

Out of Thin Air

Building above
London's rail lines



wsp

Contents

Executive Summary	3
Background	4
Why we should build above rail infrastructure	5
How much land might be available for development?	8
Making housing out of thin air a reality	10
12 benefits of rail overbuild	14
WSP project case studies	15

Executive summary

Everybody knows that we need more housing. The issue is where do we put it? London needs 50,000 new homes every year until 2025 just to keep up with housing demand. Yet between April 2016 and March 2017 only 6,423 homes (affordable and open market) were completed. Making up the shortfall therefore demands inventive approaches to development.

Rail Overbuild offers a way forward to address the pressing shortage of housing that exists in London.

We have identified sufficient land associated with railway infrastructure to yield more than a quarter of a million new homes in London. Put into perspective, that is around five times the annual minimum needed by the capital.

How did we arrive at the figure of 250,000 homes possible above London's rail lines (p8)? It's a conservative figure based on the assumption that of all land identified, only 10% is actually developed. This number refers to construction directly above rail lines, but could increase even further if it unlocks and connects to further developments adjacent to rail lines or above a station (page 15).

A previous WSP report focused on general 'overbuild' involving better land utilisation by creating new residential accommodation above existing public buildings. Here we put the case for rail overbuild and the societal benefits that can accrue from creating new residential accommodation by decking over new and existing railway infrastructure, which can include rail/underground tracks and also stations. This sort of overbuild is now being seen as increasingly viable and attractive.

The title – Out of Thin Air – alludes to a critical feature: no new land is required. These brownfield developments can be undertaken where planning controls allow building over the rail environment.

But this is much more than simply an exercise in creating housing, or even retail or office space. It is also about a sustainable vision of urban improvement that results in vibrant, connected communities; it is about developments that are infused with urban authenticity, where people aspire to live and which add value to surrounding areas.

And like all visions it looks to the future. A vision that achieves not less, but more densification in urban centres by creating pedestrian-orientated communities that will make city living a far more gratifying experience. To advance this vision, we discuss how overbuild can be achieved, its benefits and some of the underlying technical issues.

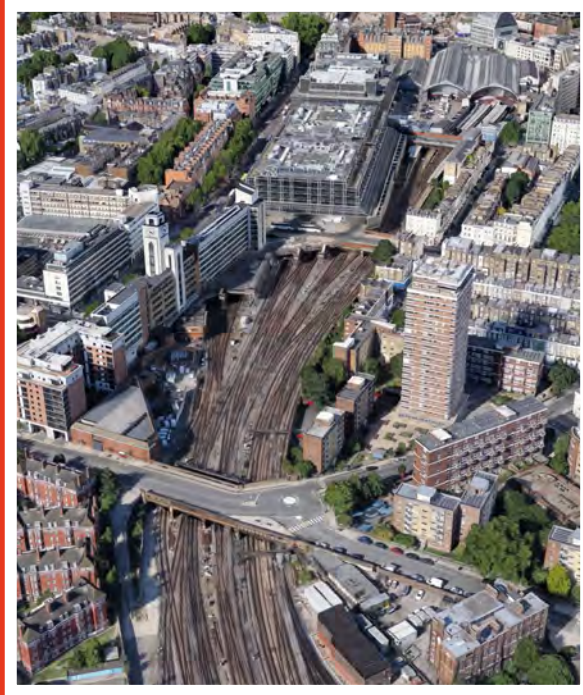
Compared to building major infrastructure projects, rail overbuild could be a quicker and less costly way to unlock large housing schemes. However, we also recognise and support the need for major infrastructure growth in the UK, such as HS2 and Crossrail 2, as drivers for housing delivery. Rail overbuild can complement such schemes.

Cities are facing a crisis in managing population growth and housing provision. Associated issues of loneliness, alienation, mobility challenges, skills shortages and a lack of social amenities aggravate the situation.

Rail overbuild is a potential way to start addressing these issues. It can help increase the supply of housing, offices, retail, other social infrastructure, and even stadiums, as well as connecting previously divided communities. Existing projects show that the engineering is possible; we can start to deliver rail overbuild now.

Before/After

How rail overbuild might be implemented near a major rail terminal in Central London



Background

Our belief in the potential of rail overbuild to unlock housing in densely inhabited cities did not come out of thin air.

In 2012, Network Rail asked WSP to contribute its 40 years' global experience of rail overbuild to a feasibility study on its applicability for twin and four track scenarios in both flat and cutting situations. We were asked to challenge standards and innovate throughout.

The client encouraged our team to examine a very wide range of deck options including arches, prefabricated trusses, semi-mechanical swinging arrangements, and construction methodologies. The WSP study also considered different overbuild scenarios in terms of building type and height. Other factors including fire, acoustics, vibration, safety, possessions, and systems' impacts were also considered.

Our approach aligns with Greater London Authority (GLA) recommendations, which advise London boroughs to 'identify and seek to enable additional development capacity' to supplement housing targets. In particular, the GLA recommends the realisation of brownfield housing capacity via intensification; town centre renewal and mixed use development (especially of surplus commercial capacity and spare public land, particularly that with good transport accessibility)¹.

Our work can also be seen as complementing the current London Plan – the Mayor's spatial development strategy – which provides a framework for the boroughs and highlights housing, transport, economic development and environment. The Plan recognises that rail lines can form barriers to movement within sites and can be used to knit the development into the surrounding area. Building over railway tracks can provide opportunities to address existing constraints.

In some cases, such as in the example on this page at Victoria, "the station, the airspace above its tracks and approaches, and nearby sites have significant potential for mixed use intensification, capitalising on enhancement to the public transport interchange and improvements to accessibility and capacity"². According to the Plan, a minimum of 1,000 new homes can be provided at Victoria.

We hope this paper goes some way to explaining just how feasible and fruitful rail over-site developments can be. For building upon existing facilities can not only provide much-needed housing but can also regenerate cities and provide benefits to developers, landlords and society as a whole.



