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van Oort, N., & van der Bijl, R. (2026). Light rail transit (LRT). In J. A. Annema (Ed.), *New Transportation Modes and Old Transportation Modes that are in the process of Renewing themselves* (pp. 343-370). (Advances in Transport Policy and Planning; Vol. 17). Elsevier. <https://doi.org/10.1016/bs.atpp.2025.11.007>

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Light rail transit (LRT)

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Summary

In this chapter, light rail will be explained and discussed. Based on literature and research, this chapter describes light rail as a mode of transport and examines what its impacts are. Finally, this chapter explains how light rail could be implemented.



1. Light rail: Definition and characteristics

In this chapter, light rail will be explained and discussed. Based on literature and research, this chapter describes light rail as a mode of transport and examines what its impacts are. Finally, this chapter explains how light rail could be implemented. Recent literature is found via Scopus, Scolar and World Transit Research (<https://www.worldtransitresearch.info/>), in addition to snowballing from a key reference Van der Bijl et al. (2018).

The term *light rail* first emerged in the mid-1970s. The [Transportation Research Board \(1978\)](#) provided the following definition:

"Light rail transit is a metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways or, occasionally, in streets, and to board and discharge passengers at track or car-floor level."

In [Van der Bijl et al. \(2018\)](#), a deeper analysis and definition of light rail is revealed, including a new definition:

"Light rail is a rail-based form of public transport used at the scale of an urban region or city. Unlike trains and metro systems, light rail is inherently suitable for integration into public space and can, if necessary, share space with regular road traffic."

[Van der Bijl et al. \(2018\)](#) argue that light rail is typically positioned within a triangular relationship between train, tram, and metro (see [Fig. 1](#)), but its boundaries remain vague and often undefined. This ambiguity has led to widespread misunderstandings and confusion about what light rail entails, making it difficult to establish a consistent regulatory framework.

The term *light rail* is often associated with lightweight vehicles or infrastructure or with tram- or metro-like operations. In general, light rail represents a loosely defined form of rail-based public transport that falls somewhere between tram and train, tram and metro, or even train and metro. This hybrid nature reflects light rail's versatility. As urban regions have expanded, residential, work, and leisure activities have become more dispersed. Light rail is used to provide high-quality, flexible public transport in this evolving context, particularly to minimize transfers while integrating infrastructure efficiently.

While train, tram, and metro systems are functionally and technically distinct, light rail overlaps with all three to varying degrees. To better characterize light rail, [Van der Bijl et al. \(2018\)](#) provide the following characteristics of Light Rail:

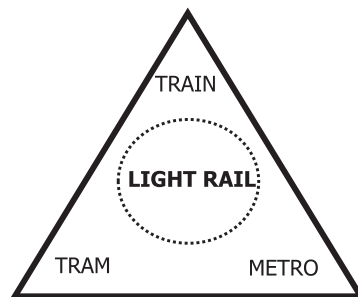


Fig. 1 Positioning of light rail ([Van der Bijl et al., 2018](#)).

- **Infrastructure:** Light rail could utilize existing tram, train, or metro infrastructure. However, tram infrastructure is generally the most suitable for light rail. To offer high quality operations in heavy traffic, dedicated tracks are crucial. Merging with slower traffic, e.g. in city centres, is possible.
- **Rolling Stock:** The light rail vehicle of choice is the state of the art, barrier-free accessible, high-capacity and high quality tram-like vehicle. The key characteristic of a light rail vehicle is its ability to legally and functionally mix with other traffic.
- **Operations:** While light rail can operate at local, regional, or even supra-regional levels, its primary focus is the urban region. Quality levels of light rail are in generally high, for instance regarding frequencies, speed, service reliability and comfort.
- **Function:** Light rail primarily serves passenger transport. Key inter-modal hubs—stations or stops where public transport, cars, and bicycles converge—are crucial for seamless integration with other transport modes.
- **Urban Planning Role:** Light rail strengthens urban structure economically and socially. It can help reduce social segregation, enhance economic centres, and improve the quality of public spaces. Moreover, light rail effectively supports transport oriented development ([Cervero, 2004](#)).

A recurring aspect of light rail research and discussions is the comparison to bus services (see e.g. [Tirachini et al., 2010](#) and [Scherer and Dziekan, 2012](#)). Relevant in that debate is the so-called Rail bonus. Provision of rail bound public transport might lead to greater benefits than comparable road bound public transport, identified by [Bunschoten et al. \(2013\)](#) This bonus is the added value causing more travelers to use rail than bus while levels of service are equal. To better understand this phenomenon, they conducted a choice experiment amongst inhabitants of Dutch cities. The choice experiment required respondents to choose between a bus alternative and a rail alternative. Both alternatives differ in the same aspects, so the difference in mode-specific constants indicates the difference in preference. The perceptions of a number of mode characteristics of bus and light rail were measured to explain the difference in preference. Finally, the transition from difference in preference to the number of travelers was made using a transport model, revealing 5–15 % higher expected ridership for rail system than bus systems with similar characteristics.

