

STEEL CONSTRUCTION Cost

STEEL
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Steel for Life and the British Constructional Steelwork Association (BCSA) are working closely together to promote the effective use of structural steelwork. This collaborative effort ensures that advances in the knowledge of the constructional use of steel are shared with construction professionals.

Steel is, by a considerable margin, the most popular framing material for multi-storey buildings in the UK and has a long track record of delivering high quality and cost-effective structures with proven sustainability benefits. Steel can be naturally recycled and re-used continuously, and offers a wide range of additional advantages such as health and safety benefits, speed of construction, quality, efficiency, innovation, offsite manufacture and service and support.



The steel sector is renowned for keeping specifiers abreast of the latest advances in areas such as fire protection of structural steelwork, UKCA Marking and achieving buildings with the highest sustainability ratings. The 'Steel Construction' series of publications has provided detailed guidance on a range of key topics and market sectors. Guidance is provided on all relevant technical developments as quickly as is possible.

The sector's go to resource website – www.steelconstruction.info – is a free online encyclopedia for UK construction that shares a wealth of up-to-date, reliable information with the construction industry in one easily accessible place.



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Introduction

by David Moore, CEO,
British Constructional Steelwork Association

Steel takes the right attitude to cost



Attitude surveys have confirmed that cost is often the key driver in selecting the framing material for a building, so it has been a major element in the decision making process that has given steel construction market shares of over 90% in single storey industrial buildings and around 65% in multi-storey buildings.

Just as the design and the construction process has to be just right, it is important that the costing process is undertaken properly if correct decisions are to be reached. Costing must be accurate as too low an estimate can result in a frustrated client when tenders come in higher than hoped; too high and the decision might go against steel, so the client misses out on what would have been the right choice on cost grounds alone, as well as missing out on the many other benefits that steel delivers at no extra cost.

The steel sector recognises the importance of achieving accurate cost estimates and has invested in providing guidance and assistance to the construction professionals involved for some years. One result is *Costing Steelwork*, a

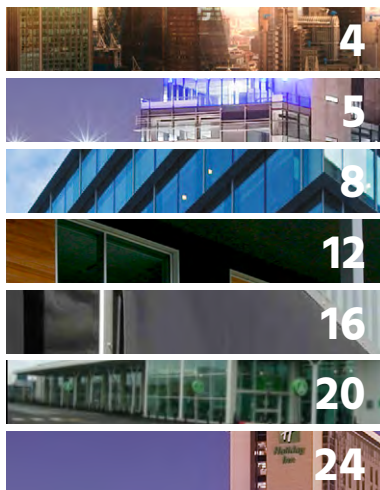
regular series from Aecom, BCSA and Steel for Life that provides guidance on costing structural steelwork. *Costing Steelwork* is produced quarterly, examining the process of cost planning throughout the design stages and highlighting the key cost drivers for different sectors.

It provides a building type-specific cost comparison and includes a cost table, which indicates cost ranges for various frame types. These cost ranges can be used at all design stages to act as a comparative cost benchmark. *Costing Steelwork* is published in *Building* magazine and subsequent articles in *Building* will provide updates using current data.

This publication gathers together the first five issues in the series to provide comprehensive guidance across the five sectors covered by the study, namely office, education, industrial, retail and mixed-use buildings with costs current as of Q3 2023.

As well as being published in *Building* the quarterly updates will always be found on the steel sector 'online encyclopedia' www.steelconstruction.info.

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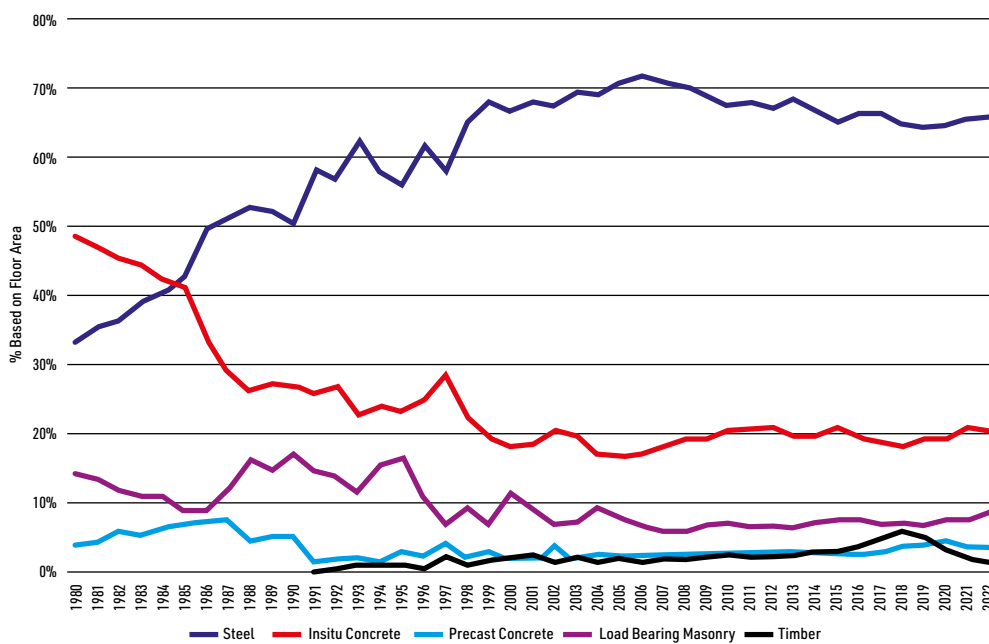
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"The Costing Steelwork series of articles produced by Patrick McNamara (director) and Michael Hubbard (associate) of Aecom is available at www.steelconstruction.info. The data and rates contained in this article have been produced for comparative purposes only and should not be used or relied upon for any other purpose without further discussion with Aecom. Aecom does not owe a duty of care to the reader or accept responsibility for any reliance on the foregoing."

The cost-effective solution

Steel has been the market leading, cost-effective, sustainable framing solution for buildings of all types for many years. Cost benefits alone would ensure its market position, but there are many other benefits to be enjoyed.



The market for structural frames - market shares. Total multi-storey buildings market, Great Britain 1980 to 2022

Steel construction has a host of advantages over alternative materials for framing buildings which can vary between projects and types of projects, but the constructional steelwork sector appreciates that cost benefits are always a key advantage for clients. That is why the BCSA invests in providing all the background advice that construction professionals need when making cost calculations and comparisons.

Attitude surveys confirm that cost is the key driver in the selection of material for building frames, for everything from logistics centres to schools, commercial developments, leisure centres and major sports stadia.

The latest in the BCSA's independently produced 40-year series of market share surveys confirms that steel is the material of choice for large sections of the market, such as single storey industrial buildings – sheds –

where the market share is over 90%, and multi-storey offices, a sector where some 65% of buildings are framed in steel.

Clearly there is considerable enthusiasm among clients and construction professionals for using steel, backed up by a compelling case on cost grounds alone. For some types of building of course there really is no alternative to steel. A major market for construction since the late 1980's has been large column-free spaces for City financial companies, for trading floors and accommodation for teams of analysts and backroom staff. The long spans demanded can only be achieved by steel.

Steel allows architects to fully realise their ambitions for these often landmark, iconic buildings, allowing the structure to be expressed, with much of the steel structure exposed. As well as providing the aesthetically pleasing, flexible open spaces these clients and their employees

expect, steel creates flexible structures able to be reconfigured for changing uses.

The most modern buildings in the City and West End particularly are now finding new ways to capitalise on this flexibility as architects report that clients increasingly demand areas be provided for a wider range of facilities for building users, including more break out areas and retail and leisure spaces. Developers across growth markets like technology and the creative industries especially see steel-framed buildings as places that foster collaborative working.

Thanks to steel's sustainability credentials such as its ability to be infinitely recycled or re-used and its lower levels of embodied carbon, buildings of all types have found achieving the highest BREEAM ratings to be a straightforward process. A steel-framed building's lower self-weight translates to smaller foundations, with favourable cost and sustainability implications.

Another sustainability related benefit is being able to achieve more floors within a particular height, or having a particular number of floors within a shorter building, thanks to the use of cellular long span beams that allow services to be carried within the structural zone.

Steel is bringing increased opportunities to building owners and users in the fast-changing retail landscape, allowing rapid response to changing shopping behaviour by, for example, reconfiguring shopping and storage space. Schools also insist on being able to reconfigure easily and quickly to accommodate changing classroom sizes and teaching methods.

This publication from the BCSA and Steel for Life provides comprehensive cost guidance across five key sectors – office, education, industrial, retail and mixed-use. All these sectors and others can provide great examples of how steel's unique qualities have delivered outstanding and cost-effective buildings.

The demands of building owners and users continually evolve, and the pace of change never seems to show signs of slowing down. Whatever the needs of the future, the UK's world-leading steel construction sector aims to ensure that steel-framed solutions will provide the cost-effective, high-quality buildings that the market clearly values.



How to cost steel-framed buildings

A key component of the cost of any building type is the frame, which for multi-storey buildings accounts for approximately 10% of the overall building cost.

The accuracy of any costing exercise depends on the level of design information on which it is based. As the design develops and more information becomes available, the extent to which the cost can be detailed increases.

RIBA STAGE 1-2

The budget set at the early stages of the design needs to reflect the final build cost despite limited information being available. This means rates used during this phase need to include items which are not yet quantifiable.