Bill Price
Strategic Growth Director
WSP

Why we should build above rail infrastructure

Housing continues to be one of London's most intractable problems. Even by the government's own admission, our housing market is broken³.

Yet despite this, London continues to be a highly attractive place to live and work. Since 2000, London's population has grown by around 95,000 every year on average and by more than 100,000 every year since 2008/2009⁴.

Housed far from their workplace, Londoners often face a long, daily commute. This is not only stressful but also creates more overcrowding on an increasingly pressurised and fragile transport system.

Building above railway infrastructure offers a more creative use of land. It also fully aligns with the three key themes running through the Mayor's Draft Transport Strategy⁵, which emphasises:

1. Healthy streets and healthy people;
2. A good public transport experience, and
3. New homes and jobs.

Rail overbuild can allow more people to live in the city; tube and/or rail services will be close by and so using public transport will be a better experience. Indeed, these developments should have very favourable public transport accessibility levels (PTAL). Proximity to stations may also mean residents choose to forego car ownership. Fewer cars on the streets (less congestion and lower emissions) could prompt residents to walk and cycle more, especially if new developments have cycle storage. These factors will contribute to the healthier streets and lifestyles envisaged by the Mayor.

As well as contributing to greater public transport use, car-free zones and more walking and cycling, rail overbuilds can provide a pleasant environment supporting new homes and jobs, especially as the development unlocks growth in the immediate vicinity.

Such a strategy could provide some of the housing and healthier environments that London needs.

³ Department for Communities and Local Government, Fixing Our Broken Housing Market, February 2017

⁴ GLA Economics, Economic Evidence Base for London 2016,

⁵ Mayor's Transport Strategy, draft for public consultation, June 2017

¹ GLA: The London Plan, Ch 3, London's People, Policy 3.3 Increasing the Housing Supply
² The London Plan March 2016, p373



CGI of 12-storey building above rail lines in West London

Housing deficit data

The capital needs 50,000 new homes to be constructed every year till 2025 just to keep up with projected housing demand. Yet between April 2016 and March 2017, only 6,423 homes (affordable and open market) were completed⁶. Making up the shortfall demands more innovative approaches to development.

Creating more homes in the city centre has been an ongoing process – since 2001, 90% of homes in London have been built within 1km of a station. In 2013, the former Mayor of London's New Draft Housing Strategy recommended that more homes could be delivered by increasing the density of new schemes (densification) and using infill developments. Part of the current Mayor's draft strategy⁷ to increase housing provision is to identify and bring forward more land for housing, supporting a more intensive use of London's available land. Rail overbuild complements such policies by creatively utilising 'land' and increasing the densification of urban areas.

Rail stations, (including connecting tracks and rail yards) sometimes occupy large tracts of land. Given their status as multi-modal interchanges with high passenger throughputs, they offer excellent opportunities for oversite developments.

A rail overbuild might involve building over a station, rail tracks and adjacent land. When it encompasses a broader area beyond the immediate station, it can unlock greater development potential. Like many landlords, owners of railway land

normally have air rights above their real estate which gives them the opportunity, subject to planning policy considerations, to develop above the facility. This prospect may be sold or leased to other parties.

Using air rights to create new developments above railway assets has many benefits, not least of which is that no new land is required. You are literally creating land 'out of thin air'. So housing over existing railway infrastructure can increase the availability of residential accommodation in the capital and help alleviate the current housing shortage.

Our suggested overbuild schemes comprise 12-storey developments that could equally be given over to residential or commercial purposes. These oversite developments could also form part of adjacent site developments (ASD) that create new communities, fuel economic growth and jobs, and generate revenue for both local authorities and land owners.

Rail overbuild should appeal to rail asset owners who seek to increase non-fare revenue by attracting residential, commercial, retail and leisure developments in, above and around their assets. Local authorities may also welcome such developments as a means to both reduce housing shortages and regenerate inner city areas. There are also the financial benefits that can accrue to a local authority in the form of community taxes, business rates, land value capture, Development Rights Auction Models (DRAM), community infrastructure levies and public realm benefits.

Before/After

What building above an Underground station in London might look like



Rail overbuild is not new

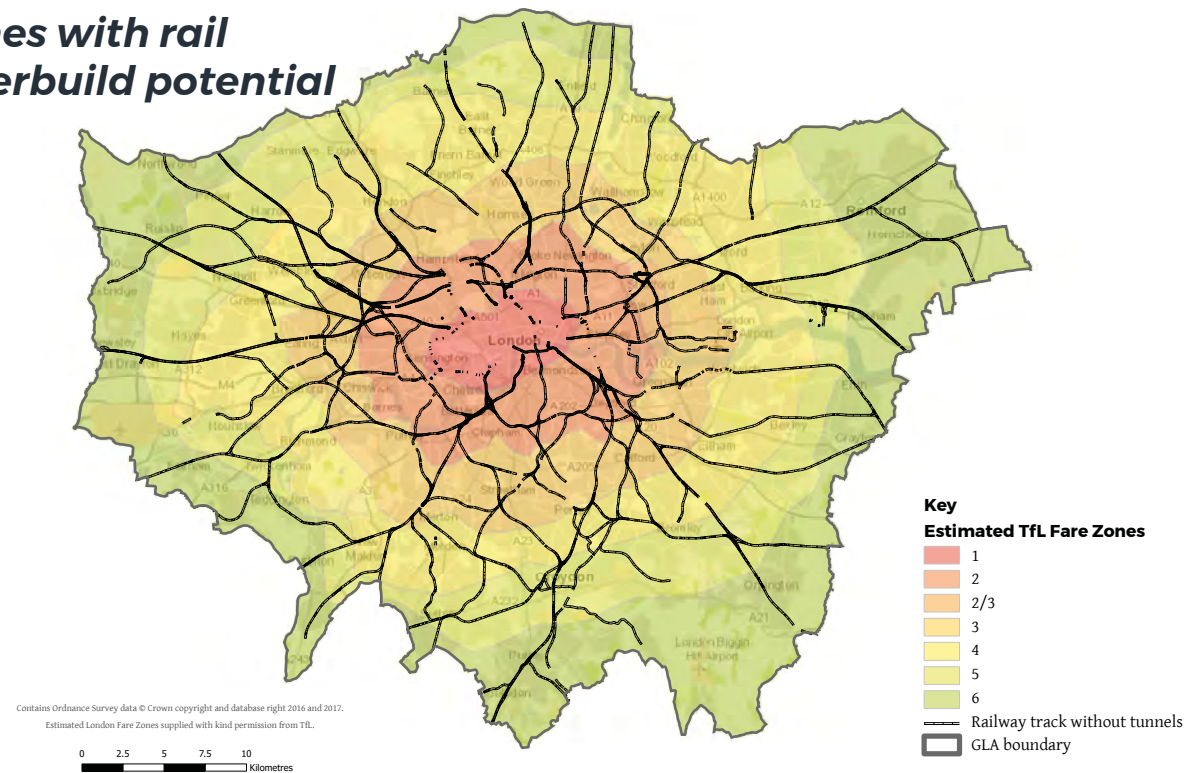
WSP has over 40 years' experience in designing rail overbuilds over challenging railway environments. This includes one of New York's first air-rights developments at Park Lane, where two 20-storey apartment buildings straddle the tracks.