Much research and literature on light rail is based on case studies of successful or failed projects, introduced in end of the previous age in Europe and the US, as for instance [Brandl and Axhausen, \(1998\)](#), [Elmberg \(1985\)](#), [Dueker and Bianco \(1999\)](#), [Vigrass and Smith \(2005\)](#) and [Novales et al. \(2002\)](#). The text [Box 1](#) below also shows multiple case studies (referred to in this chapter).

Box 1 Ligh rail cases.

The following projects and analyses are based on [Van der Bijl et al. \(2018\)](#); marked by # and recent new (and unpublished) research into some recent cases (marked by *). This collection of cases is representative of the phenomenon of light rail worldwide, since all forms of light rail are expressed in them as well as the different ways in which the making of light rail is justified and organized.

= Aachen/ Aix-la-Chapelle (Germany) – Campusbahn, an example of a failed project (2009–2013) due to declining support and the final death blow by the negative outcome of a referendum (2013). #.

= Dublin (Ireland) – Luas, an example of a complicated and difficult planning process (1987–2000); first high quality tram line eventually installed (2004).#.

= Jerusalem (Israel) – Red line, controversial light rail project and an example of a complicated and difficult planning and construction process; first tram line after severe delays installed (2011).

= Gold Coast (Queensland, Australia) – G:Link, Gold Coast Light Rail, serves fast expanding urban development (2014).#.

= Groningen (Netherlands) – RegioTram, failed city light rail project; the intended regional expansion by means of tram-train also failed (2006–2013).#.

= La Réunion (France/DROM-COM) – oversized and very complicated and expensive tram-train project, failed due to overambition (2010 †).#.

= Leeds (England) – Supertram, one of many English examples of abandoned tram projects (2004 †). #.

= Liège (Belgium) – T1, an example of a complicated and difficult planning process tailored by DBFM contract (2013–2025); lightrail eventually installed (2025).#.

= Liverpool (England) – Merseytram, one of many English examples of abandoned tram projects; it took a few years to pull the plug on the project (2005–2008 †).#.

= Luxembourg city (Luxembourg) – Initially a failed tram-train project (2004 †). Later an urban light rail project (Luxtram), the first phase of which was realised in stages (construction 2017–2025). Further city and region extensions have been approved by the administration and are in preparation. #.

- = Olsztyn (Poland) – After complications and retendering, the city light rail project was successful (approval 2009; construction 2012–2015). Phased expansion has taken place continuously since then. #.
- = Paris/Ile-de-France (France) – T1 (Saint Denis-Courneuve-Bobigny), new generation light rail project plagued by cost overruns, delays and technical problems; tramway eventually installed (1992). #.
- = Portland (Oregon, USA) – MAX (Metropolitan Area Express) & Portland Streetcar, showcase light rail project & pioneer second generation tramway project in the United States, obviously inspired by European examples (1986 & 2001). #.
- = Nantes (France) – Tramway de Nantes, first of the new generation of urban tram systems in France (1985). #.
- = Nice (France) – T1, new generation light rail project, including renovation sewer system (2007). #.
- = Sidney (New South Wales, Australia) – new generation light rail system (1997). #.
- = Srinagar & Jammu (India) – Srinagar Metro, metro project but referred to as LRT (planned opening 2027). *.
- = Stockholm (Sweden) – Spårväg City, an example of an urban light rail project, contract form converted from integrated to classic; first stage (2010). #.
- = Strasbourg (France) – Most well-known and successful new generation tramway (e.g. economic effects) in France (1994). #.
- = Tampere (Finland) – an example of a comprehensively justified new generation light rail project (2023). *.
- = Utrecht (Netherlands) – Uithoflijn, new light rail, an example of project organisation mitigating incremental planning processes (2019).



2. The impacts of light rail

Light rail has a history of complicated decision making [De Bruijn and Veenman \(2009\)](#), including discussions on justification of the (high) investments and operation costs. Light rail is primarily an urban facility and has significant spatial implications due to its infrastructural components. The (potential) impacts also include sustainability and inclusiveness. As outlined in the definition of light rail in the first section, rail-based transport distinguishes light rail from urban bus projects. The financing, integration, and maintenance of this rail infrastructure heavily impact (the length of) decision-making and the associated reasoning.

Investments in public facilities, such as light rail, can be justified based on various considerations, which are often beyond the mobility domain. In

order to structure discussions and decisions on (wider) impacts of light rail, [Van Oort et al. \(2017\)](#) developed a conceptual framework identifying and categorizing expected or desired impacts of light rail and matching them to potential objectives of urban mobility systems (see [Fig. 2](#)). The five domains of the framework support structural assessment of all impacts of a light rail project and are explained in more detail below.