At this critical stage in the project, much of the decision making on the frame construction method takes

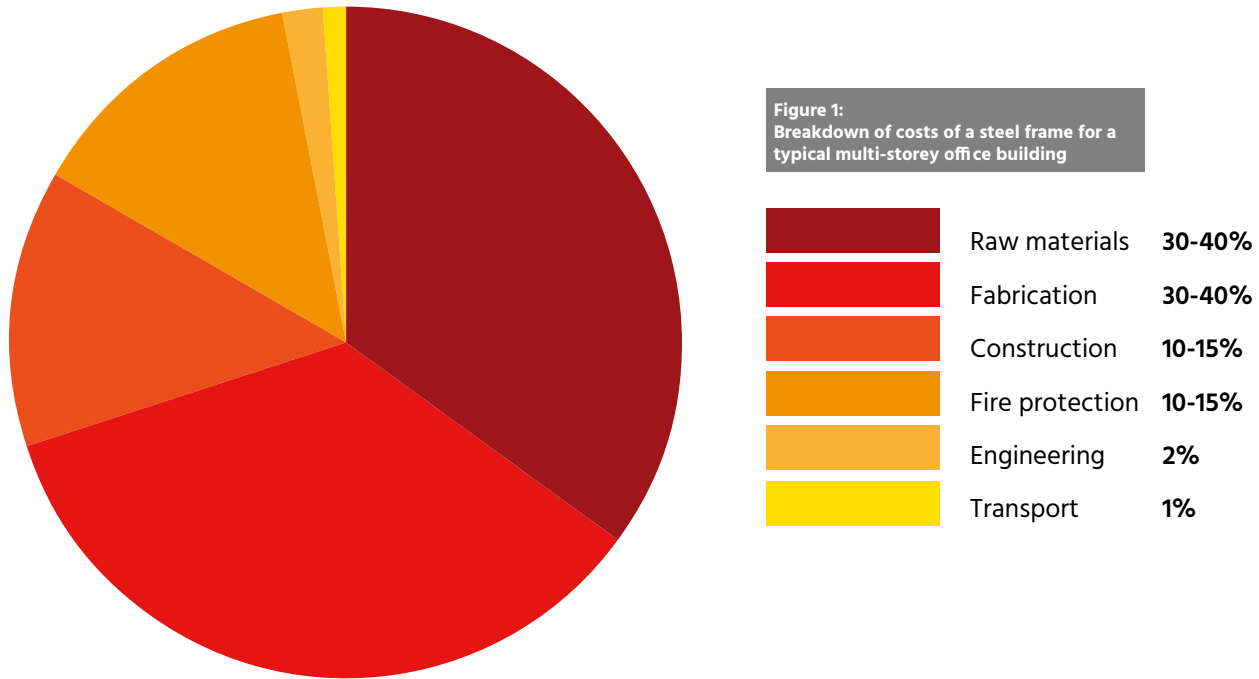
place. The steel frame design is represented as a relative weight (kg/m²) as opposed to a framing layout with beam sizes. Costs and rates based on a kg/m² design intent should consider the following:

- The steelwork quantity based on gross internal floor area (GIFA) or relative areas that the steel frame covers, which will depend on the building type and loading requirements
- How the kg/m² benchmarks against similar buildings
- If the quantity of steel (kg/m²) accounts for fittings and steel-to-steel connections or whether an

additional allowance needs to be made

- The potential mix of steel members: columns, beams, fabricated sections etc
- Consideration of the fire protection method and fire rating
- Non-standard details such as cantilevers and transfers
- The erection and lifting strategy and whether there will be a need for some members to be erected with mobile rather than tower cranes.

In addition, typical items that would not be covered in primary steelwork (kg/m²) but will need to be considered include:



- Secondary steelwork including framing to risers, lifts and cladding
- Connections to concrete or existing structures.

Following consideration of all of the above a “blended all in” rate is then derived and applied to the calculated kg/m². These rates will then be reviewed against similar projects and steel frame types which provide analysis against benchmarks.

Market testing should also be sought through consultation with steelwork contractors to ensure the accuracy of rates, forming a credible foundation for the steelwork costings to be developed in the subsequent design stages.

RIBA STAGE 3-4

As the design progresses, technical information from the structural engineer on the proposed frame will become available, allowing a more accurate and developed quantification of the frame cost, which will now include a piece count and review of the design evolution.

Other information likely to become available at this stage includes:

- Drawings showing the frame configuration
- Cores and shear walls
- Column and beam sizes and types
- Floor construction details

- The strategy for integration of mechanical and electrical services.

The developing steel frame design can then be broken down into three components:

- Main members: primary supports that carry the loads, such as beams, columns and trusses
- Secondary members: those carrying specific loads
- Fittings and connections: bracing, stiffeners and the joints that transfer forces between the structural elements
- Miscellaneous: items such as temporary steelwork, metal decking to composite floors, stairs, riser decking, external core angles, tower crane grillages, and stubs for BMU tracks.

It is still important at this stage in the design process to continue to determine and redress what has not been included within the drawings and ensure that these missing elements are taken into account. For example, the extent of secondary members should not be overlooked as these can account for a significant proportion of the overall steel piece count and cost.

To calculate the cost of the structural frame, each of the

components noted above will have a rate per tonne applied and then totalled. This rate should include the raw materials, fabrication, construction, fire protection, engineering and transport costs (Figure 1).

There are risks and limitations in cost planning steelwork based on a simple rate per tonne, as this does not take into account specific features such as long-span beams, cranking or tapering, curvature of steel, hollow sections, cantilevers, irregularity of grid, back propping and movement connections, all of which may require an adjustment to the basic applied steelwork rate.

SOURCING COST INFORMATION

When estimating and cost planning buildings it is important to assess the relevance of the source cost information. If this is sourced from previous projects then the base date and building form must be considered and compared between the current and past projects.

Figure 2 represents the costs associated with the structural framing of a building expressed as a cost/m² on GIFA. It should be used for comparative purposes to provide a benchmark.

The range of costs represents the variances in the key cost drivers, as



The Donaldson's residential project in Edinburgh chose a steel-framed solution for its cost-effectiveness

Figure 2: Indicative cost ranges based on gross internal floor area, as at Q3 2023

noted later in this publication.

If a building's frame cost sits outside these ranges this should act as a prompt to interrogate the design and determine the contributing factors.

The location of a project is a key factor in price determination and indices are available to enable the adjustment of cost data across different regions. The variances in these indices, such as the BCIS location factors (Figure 3), highlight the existence of different market conditions in different regions, which must not be overlooked.

TO USE THE TABLES

1. Identify which frame type most closely relates to the project under consideration
2. Select and add the floor type under consideration
3. Add fire protection if required.

For example, for a low-rise building with a composite metal deck floor and 60 minutes fire resistance, the overall frame rate (based on the average of each range) would be: £166 + £110.50 + £28 = £304.50 per m² GIFA

The rates should then be adjusted (if necessary) using the BCIS location factors appropriate to the location of the project.

TYPE	Base index 100 (£/m ²)	Notes
Frames		
Steel frame to low-rise building	150-182	Steelwork design based on 55kg/m ²
Steel frame to high-rise building	252-285	Steelwork design based on 90kg/m ²
Complex steel frame	285-337	Steelwork design based on 110kg/m ²
Floors		
Composite floors, metal decking and lightweight concrete topping	86-135	Two-way spanning deck, typical 3m span with concrete topping up to 150mm
Precast concrete composite floor with concrete topping	132-185	Hollowcore precast concrete planks with structural concrete topping, spanning between primary steel beams
Fire protection		
Fire protection to steel columns and beams (60 minutes resistance)	22-33	Factory-applied intumescent
Fire protection to steel columns and beams (90 minutes resistance)	27-44	Factory-applied intumescent
Portal frames		
Large-span single-storey building with low eaves (6-8m)	109-143	Steelwork design based on 35kg/m ²
Large-span single-storey building with high eaves (10-13m)	133-170	Steelwork design based on 45kg/m ²

Figure 3: BCIS Location Factors, as at Q3 2023

Location	BCIS Index	Location	BCIS Index
Central London	127	Nottingham	102
Manchester	102	Glasgow	92
Birmingham	96	Newcastle	90
Liverpool	97	Cardiff	94
Leeds	92	Dublin	90*

* Aecom index

Offices

Key cost drivers

Once the design has developed sufficiently to cost the specific building design rather than utilising typical ranges, key cost drivers remain important for making sure a realistic cost is included within the cost plans. There are a number of unique design aspects that need to be taken into account for commercial buildings. These factors could also be used to drive cost efficiencies. A number of these factors are focused on the weight of steel but there are other influencing factors which can have a significant impact on costs.

CORE OPTIONS

Whether the core is constructed from concrete or steel will have varying cost impacts on the steel frame. A concrete core will mean introducing an additional trade. This will need to be factored into the steel frame installation programme and may occasionally result in shared tower crane usage. An additional consideration will be the requirement to cast in fixings and site welding fin plates to allow steel to concrete connections, which should be factored into the costs. In comparison, a braced steel core is a lightweight and flexible solution when compared with the concrete equivalent. The key cost drivers in this instance will include an increased installation piece count, which will consist of relatively lightweight profiles. These have a direct bearing on the associated rate (£/tonne). The effect of a lightweight steel core on foundation costs should also be considered.