Nearer home, technologically complex projects at Liverpool Street and Charing Cross stations completed in the 1980s and 90s significantly increased the value of the rail hubs and helped regenerate the respective areas.

The overbuild at Cannon Street (2011) exploited air rights to create a mixed-use development of offices and retail designed to unlock the commercial potential of the station and the surrounding area. The dramatic steel mega-structure spans and cantilevers over the railway, the Underground station and tracks.

Within such scenarios, the station – in addition to being a transport node – becomes an attractive retail and commercial destination in its own right.

Lines with rail
overbuild potential



How much land might be
available for development?

Using spatial analysis and mapping layers for Greater London’s untunnelled railway and tube lines, we identified exposed land areas and calculated the overbuild development potential. To generate a developable area we identified zones of 10m on both sides of the existing tracks. The analysis identified 1,142km of uncovered (i.e exposed) track in London. This was proportioned into borough potential as well as estimated TfL fare zones. Inner and Outer London zones have been defined as per the Office of National Statistics (ONS) definition.

The Ordnance Survey railway data allowed us to identify the following types of feature:

- Breaks in the tracks made by existing roads and bridges
- Breaks in the tracks made by tunnels
- Cuttings on the London Underground created by small stretches of untunnelled track
- Multi-tracks e.g. as at major stations, and
- National Rail, Overground and Underground tracks.

Calculating potential

To realise the number of residential units possible within the developments, we assumed apartments having an area of 100m². Of the railway land we identified as developable for overbuild, we assumed a conservative 10% could be developed for one reason or another. The homebuilding potential would be greatly increased if a higher percentage is adopted.

As a general and acceptable development target, we considered 12-storey developments to give our rail overbuild potential. This mid-rise figure is unlikely to be contentious from a planning and social viewpoint as it makes good use of land. However, we recognise that in Central London, where there is a greater preponderance of tall buildings, a rail overbuild could go much higher. In outer boroughs a lower height than 12 storeys may be appropriate.

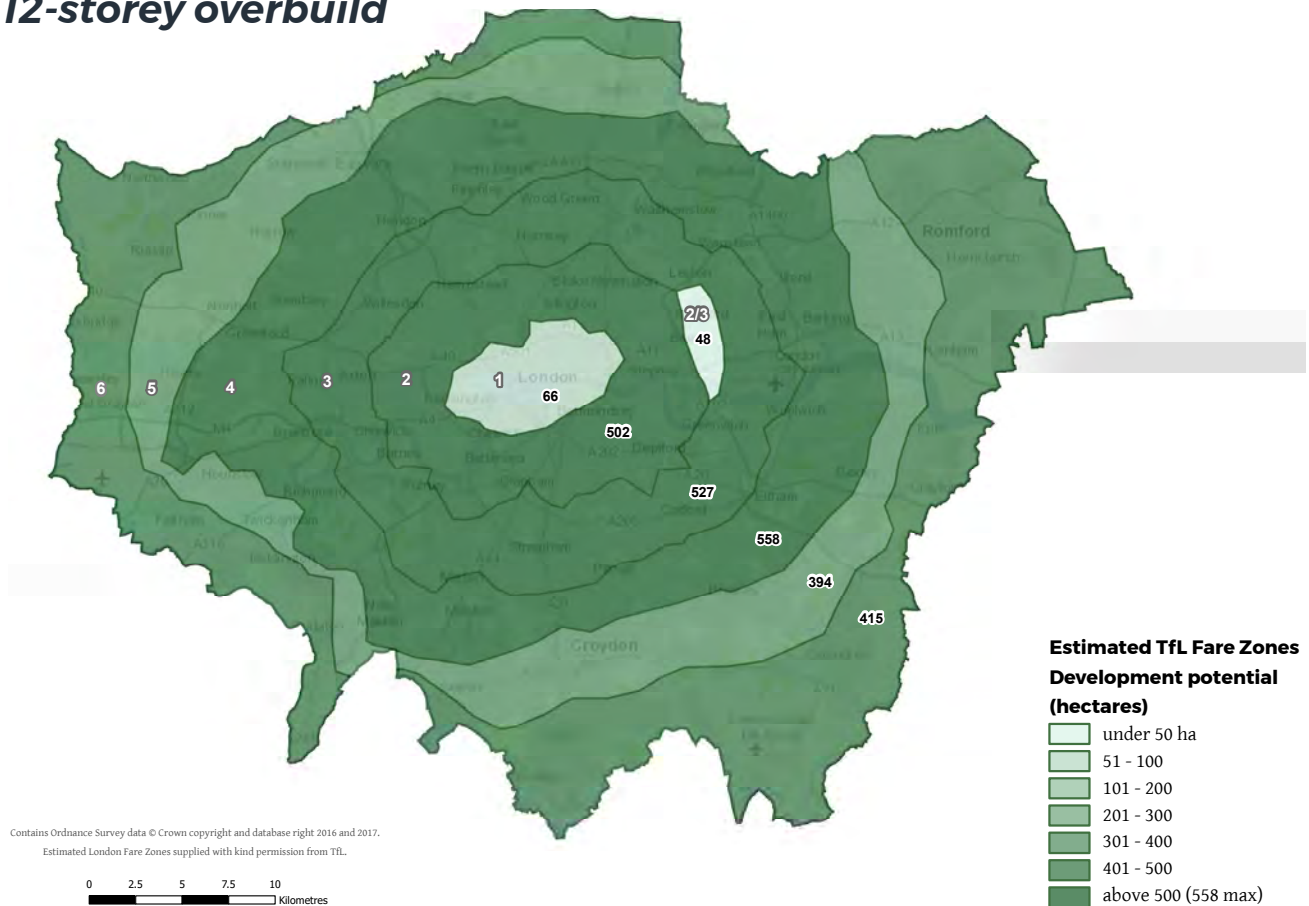
The amount of available land for development in hectares is shown opposite.

