020.

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

Transport mode	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, 2020; MDS Transmodal, 2019; ORR, 2020.

- Estimated that road, rail and water accounted for 82%, 12% and 6% of all aggregate, cement and concrete lifted, respectively, in UK in 2018
- Estimated that road, rail and water accounted for 67%, 28% and 5% of all aggregate, cement and concrete toone-kilometres, respectively, in UK in 2018
- Difference due to longer average distance over which these goods are moved by rail compared to road

Estimated goods lifted and moved related to entire construction industry in Britain in 2018 by transport mode

Transport mode	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, 2020; MDS Transmodal, 2019; ORR, 2020.

- Estimated that road, rail and water accounted for 91%, 6% and 3%, respectively, of all goods lifted in entire construction industry in UK in 2018
- Estimated that road, rail and water accounted for 82%, 15% and 2%, respectively, of all tonne-kilometres in entire construction industry in UK in 2018
- Difference due to longer average distance over which these goods are moved by rail compared to road

Logistics activities on construction sites requiring plant and equipment

- Materials handling
- Access
- Digging & excavating trenches
- Moving soil
- Dredging
- Tree cutting
- Demolition
- Levelling surfaces
- Making bore holes
- Pile driving

Wide range of machinery used on construction sites

- Loaders
- Telehandlers
- Fork lifts
- Boom lifts
- Dump trucks
- Tower cranes
- Excavators
- Backhoe

- Bulldozers
- Graders
- Trenchers
- Pavers
- Compactors
- Feller bunchers
- Demolition machines
- Pile boring machines

Problems that arise in construction supply chains

- McKinsey and Company study (2017):
  - poor procurement: overpaying up to 15% for materials & services
  - poor supply chain management: 10-30% of cost & time overruns
- Problems can arise in:
  - material flow
  - communication (internal within one company or external between companies)
  - other issues (such as changes made by the client, lack of standardisation and weather)
- Where problems arise:
  - construction site project processes
  - wider supply chain
  - intersection between these two
- Much scope for greater collaboration across organisations in construction project
- But multi-stakeholder, fragmented and temporary nature make this challenging

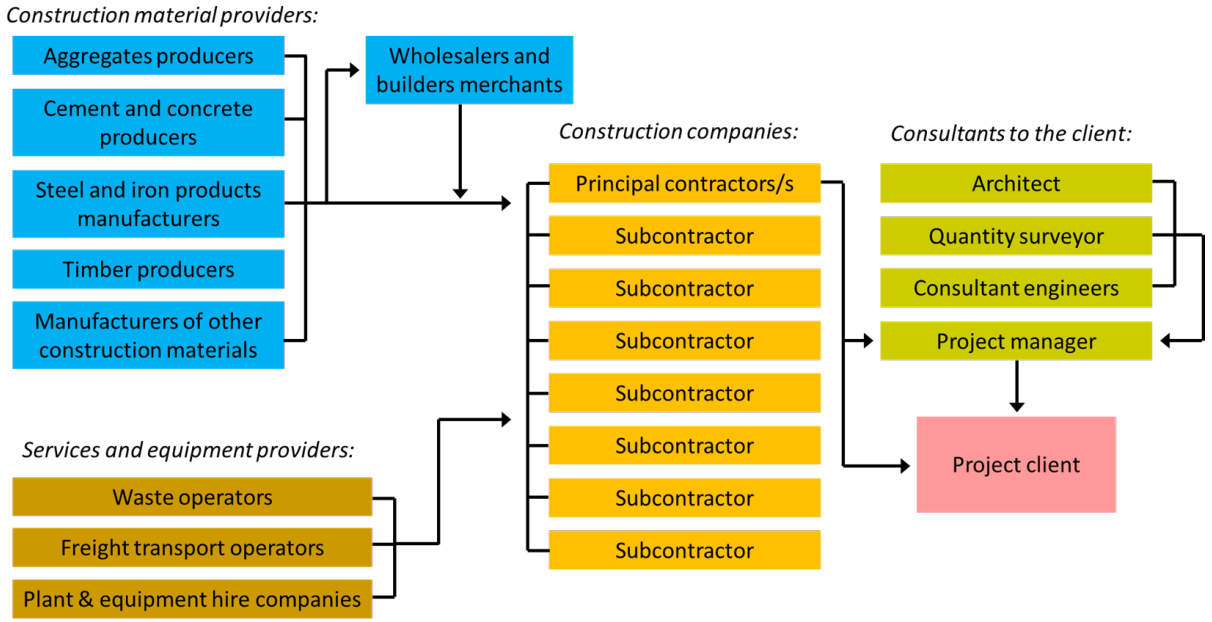
Construction supply chain: challenges and consequences

Challenges

- Project-based: each project unique with specific start and end point
- Large number of companies providing different services
- Many small companies
- Substantial use of sub-contracting
- Lack of communication and data flows
- Poorly skilled workforce
- Lack of logistics management

Consequences

- *Complex supply chain*



- *Little supply chain collaboration*
- *Poor productivity*
- *High levels of waste*

Conflicting incentives for construction supply chain parties under traditional contract relationships

