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# Out of Thin Air: The Potential for High-Rise Housing Over Rail Lines

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Abstract

*Cities are facing a crisis in providing housing and managing population growth. The author's team has identified sufficient land associated with railway infrastructure to yield more than 250,000 new homes in London built above rail lines, providing around five times the annual minimum needed by the capital. This paper illustrates several feasible scenarios and real-life projects that could serve as guides for providing housing to space-constrained cities around the world.*

**Keywords:** Infrastructure, Urban Design, Transit-Oriented Development

> "London needs 50,000 new homes to be constructed every year until 2025, just to keep up with projected housing demand. Yet between April 2016 and March 2017, only 6,423 homes were completed."

## Why We Should Build Above Rail Infrastructure

Compared to building major new infrastructure projects, rail overbuilds could be a quicker and less costly way to unlock large housing schemes. No new land is required for such developments – they can be undertaken where planning controls allow building over the rail environment.

In this research effort, the author's team has assumed that only 10% of the land identified is actually developed, with residential accommodation built directly above rail/metro lines and stations. However, this could increase even further if it unlocks and connects to further developments adjacent to rail lines or above a station. This sort of overbuild is now being seen as increasingly viable and attractive.

Rail overbuild is a potential way to start addressing challenging urban issues. It can increase the supply of housing, offices, retail, other social infrastructure, as well as connecting previously divided communities. Existing projects show that the engineering is possible, which means rail overbuilds can be delivered now.

Housing is one of London's most intractable problems. Even by the government's own admission, the UK housing market is broken (MHCLG 2017). Yet London, like many urban centers globally, continues to be a highly attractive place to live and work: since 2000, its population has grown by around 95,000 every year on average, and by more than 100,000 every year since 2008/2009 (GLA Economics 2016).

The shortage of housing in or near the center means many Londoners are housed far from their workplaces, often facing a long, daily commute. This is stressful and creates more overcrowding on an increasingly fragile and strained transport system.

Rail overbuild offers a more creative use of land, allowing more people to live in the city; tube/metro and/or rail services will be close by, and so using public transport will be a better experience. Indeed, these developments should have very favorable 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 of London.

As well as contributing to greater public transport use, car-free zones and more walking and cycling, rail overbuilds can provide a pleasant environment that supports 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 urgently requires.

## Housing Deficit Data

London needs 50,000 new homes to be constructed every year until 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 completed (GLA 2017a). Making up the shortfall demands more innovative approaches to development.

Creating more homes in the city center has been an ongoing process – since 2001, 90% of homes in London have been built within one kilometer of a rail 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 and using infill developments. Part of the current Mayor's draft strategy to increase housing provision is to identify and bring forward more land for housing, supporting a more intensive use of London's available land (GLA 2017b). Rail overbuild complements such policies by creatively utilizing 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. An 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 (see Figures 1 and 2).

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 offers many benefits, especially as no new land is required. One is literally creating land "out of thin air," which can increase the availability of residential accommodation and help alleviate the current housing shortage.

Figure 1. Victoria Station, London, with platforms already partially overbuilt with low-rise commercial development and a coach station. Source: Google Earth.

Figure 2. Victoria Station, London, with further decking, supporting a mixed-use development located over the approach tracks.

Given the ongoing concerns with tall buildings over 20 stories currently occupying London, particularly speculative residential developments (Pipe 2018, Weiss & Cook 2017), a conservative proposal might advocate overbuild schemes comprising 12-story 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 (see Figure 3).

Local authorities may also welcome such developments as a way to both reduce housing shortages and regenerate inner-city areas. There are also financial benefits that can accrue to a local authority in the form of community and business taxes, land value capture, Development Rights Auction Models (DRAMs), community infrastructure levies and public-realm benefits.