[Van Oort et al. \(2017\)](#) argue that traditional approaches to transport planning and infrastructure assessment tend to prioritize direct mobility outcomes—such as reductions in travel time—while often overlooking broader societal and spatial impacts. To address this gap, the authors introduced the **5E model**, which encompasses a wider range of intended outcomes. The model comprises the following five dimensions, including examples discussed in [Van Oort et al. \(2024\)](#):

1. **Effective Mobility** – This dimension focuses on the operational performance of transport systems, emphasizing aspects such as speed and service reliability (e.g., [Anderson and Daganzo, 2019](#); [Van Hagen and van Oort, 2019](#)).
2. **Efficient City** – This refers to the spatial suitability and contribution of transport to urban (re)development and land use efficiency (e.g., [Knowles and Ferbrache, 2015](#)).
3. **Economy** – This component highlights the role of mobility in fostering economic prosperity and overall well-being within urban contexts (e.g., [Hensher et al., 2021](#)).
4. **Environment & Health** – This dimension addresses sustainability goals, including reductions in carbon emissions, improvements in air



Fig. 2 5E framework ([Van der Bijl et al., 2018](#)).

quality, and promotion of healthy lifestyles, as well as consideration of lifecycle environmental impacts (e.g., [Kapetanović et al., 2019](#)).

5. **Equity** – This aspect pertains to inclusive mobility, ensuring accessibility for all population groups (e.g., [Bastiaanssen and Breedijk, 2022](#); [Durand et al., 2023](#)).

The relative importance of each of the five dimensions varies depending on governmental priorities and specific case contexts, making it a central issue in policy debates. Trade-offs are often necessary, as prioritizing one dimension may conflict with or diminish the emphasis on another, thereby influencing policy choices and the design of transport infrastructure and services. The 5E model has proven to be a useful tool in evaluating and balancing the costs and benefits of various transport projects, including initiatives focused on cycling and public transit ([Van der Bijl et al., 2018](#); [Van Oort and Yap, 2021](#)). The five elements are discussed in more detail and linked to light rail below.

2.1 Effective mobility

Effective mobility relates to the mobility related impacts of a light rail system (e.g. capacity and quality) and how effective the system is in that regard (e.g. with regard to the expected ridership numbers and investment costs). Deciding whether light rail is a cost-effective or at least a suitable mode of transport for a given public transportation task is often the subject of ideologically charged debate ([Van der Bijl et al., 2018](#)). Discussions on the necessity and usefulness of a light rail line are frequently conducted among advocates of different ‘schools’ of thought, ‘believers’ or “blind commitment” for light rail, bus, or other public transport and mobility solutions (see e.g., [Hensher and Golob, 2008](#)). However, a well-founded decision should be based on a neutral evaluation of the goals and expected impacts of the proposed mode of transport, whether it is light rail, bus or anything else. The evaluation should stand independently, without pre-conceived preferences for light rail or any other form of public transport. Offered capacity and quality is an important aspect of the expected impacts, directly linked to expected ridership numbers, passenger satisfaction and modal shift.

Light rail has the potential to achieve high quality levels. When planning and operating light rail is crucial to invest in proper infrastructure, rolling stock and service supply as a condition for this quality. Literature and customer satisfaction surveys show that frequency is a crucial quality

aspect (Fadaei and Cats, 2016), whereby high frequencies offer freedom to travel anytime, without (hidden) waiting time. Secondly, travel time and its reliability are important, as discussed by Van Oort (2014). Peek and van Hagen (2002) discuss that beyond these “dissatisfiers” (aspects that passenger take for granted), satisfiers, such as convenience and comfort, are also crucial for a high level of ridership and modal shift from private cars.

Various studies on the transport characteristics of commonly used modes, such as light rail and bus, indicate that their suitability—and thus their effectiveness—is closely related to the scale and size of the transport demand within an urban environment (Hass-Klau et al., 2004).

In Western Europe, the required ridership level for an effective light rail system is typically around 20,000 passengers per day per direction. This is three to four times higher than that of a conventional bus and about twice as much as a double-articulated bus. The required ridership level is, of course, context-dependent.

In some cases, the choice for light rail is beyond debate. The Utrecht Uithooflijn project is an example of such a case (Van Oort, 2016). Operational costs and the required reliability could not be efficiently achieved by any mode other than light rail. Even advanced bus technologies, such as double-articulated buses, were deemed unsuitable.

While transport effectiveness is an important argument for investing in light rail projects, other types of justification often could play a significant role in justification and decision making as well. Therefore four additional argumentation types are discussed in the following sections.

2.2 Efficient cities

In this section, it will be shown that light rail and other high-quality, fixed-infrastructure public transport systems can significantly influence urban development. Through careful planning and design, the inherent qualities of light rail can be harnessed to develop for instance housing projects that are both practical and impactful. Unfortunately, the contribution of urban planning is often reduced to aesthetic considerations, focusing primarily on enhancing the cityscape or urban ambiance (Van der Bijl et al., 2018). While visual appeal and atmosphere are important and can even lend iconic value to light rail systems—contributing to city branding—this narrow focus underestimates their broader potential as strategic tools for spatial development and transport planning.