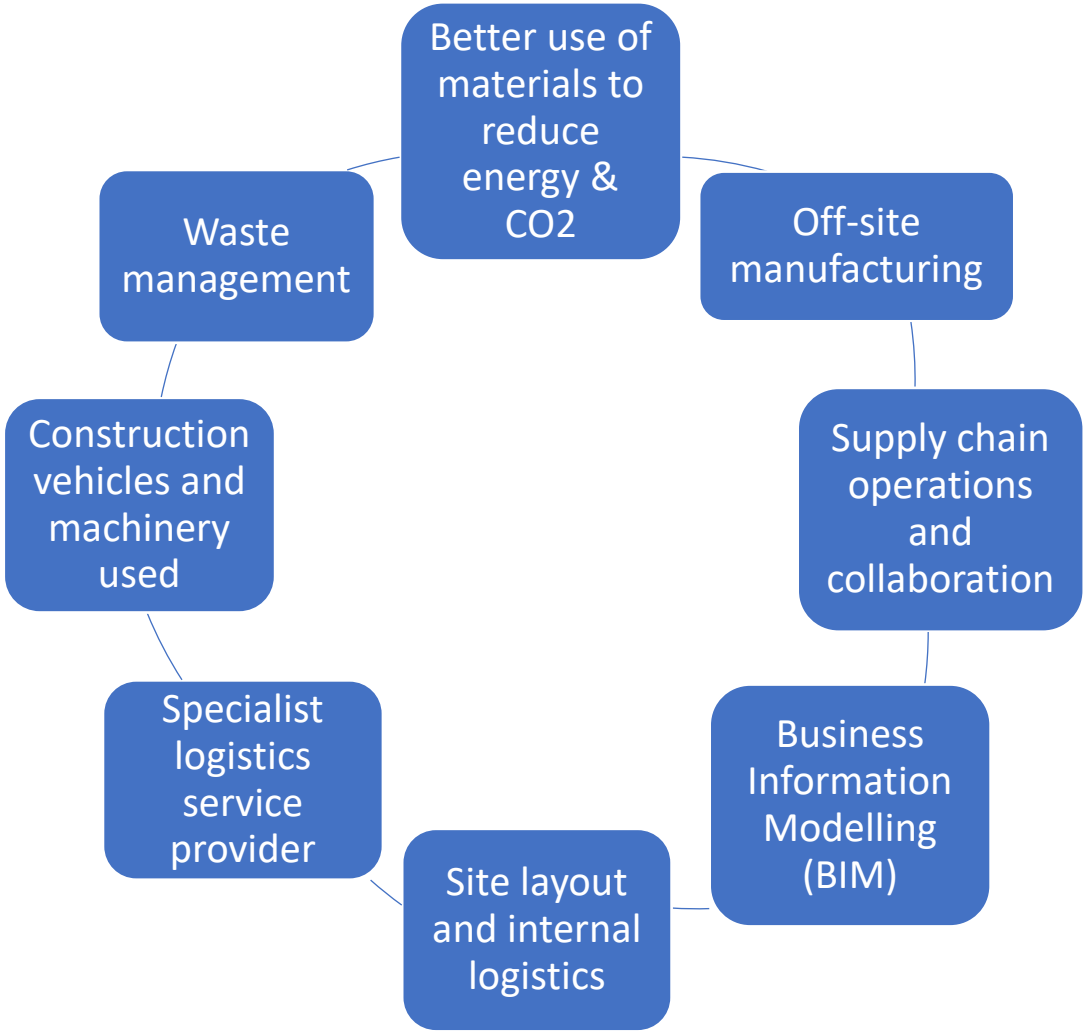
Party	Motivation	Clashing behaviours
Client/Owner	Reliably deliver project in timely fashion	Constantly push contractors and suppliers to expedite production and delivery; engage expediters for critical path items
	Receive value for money	Seek cost savings throughout (e.g., contractors, suppliers, labour, 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.
OEMs 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.

Improving supply chain operations and collaboration in construction

- Better and more collaborative supply chain management can lead to improved:
  - product procurement
  - stock control & inventory management
  - management of deliveries & collections from construction sites
  - construction activity decision-making
  - costs & productivity (as well as social & environmental impacts)
- Mace focuses on importance of logistics performance and building long-term relationships with supply chain subcontractors:
  - Since 1990s - real time system to monitor logistics performance and share with partners
  - 2006 – set up in-house business school to train its own staff and subcontractors in supply chain management
- 'Supply Chain Sustainability School' set up in 2012 by 7 major UK construction companies: available to clients, subcontractors and supply chain partners to share knowledge and experience and increase skills and collaboration

Supply chain & logistics innovations in construction



Construction site layout and internal logistics problems

- Site layout important as a dangerous location with constrained size
- Materials have to be received, stored and moved around to avoid delays
- Traditional approach:
  - many subcontractors each taking own responsibility for their materials and on-site logistics activities
  - site layout and logistics in theory overseen by principal contractor but no overall logistics planning
  - outcome: unavailability of materials, tools and machinery where and when required on site
- On-site logistics is important project cost and has major impact on productivity
  - inconsistencies, duplication and gaps in on-site logistics activities
  - operational confusion and inefficiencies
- Study estimated that craftsmen in Scandinavia spend 14% of working time moving materials and equipment to assembly area (Strandberg and Josephson, 2005)
- Swedish construction workers spent, on average, 50% of their time waiting and handling materials (Josephson and Saukkoriipi, 2007)

Use of specialist logistics service provider

- Principal contractor can engage specialist construction logistics provider to take control and improve site logistics through planning and control
- Tasks can involve:
  - On-site coordination, storage and handling of the construction materials and waste on the site only
  - Above plus coordination and management of delivery and collection arrangements and operations (including booking systems and vehicle marshalling on arrival)
  - Above plus consolidating flows of products upstream of site to reduce deliveries to site and storage on site (i.e. operating off-site Construction Consolidation Centre)
- Potential benefits:
  - Improve site productivity: reduce total project time & cost
  - Could result in overall project cost savings of 2-4% (Sullivan, 2010)

Business Information Modelling (BIM) in construction

- BIM – computer modelling software allows (Beaumont and Underwood, 2015):
  - creation of virtual 3D building or infrastructure
  - virtual testing of that building and processes to be used for its production
  - Virtual management of production process, including data associated with this
- Lets all stakeholders in supply chain (architects, engineers and construction contractors) gain insight and information to better plan, design, construct, and manage the sequence of activities before and during construction
- Can provide productivity and quality improvements, and reduce waste, time taken and project costs in design and construction phase (World Economic Forum and Boston Consulting Group, 2018)
- BIM requires collaborative working and data sharing between construction supply chain parties (has not traditionally happened)