Estimated rail land by Borough
for 12-storey overbuild



Borough	Hectares
Brent	161
Ealing	154
Croydon	142
Bromley	127
Lewisham	115
Barnet	110
Newham	105
Wandsworth	93
Havering	86
Hillingdon	84
Enfield	82
Merton	74
Camden	74
Lambeth	71
Haringey	67
Harrow	66
Hounslow	66
Southwark	66
Hammersmith and Fulham	63
Richmond upon Thames	62
Waltham Forest	62
Barking and Dagenham	61
Bexley	58
Tower Hamlets	56
Greenwich	48
Kingston upon Thames	46
Sutton	45
Islington	37
Redbridge	36
Hackney	32
Westminster	21
Kensington and Chelsea	21
City of London	2

Estimated rail land by TfL Fare Zone
for 12-storey overbuild



Total homes potential

Based on borough boundaries, our total figure for Greater London came to 239,523 homes total.

In Inner London 82,324 homes are possible
In Outer London 157,199 homes are possible

Based on TfL fare zones, which includes areas outside Greater London.

Zones 1 - 6 250,969 homes are possible
Zones 1 + 2 56,836 homes are possible



Making housing out of thin air a reality

We have shown that building over the rail environment can yield around 250,000 new homes – that is around five times the annual minimum that London needs. Or to put it another way, five years' worth of housing. This number could be significantly higher if a smaller area per apartment was adopted. Ideas of this type have been advanced by some as a part-solution to the housing shortage.

But it's not just about creating new homes. It's also about creating new, safe, vibrant communities that provide greater transport mobility, reduce car ownership, and contribute to greenhouse gas emissions reductions. When an over-site development forms part of a wider adjacent site development, the societal effects can be spread over a wider area into the local community. More than that, such developments achieve the densification that London's local authorities can use as economic development tools to provide growth and jobs in the community. Ultimately, increasing the incidence of rail overbuild can contribute to making cities more liveable, more lively and more sustainable.

To create such a community above rail infrastructure requires certain engineering techniques and environmental considerations. Here we discuss those in more detail.

Creating a safe, healthy environment

Rail overbuilds can facilitate the Healthy Streets advocated by the Mayor and allow the minimum 20 minutes of Active Travel that will help Londoners stay healthy.

Quality of life will be further enhanced by architectural aesthetics, layout, lighting and materials, all of which will play a key role in determining whether such developments are attractive to live and work in.

Incorporating acoustic mitigation measures right from the start is critical to maximise comfort for residents, employees and other users of the development. And because poor air quality is a fact of life for the majority of urban developments, getting ventilation right is also important.

ACOUSTICS...the quiet life...

When designing in the railway environment, developments must take into account railway-induced ground-borne noise and vibrations, as well as airborne noise generated by trains.

Railway-induced ground-borne vibration entering a building can cause structure-borne noise which occurs when imperceptible levels of vibration set the building surfaces into motion. This produces a low-frequency audible rumble sound often causing human discomfort, annoyance and even sleep disturbance⁸. Vibration can also affect the operation of sensitive equipment that might be installed say, in healthcare facilities.

Recent years have seen great strides taken in assessing and predicting structure-borne noise and vibration. With the development of personalised numerical modelling techniques the range of uncertainty has been significantly reduced.

Today's computational techniques avoid blanket prescriptive measures, allow more effective forecasting of structure-borne noise and vibrations and enable less costly options to be explored. In

the past they would have been difficult to achieve economically.

Typically, achieving an adequate noise and vibration environment inside buildings can be met in part by:

- Adjusting the raft foundation design to minimise vibration transfer;
- Tuning the thickness and span of floorplates;
- Using specific construction materials to limit resonances within a structure;
- Segregating sensitive spaces from critical vibration-affected areas;
- Utilising 'room-in-room' (i.e. creating a floating room using springs and resilient pads), and
- Where necessary, using base isolation (i.e. springs or elastomeric bearings) to dynamically disconnect the superstructure from the base of the building.

Extreme low levels of vibration can be achieved but over engineering can impact costs. Therefore, a tailored assessment approach which takes into consideration the proposed building design and layout could identify specific cost-effective mitigation measures. Given that vibration levels tend to diminish as vibration propagates up the building, it makes sense to place residential accommodation up top, with commercial and retail units on the lower floors in a mixed-use scenario.

It should be remembered that railways generate different levels of noise and vibration. Variables involved include track drainage, ballast condition, track curvature, wheel profiles, speed, braking and freight, which will all vary over time. The overbuild should be designed to accommodate these.

Better exclusion of outside noise can be achieved by non-openable windows. In such a scenario, mechanical cooling can be used to prevent overheating of the internal environment.