FLOORPLATE CONFIGURATION

When deciding on floorplate configuration it is important to understand the drivers for the desired layout and the potential cost implications of this choice. Floorplate configuration can vary across projects and can be influenced by a range of factors, for example, the design aspiration and/or site constraints. The simplest option is to adopt a regular framing layout where the steel-to-steel

connections are at 90 degrees, which allows for a more straightforward construction. In contrast, adopting an irregular layout has the potential to affect the fabrication costs as this approach will require splayed connections and necessitate increased cutting of the floor deck. Another consideration is curved floorplates, which can incur cost premiums as a result of increased manufacturing processes and wastage.

REPETITION

The absence of repetition of the floorplate stack should also be considered as it will lead to the requirement of a transfer structure, increasing costs. Alignment must also be considered. If there is a lack of column alignment this may result in the introduction of localised transfers. As well as impacting the costs this could compromise the services zone.

SECURITY/ROBUSTNESS

Design requirements to strengthen the frame in response to the building's security assessment rating will mean increased structural demands on connection details and edge beams, particularly at the lower levels of the building, eg provision for column removal without progressive collapse of the building.

FLOOR RESPONSE FACTOR

For most multi-storey commercial



6 Wellington Place in Leeds is one of a number of steel-framed offices to be built in the city in recent times

buildings, straightforward steel construction will meet the required vibration performance criteria without modification. However, stiffening may be required to meet particularly onerous floor vibration design criteria, in which case deeper and heavier beams would be needed.

STRUCTURAL ZONE

There is an optimum structural zone where beams work efficiently. However, with the introduction of services and the desire to increase floor-to-ceiling heights this zone can become compromised. The reduced structural zone may make the frame less efficient and increase steel member weights.

SERVICE INTEGRATION

When penetrations are required within the beam depth to allow services to distribute throughout the floorplates, the size and positioning of these can have an impact on the performance of the beam. Ductwork distribution can



result in oversized penetrations; should this occur there will be a requirement to stiffen the holes in order to maintain the integrity of the beam. This involves the welding of additional plates and angles to the beam. The effect of service integration in terms of reduced overall building height should also be considered.

ERECTION OF STEELWORK

The erection of steelwork is reliant on crane hook time; therefore, multiple small beams will have a disproportionately high erection cost when compared against a large single beam. Tower cranes are the main source of lifting on-site. Crane capacity should be factored in to the logistics strategy as any individual members that exceed the tower crane capacity will need to be erected by utilising mobile cranes (with their associated road closures and space requirement). In cost planning buildings, allowances should be made for tower cranes with sufficient capacity

to lift the majority (if not all) of the components necessary to construct the building. Where specific specialist lifts are required then allowance needs to be included within the overall building budget (this is not specific to steel framing and should be taken into account when considering the building as a whole).

FIRE PROTECTION

The first thing that needs to be established is what fire rating is required (60, 90 or 120 minutes). Next the proposed method of applying the fire protection should be considered – offsite applied thin film intumescent coatings are commonplace particularly as it removes work from site. However, other methods are available such as boarded, on-site applied cementitious coating or concrete encasement. When approaching the costs and making comparisons, programme effects need to be factored into the overall cost planning process.

LOGISTICS AND PROGRAMMING

Site conditions have a direct impact on costs which manifests itself in the erection and package-specific preliminaries costs. In extreme cases the site conditions determine the design solution, eg constructing above railway lines, sites adjacent to or over rivers, or sites with restricted access (double handling). Site-specific preliminaries are influenced by tower crane availability, building height, uniformity of grid, on-site welding requirements, delivery timings and quiet periods.

MARKET INFLUENCES

External factors such as currency exchange rates, buoyancy of the market, labour availability and commodity prices all influence market dynamics and as such should be considered at the time of developing the cost plan. It is advisable always to include exchange rates in the basis and assumptions of the cost document.

Offices

Cost comparison

Costing a 10-storey Grade A building in central London



One Kingdom Street, Paddington

The building used for the cost model is a multi-storey office structure; One Kingdom Street, London. The project is located in the Waterside regeneration area near Paddington railway station in Central London. This Grade A office building was completed in 2008.

The building's key features are:

- 10 storeys, with two levels of basement
- Typical clear spans of 12m x 10.5m
- Three cores - one main core with open atrium, scenic atrium bridges and lifts

- Plant at roof level

This building was originally part of the Target Zero study conducted by a consortium of organisations including Tata Steel, Aecom, SCI, Cyril Sweett and BCSA in 2010 to provide guidance on the design and construction of sustainable, low and zero-carbon buildings in the UK.

This cost comparison updates the cost models developed for the Target Zero project and provides up-to-date costs at Q3 2023 for the two alternative framing solutions considered.

ABOUT THE BUILDING

As noted in the original Target Zero study, the building accommodates 24,490m² of open-plan office space on 10 floors and, on the eastern half of the building, two basement levels providing car parking and storage. The gross internal floor area is 33,018m². The 40m-high building is rectilinear with approximate dimensions of 81m x 45m. The front facade faces north and comprises a reverse ellipse along the length of the building plan on podium and first floor levels.

Figure 4: Key costs £/m² (GIFA), for Central London office building

Elements	Steel composite	Post-tensioned concrete flat slab
Substructure	93	98
Frame and upper floors	559	542
Total building	3664	3750

One Kingdom Street has three cores and is designed around two central atriums on its southern elevation, which house six scenic wall chamber lifts. The western half of the building is partly constructed on a podium transfer structure enclosing works access for Crossrail.

One Kingdom Street has a steel frame, on a typical 12m x 10.5m grid, comprising fabricated cellular steel beams supporting a lightweight concrete slab on a profiled steel deck. The larger span is dictated by the location of beams within the Crossrail podium deck on which they are supported. The steel beams are designed to act compositely with the concrete floor slabs through the use of welded shear studs.

The cellular floor system enables the services to be integrated within the structural zone, ie within web openings in the beams. The clear floor-to-ceiling height in the office areas is 2.8m. Upper floors support a 175mm raised floor and a perforated metal tile suspended ceiling incorporating acoustic insulation.

The foundations comprise 750mm diameter bored-piled foundations with insitu concrete pile caps. Ground beams provide lateral restraint to the pile caps. The piles are the same size as those used to support the existing Crossrail podium in order to reduce potential differential settlement arising from the use of different pile diameters.

The office areas are clad with an anodised aluminium curtain walling system consisting of storey height double-glazed windows units on a 1.5m module. Vertical fins at 3m centres support the external aluminium louvers

for solar shading on the southern elevation and part of the east and west elevations.

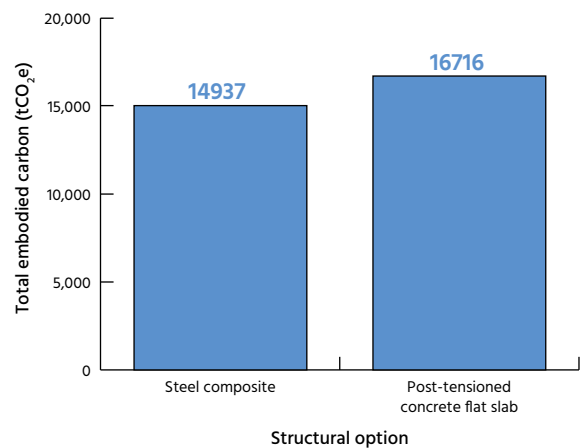
COST COMPARISON

Two structural options for the office building were assessed: the base case as described above and a 350mm thick post-tensioned concrete flat slab with a 650 x 1050mm perimeter beam.

The costs, which include preliminaries, overheads, profit and a contingency, are summarised in Figure 4.

The analysis shows that the cost of the steel composite solution is 3% higher than the post-tensioned concrete flat slab alternative in terms of the frame and upper floors, but 2% lower on a total building basis. The lighter

Figure 5: Embodied carbon comparison



frame weight and the increased speed of erection results in reduced foundations and a quicker programme.

EMBODIED CARBON COMPARISON

The original Target Zero project also included a comparison of the embodied carbon of the two framing solutions. This was on a “cradle-to-cradle” basis that included the manufacture and transport of construction materials, the construction process and the demolition and disposal of the building materials at the end-of-life.

The results, which are presented in Figure 5 showed that the embodied carbon of the steel composite solution was 11% lower than the post-tensioned concrete flat slab alternative.

Key cost advantages of steel framing for office buildings

- **Column-free floorplates** Steel framing is an economic means of providing long spans without the requirement for intermediate columns, thus creating increased open-plan space which is advantageous to office building letting.
- **Adaptability** Tenant alterations are considerably less complex with steel-framed buildings, particularly major alterations such as the introduction of internal accommodation stairs or double-height spaces.
- **Offsite manufacture** This results in a reduction in on-site labour, which as a consequence reduces health and safety risks.
- **Services integration** The integration of services within the structural elements of buildings leads to economies in construction by reducing the floor-to-floor height, which has a double benefit of reducing the external cladding required and also reducing heat loss through the envelope. In multi-storey buildings, service integration can allow extra floors to be provided within the same overall building height.
- **Lightweight** The reduced weight of a steel-framed building has a beneficial effect on the foundation design. It also allows the building to be constructed over restricted load areas such as railway station boxes and transfer structures.
- **Programme** Steel frame installation and its ability to be pre-manufactured offers programme advantages due to certainty of delivery and speed of installation.