Source: https://commons.wikimedia.org/wiki/File:SafetiBase.jpg

Source: https://upload.wikimedia.org/wikipedia/commons/8/84/Instant_Clash.jpg

Off-site manufacturing (1)

- Involves production, preparation and assembly of building products in factories upstream of construction site
- These components then delivered to construction site and assembled
- Removes need for complicated building processes on site that require many different contractors and complicated sequencing of tasks in small and non-optimal working environment

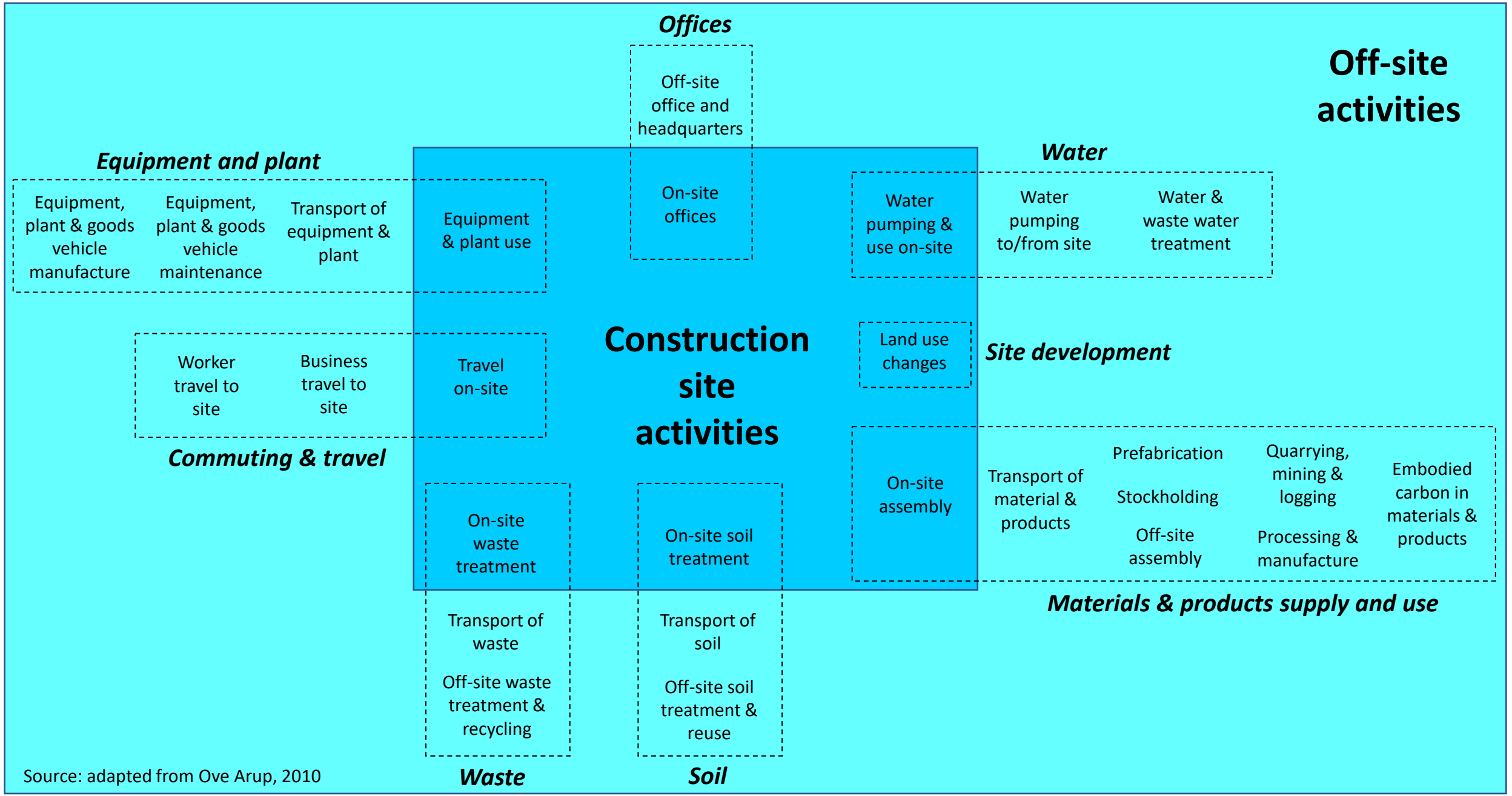
Source: https://commons.wikimedia.org/wiki/File:Crossbox_CG_Architectes.jpg

Off-site manufacturing (2)

- Off-site manufacture can result in:
  - Potential 20–60% reduction in construction programme time
  - Potential 20–40% reduction in construction costs
  - Can help prevent on-site project delays and defect rates
- Off-site manufacture can also help:
  - Improve on-site worker safety
  - Overcome shortage of construction workers (potential reduction of 70% or more in on-site labour)
  - Reduce noise and air pollution at construction sites
  - Reduce goods deliveries and other travel to site