When supported by dedicated infrastructure, including stations and stops, light rail can serve as a powerful instrument in shaping urban and

regional form as convincingly illustrated by the case of Portland, Oregon; [Van der Bijl et al., 2018](#). At its best, it can (re)structure cities, metropolitan regions, and specific areas such as neighborhoods and underdeveloped districts. In this capacity, light rail can counteract uncontrolled urban sprawl, provided that major lines are integrated into the spatial and urban design strategies of new or redeveloped zones. Equally important is ensuring that the relationship between public transport infrastructure and spatial-functional development is explicitly considered in political and administrative decision-making processes.

In fact, light rail can be regarded as a fundamental component of urban development, particularly when it involves a significant investment in fixed infrastructure. Such infrastructure is typically characterized by a long technical and economic lifespan—often 20–30 years or more—ensuring durable and stable connections that remain operational over extended periods.

When urban development is concentrated around transit nodes, such as stations and key stops, the concept is known as Transit-Oriented Development (TOD) ([Curtis et al., 2009](#)). The fixed nature of LRT infrastructure can efficiently facilitate spatial structuring in TOD contexts, channeling real estate investment and programmatic development into well-connected hubs—especially those with a nodal function. However, successfully implementing TOD has proven to be challenging. [Tan \(2013\)](#) identifies a range of constraints, particularly formal barriers such as institutional complexity and administrative fragmentation, which create ambiguity in role definitions and accountability. She also notes *informal barriers*, including a lack of urgency and general indifference toward public transport. These observations are echoed by [Basheer et al. \(2020, 2021\)](#).

Research conducted in the United States, Europe, and more recently Asia, affirms the value of TOD for rail-based public transportation and vice versa ([Cervero, 2004](#); [Van der Bijl, 2014](#); [Singh et al., 2017](#)). Another dimension of efficiency pertains to the spatial demands of different transport systems—not just roads and stops, but also associated infrastructure such as parking. Car-oriented transport, in particular, requires substantial spatial resources. Research by [Stam et al. \(2021\)](#) illustrate in [Fig. 3](#) the varying space requirements of different transport modes, highlighting the spatial efficiency of active mobility and public transport—assuming these systems are well-designed and effectively managed.

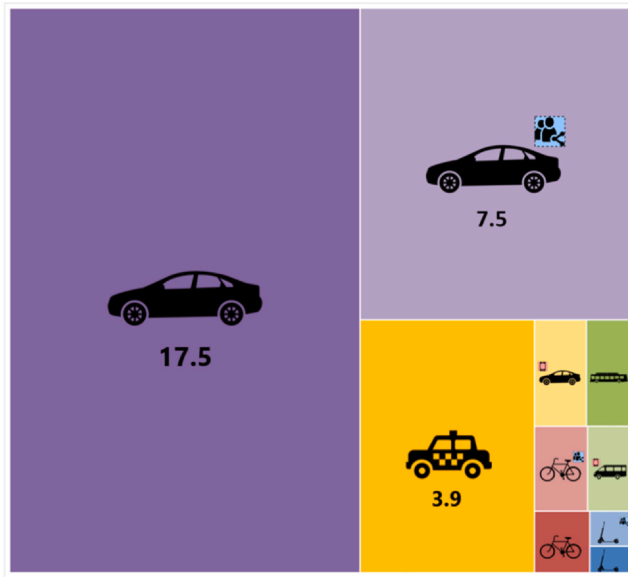


Fig. 3 Required space per passenger per mode (m²) (Stam et al., 2021).

2.3 Economy

A substantial body of research supports the view that rail-based public transport can serve as a key enabler of urban development, often generating positive economic impacts. However, scholars such as [Hass-Klau et al. \(2004\)](#) emphasize that these benefits typically materialize only when accompanied by coherent strategies involving coordinated interventions, targeted investments, and sustained support. Achieving such outcomes requires collaboration not only from private stakeholders with commercial interests but also from public actors—particularly local governments—that play essential roles in stimulating, coordinating, and facilitating infrastructure development and economic growth.

In this context, [Knowles and Ferbrache \(2015\)](#) highlight how the operation of light rail systems can enhance an area's attractiveness, thereby encouraging *inward investment*—for example, firms choosing to establish or expand operations along rail corridors. Improved accessibility tends to increase land and property values, which in turn creates opportunities for developers to contribute to localized investment. Additionally, enhanced connectivity supports the broader urban economy by enabling other key actors, such as local businesses and public institutions, to engage more

productively within the urban fabric. That said, Knowles and Ferbrache also caution that isolating the specific economic contributions of rail-based public transport from other concurrent developments remains a complex task.

With respect to commercial property values, several studies document measurable impacts. For instance, in San Jose, commercial lease rates between 1984 and 2000 were found to be 13 % higher within 400 m of light rail stations compared to those located more than 1200 m away. Similar trends were observed in Dallas, where the differential reached 22.7 %, and in Santa Clara, where it ranged between 7 % and 10 % (Weinberger, 2001; Crocker et al., 2000; Hass-Klau et al., 2004; Mohammad et al., 2013).