Education

Key cost drivers

There are a number of factors which can have a significant influence on the cost of education buildings. While the standard considerations still apply such as logistics, building form, fire protection levels and erection, specific key cost drivers for education buildings include:



The steel frame at the City of Leicester College provided flexibility for future expansion

BUILDING REQUIREMENTS

There are several functions that make up an education building beyond the classroom. These include functions such as sports halls, workshops, laboratories and other uses, all of which have their own specific requirements.

For example, column-free spaces will be required for a sports hall and larger-plan space will be required for workshops/technical rooms. These areas and requirements do not always sit with the standard structural grid and therefore the extent of these will influence the final solution and cost.

The differing requirements of schools versus further education (FE) and higher education (HE) institutions should also be considered.

Unlike schools, a number of these establishments will need to adjust courses to meet demand, so their offering, their requirements and therefore how they configure their buildings will vary from year to year. As the range of subjects taught is also greater than in schools, more specialist space is typically required, such as workshops, studios, laboratories and lecture theatres.

END USER REQUIREMENTS

Working with the project's stakeholders to ensure the integration of actual requirements with the building and availability of solutions can also affect the programme for education buildings in particular.

This is because the stakeholders can be both internal and external to the project and extremely diverse. Direct end users include staff and students; and external stakeholders include those such as education departments, local authorities, boards of governors, parents and disability support groups.

INFORMATION AND COMPUTER TECHNOLOGY (ICT)

The emphasis on ICT requirements including the future-proofing of systems can put additional constraints on the building. This can result in additional services distribution through vertical risers and routes through the structure. The consequence of this requires more co-ordination and additional penetrations through structural elements.

LOGISTICS AND PROGRAMMING

Site conditions have a direct impact on costs which manifests itself in the erection and package-specific preliminaries. Site specific preliminaries are influenced by tower crane availability, building height, uniformity of grid, on-site welding requirements, delivery timings and quiet periods.

While the programme is a consideration for all construction

projects, it tends to be a key driver for education projects because of the constraints of the academic calendar and the common requirement for new or refurbished space to be provided to coincide with the beginning of an academic year.

This can result in contractors and subcontractors having a large number of projects to construct all within similar timeframes. This will inevitably lead to some projects being favoured by the market over others, which can result in variations in pricing.

Throughout the design process, it is important to liaise with the market and to ensure that sufficient time is given to tender periods; it is also important that the market is aware of the project and has factored it into future workloads.

MARKET INFLUENCES

External factors such as currency exchange rates, buoyancy of the market, labour availability and commodity prices all influence market dynamics and as such should be considered at the time of developing the estimate/cost plan. It is advisable to always include exchange rates in the basis and assumptions of the cost document.

MODERN METHODS OF CONSTRUCTION

Education requirements based on function and size are relatively prescriptive, which allows for a greater degree of offsite manufacture and modularisation. Developing a kit of parts for educational projects may be beneficial and can be compatible for steelwork solutions. Such an adaptable system has the ability to be used on any size of school bringing a greater degree of certainty on cost, programme and quality.

PROCUREMENT

The type of procurement needs to be taken into consideration as this is likely to have an influence on the costs. Education projects can be single projects or part of a framework, either regional or national.

RISK ALLOCATION

Public projects as a rule are more risk averse and, as such, the risks are passed on to the contractor where possible. This will manifest as a cost premium within tender returns.

The Employer's Requirements set out comparatively high liquidated damages to act as a deterrent to non-completion within the set timescales - this may restrict the tender list and put added pressure on cost.

SITE CONFIGURATION

Site configuration will impact on the building design in a number of areas, including floorplate configuration, grid and building height. It can therefore also be a key consideration when estimating the structural frame cost of schools, as a school building on an unrestricted site would typically be single storey, whereas a tight site may result in two or more storeys being required to maintain the minimum requirements of external space provision.

This may have an associated cost impact both in terms of site logistics and a longer programme attracting higher costs for preliminaries. A more repetitive structure will be more cost-efficient both in terms of material cost and on-site erection, so the extent to which a proposed building utilises repetition in its design influences the cost planning.

It is also important to identify if the proposed construction works are to take place on an existing campus, which is

common for education projects.

A site within an existing campus will typically require restrictions to working times to limit noise, which may attract additional cost for preliminaries and may impact on programme.

THERMAL MASS

Thermal mass has traditionally been identified as a cost-effective method of reducing operational carbon by lowering the requirements for mechanical heating and cooling through the use of the building fabric, in particular the cooling of the building by the introduction of night-time purging (drawing cooler night-time air into the building to pre-cool the slabs, which is slowly released during the following day).

Introducing thermal mass into the building can primarily be done in the floor slab build-up. The increased mass also helps with noise transfer and is likely to be introduced using precast concrete floors.

Independent research has shown that the optimum thickness of concrete floor slab for providing thermal mass on a diurnal cycle of heating and cooling in the UK is 75-100mm. This thickness of concrete floor slab is available in almost all steel-framed buildings.

Key cost advantages of steel framing for education buildings

- **Erection time** Due to the extent of prefabrication in structural steel assembly the on-site erection time is significantly reduced. This speed of construction is particularly important due to much of the work being undertaken (particularly extensions) during non school periods. The main continuous non school period is during the summer shut down which restricts the available time to carry out the works. The adoption of a steel frame works well with the restrictive periods available and allows for the outer shell to be in place leaving only internal works which can be better accommodated during the school periods as required.
- **Flexibility** A well designed building should allow for future uses, steel-framed buildings are easily adapted in comparison to buildings constructed with loadbearing masonry. The flexibility of the framing allows horizontal adaptation where rooms can be altered in size to accommodate changing requirements. Adopting a steel frame allows the design to accommodate the various functions, all of which may not suit a rigid layout where workshops have differing sizes to classrooms, for example. In the instance of column-free space for sports halls, these need to be achieved by a steel-framed solution.
- **Offsite manufacture** Steel components are manufactured offsite with the main site activity being assembly. This results in a reduction in on-site labour which as a consequence reduces health and safety risks. Particularly in large buildings or programmes of works there is likely to be a drive towards standardisation which allows for the adoption of modern methods of construction. These are made more viable with the volume of repetition and are well suited to a steel-framed building.
- **Restrictive/existing sites** Steel is particularly relevant to projects requiring an extension to existing buildings and/or the development of additional buildings within a campus due to its prefabricated nature. A key advantage of steel is that it arrives on-site prefabricated which in conjunction with the speed of erection limits the amount of disruptive time to the adjacent buildings.



Education

Cost Comparison

Costing a secondary school building in Merseyside

Christ the King Centre for Learning, Knowsley, Merseyside

The building used for the cost model is the Christ the King Centre for Learning, a secondary school in Knowsley, Merseyside.

The building's key features are:

- Three storeys, with no basement levels
- Typical clear spans of 9m x 9m
- 591m² sports hall (with glulam frame), 770 m² activity area and atrium
- Plant at roof level.

This building was originally part of the Target Zero study conducted by a consortium of organisations including Tata Steel, Aecom, SCI, Cyril Sweett and BCSA in 2010 to provide guidance on the design and construction of sustainable, low and zero-carbon buildings in the UK.

This cost comparison updates the

cost models developed for the Target Zero project and provides up-to-date costs at Q3 2023 for the three alternative framing solutions considered.

ABOUT THE BUILDING

Christ the King Centre for Learning secondary school in Knowsley, Merseyside, was part of the Building Schools of the Future programme (BSF), it was completed in December 2008 and constructed to be occupied by 900 pupils and 50 staff. The gross internal floor area of the school is 9,637m². The building is based on a 9m x 9m structural grid with many classrooms 9m deep.

The main architectural features of the building are: a standardised 9m x 9m structural grid, a 591m² sports hall, a winter garden covered by an ETFE roof, a three-storey high atrium and

some external terraces at upper floors. The school has a structural steel frame supporting precast concrete floor slabs and is clad in a combination of timber cladding, aluminium curtain walling and terracotta rainscreen.

COST COMPARISON

Three structural options for the building were assessed as shown in Figure 6 which include;

- Base case: Steel frame; 250mm hollowcore precast concrete planks; 75mm structural screed
- Option 1: In situ 350mm reinforced concrete flat slab with 400 x 400mm columns
- Option 2: Steel frame; 130mm concrete topping on structural metal deck.

The comparative costs highlight the importance of considering total building

cost when selecting the structural frame material during design. The concrete flat slab option has a marginally lower frame and floor cost compared with the steel composite option, but on a total building basis, the steel composite option has a lower overall cost (£4,013/m² compared with £4,049/m²). This is because of lower substructure and roof costs and lower preliminaries resulting from the shorter programme.