Source: https://commons.wikimedia.org/wiki/File:SafetiBase.jpg

Processes related to construction projects that result in GHG emissions



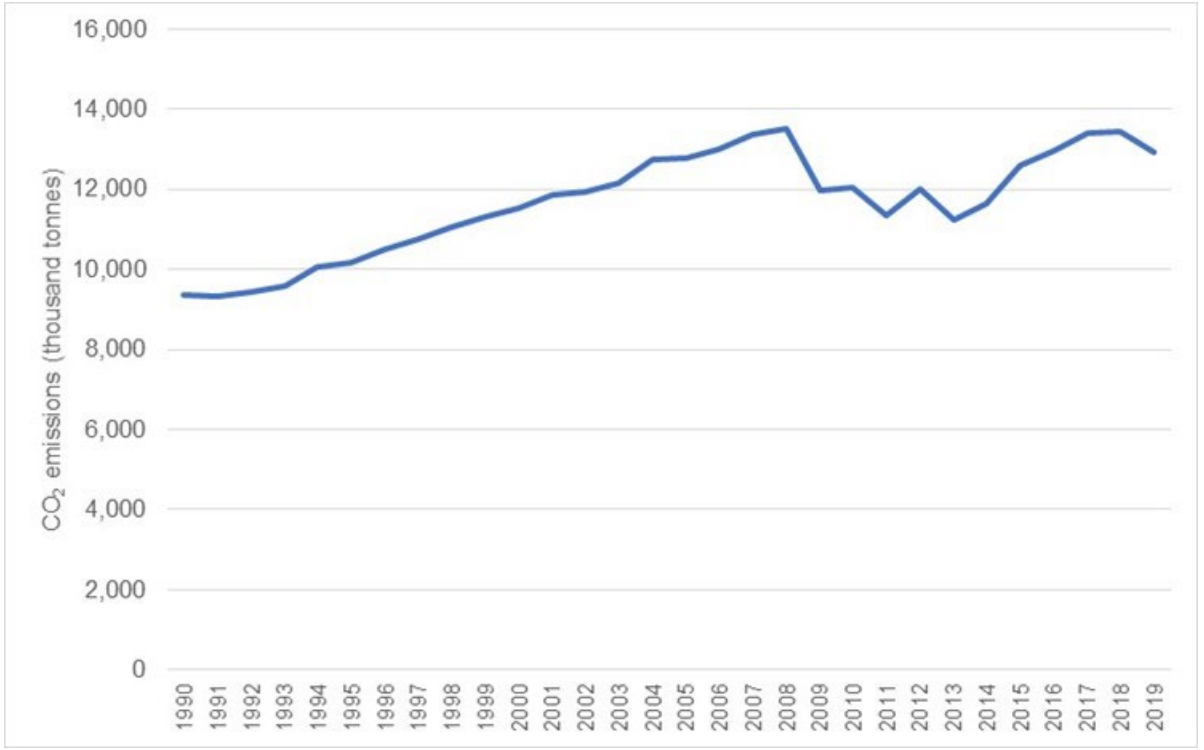
Source: adapted from Ove Arup, 2010

CO_2e emissions from construction industry

UK total:

- Construction industry responsible for 10% of CO_2e emissions in UK (not including the manufacture of construction materials and freight transport in construction - ONS, 2021)
- Built environment accounts for approximately 40% of UK energy consumption (HM Government, 2018)
- UK construction CO_2e 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

CO_2e emissions from UK construction industry, 1990-2019



Notes: Does not include GHG emissions from the manufacture of materials and products used in construction or from freight transport in construction.
Source: BEIS, 2020

Skanska UK assessment of CO_2e from its construction supply chain including freight transport

- Freight transport operations by Skanska, its subcontractors, waste operators, and freight companies and suppliers delivering materials estimated to account for about 10% of its total CO_2e emissions in 2018
- Plant, equipment and energy used on construction sites by Skanska staff and subcontractors accounted for about 15% of total CO_2e emissions in 2018

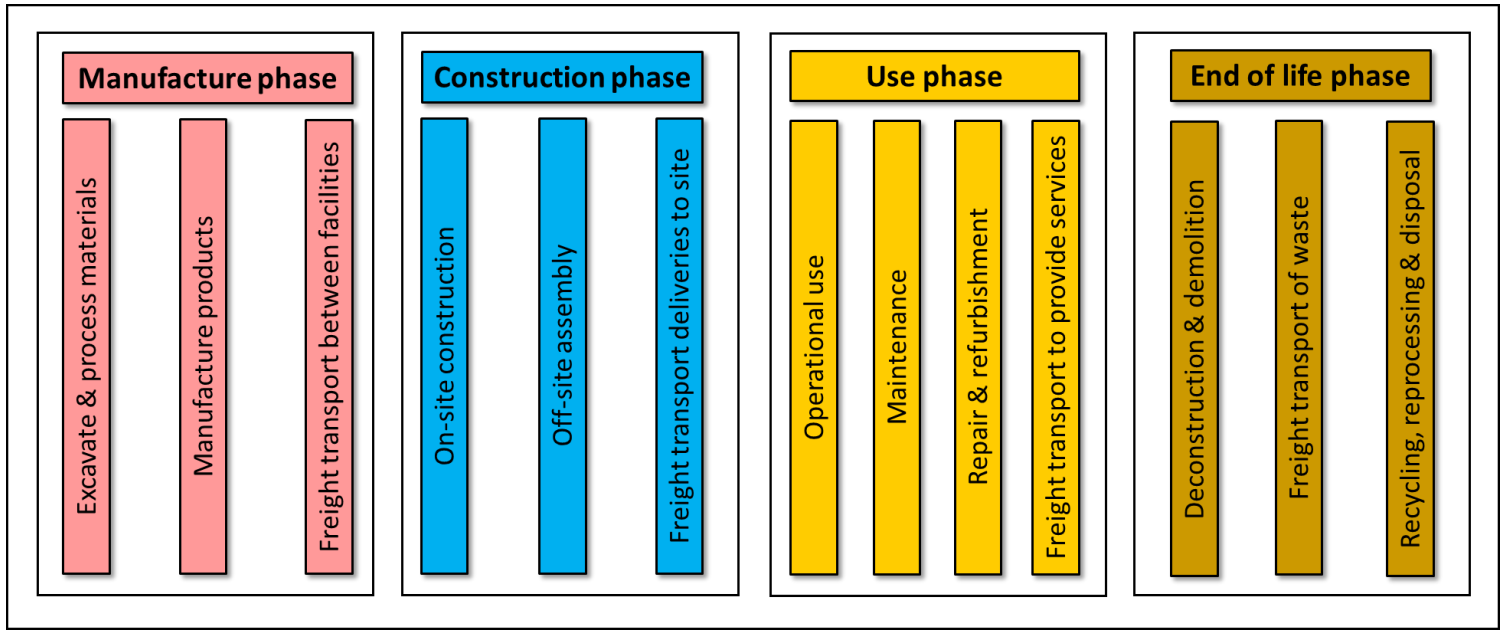
CO_2e emissions from Skanska UK construction operations, 2018