## Not A New Idea, However…

Air-rights development over rail lines is of course, not a new concept. Commercial real estate has been built over tracks and stations since the early 1900s, when William J. Wilgus, an engineer for the New York Central Railroad, proposed "taking wealth from the air" above the approaches to Grand Central Terminal in New York. (Gray 2010).

Figure 3. Schematic illustration of a 12-story flexible overbuild above rail tracks. © WSP

Figure 4. Cannon Street Station, London. © Sunil Prasannan

In the UK, technologically complex projects at London's 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 in 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 (see Figure 4). The dramatic steel megastructure spans and cantilevers the railway and Underground tracks. Within such scenarios, the station – in addition to being a transport node – becomes an attractive retail and commercial destination in its own right. Yet, while increasingly a common practice in other cities, the idea of high-density residential buildings constructed over rail lines is only just now taking hold in London.

## Availability of Developable Land

Using spatial analysis and mapping layers for Greater London's un-tunnelled railway and tube lines, the author's team identified exposed land areas and calculated the overbuild development potential. To generate a developable area, it identified zones of 10 meters' width on both sides of the existing tracks. In total, the analysis revealed 1,142 kilometers of uncovered track in London. This was broken down for individual boroughs as well as estimated for Transport for London (TfL) fare zones. Inner and Outer London zones have been defined as per the Office for National Statistics (ONS) definition (ONS 2017).

The Ordnance Survey railway data (OS 2018) allowed the identification of the following types of features:

- 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-track locations, e.g. as at major stations, and
- National Rail, Overground and Underground tracks.

### Calculating potential

To realize the number of residential units possible within the developments, the author assumed apartments having an area of 100 square meters each. Of the railway land identified as developable for overbuild, it was assumed that a conservative 10% could be developed for one reason or another. The home-building potential would be greatly increased if a higher percentage were adopted.

As a general and acceptable development target, 12-story developments were considered to give the 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, it is recognized that in Central London, where there is a greater preponderance of tall buildings, a rail overbuild could go much higher. In outer boroughs, a height below 12 stories may be more appropriate. A summary of potential homes that could be built over rail in Greater London follows in Table 1.

## Making Housing "Out of Thin Air": A Reality

Building over London's rail environment can yield more 250,000 new homes, around five times the annual minimum that London needs. This number could be significantly higher if smaller apartment areas are adopted. 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 reductions in greenhouse gas emissions. When an over-site scheme 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 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 livable, more lively and more sustainable. To create such a community above rail infrastructure requires certain engineering techniques and environmental considerations. These are discussed in more detail below.

| By Transport for London Fare Zone: | |
|---|---|
| Zones 1+2 (central area) | 56,836 |
| Zones 1-6 (all zones) | 250,969 |
| **By Borough Boundaries:** | |
| Inner London | 82,324 |
| Outer London | 157,199 |
| **Total** | **239,523** |

Table 1. Potential number of 100 square-meter homes in Greater London, on sites over rail lines, if built to an average height of 12 stories.

> "To determine the number of possible residential units, apartments were assumed to be 100 square meters each. It was assumed that a conservative 10% of land over railway lines could be developed for one reason or another."

### Acoustic mitigation

Incorporating acoustic mitigation measures right from the start is critical to maximizing comfort for residents, employees and other users of the development. Developments in the rail environment must account for 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 disturbance (D'Avilez 2017). Vibration can also affect the operation of sensitive equipment that might be installed in healthcare or scientific facilities.