Comparable cases of light rail stimulating inward investment have been reported in various international contexts. Conventz et al. (2013) examine such instances in locations including Ørestad (Denmark, where Denmark's Radio relocated), the West Midlands, Montpellier, Rouen, Calgary, Vancouver, and St. Louis (though Ørestad and Vancouver represent metro systems). These examples reinforce the broader argument that high-quality, rail-based public transport can serve as a catalyst for spatial and economic transformation when embedded in a supportive institutional and planning framework. Van der Bijl et al. (2018) consider the Strasbourg tram an example that convincingly shows the economic effects of a tram system on the city centre.

2.4 Environment

Looking at the now available literature and research (including many of the examples in the box), one can only conclude that public transport should be considered one of the most environmentally friendly forms of transport. According to the World Resources Institute (WRI), there is no better solution to move large numbers of people efficiently, cheaply and sustainably (WRI, 2023). The scientific literature has long pointed to the sustainable qualities of public transport. A 'modal shift' to public transport can achieve sustainable urbanization and mobility goals, but it should be noted that at the same time a redistribution of public space is needed, with less space for car mobility (see, for example, Banister, 2008). For example, there are good opportunities to substantially reduce CO₂ emissions in cities by stimulating public transport.

Recent life cycle assessment (LCA) and transport studies consistently show that public transport can significantly reduce greenhouse gas (GHG) emissions and energy use, particularly in dense urban areas where

occupancy is high. Private cars (single occupancy) typically emit $\sim 150\text{--}250$ gCO₂e per passenger-km, while diesel buses range around $\sim 80\text{--}187$ gCO₂e/pkm and electrified rail as low as $10\text{--}80$ gCO₂e/pkm, depending on occupancy and energy source (Amatuni et al., 2020; Chester and Horvath, 2009). Battery-electric buses demonstrate lifecycle GHG reductions of 30–70 % compared with diesel, conditional on electricity mix and battery lifetime (Lajunen and Lipman, 2016; Zhang et al., 2021). Hydrogen buses can achieve similar or greater reductions if powered by green hydrogen, though results vary widely depending on hydrogen production pathways (Miller et al., 2022).

At the household level, modal shift and car ownership reduction yield substantial benefits. Empirical studies of car-sharing and modal substitution show household transport emissions reductions of $\sim 20\text{--}50$ %, with the higher end achieved when public transport and active travel replace private car trips (Figenbaum and Kolbenstvedt, 2016; Katzev, 2019). These findings confirm that encouraging shifts toward electrified, high-occupancy public transport systems represents one of the most robust pathways to decarbonize urban mobility, though benefits remain sensitive to occupancy levels, fleet technology, and grid decarbonization.

2.5 Equity

High-quality public transport is sustainable, but not only in the environmental sense, as argued in the previous paragraph, but also in a social sense. In the English language, sustainability has a broader meaning. The term stands in the first place for a community that knows how to live on, in other words, a community that is socially sustainable. The second meaning relates to the condition for this, namely ‘environmental sustainability’, recognized in the theory of Raworth (2018). Translated to public transport, it comes down to the fact that high-quality, i.e. sustainable public transport is socially justified because it ensures that the ecological ceiling is not exceeded and at the same time that no one falls through the social floor. Everyone in community, or in society belongs, should be able to participate. Sufficient mobility (among a lot of other things) is essential for this. When people do not have sufficient means of mobility, there is transport poverty. Already in the past two decades, this phenomenon of ‘transport poverty’ has been researched, especially in England; see for example the report of the ‘charity’ Sustrans (2012). This form of poverty leads to social exclusion, as extensively researched by Lucas (2004, 2012) and Currie and Delbosc (2011).

Sustainable mobility is a prerequisite for inclusiveness, while public transport represents a crucial elaboration of this condition. If this condition is not or insufficiently implemented, there is social injustice. The term ‘equity’ (E5) refers to fairness and justice and the need to identify and prevent ‘involuntary transport disadvantages’ (Jeekel, 2018) up to serious transport poverty. Researchers such as Banister (‘Inequality in Transport’, 2018) and