Category	Proportion of CO2e 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 (inc. freight & plant)	13.8%
Waste	1.5%
Materials	75.9%
TOTAL	**100%**

Source: Skanska UK, 2019

Assessing energy efficiency and CO_2 emissions of buildings

- Assessment of energy and emissions of buildings often only takes account of operational life ('use phase') of building
- Even then, such assessments often omit energy and emissions associated with maintenance and refurbishment during life of building
- Proper consideration must take account of energy used to construct and dispose of it at end of its operational life - referred to as 'embodied' energy and emissions
- Better materials and building design improve embodied energy and efficiency



Sustainability targets and plans of the Top 15 UK construction companies (1)

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, 2020, 2021; Keller, 2021; Kier, 2019; Kier, 2020, 2021; Interserve, 2020; Laing O'Rourke, 2021; MACE, 2020, 2021; Morgan Sindall, 2020; 2021; Multiplex Europe, 2021; Skanska UK, 2021; Willmott Dixon, 2020.

Sustainability targets and plans of the Top 15 UK construction companies (2)

- All of the top 15 UK construction companies shown in table on previous slide have at least a stated intention to reduce their CO_2e emissions in their published sustainability plans
- 10 of the 15 have set a specific reduction target and date for their CO_2e emissions.
- 9 of the 15 consider the CO_2e emissions arising in their supply chains from subcontractor activities and the supply of materials as part of these commitments.
- 6 of the 15 have set specific targets and dates for waste reduction
- 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
- 6 of the 15 also mention off-site manufacturing
- These major construction companies rarely include freight transport considerations in their sustainability plans concerning CO_2e 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

Waste management in construction

- Environmental taxes introduced in UK to reduce waste:
  - Landfill Tax (1996) - to reduce waste going to landfill – per tonne tax for disposing of waste at landfill site
  - Aggregate Levy (2002) tax on primary virgin aggregates (rock, sand and gravel used in construction - to encourage shift in demand to recycled and secondary construction material
  - Recycled and secondary aggregates comprised 29% of total aggregates supply in the UK in 2017
  - 92% of non-hazardous construction and demolition waste recovered in UK in 2016
- Construction industry working with UK Government to develop a route map of how to achieve ‘zero avoidable waste’
- Focus on better building design and construction practices
- Tackling flytipping

Source: https://commons.wikimedia.org/wiki/File:D%C3%BClmen,_Abbrucharbeiten_ehem._KiK-Geb%C3%A4ude_--_2016_--_1410.jpg

Source: https://commons.wikimedia.org/wiki/File:D%C3%BClmen,_ehem._Diskothek_%22Fantasy%22_--_2020_--_0183.jpg

Innovation in freight flows to/from construction sites

Goods vehicle issues:
- Fuel source
- Vehicle design

Goods vehicle driver training

Construction consolidation centres

Traffic management schemes for goods vehicles
- On-street waiting areas
- Holding areas
- Timing of deliveries
- Use of traffic marshalls
- Providing drivers with site & route information
- Delivery Management Systems

Planning conditions for site logistics

Logistics operation good practice safety schemes
- CLOCS
- FORS
- CCS

Traffic management schemes for cyclists and pedestrians
- Keeping cycle lanes operating
- Checking footways
- Understanding vulnerable road users

Use of specialist logistics service provider

Use of cargo cycles

Use of non-road modes

Fuel source of goods vehicles & machinery used on construction sites

- Most goods vehicles and construction machinery powered by diesel fuel at present
- Machinery: Start-stop technology shuts down site machinery engines when stationary - reduces fuel consumption by 30%
- In longer term, electricity or hydrogen fuel has potential to remove CO_2 emissions and local air pollution, as well as reducing noise
- In 2021, Mayor of London implemented a Low Emission Zone for Non-Road Mobile Machinery (NRMM) - all construction site engines with a power rating between 37 kW and 560 kW must meet specified local air pollution emissions standards

Source: https://commons.wikimedia.org/wiki/File:In%C3%ADcio_das_obras_da_Ponte_sobre_o_rio_Tiet%C3%AA_da_SP-147_(37712307585).jpg

Source: https://commons.wikimedia.org/wiki/File:ALRO_Heavy_equipment_2.jpg

Source: https://commons.wikimedia.org/wiki/Category:Loaders#/media/File:HZM_XC30.jpg