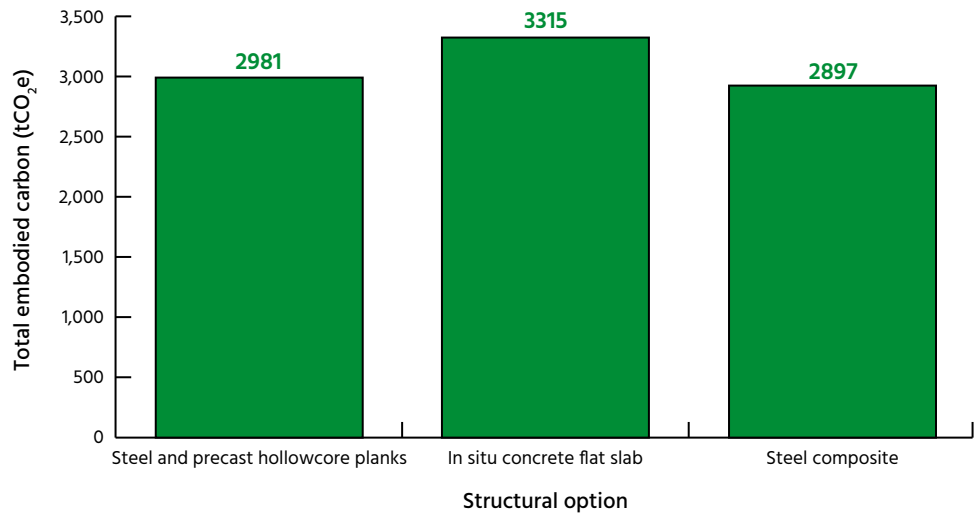
EMBODIED CARBON COMPARISON

The original Target Zero project also included a comparison of the embodied carbon of the three framing solutions. This was on a “cradle-to-cradle” basis that included the manufacture and transport of construction materials, the construction process and the demolition and disposal of the building materials at the end-of-life. The results, which are presented in Figure 7 showed that the embodied carbon of the steel frame solution with precast hollow core floor slab was 11% lower than the in situ concrete flat slab alternative while the steel frame solution with decking and in situ concrete topping was a further 3% lower.

Figure 6: Key costs £/m² (GIFA), for Merseyside secondary school

Elements	Steel and precast hollowcore planks	In situ concrete flat slab	Steel composite
Frame and upper floors	381	322	341
Total building	4090	4049	4013

Figure 7: Embodied carbon comparison



Christ the King Centre for Learning, Knowsley, Merseyside

Industrial

Key cost drivers



The industrial sector covers a range of building functions and types, including distribution centres, warehouses and small industrial units. The sector is characterised by a common requirement for long span structural solutions. The standard cost considerations apply, but as the building form shows less variation, location is more important. Key cost drivers for industrial buildings include:

LOGISTICS AND PROGRAMMING

Speed of erection is a key consideration and characteristic of construction in this sector. Generally a quick turnaround on site is expected, and therefore framing methods that allow for this are the primary choice. The component sections used in industrial projects are relatively large due to prefabrication, which requires sufficient space on the site to allow for unloading. However, this is largely offset by the common requirement for service yards and car parks in industrial projects, as this provides sufficient areas of the site that are not

being built upon and can therefore be used for construction set-up, loading and lay down areas.

SITE CONSTRAINTS

The location of the site is an important factor and has a direct impact on logistics and the project programme. New-build warehouse units are ideally located with access to the road network to allow for distribution and delivery of goods. This can result in sites being adjacent and close to areas of heavy traffic, which in turn can lead to restrictions on deliveries during the construction stage. In many

cases new junctions may need to be created on existing highways to allow access to these new units. The added time and cost of this will need to be taken into consideration. As noted, industrial buildings are generally assembled from prefabricated components, which requires the building to be assembled using cranes. If the project site is close to railways or similar infrastructure, this will necessitate the derating of cranes for safety reasons (for example, ensuring reduced lift capacity). The requirement to have a safety factor on crane lifts will result in uprated (larger) cranes; this will increase the erection costs.

ADAPTABILITY

When designing and/or reviewing a site for a potential industrial building it is important to determine whether the building's requirements are likely to change over time to try to minimise additional development costs at a later date. The most common change is an increase in area requirement. It is important that the building design is



Magna Park in Milton Keynes is one of many distribution parks in the UK to be built entirely with steel-framed buildings

developed to allow for easy extension without having a detrimental impact on the operation of building.

ANCILLARY ACCOMMODATION

Additional functionality in the form of ancillary spaces is generally required in industrial buildings; this could include space for office working and visitors. The building height is generally driven by the building function, and this is also a key driver of the requirements for ancillary accommodation and the structure needed to provide it, which will affect the overall building frame weight.

The benefit here of the large-volume space common to industrial buildings is that office accommodation can be located on a mezzanine to minimise loss of storage space. For high eaves buildings, the extent of the proposed upper floor areas should be considered as this can vary significantly between buildings, with ancillary space potentially being provided across as many as three mezzanine levels. The frame costs for these buildings will need to be looked at

carefully on a building-by-building basis, with adjustments likely to be required to standard cost ranges.

Depending on the extent and type of external visitors, it is not unusual for the facade treatment to the office area to be different from the main warehouse facades. These are often fully glazed with canopies and subject to aesthetic treatments. The building frame needs to be able to take this alternative elevational treatment into account.

BUILDING HEIGHT

This is a particularly important cost driver for industrial buildings and should be a key consideration during early cost planning when estimates are likely to be based on a frame weight per m² of floor area. While the gross internal floor area may be the same, the weight of the steel frame will vary between a low and high eaves building on a kg/m² basis, resulting in different overall frame costs per m² GIFA. Furthermore, should the proposed building have a very high bay configuration, with clear heights of up to 20m, adjustments will need to be made to the high eaves typical cost range to account for the further increased frame weight.

DESIGN FEATURES

At the early design stages it is also important to gain an understanding of any design features that may require variations to the standard steel portal frame. For example, the incorporation of northlights for architectural, planning or site orientation reasons can result in an increase to the frame cost due to the additional steelwork required to form the more complex roof profile. With these being function-driven spaces, the end use of the building has a larger bearing on the design.

FIRE PROTECTION

Another cost driver for industrial buildings is fire protection. Typically, fire protection is required only in single-storey buildings, where it is needed to satisfy boundary conditions or where there is a need to access the roof (such as for plant access). However, for buildings with upper floor levels, mezzanines or internal offices, the fire strategy will need to be clarified with the design team during cost planning to ensure that the extent and method of protection required is captured.

Key cost advantages of steel framing for industrial buildings

- Adaptions** It is relatively simple to extend a steel-framed building, as making steel-to-steel connections is very straightforward. A major advantage of using steel framing is the level of prefabrication, which minimises time on-site. The connections to the existing frame can be made with discrete pockets in the facade so that the waterproofing of the building is not compromised. The extension can be built independently of the existing building, with the final structural bays and cladding connected at the latter stages of the construction. The limited time required to make this final connection allows the final works to be undertaken outside operational hours, which keeps disruption to an absolute minimum.
- Building height** Steel portal frames can also be constructed to a range of building heights to provide the high eaves required for certain building functions. For example, distribution centres typically include overhead craneage and therefore require a clear internal height of 10–13m or more, while warehouses are more likely to require between 4m and 6m of clear height, depending on the storage racking system used.
- Internal space requirements** Large column-free space with high eaves is the optimum design for distribution centres and allows flexibility in offloading and storage. These large column-free volumes can be achieved at relatively low cost with a steel portal frame. Often on multi-span frames the intermediate valley columns are omitted (“hit-and-miss”) so that on, say, a 45m-span frame, with bay centres of 8m, each column-free “box” covers an area of more than 700m².
- Flexibility** The need for large column-free spaces is easily accommodated with steel frame construction. It allows for the maximum usable space to be achieved. This ability to deliver long-span solutions provides the flexibility to set out columns in the optimum position to allow easier vehicle movement and reduce obstructions within the main building volume.
- Lightweight structure** The lightweight nature of a steel portal frame can reduce the size of the required foundations and therefore the extent of the associated excavation, substructure and ground risk. This can be particularly beneficial on previously developed or urban sites, where substructure costs are a significant proportion of overall building costs.
- Prefabrication** Aside from the obvious speed of works on-site, a major advantage of prefabrication is the reduced/lack of wet trades on-site. This dry construction method eliminates dust or other pollution which could contaminate produce or stock stored in an existing facility. This ability to construct without risk of contamination is essential when extending existing facilities.

Industrial Cost Comparison

Costing a distribution warehouse in Stoke-on-Trent

The building used for the cost model is a distribution warehouse on ProLogis Park in Stoke-on-Trent.

The building's key features are:

- Warehouse: four-span, steel portal frame, with a net internal floor area of 34,000m²
- Office: 1,400m², two-storey office wing with a braced steel frame with columns.

This building was part of the Target Zero study conducted by a consortium of organisations including Tata Steel, Aecom, SCI, Cyril Sweett and BCSA in 2010 to provide guidance on the design and construction of sustainable, low and zero carbon buildings in the UK. This cost comparison updates the cost models developed for the Target Zero project and provides up-to-date costs at Q3 2023 for the three alternative framing solutions considered.

ABOUT THE BUILDING

The building on which the warehouse research was based was the DC3 distribution warehouse on ProLogis Park, Stoke-on-Trent. The distribution

warehouse was completed in December 2007 and was at the time leased to a large UK retailer.

The net internal floor area of the warehouse is 34,000m². Attached to the warehouse is a two-storey office wing providing 1,400m² of space.