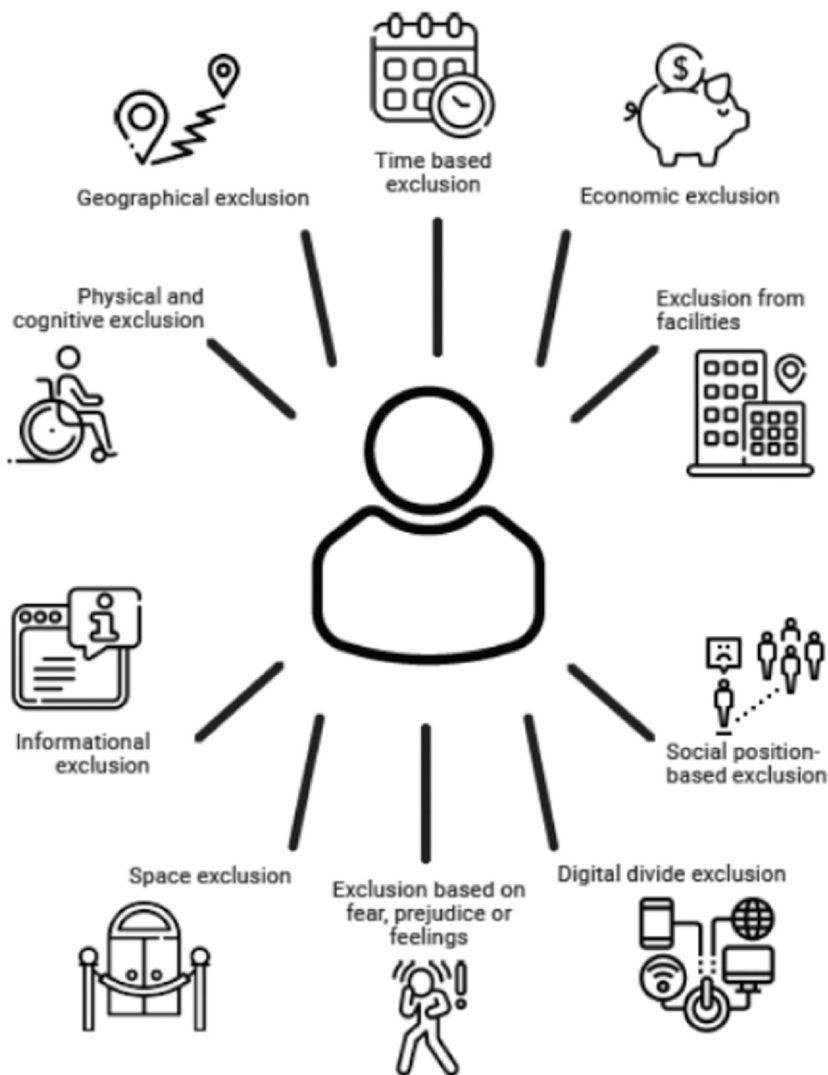


Fig. 4 10 Dimensions of exclusions (Bruno et al. 2024).

Martens ('Transport Justice: Designing Fair Transportation Systems', 2017) have put this topic firmly on research and policy maps. The 'Sustainable Development Goals' of the United Nations are in line with this, in particular SDG 11.2 entitled 'access for all; expansion of public transport' (UITP, 2023).

From an operational point of view, the theme of 'equity' can be elaborated by empirical-numerical mapping of how, for example, work locations can be reached for different population or target groups (see, for example, Fransen, 2017). The Netherlands Environmental Assessment Agency (PBL) has published a study entitled 'Access for everyone?' (Bastiaanssen and Breedijk, 2022) 'accessibility analyses'. They note large differences in accessibility between the modes of transport. The car scores best. For example, work and facilities appear to be more accessible than by public transport. The researchers conclude: "People who (have to) rely on public transport have considerably less accessibility, especially if they live in rural areas, in the outskirts of cities or in suburban centres. Moreover, public transport accessibility decreases during off-peak hours in all types of areas, due to lower transport frequencies. In addition to these types of exclusion, Bruno et al. (2024) analyse 10 types of exclusions, shown by Fig. 4. Light rail could affect multiple of these types of exclusions and these should thus be included in the assessment.



3. Getting light rail done

Finally, it is all about getting light rail projects accomplished. The question is which issues have derailed light rail projects in the past two decades, or made them successful. Based on previous work (Van der Bijl et al., 2018; 2024), a checklist has been drawn up (including examples) with which projects can be screened and supported. A few examples illustrate the most important issues, providing (in a nutshell) a sample of factors, actors and institutions, including their context, that have played a role in the failure or success of a project. The realization of high-quality public transport lines appears to be anything but a simple matter. There are numerous topics that require results for both the intended construction as well as the subsequent operation and maintenance of light rail systems.

3.1 Backgrounds

Looking back over the past decades, it appears that smooth planning and accomplishment of larger projects in particular is far from self-evident.

Light rail projects are by definition comprehensive and inextricably linked to urban planning, urban design – and often also to urban (re)development. In general, urban development projects are always complex, especially if they include an infrastructural component. Peter Hall's classic study 'Great planning disasters' [Hall \(1982\)](#) makes this very clear. Many large projects fail, or are delivered at unexpectedly high costs and are rarely without defects and delays. Unfortunately, many public transport projects also fall into this category of slow, complicated undertakings. For example, Hall investigated the complicated early history (1949–1974) of the Bay Area Rapid Transit (BART), a completely new rail system in the urban area of the San Francisco Bay Area in the American state of California. In the first years after the opening of the first BART route (1972), usage turned out to be far below the calculated forecast. Hall concludes, among other things, that the planners had been over-optimistic in their estimation of the number of motorists who would switch to the new public transport system. Estimations of the construction costs had also been accepted, in Hall's words 'without any elementary scepticism'. Everyone wanted to believe in the prediction, because they thought that the project could really combat congestion on the roads. 'Because of this desire, there was a mass suspension of disbelief, and almost ideological commitment to a new system', Hall writes. Even when new public transport is successful (many years later BART did much better, by the way), in many cases it turns out that the underlying planning process was extremely difficult.