Goods vehicle issues – Alternative fuel options for construction vehicles

SANY Group: hydrogen fuel cell powered dump and mixer truck

Volvo Trucks: battery electric mixer and FMX with hooklift truck

Komatsu: hydrogen fuel cell powered dump truck

CAT Trolley Assist: diesel –electric overhead catenary mining trucks

Source: Corporate websites

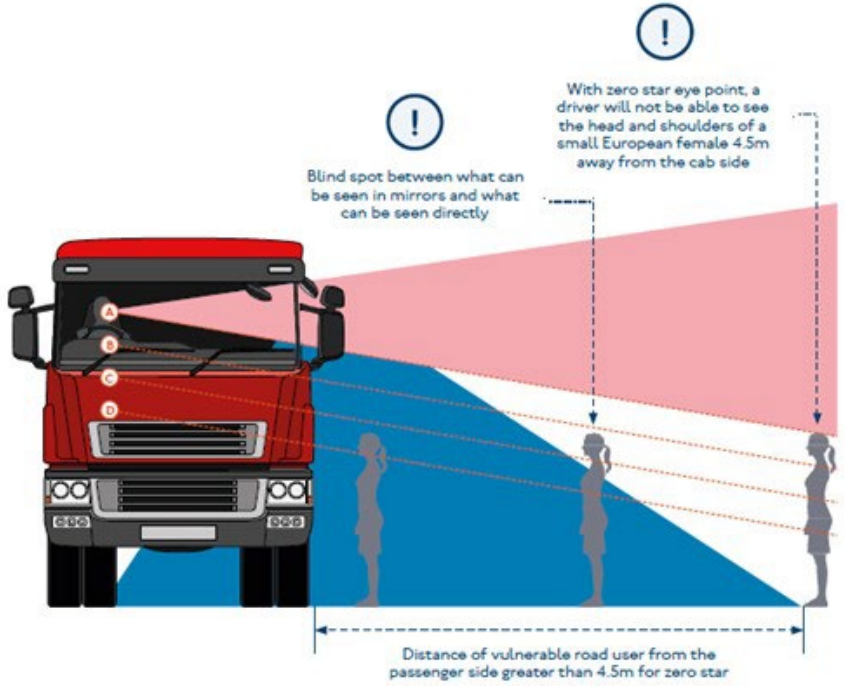
Vehicle design: Direct Vision Standards in London

- Construction vehicles over-represented in fatalities with cyclists in London
- Driver visibility from construction vehicle cabs (high-up) found to be poor

Good direct vision

Poor direct vision

HGV star rating boundaries



Category	Description
A	Zero star eye point
B	One star eye point
C	Three star eye point
D	Five star eye point

Source: Transport for London, 2019

Traffic Marshalls at construction sites

- Employed at large construction sites and roadworks to help ensure safety for workers and general public
- Three types of Traffic Marshall and duties (Davies, 2020):
  - those at interface between construction site and public road network, controlling and managing vehicles entering and leaving site
  - those within construction site to ensure the safe movement of plant and vehicles
  - those who manage traffic at temporary streetworks and roadworks

Providing drivers with site & delivery information

- Make drivers aware of construction site and its delivery and unloading arrangements in advance
- Can include details of approach to site and footage of gate / entry point, one way systems, holding areas, and pedestrian crossing locations
- Various forms of media used:
  - Printed booklets
  - Videos
  - Digital information
  - Training session
  - Site induction

Delivery Management Systems (DMS)

- DMS used to plan and manage vehicles making deliveries to construction site
- Notifies contractors of vehicle arrival and help control and coordinate on-site activity
- Help ensure vehicles operate safety at site
- Most basic form of DMS could be paper- or spreadsheet-based
- For larger sites, usually internet-based, fully-computerised software allowing all contractors and suppliers remote access containing:
  - delivery booking diary with delivery dates, times, locations and arrangements,
  - vehicle tracking and tracing to and from site as well as on-site
  - can be used in conjunction with off-street holding areas and on-street waiting areas
  - software contains planned and historical data

Traffic management schemes for goods vehicles

Unmanaged vehicle arrivals

- Problematic as can cause:
  - vehicles queuing on-street
  - vehicles circulating in the area while awaiting entry to site
  - vehicles reversing and turning

On-street waiting area

- If construction site road has capacity (more than one lane and enough width):
  - May be possible to use nearside lane for vehicle waiting
  - Waiting lane managed by personnel from construction site

Off-street holding area

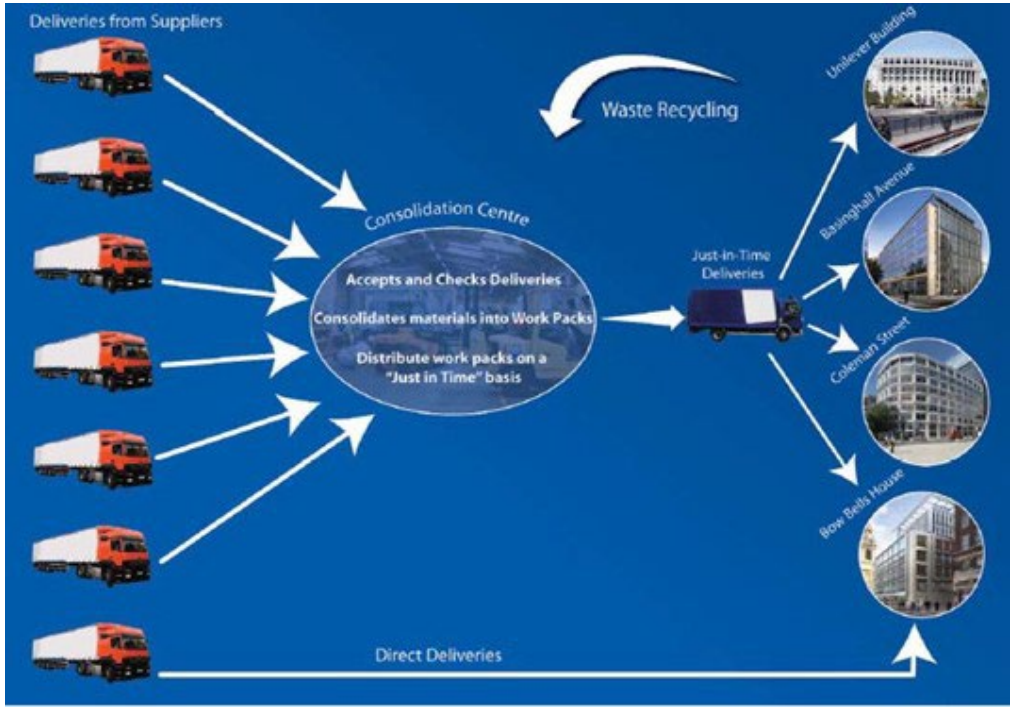
- Where space is available:
  - off-street 'holdings areas' close to / at construction site/s where vehicles wait
  - drivers can take rest breaks and be provided with refreshments
  - then called to travel to site when space is available and site staff ready
- As suitable space is limited, can be shared by several construction sites