The warehouse structure is a four-span, steel portal frame. Each span is 35m with a duo-pitch, lightweight roof supported on cold rolled steel purlins. The facade columns are at 8m centres and internal columns at 16m. The primary steel beams support the intermediate rafters. The office structure is a braced steel frame with columns on a 7.3m x 6.4m grid. The first floor comprises precast concrete units. The warehouse and office buildings are clad in steel built-up systems and the warehouse roof has 15% rooflights. The building is supported on concrete pad foundations.

COST COMPARISON

Three frame options were considered to establish the optimum solution for the building, as follows:

- The base option – a steel portal frame

with a simple roof solution

- Option 1 – a hybrid option, consisting of precast concrete columns and glulam beams with timber rafters
- Option 2 – a steel portal frame with a northlight roof solution.

The steel portal frame option provides the optimum build value at £920/m², with the glulam option being the least cost-efficient. This is primarily due to the cost premium for the structural members required to provide the required spans, which are otherwise efficiently catered for in the steelwork solution. The consequence of having a hybrid option is that the component elements are from different suppliers, which contributes to the increases in cost.

The northlights option is directly comparable with the portal frame in relation to the warehouse and office frame; the variance is in the roof framing. There is significantly more roof framing to form the northlights. The additional costs beyond the frame are related to the glazing of the northlights and the overall increase in relative roof area. Overall, the steel portal frame option efficiently



Distribution warehouse on ProLogis Park in Stoke-on-Trent

satisfied the brief from both cost and time perspectives.

EMBODIED CARBON COMPARISON

The original Target Zero project also included a comparison of the embodied carbon of the three framing solutions. This was on a “cradle-to-cradle” basis that included the manufacture and transport of construction materials, the construction process and the demolition and disposal of the building materials at end-of-life.

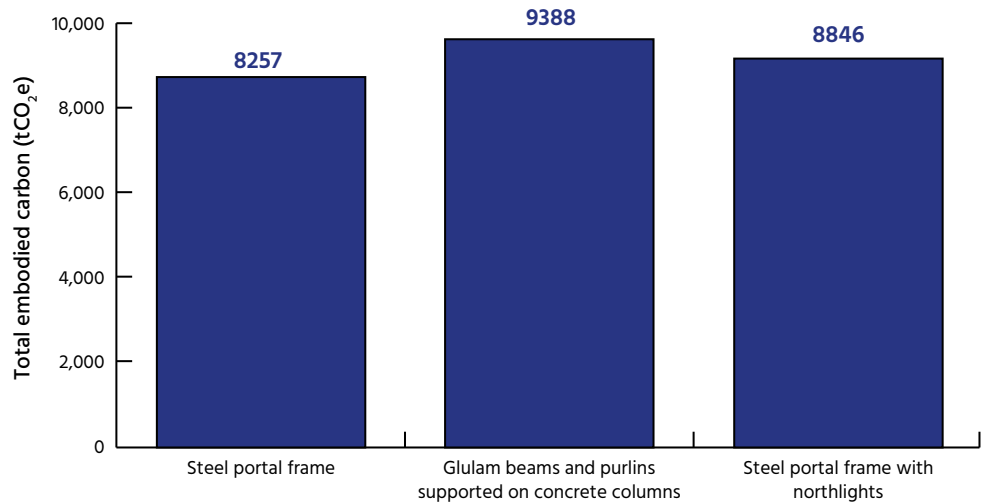
The results, which are presented in figure 9, show the total embodied carbon impact of the base-case warehouse building and the two alternative structural options studied. Relative to the base case, the concrete/glulam structure (option 1) has a higher (14%) embodied carbon impact and the steel portal frame with northlights (option 2) has a 7% greater impact.

Normalising the data to the total floor area of the building gives the following embodied carbon emissions of 234, 266 and 251kgCO₂e/m² for the base case and structural options 1 and 2 respectively.

Figure 8: Key costs £/m² (GIFA), for Stoke-on-Trent distribution warehouse

Elements	Steel portal frame	Glulam beams and purlins supported on concrete columns	Steel portal frame with northlights
Warehouse	123	187	143
Office	188	227	188
Total frame	127	189	145
Total building	920	995	964

Figure 9: Embodied carbon comparison



Distribution warehouse on ProLogis Park in Stoke-on-Trent

Retail

Key cost drivers

The standard cost considerations of logistics, building form, fire protection levels and erection are still relevant to retail buildings. Other key cost drivers for retail buildings include:

ADAPTABILITY

When designing a retail building it is important to realise that the building's day one requirements are likely to change over time. There is a continual need for retailers and their buildings to remain relevant and to be able to respond faster and faster to the changing requirements of the customer, who is increasingly using online retail and omni-channels to shop. The fast-paced, changing nature of retail means that buildings need to be easily adaptable to accommodate tenants' changing requirements, with retail boxes easily transformed into different types of offer such as pop ups, "box park" type offers/exhibitions and public uses.

LOCATION

Considering location, catchment/demographic and access is important, as these remain key drivers when reviewing potential sites. It is rare that the perfect site exists, so there is a need to determine how a retail development can be accommodated. This may well form part of a new regeneration of an area or working around sites that are constrained.

MIXED-USE

Developers need to provide the correct mix to attract customers, with brand recognition becoming more important



Block 1 of The Moor shopping centre, Sheffield, being erected

both in terms of customers and other retailers. The context of new retail is frequently taken into account, with wider developments being important; these can be developing new destinations and/or regenerating areas. Even in retail-led schemes it is not uncommon for the retail to form part of a larger building with residential and/or office space above. In these hybrid/mixed-use buildings the structure and cores associated with the other uses need to be factored into the retail design through positioning and transfers in order to avoid compromising the retail sales area.

ENVIRONMENT AND PUBLIC REALM

The areas surrounding the building are becoming an increasingly important consideration, as they serve to attract customers and give the centres a sense of place. There is a strong push towards place-making on retail-led schemes. The prominent front door to the building needs to be complemented by a public realm that sets the tone for the development as a whole. The integration of the building with the wider public realm and infrastructure provides a challenge for the design of the building and how this is interpreted.

Key cost advantages of steel framing for retail buildings

- **Flexibility** While other frame solutions can offer a level of flexibility, which is usually incorporated in the base build to suit known changes that will occur at a later stage, a steel frame can offer more flexibility and is also more readily adaptable than other frame solutions. In particular a steel frame can easily accommodate late, unforeseen changes which are common in retail as tenants' needs change.
- **Offsite manufacture** The majority of components of the steel frame can be manufactured offsite. This mitigates programme risk as materials can be stockpiled ready for incorporation into the building. The reduced erection time on-site is a clear benefit and can facilitate earlier handover of areas for fit-out. This allows certainty of overall timescales, which has time, cost and flexibility benefits, although the client should be aware this may require earlier engagement with the supply chain.
- **Programme certainty** The criticality of opening dates makes time the priority on a large number of projects. While the steel frame erection can be carried out in a reduced period, the project could have sustained delays during earlier activities. Should delays be incurred, then there needs to be a review of what mitigation measures can be undertaken. Steel erection being a dry activity involving the assembly of components means there are no curing periods that need to be taken into account, and therefore acceleration measures can readily be taken into consideration. This could be achieved by introducing a back shift or other out-of-hours works to erect components that have been stockpiled ready for incorporation.
- **Restrictive and existing sites** Steel is particularly relevant to projects requiring an extension to existing buildings and/or the development of additional buildings as a result of its being prefabricated. A key advantage of steel is that it arrives on-site prefabricated – which, in conjunction with the speed of erection, limits the amount of disruptive time to the adjacent buildings

PROGRAMMING

Speed of erection is a key consideration. The tendency is to adopt methods that allow for a quick turn around on-site, and it is important to ensure certainty of programme. When planning retail projects there are key periods in the year when the doors need to be open.

The major window for sales is the Christmas period including the pre- and post-sales events in November and January. Having an opening date in February is not beneficial. The optimum times for an opening would be September or October; the store is then fully operational with any defects resolved by the stage at which the main retail period starts. Each individual retailer's exposure to different markets can vary this time period. As well as taking the fully operational/doors-open date into consideration, retailers need to factor in the fit-out of the building/unit, staff training and soft openings. Sufficient time needs to be allowed post-completion of the building shell for these activities when determining the practical completion date for the shell/building works.

Due to the critical nature of the retail seasons, offsite manufacturing or other methods of construction should be considered to ensure the milestone programme dates are met.

SITE CONFIGURATION

Site configuration will impact on the building design in a number of areas, including floorplate configuration, grid and building height. It can therefore also be a key consideration when estimating the structural frame cost of a building. While it is preferred to have all the building uses on a single floor, it is not always possible to have such an unrestricted site. Consequently it is often necessary to spread the functions over several storeys.

Constrained sites have an associated cost impact in terms of both site logistics and a longer programme attracting higher costs for preliminaries. A more repetitive structure will be more cost-efficient both in terms of material cost and on-site erection, so the extent to which a proposed building utilises repetition in its design influences the cost planning.

MARKET INFLUENCES

External factors such as currency exchange rates, buoyancy of the market, labour availability and commodity prices all influence market dynamics, and should therefore be considered at the time of developing the estimate/cost plan. It is advisable to always include exchange rates in the basis and assumptions of the cost document.