Building the rail box

In 2012 Network Rail appointed WSP to undertake a generic feasibility study on rail overbuild. The output of the study yielded important conclusions in terms of buildability:

- **The rail box should be as compact as possible with walls constructed inside the rail impact zone:**

In a rail overbuild, the oversite development straddles the railway corridor. The reinforced concrete rail box allows the railway to function and maximises the development space above; the compact, short-span beams ensure deck costs are in better proportion to the overall development value.
- **Side walls of solid concrete are preferred to individual columns:**

Total enclosure provides improved acoustic isolation and better contains potential rail impact events.
- **Deck (horizontal structure) should be reinforced concrete to help address fire, robustness, and maintenance issues:**

The technical performance properties of reinforced concrete are well documented. But the material also offers opportunities for off-site manufacture which could bring significant savings in time, cost and buildability.
- **Vibration control should be addressed outside the rail enclosure and not as part of the base rail works:**

Measures to isolate noise and vibration are not part of the rail box construction (the realm of the rail authority) but part of the developer's

overbuild. Resolving such issues can be achieved satisfactorily using tried and tested materials and construction techniques.

- **Factors influencing development:**

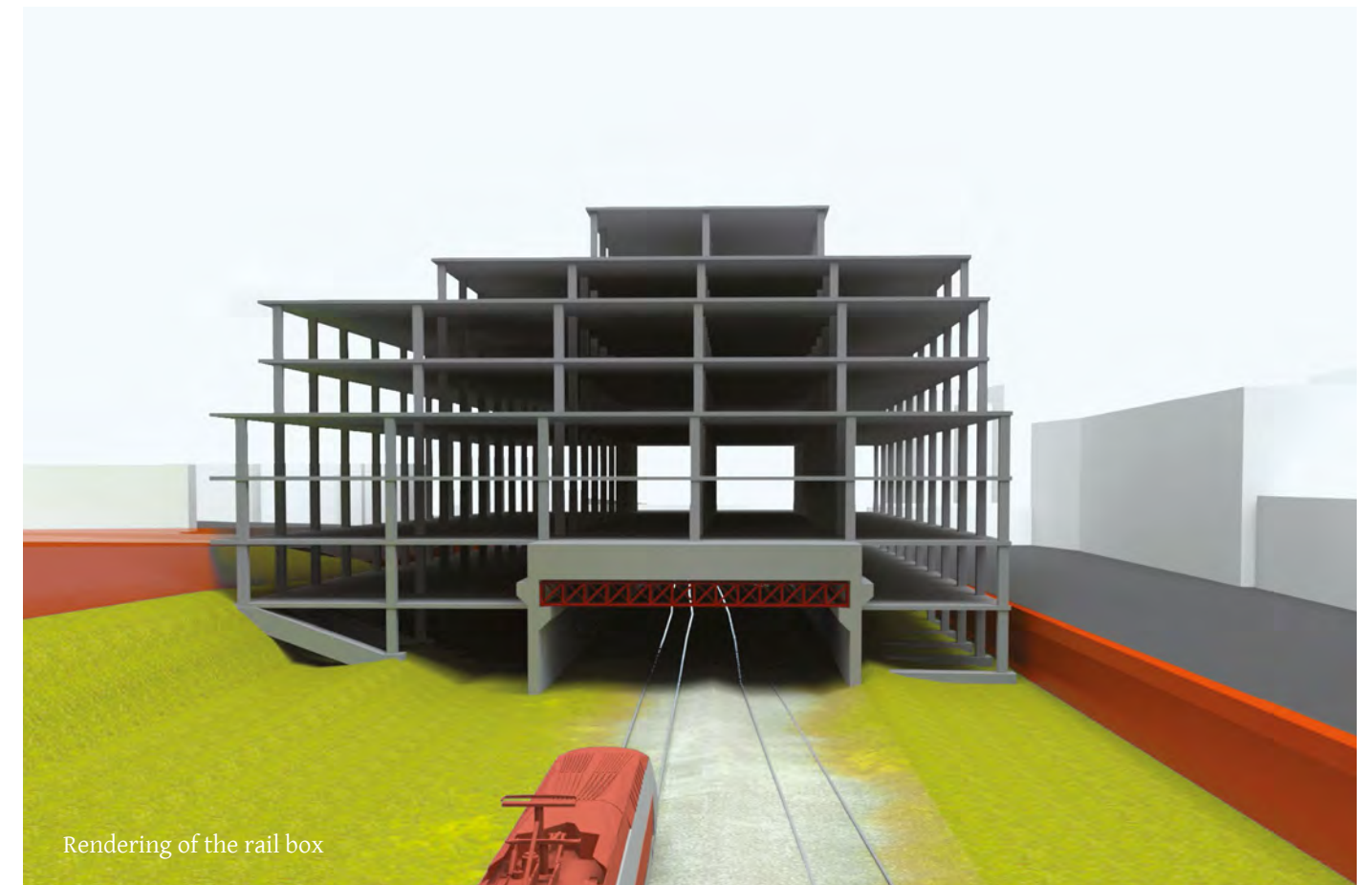
As with any commercial development, the success of a rail overbuild will be determined by the business case. Construction projects can fail for a variety of reasons, but success will be more likely if the following are resolved:

- **Decking over the railway.** Creating the box to envelop the rail corridor lies at the heart of an overbuild. However, decking costs can be high, depending on span and width. Costs will be minimised if the corridor is enclosed with simple, short-span construction, minimal beam depths, walls instead of columns, and simple foundations.