Source: concepts and picture - Michael Barratt

Construction consolidation centres (CCCs)

- Goods delivered to CCCs instead of direct to construction site
- Then delivered on to site as required in well-loaded, planned vehicle trips
- Objectives:
- Reduces total distance travelled by poorly-loaded goods vehicles making deliveries to construction sites in urban areas
- Reduces vehicle queuing and traffic impacts at/near site
- Packaging and waste can be collected from site
- Storage location for materials and equipment: frees up space on site and reduces theft and waste
- Offers opportunity to operate cleaner goods vehicles for this short-distance delivery from CCC to site

London CCC operation to four construction sites in city centre



- Trial from 2005-2007
- 5,000 sq. m. facility located 5 km from sites
- 10 days of storage space
- Fleet of 6 rigid goods vehicles

London CCC results

Key Performance Indicator	Target	Achieved
Reduction in freight journeys	40%	60-70% of journeys via LCCC 40% of journeys to construction site
Reduction in journey time of supplier deliveries to contractors	30-60 minutes	120 minutes
Delivery reliability	97%	97%

Plus, labour force productivity on construction sites increased by up to 25 minutes per person-day

Source: Transport for London, 2008

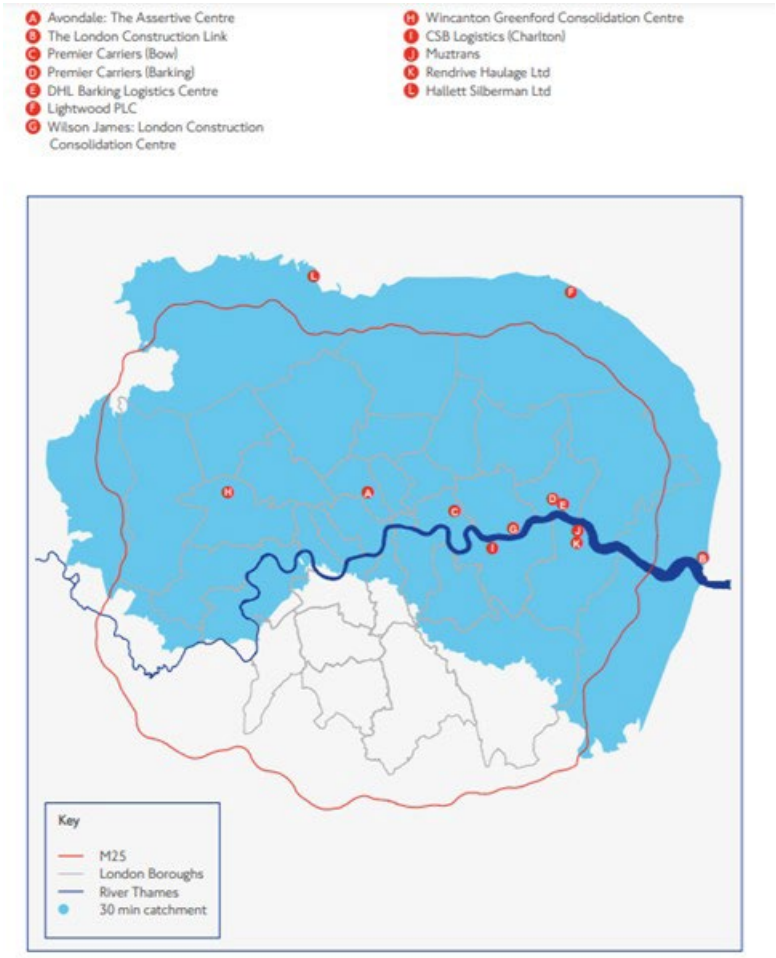
Hammarby construction site and CCC in Stockholm

- 8000 new apartments in busy location
- CCC close to construction site
- 3,500 sq. m. of storage indoors and a further 4,000 sq. m. outside

Source: Ottoson, 2005

- Results:
  - reduced vehicle activity to site (down by 60%)
  - reduced vehicle queuing times at site (down by 90%)
  - vehicle load factors to site increased from 50% to 85%
  - helped on-time completion of project
  - reduced theft and waste

Directory of London CCCs



Planning conditions for site logistics

- Depending on size of construction project, various documents required by planning authorities as part of planning application that relate to transport and logistics arrangements for site
- Construction Logistics Plans (CLPs) - logistics impacts and how these will be minimised:
  - site opening times and entry and exit points
  - details of quantity of construction traffic that will be generated
  - routes these vehicles will use to avoid sensitive areas
  - goods vehicle booking and scheduling arrangements
  - traffic management and road safety approaches to be used
  - details of the use of more sustainable, non-road modes where feasible

Non-road modes to/from construction site

- Non-road transport modes have been extensively used on some large public sector construction projects where site are rail- or water-connected
- Rail freight:
  - Olympic Park in London for 2012 Games (aggregates and tiles)
  - HS2 rail line - 10 million tonnes of aggregates to construction sites
- Water:
  - Spoil from the tunnelling work for Crossrail (5 million tonnes) and the Northern Line extension at Battersea (850,000 tonnes)
  - Thames Tideway sewer project - 5 million tonnes of spoil plus inbound materials
- Research indicates lack of transport infrastructure and logistics operations barriers greatest, followed by financial barriers (steer davis gleave, 2017)
- Lack of awareness and information of non-road mode potential

Source: https://commons.wikimedia.org/wiki/File:59_201_%26_66_009_Acton_Yard.jpg

Source: https://commons.wikimedia.org/wiki/File:An_afternoon_at_Stenson_Junction_-_8807208219.jpg