INTERNAL SPACE REQUIREMENTS

The preferred design is to have limited interruptions to the sales area of the building; this leads towards large, column-free spaces. When dealing with standalone buildings this is relatively easy to accommodate; however, when considered against the requirements of a mixed-use building there are the added complications of structural loads, frame layouts and associated structural transfer costs and practicalities to be dealt with, whilst maintaining the integrity of the retail concepts.

Retail

Cost Comparison

Costing a supermarket in Stockton-on-Tees



The Asda store in Stockton-on-Tees

The building used for the cost model is an Asda food store in Stockton-on-Tees, Cleveland. The building's key features are:

- Total floor area of 9,393m²
- Retail area based on 12m × 12m structural grid.

This building was part of the Target Zero study conducted by a consortium of organisations including Tata Steel, Aecom, SCI, Cyril Sweett and BCSA in 2010 to provide guidance on the design and construction of sustainable, low- and zero-carbon buildings in the UK. This cost comparison updates the cost models developed for the Target Zero project and provides up-to-date costs at Q3 2023 for the three alternative framing solutions considered.

ABOUT THE BUILDING

The building on which the supermarket research was based is an Asda food store in Stockton-on-Tees. This supermarket, built adjacent to the site of a former Asda store, was completed in May 2008.

The building's total floor area of 9,393m² is arranged over two levels. The retail floor area, which includes a 1,910m² mezzanine level, is 5,731m². The remaining (back-of-house) accommodation includes offices, warehousing, cold storage, a bakery and a staff cafeteria.

The retail area is based on a 12m × 12m structural grid. Back-of-house, the grid reduces to a 6m × 12m grid increasing to a 16m × 16m grid in

the warehouse area, at the rear of the building.

The base case and chosen solution for the supermarket is a steel frame supported on CFA concrete piles and a suspended concrete ground floor slab. The roof is a mono-pitch, aluminium standing-seam system; external walls are clad with steel-faced composite panels. Windows and the main entrance elevation comprise aluminium curtain walling with argon-filled double glazing.

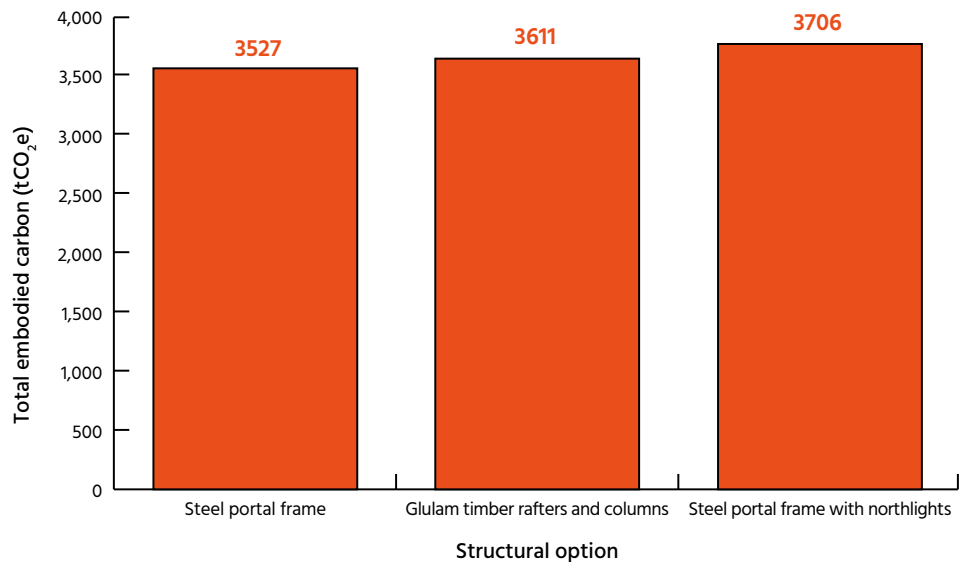
The upper floor (back-of-house) comprises structural metal decking supporting in-situ concrete. The retail mezzanine floor comprises plywood boarding on cold-rolled steel joists. The building is oriented with the glazed



Figure 10:
Key costs £/m² (GIFA), for Stockton on Tees food store

Elements	Steel portal frame	Glulam timber rafters and columns	Steel portal frame with northlights
Structural unit cost	185	233	209
Total building unit cost	3345	3401	3358

Figure 11:
Embodied carbon comparison



front facade and store entrance shown facing north-west.

COST COMPARISON

Three frame options were considered to establish the optimum solution for the building, as follows:

- Base option – a steel portal frame on CFA piles
- Option 1 – glulam timber rafters and columns on CFA piles
- Option 2 – a steel portal frame with a northlight roof solution on driven steel piles.

The steel portal frame option provides the optimum build value at £3,345/m², with the glulam option the least cost-efficient. The increased costs is due to the direct comparison

of the steel frame solution against the glulam columns and beams/rafters. A significant proportion of the cost for the building is in the M&E services and fit-out elements, which effectively reduce the impact of the structural changes to the overall building.

The northlights option is directly comparable with the portal frame in relation to the main supermarket; the variance is in the roof framing as there is significantly more roof framing to form the northlights. The additional costs beyond the frame are related to the glazing of the northlights and the overall increase in relative roof area. The main benefit of this option would be the increased natural light provision and added natural ventilation flexibility.

EMBODIED CARBON COMPARISON

Figure 11 shows the total embodied carbon impact of the base case supermarket building and the two alternative structural options studied. Relative to the base case, the glulam structure (Option 1) has a 2.4% higher embodied carbon impact and the steel frame with northlights (Option 2) has a 5% higher impact.

Normalising the data to the total floor area of the building gives the following embodied carbon emissions of 376, 384 and 395kgCO₂e/m² for the base case and structural Options 1 and 2 respectively.

Mixed-use Key cost drivers

Mixed-use buildings are unique in composition. The mix of uses in a single building creates a series of integration issues from structural, services and aesthetic perspectives. The term 'mixed-use' does not narrow down the building type but refers to hybrid buildings with any number of combinations. Each have their challenges, but all mixed-use buildings have common key cost drivers and issues:



Lime Street regeneration in Liverpool: a mixed-use scheme consisting of student accommodation, a hotel and retail/leisure

STACKING BUILDING USES

A key consideration is how the different uses are stacked within a building. In some instances there are multiple uses within a single building, such as the Shard, which has the building types stacked on top of each other (offices, hotel, residential and public gallery). By comparison, buildings such as MediaCityUK are more akin to a campus, with the different uses coming off an integrated podium.

STRUCTURAL ALIGNMENT

The layout and structural grid will vary between building types; this is driven by necessity in many instances. The preference for large retail units or supermarkets is to have a large, open-plan space with limited or no visual interruptions. This can be compared against residential developments which have an efficient frame set out against apartment sizes and layouts. When the structural grids are not compatible it is necessary to consider transfer structures to allow the transition from one building type to another. It is possible

in some cases to deal with the transfers within the depth of the transitional slab. However, this is not always the case and a deeper transfer structure might need to be considered depending on the extent of the loads: this may have to occur over several storeys.

When a transfer structure is required it is important to understand the optimum solution. The initial approach should be to determine whether, through compromise or slight adjustments to the grid, if the transfer can be eliminated. Where it is not possible to avoid transfers, careful consideration needs to be taken to determine which solution works practically, while still maintaining servicing zones and aesthetic considerations.

CORE OPTIONS

Where building types do not naturally stack on top of each other, the type of core and the servicing strategy of the building are key areas of consideration. In the case of large, open-plan spaces at the base or podium level of a building

with alternative uses above, it is often advantageous to transfer out the core at the lower levels. Structurally it is possible to achieve this using a braced steel core, which is easier to drop out than a concrete core. The issue arises when the fire, vertical transportation and services strategies of the building are considered. There are key elements within the building which must run from ground level up through the building above; these include fire escapes, lifts and primary services and risers. It is possible to introduce offsets but not possible to eliminate them in their entirety.

How the functional aspects of the upper-building types are dealt with are key cost drivers, as there are various ways of addressing the issue particularly where offset options can be considered.

LEVEL OF FLEXIBILITY

When designing mixed-use buildings, developing a solution that can be adapted to the ultimate building uses is key. It is therefore important to establish the uses that are required and,

Key cost advantages of steel framing for mixed-use buildings

- **Column-free floorplates** Steel framing is an economic means of providing long spans without the requirement for intermediate columns, thus creating increased open-plan spaces which are advantageous to adapting to various structural grids. This in turn reduces potential elements that would otherwise need to be transferred.
- **Offsite manufacture** There are invariably an increased number of uniquely framed floors, which are commonly a trait in mixed-use buildings. These floors will have a framing solution that differs from the regular floorplates. The approach to these floors needs to be planned to ensure that the detailing and site construction can be undertaken without any delays or issues arising. Complex interfaces can also be designed and fabricated with any issues having been dealt with prior to the components arriving on-site. Additionally, it allows unique floors and transfers to be set out and in extreme cases test fitted before arrival to site.
- **Site constraints** Steel-framed solutions allow sites that might be deemed too difficult for development to be considered.

An example of this is rail infrastructure over site developments (OSDs). This is of particular interest when evaluating mixed-use developments, due to the variety of building uses that could be considered. The direct links these sites have with public transport and increased footfall will have particular benefits to retail uses. However, retail use in isolation might not be sufficient to warrant the expense incurred in building over a station, therefore the ability to be able to consider multiple uses makes this option more viable. It would be difficult to realise these development opportunities without the use of structural steelwork.