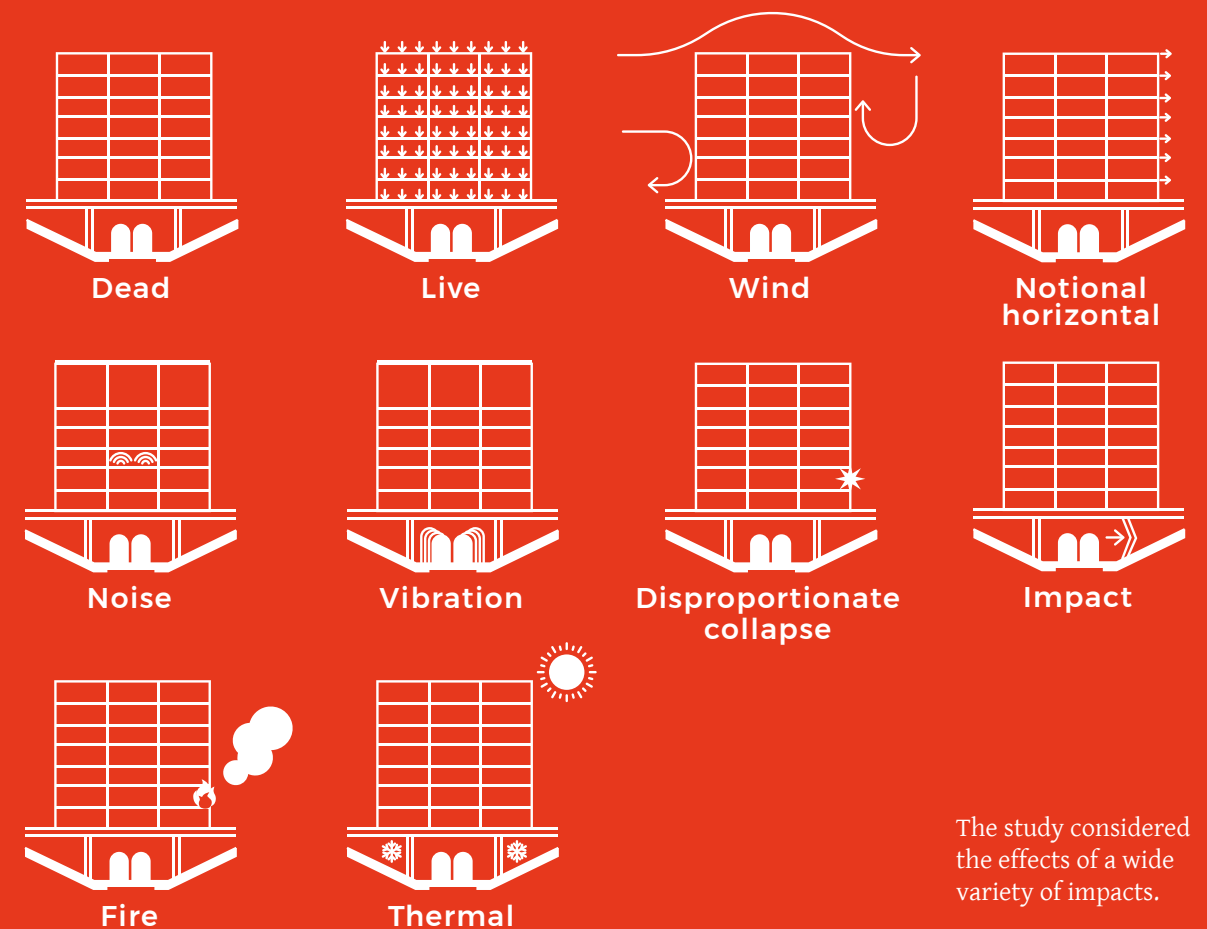
- **Early collaboration.** Early collaboration between the design team, developer, local authority, contractor, rail authority, train operating company and, where appropriate, TfL and GLA should help ensure that the risks and uncertainties associated with construction in the rail environment are understood and carefully considered.

- **Approvals and possessions.** It is in the interest of all parties for these to be expedited with minimal delay in order to avoid extended programme periods.

Failure to resolve the above mentioned issues could result in delays, cost overruns and even scheme cancellation. Yet given London's completed rail overbuilds it can be seen that these problems are being successfully resolved.



Rendering of the rail box



The study considered the effects of a wide variety of impacts.

12 benefits of rail overbuild

- Building over existing infrastructure requires no new land;
- Overbuilds in inner city locations are ideally located for residents: the ultra-close proximity to transport facilities provides greater mobility options and could tempt homeowners to either forego car ownership altogether or else reduce multi-car ownership, thereby increasing notional disposable income.
- Overbuilds can increase public transport ridership. In turn this will mean lower greenhouse gas emissions and require less car-parking space;
- Rail overbuilds can better integrate a station into its surroundings; the station development becomes a connector within the urban realm. And by incorporating adjacent site development, rail overbuilds spread their communal benefit over a wider area;
- Mixed-use rail overbuild environments contribute to public safety, particularly for pedestrians, given they foster activities throughout the day and much of the evening;
- Rail overbuilds provide opportunities to create new pedestrian-friendly environments, creating social value and forming attractive places where people want to live;
- Rail overbuilds offer financial incentives for rail asset owners who may gain commercial benefit from the development and from which they can reinvest the proceeds into improving city infrastructure;
- Uplift can be created in the value of the immediate surrounding area and generate household and business rates, as well as other revenue for the local authority;
- Rail overbuild schemes can fulfil local authorities' preference for higher densification and be used as tools of economic development;
- Provide a sustainable solution to urban development;
- In resolving rail-bridging issues – e.g. structural, acoustic, air quality, vibration, utilities, economy – the overbuild provides precedents for future developments;
- The station/transport hub becomes a destination in itself thanks to the resulting retail and commercial development in and around it.



WSP project case studies

Earl's Court regeneration plan

Part of the masterplan to regenerate the 32 hectare Earl's Court site involves the creation of four new distinct urban villages that will include the completion of over 6,700 homes by 2026. This major scheme will include community amenities, retail, work space, offices, hotels, health and leisure, plus the generation of a forecasted 10,000 new jobs.

As the client wants to retain a very long-term stake in the estate, achieving sustainability standards in environmental, water, waste, design and construction, energy and transport is a crucial factor.

The site is dissected by a cutting containing the District and West London rail lines which forms a barrier to pedestrian and cyclist movements. Decking over the rail lines facilitates the proposal to create a highly walkable and cyclable environment and to include off-site pedestrian improvements as part of a comprehensive public realm strategy for the surrounding area. And decking over the West London Line will dramatically improve the site's permeability and enable the addition of a new route to the London Cycle Network, linking Hammersmith with Earl's Court town centre.