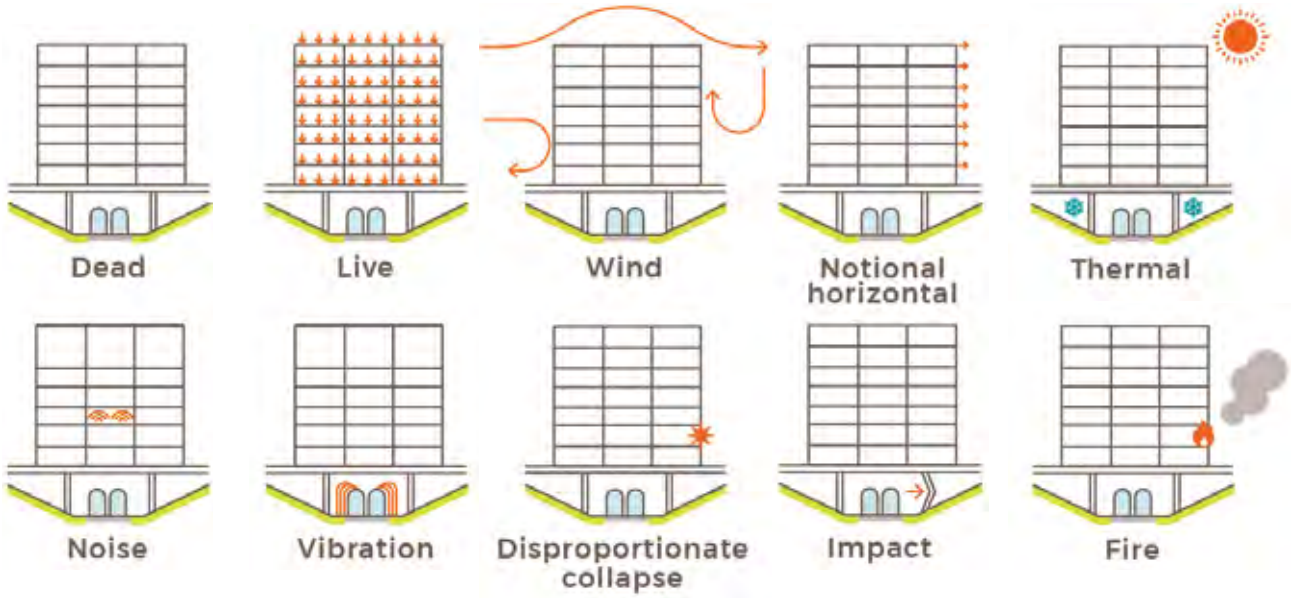


Figure 5. A 2012 Network Rail-commissioned study considered a wide variety of impacts of overbuilding rail lines with mixed-use development. © WSP

Recent years have seen great strides taken in assessing and predicting structure-borne noise and vibration. With the development of personalized numerical modeling 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. Typically, achieving an adequate noise and vibration environment inside buildings can be met in part by:

- Adjusting the raft foundation design to minimize vibration transfer;
- Tuning the thickness and span of floor plates;
- Using specific construction materials to limit resonances within a structure;
- Segregating sensitive spaces from critical vibration-affected areas;
- Utilising "room-in-room" techniques (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.

Extremely low levels of vibration can be achieved, but over-engineering can increase costs. Therefore, a tailored assessment approach that 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 in a mixed-use scenario to place residential accommodation near the top, with commercial and retail units on the lower floors.

Also, 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 type of freight, which will all vary over time. The overbuild should be designed to accommodate all of these. Nearest the tracks better exclusion of outside noise can be achieved by non-openable windows, supplemented by mechanical cooling to prevent overheating of the internal environment.

## Building the Rail Box

In 2012, Network Rail appointed the author's team to undertake a generic feasibility study on rail overbuilds (see Figure 5). The output of that study yielded important conclusions in terms of constructability:

- *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 maximizes the development space above (see Figure 6); its 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.

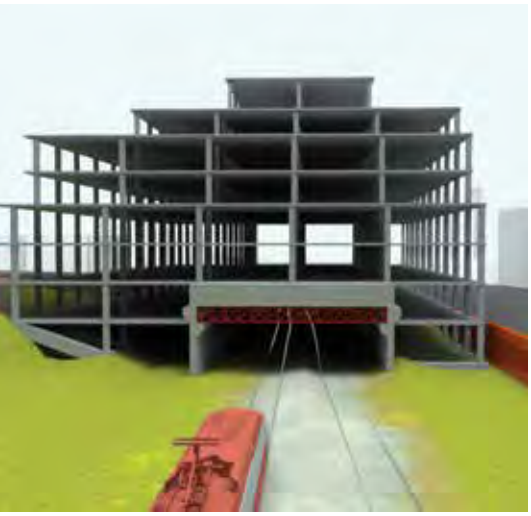

Figure 6. A sectional perspective of a rail-overbuild structure illustrates best practices, including placing side walls of solid concrete alongside the active lines.