- **Services integration** Steelwork through its adaptability and framing form allows for ease of services integration and co-ordination throughout the building. The integration of services within the structural elements of buildings leads to economies by reducing the floor-to-floor height, which has the double benefit of reducing the external cladding required and also reducing heat loss through the envelope. In multi-storey buildings, service integration can allow extra floors to be provided

within the same overall building height. Additionally, the transfer structure can be framed and accommodated with trusses which are not continuous solid barriers, thus allowing services to pass through the structural zones.

- **Lightweight** The reduced weight of a steel-framed building has a beneficial effect on the structure and foundation by which the building is supported. Structural steel permits the upper building types to be constructed over restricted load areas, such as railway station boxes and transfer structures, where this otherwise might not be possible. Another benefit is that it allows the upper levels to be hung from the roof, thereby divorcing the structural dependency and reliance of the differing building uses throughout the building.
- **Programme** The use of a steel frame can also assist in meeting and even reducing construction programmes. With so much work carried out offsite, the on-site construction programme is reduced and the build programme is relatively unaffected by adverse weather conditions. Additionally, the impact of steel-based construction on local communities is minimised by the relatively short building programme, minimal site deliveries and the dry, dust-free and comparatively quiet construction process.

following this, decide how best to place or stack these uses. Another question is whether the site is sufficient to place areas of large-span or open spaces adjacent to the main building stack: typically this applies to leisure, retail and entertainment venues as opposed to smaller grid uses such as residential. Having this level of flexibility is essential if major issues with transfer structure and MEP servicing are to be avoided.

SECURITY, FIRE AND ACOUSTIC REQUIREMENTS

Different building uses will be required to meet different security, fire and acoustic criteria. In addition to the specific criteria for the individual uses, there are further requirements where the building transitions from one use to another.

At the transition points and levels there is a requirement for full separation from a security, fire and acoustic perspective.

How this separation is achieved can be a significant cost driver; the level of

separation is driven by which building uses sit adjacent to each other. The context of what is above the lower levels needs to be taken into consideration. Key structural requirements such as preventing progressive collapse may require the additional structure to be accommodated at the lower levels. The risk of transferring out a large proportion of the structural grid puts pressure on the remaining columns at ground-floor level – this is not a risk for single-storey or low-rise versions of the ground-floor use such as retail or leisure. However, they have a major impact on the potential high-rise or multiple-storey building that sits above.

SERVICE INTEGRATION

There is added services co-ordination required when considering mixed-use buildings. The requirements of the other uses contained within the building need to be factored into the space planning of each building use. Where possible, it is advantageous to align uses so that commonality of requirements can be

incorporated without adverse impacts. Connectivity of services is an important consideration, which invariably leads to larger ducts needing to be factored into the design in addition to what servicing is required for each of the uses.

For example, kitchen extraction ducts need to be taken to the highest point of a building: therefore when placing a tower over a restaurant it will result in fire-rated ductwork taken from the base of the building to the roof. Where the plant is positioned is important; should all the plant be housed in the basement or on the roof the servicing for all the use types needs to be accommodated into the risers, which has a knock-on effect to services distribution and riser sizes. Both options will have their own associated cost implications.

A benefit of mixed-use is that the different uses have different peak load times. Residential peak loads are early morning and evening, whereas offices peak during daytime working hours. This allows efficiencies in plant sizing and heat recovery.

Mixed-use Cost Comparison



Costing a mixed-use hotel and office building in Manchester

The building used for the cost model is the Holiday Inn tower located in MediaCityUK, Manchester. Phase one of MediaCityUK started in 2007 and completed in 2011.

The 17-storey Holiday Inn tower attached to the main studio building was part of the Target Zero study conducted by a consortium of organisations including Tata Steel, Aecom, SCI, Cyril Sweett and BCSA in 2010 to provide guidance on the design and construction of sustainable, low- and zero-carbon buildings in the UK. This cost comparison updates the costs for models developed for the Target Zero project and provides up-to-date costs at Q3 2023 for the three alternative framing solutions considered.

ABOUT THE BUILDING

The 17-storey Holiday Inn tower is

attached to the main studio building at ground-floor, mezzanine and first-floor levels. An atrium connects the office floors of the tower block to the studio block (floors two to six).

The building accommodates 7,153m² of open-plan office space on five floors (floors two to six) and 9,265m² of hotel space on eight floors (floors eight to 15). The ground and mezzanine floors accommodate the hotel reception and a restaurant. Floor seven houses plant for the office floors and Floor 16 houses plant serving the hotel.

The gross internal floor area of the building is 18,625m². The 67m-high building is rectilinear with approximate dimensions of 74m × 15.3m.

The building has a steel frame structure with Slimdek floors. The steel columns are located on a 6.35m × 2.6m × 6.35m grid spaced at 7.5m. Two

concrete cores, one at each extremity of the building, provide the stability of the tower as well as housing the risers and lifts. The foundations are 750mm-diameter CFA concrete piles.

COST COMPARISON

Three frame options were considered to establish the optimum solution for the building, as follows:

- Base option – steel frame with Slimdek floors
- Option 1 – concrete flat slab
- Option 2 – composite deck on cellular beams (offices) and UCs used as beams (hotel).

The steel frame with composite deck provides the optimum build value at £3,431/m².

However, it is important to note some project-specific factors influencing the decision to use a Slimdek solution for the actual,

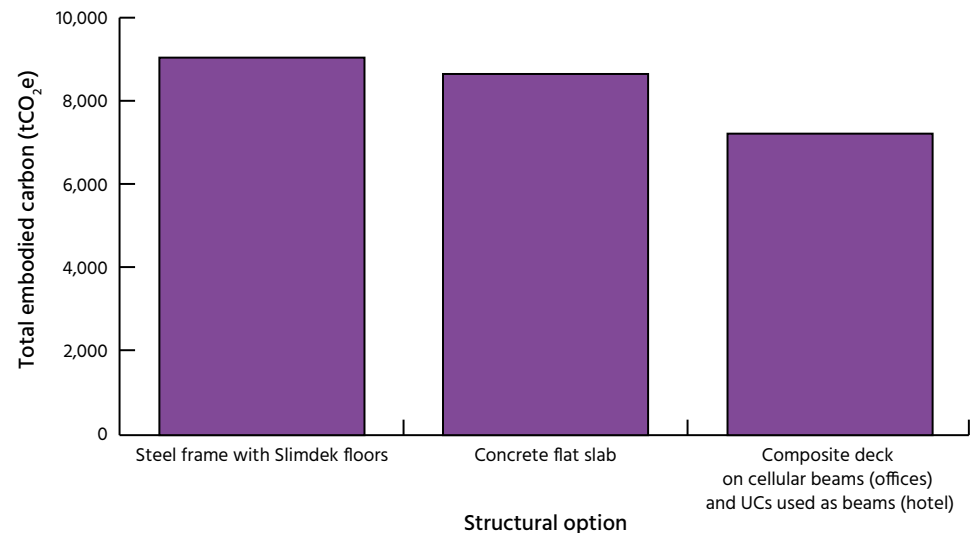


MediaCityUK in Manchester

Figure 12: Key costs £/m² (GIFA), for hotel/office building in Manchester

Elements	Steel frame with Slimdek floors	Concrete flat slab	Composite deck on cellular beams (offices) and UCs used as beams (hotel)
Structural unit cost	688	500	470
Total building unit cost	3705	3492	3431

Figure 13: Embodied carbon comparison



and hence the base case, building structure. The Holiday Inn tower building is connected to an adjacent studio block between floors one and seven. The long-span requirements for the studio could only be achieved using steel and therefore it was preferable to use a steel structure for the tower block to facilitate the integration of the two structures. Speed of construction was also important for the tower block, and this integration gave programme benefits relative to concrete solutions.

The mixed-use tower block was originally designed with the lower floors as residential accommodation. Key design considerations for the hotel/residential tower block were floor depth and acoustic performance, and hence a Slimdek design was chosen. It was not possible to achieve the required

floor depths using a cellular steel beam solution with downstands. The decision to change the residential accommodation to office floors was taken only at a very late stage of the project; this, coupled with the time constraints for the project, precluded redesign of the tower block and hence the original Slimdek design was constructed.

The base case building structure is therefore a relatively unusual solution reflecting the constraints imposed by the wider MediaCityUK development and Options 1 and 2 are arguably more typical solutions for a building of this type.

EMBODIED CARBON COMPARISON

The original Target Zero project also included a comparison of the embodied carbon of the three framing solutions.

This was on a ‘cradle-to-cradle’ basis that included the manufacture and transport of construction materials, the construction process and the demolition and disposal of the building materials at the end-of-life.

The results, which are presented in figure 13, show the total embodied carbon impact of the steel frame with Slimdek floors (Base case) and the two alternative structural options studied. Relative to the Base case, the concrete flat slab (Option 1) has a 2.8% lower embodied carbon impact and the steel composite frame (Option 2) has a 17.8% lower impact.

Normalising the data to the total floor area of the building gives the following embodied carbon emissions of 480, 467 and 395kgCO₂e/m² for the Slimdek solution, the concrete flat slab solution, and the steel composite solution respectively.



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