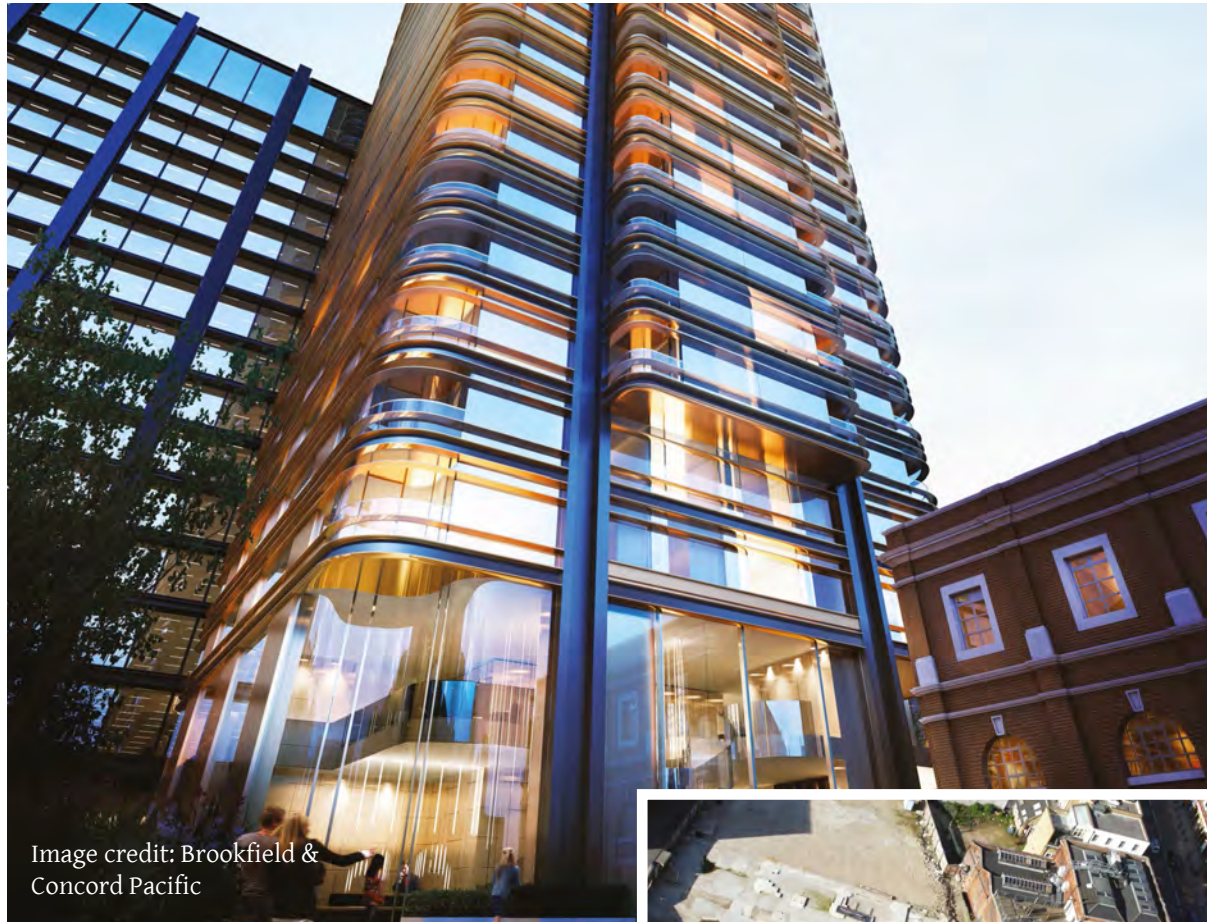


Image credit: Brookfield & Concord Pacific

Principal Place, Shoreditch

Situated around 200m north of Liverpool Street station, Principal Place is a major new mixed development that includes a 60,000m² contemporary office building and a 50-storey residential tower. Both are connected by a generous public piazza with retail space to create a new, vibrant destination.

Unlocking the site's full development potential would not have been possible without building the piazza over the 28.5m wide, 7m-deep open railway cutting containing six rail tracks to and from Liverpool Street Station. The steel and concrete piazza deck comprises a grillage of primary and secondary plate girders supported by a new wall built beside the railway.

Further complexity arose from placing foundations or supports in the very limited space between the rail tracks. Furthermore, a column of the 15-storey commercial building is supported on a pair of steel plate, concrete-encased girders which cantilever over the eight-track corridor and are supported by a reinforced concrete basement wall to the west. Construction of the deck was made possible through the close cooperation between rail authorities, the contractor and the consulting team working within an operational railway environment.