This certainly also applied to the early planning history of the Luas tram project in Dublin (Ireland; 'luas' is Irish for 'speed'). Journalist for the Irish Times Frank [McDonald \(2000\)](#) describes this history (1987–2000) as a dramatic series of (non-)decision-making, fuelled by prejudice, incompetence, continuous opposition and resulting in considerable delays.

Peter Hall was a pioneer with his study of the demise of large projects. The well-known Danish economic geographer Bent [Flyvbjerg \(1998\)](#) proves to be a successor with his classic 'Rationality and power' (1998). In this study he investigates how power relations are anchored and active within the local government of the Danish city of Aalborg. Based on this case, one can note that ambitious urban development plans such as those put on the agenda by cities like Aalborg in the 1970s can hinder improvement of public transport. Comprehensive plans in which practical, but above all ambitious urban development, as well as ecological and social issues are integrated, run a great risk of becoming too large and unmanageable, especially if rail infrastructure is at stake.

Unlike Hall, [Flyvbjerg \(2007\)](#) studies large, complex projects in a much more systematic and comprehensive manner. For example, he has compiled a database of no fewer than sixteen thousand projects. This impressive collection shows that delays and cost overruns are the rule rather than the exception. Construction costs in particular are underestimated, as are organizational and institutional complexity. Flyvbjerg notes in one of his later studies ([2007](#)) that, in general, rail projects often involve considerable cost overruns.

Many of the light rail cases that have been investigated in [Van der Bijl et al. \(2018\)](#) confirm this observation. For example, the first new generation light rail project in Paris/Île-de-France (T1, Saint Denis-Courneuve-Bobigny, opened in 1992). Cost overruns, delays and technical problems characterised this project during the planning and first years of operation. For example, the superstructure of the original line had to be completely renovated as early as 2001. Flyvbjerg seems to have a point in these types of cases. In contrast, it could be argued though that light rail projects such as this T1 are much more than just a transport project. They also involve urban renewal and reinforcement in spatial, social and economic terms, as discussed in the previous section. The correspondingly increased size and complexity increase the risk of (additional) cost overruns.

3.2 Project checklist

With his American colleague Dan Gardner, [Flyvbjerg recently \(2023\)](#) published a book describing the fate of basically every project. Whether it concerns a home renovation or a space mission (or anything in between), the issues are always similar. Freely and loosely interpreted, some of these issues have been briefly translated into the practice of light rail and tram projects. Firstly: every project is a matter of modesty, because projects are never unique (although those involved often see it as something unique). Many light rail projects have already been carried out, so it is important to learn from these projects (see cases in the box). Furthermore, the overall preparation represents an essential issue. Careful planning forms the basis of every project. What does the project entail and how can it be realised? The project objective must always be clearly in mind, because if the light rail project ultimately turns out not to be justified, yet another failure is a fact. Once underway, projects tend to drag on. Recognising problems on time is a prerequisite for the successful progress of every project. Bringing this issue under control is a major challenge, because the many different components of a light rail contain just as many problems. After all, light rail

projects include urban integration, infrastructure, networks and operation, to name just a few important components. That is why problems are not always recognisable as such. In the worst case, a project can therefore be burden with a ‘black swan’, i.e. unexpected, problematic event. In this way the project can ultimately fail, for example due to irresponsible cost increases and out-of-control schedules. Black swans are particularly dangerous because they represent unknown matters that ideally should already be known. All these issues make it essential to recognise the risk of delays, because these delays imply danger of chain reactions, causing delays to pile up.

The interim conclusion is, that it is an art to bring light rail projects to a successful conclusion. So, how does one achieve success despite the high level of difficulty? To support the answer to this question, a checklist based on research into light rail projects (Van der Bijl et al., 2018) is generated, which can now be used to screen and support light rail projects.

The project checklist covers nine points (see Table 1) to assess the feasibility and fallibility of a project. Similarly can the project risks be visualized. In addition, the nine points provide a basis for determining the level of reality of a project and thus also its status. In this way, a clear distinction can be made between a ‘real’ project and a fledgling idea. Even if an idea has already been thought through in detail, it is still far from a project, because when going through the checklist it will have become apparent that important issues such as decision-making and financing have not (yet) been adequately determined and arranged. Provided with appealing, representative examples the following issues are described below.

Table 1 Light rail project check list.

1. Content, scope, interfaces, phasing
2. Technology, safety
3. Financing, funding, business case
4. Societal justification
5. Political and administrative decision-making
6. Support from politics, stakeholders and population
7. Planning and project organisation
8. Tendering, contract form, concession
9. Construction, operation, robustness

3.2.1 Content, scope, interfaces, phasing

The description of the content defines a project. What kind of light rail is intended? The definition strongly affects its size. How big is the project? Content and size are also sometimes referred to together as the 'scope'. The more complicated and larger this scope, the greater the number of interfaces. A light rail project will always affect its environment and in several respects (spatial, social, economic, legal, etc.) have to deal with or partially coincide with contextual characteristics and related interventions. There are almost always multiple overlaps with other (sub)projects at stake. All this usually makes a project complicated. That is why it is not unusual to phase the light rail project, as happened in Luxembourg for instance. The case of La Réunion, on the other hand, shows that an overly ambitious, big project can ultimately lead to its demise. However, sometimes a project is unavoidably larger, such as in Nice where the projected first light rail line (T1) coincided with the complete renovation of the main sewer and the necessary redevelopment of the public space along the intended route.