Figure 7. Rendering of the 32-hectare Earl's Court development in London, built over a rail junction. The scheme will include more than 6,700 homes by 2026.

- *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 constructability.
- *Vibration control should be addressed outside of 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 line owner) but part of the developer's brief.
- *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:

    - *Box structure design.* 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 minimized 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 owners and operators, and city authorities 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 development program periods.

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

## Project Case Studies

### Earl's Court Regeneration Plan, London

Regenerating the 32-hectare Earl's Court site (see Figure 7) involves creating four new distinct urban villages that will include 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. The site is bisected by a cutting containing the District and West London rail lines, which form a barrier to pedestrian and cyclist movements. Decking over the rail lines facilitates the potential 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.

### Principal Place, Shoreditch, London

Principal Place is a major new mixed-use development that includes a 60,000 square-meter contemporary office building and a 50-story residential tower, both connected to a generous public piazza built on a steel grillage over the 28.5-meter-wide, seven-meter-deep open railway cutting (see Figure 8). This complex project involved placing foundations or supports in the very limited space between the rail tracks, while a column of the 15-story commercial building is supported on steelwork cantilevered over the tracks.

### Royal Mint Gardens, Tower Hill, London

Comprising a mix of three- and nine-story blocks, Royal Mint Gardens provides 254 high-quality residential units and communal amenity spaces, articulated by new public spaces, communal roof terraces and courtyards (see Figures 9 and 10). The development maximizes the site's high- and low-levelDocklands Light Rail (DLR) lines and cantilevers over viaducts of another rail line. Spaces within the viaducts are also utilized. Transfer structures were used to realize the project, while meeting the requisite vibration and noise isolation standards covering rail box containment and acoustically-isolated foundations.

Figure 8. Principal Place, a two-tower project built over the railway approaches to Liverpool Street Station. © Brookfield, Concord and W1

### Riverside South, New York

Riverside South on the Upper West Side of Manhattan is New York City's largest-ever all-residential development, covering 30 hectares of former rail yards (see Figure 11). Comprising 5,700 apartments spread over 16 buildings of 15-49 stories, it also has 3,500 parking places under the buildings, retail space, parkland and rejuvenated highway and public transportation facilities. To achieve this dense residential development required decking over active railroad tracks. Pre-stressed, precast concrete planks were used to span the tracks, supported at either end by 600-millimeter-thick reinforced-concrete crash walls. The loads from the apartment blocks are borne by 1,200- to 1,800-millimeter-deep transfer beams.

## Conclusion

The potential to deliver hundreds of thousands of new homes to supply-starved London is hiding in plain sight – on the unclaimed "air" above the city's sprawling rail network. While questions of appropriateness and constructability are perhaps higher than in other locations, the stakes of inaction are also high. If London and similarly expensive, increasingly unequal cities are to maintain

Figure 9. Royal Mint Gardens, London, is being built over three railway lines at different levels. © IJM Land

Figure 10. Royal Mint Gardens construction view. Steel beams bridge the structure over one of the rail lines on site. © IJM Land

Figure 11. Riverside South, New York City, provides 5,700 apartments set on decks over a former rail yard. © Jim Henderson (cc by-sa)

quality of life and retain a skilled and valuable workforce, innovative actions must be taken to accommodate them. Railway overbuilds provide a strategy to build more environmentally sound, and inherently transit-oriented communities for our burgeoning cities.■

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