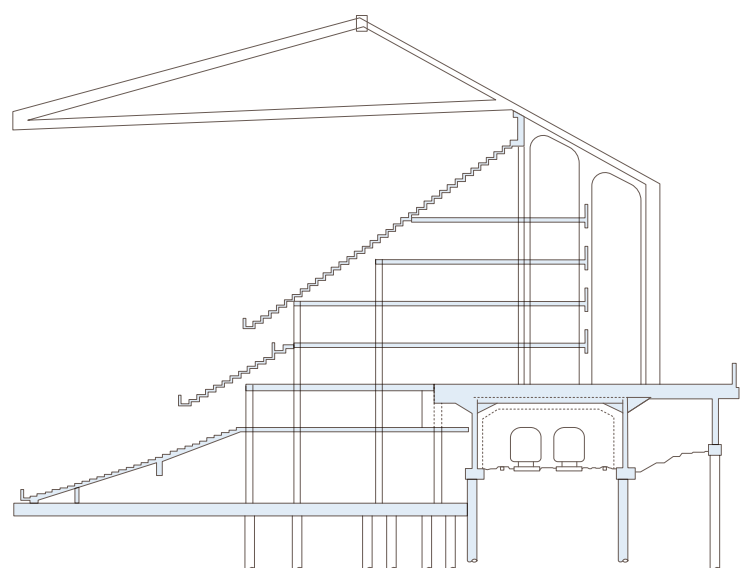
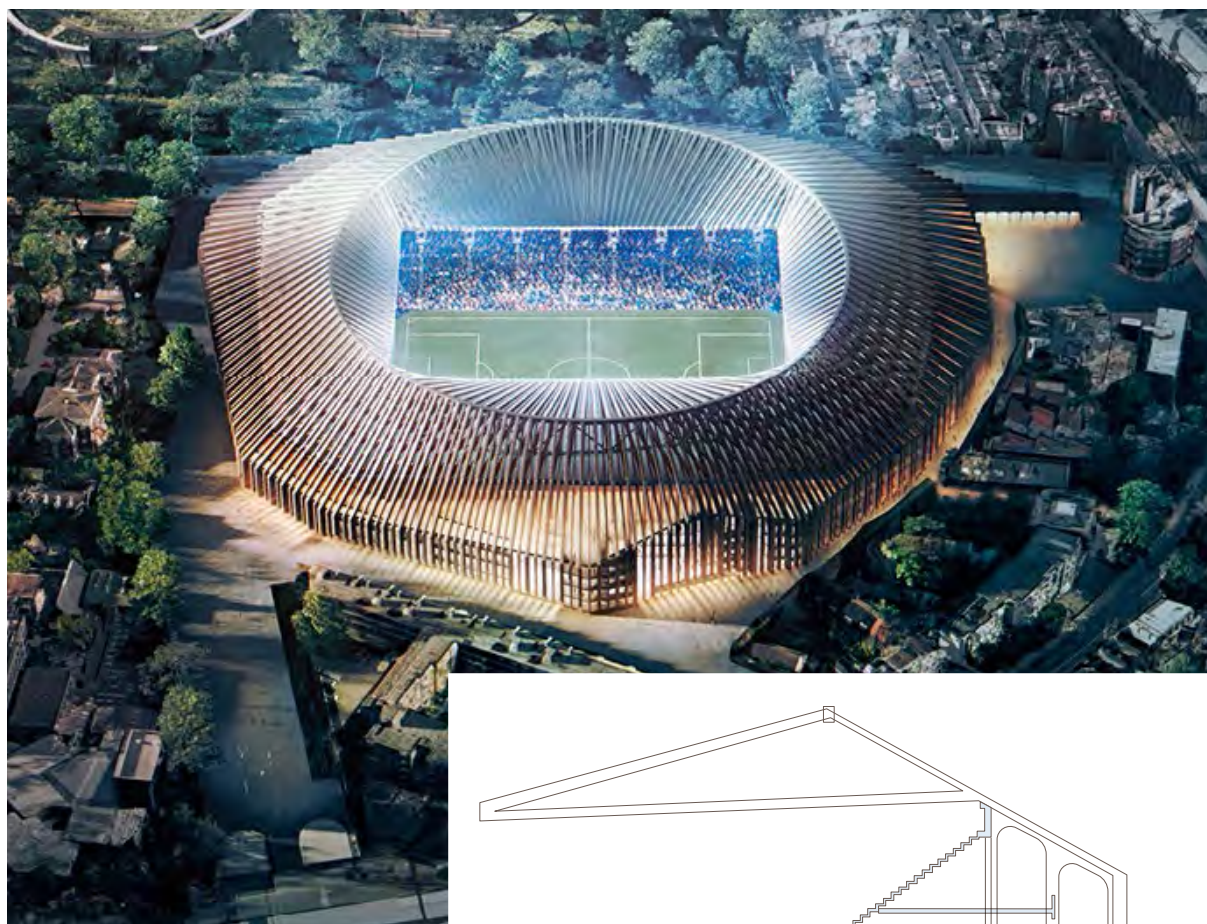


Royal Mint Gardens, Tower Hill

Comprising three blocks (13 to 15 storeys) connected by nine-storey link blocks, Royal Mint Gardens provides 254 high quality residential units and communal amenity spaces. To offer variety to residents, architect Farrells and their landscape designers have created new public spaces, communal roof terraces and courtyards.

The development fully maximises the site's potential and is arranged over the high level Docklands Light Rail (DLR) line feeding into Tower Gateway; the low level DLR line feeding into

Bank station, and cantilevers over viaducts of the Fenchurch Street Network Rail Line. Spaces within the viaducts are also utilised. Transfer structures were used to realise the project, while meeting the requisite vibration and noise isolation standards with rail box containment and acoustically-isolated foundations. Construction logistics over and adjacent to the railway were carefully considered in order to adhere to DLR and Network Rail asset protection.



Stamford Bridge, Chelsea

Rail overbuild doesn't just have to facilitate housing. Chelsea Football Club's proposed new stadium is a fine example of how a site constrained by adjacent rail lines can be successfully built over to maximise development potential. The club's desire to increase spectator capacity from 40,000 to 60,000 will necessitate rafting over two lengths of track – the West London line to the east and the District Line to the northwest – in order to make space for the new stadium.

More than half a kilometre of decking will be required: the proposed rail box around the West London Line will support the East stand directly above it while the majority of the deck over the District Line will create new space for fans exiting to and from the nearby underground station. Both rafts play their part in unlocking the site's development potential.



Riverside, New York

Looking outside of the UK, the Riverside South development on the Upper West Side of Manhattan is the largest residential development ever in New York City, covering 30 hectares of former rail yards. It comprises 5,700 apartment units spread over 16 buildings of 15-49 storeys, and also has 3,500 parking places under the buildings, retail space, parkland and rejuvenated highway and public transportation facilities.

To achieve this intense residential development required decking over active railroad tracks. Pre-stressed, precast concrete planks were used to span the tracks, supported at either end by 600mm-thick reinforced concrete crash walls. Although the deck serves as a construction table for the development above, the loads from the apartment blocks were borne by 1200-1800mm-deep transfer beams.



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November 2017