Supply chain activities for a construction project that can result in economic, social and environmental impacts

Greenhouse gas emissions

Local air pollution & dust

Water consumption

Sediment run off and toxic spills

Land contamination

Noise & disturbance

Consumption of resources

Visual intrusion

Loss of open space and habitat

Site worker injuries & deaths

Permanent changes to natural environment

Road traffic collisions

Loss of archaeology

Deterrence & inconvenience to pedestrians & cyclists

Road traffic congestion

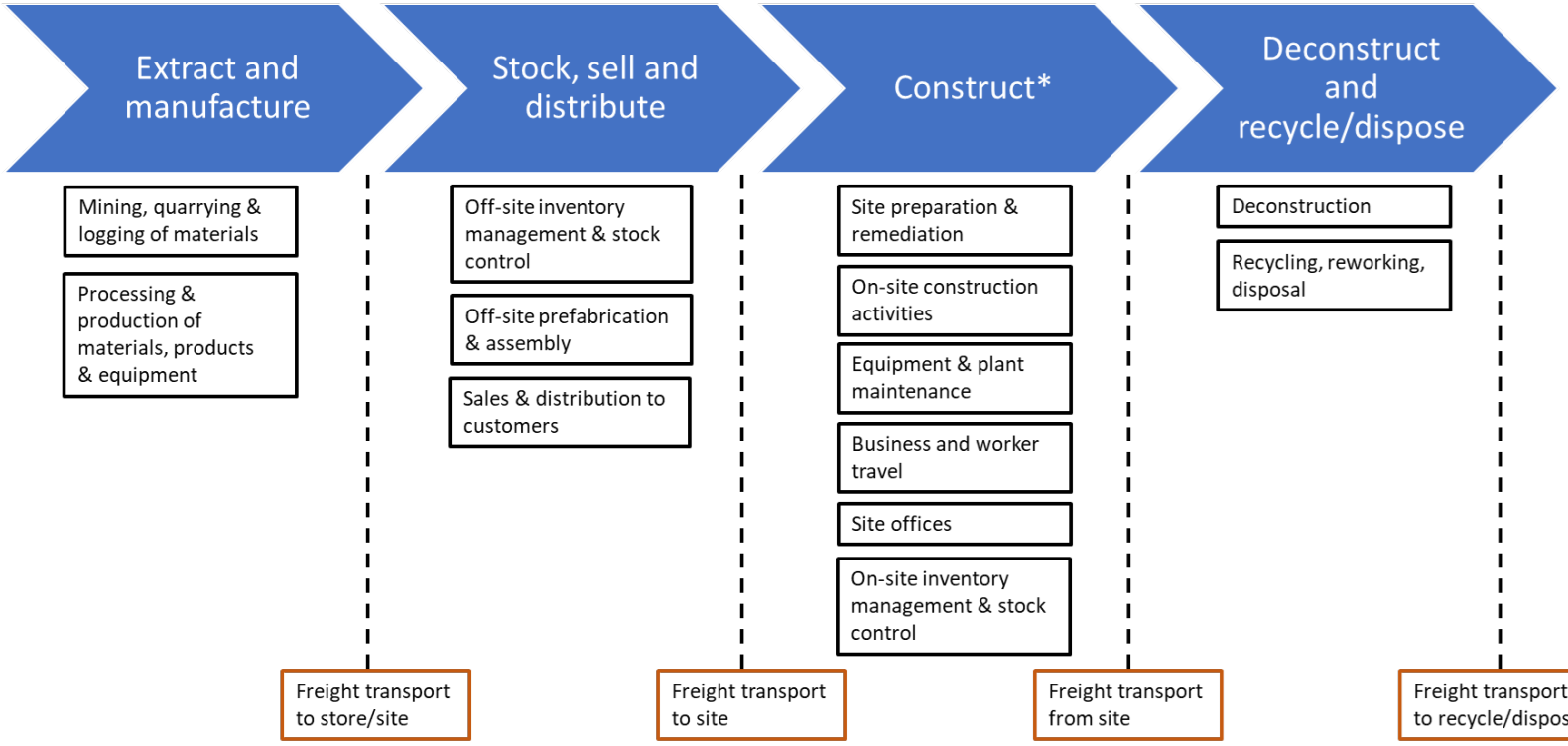
Project efficiency & productivity

Generation of crime

Waste generation

Flytipping of waste

Impact on bus services



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

Categories of construction logistics sustainability 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	✓	✓	✓			✓		✓
Driver training and fleet management	✓			✓	✓	✓	✓	✓

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								
Vehicle routeing for journey co-ordination and arrival time	✓	✓	✓	✓	✓	✓	✓	✓
Use of non-road modes	✓	✓	✓	✓	✓	✓	✓	✓
Use of non-motorised road vehicles (e.g. cargo cycles)	✓	✓	✓	✓	✓	✓	✓	✓
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	✓			✓	✓	✓	✓	✓

Source: authors' own analysis from evidence review.

Categories of construction logistics measures and stakeholder(s) best placed to implement them

- Table shows stakeholders in construction supply chain best placed to take lead in implementation & requirements of construction logistics sustainability measures
- Actions available to national, international & local government & planning authorities fall into two categories: mandatory & advisory
- Mandatory actions include national & international regulatory requirements concerning goods vehicle engine emissions standards, national & local vehicle construction requirements to enhance safety, & local requirements concerning transport & traffic management arrangements (such as vehicle routes & times of operation) that must be put in place for construction site or quarry as part of planning conditions
- Advisory actions include encouraging construction companies to: join CLOCS, fleet operators joining FORS, adopt driver training & use telematics & fleet management systems, & use non-road modes where possible

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		✓				✓

Source: authors' own analysis from evidence review