3.2.2 Technology, safety

Closely related to the previous point are the selected rolling stock technology, infrastructure and technical facilities. With regard to rolling stock, it is common practice to have vehicles supplied by industry (after tendering). Proven technology is preferably chosen not only for rolling stock, but also for infrastructure and technical facilities.

Finally, safety relates to the technology mentioned here, but also to traffic and social aspects. The new light rail in Luxembourg is an inseparable part of the public space. In addition to technical reliability, traffic safety and social safety are basic conditions for the success of this project.

A high degree of technological complexity places a heavy burden on the (financial) feasibility and achieved reliability of a project. For example, for further extensions Luxembourg has decided to preferably no longer use its ACR (CAF's Acumulador de Carga Rápida) fast charging system, which has now been applied to the central, inner-city section of the line. Another example: it is notorious that many tram-train projects have not succeeded, partly due to technical complexity. Luxembourg's first project is an example of this; de facto cancelled in 2005 when the national railway company CFL announced that it was unable to operate a tram-train network.

3.2.3 Financing, funding, business case

When the (first part of a) project has been established in accordance with the previous two points, the final financial basis can be laid. The balance found between the feasibility of the project and the available financial resources is marked by business justification, usually recorded in a so-called business case. Moreover, a project is also determined in terms of size and technology by the available financial resources. Luxembourg is a wealthy place and can afford an expensive tram and free public transport. Nearby, across the border in France, the city of Metz opted for a high-quality bus at the time due to fewer available resources (Van der Bijl and Van Oort, 2024). Funding and financing in turn depend on the creation contracts (see the last point).

3.2.4 Societal justification

A cost-benefit analysis may be mandatory for a project. But in addition to such a political-technical motivation, a broad social argumentation can underline the necessity and thus feasibility. For this, already an additional, 'broad' assessment using the 5E model (see above) is advocated. Bringing societal justification into the spotlight implies working on the 'why' of the project, instead of too quickly and too one-sidedly emphasizing 'how' the project should be tackled and 'what' exactly needs to be done. Traditionally, the latter is being worked on intensively and almost exclusively. As a result, the comprehensive argumentation of a societal justification is not sufficiently highlighted. The 'why' of a light rail project requires constant attention. A good example of a broadly justified light rail project is Tampere (Finland), with which social, ecological and especially economic sustainability goals were pursued; although economic considerations overruled the other aspects (Stenhäll and Rossi, 2014). It is striking that Luxembourg has opted for light rail mainly because of its greater capacity (the importance of the other E's nevertheless appears to be recognised, which was one of the arguments for making public transport free).

3.2.5 Political and administrative decision-making

Whether a project succeeds largely depends on political decision-making. Regardless of the correct or incorrect, justified or unjustified political considerations, every project benefits if the substantive, technical, financial and social factors related to the project (see the previous points) have been thoroughly prepared in an administrative environment. Only then can the administrative decision-making process pave the way for final political

decision-making. Light rail projects almost without exception represent long-term undertakings, which means that faltering political decision-making (or non-decision-making) poses a risk of the project not being completed. Luxembourg, with its more than twenty years of thinking and planning, is a textbook example of this. However, social perseverance, conceptual revision and pragmatic phasing ultimately kept this project on track. Unfortunately, there are many examples of projects, particularly in England, that did not make it as a result, such as Leeds and Liverpool.

3.2.6 Support from politics, stakeholders and population

Whether a light rail project goes ahead depends entirely on the societal support. Obtaining political support is part of this, which increases in complexity when multiple political arenas are at stake. If the planned light rail line crosses several municipalities, it will not be any easier to get enough politicians to point in the same direction (and keep them doing so). The social support does not only include politicians, but always all other stakeholders, i.e. all those interested parties who directly or indirectly are or getting related somehow to the project. This may involve a candidate company who wants to participate in the tender, an advisory traveller interest group, a shopkeeper that has to surrender parking spaces, the management of an adjacent project and all those civil servants and experts who are responsible for sub-aspects. In addition, participation by the local population cannot be levelled out.

Many public transport projects have failed because residents and local entrepreneurs, for whatever reason, turn against them. Some of our cases (e.g. RegioTram Groningen) show that often such social resistance arises from a 'technocratic attitude' of both political, administrative and civil service decision-makers, as well as those working in the project organisation (see next point). Whether consciously or unconsciously, they focus too much on management and engineering, which makes them unable to truly empathise with all stakeholders, in particular not with resisting local residents and local entrepreneurs.

The Luxembourg city tram project has largely enjoyed sufficient social support, despite but also thanks to years of discussion about the merits of the project. In contrast, Aachen with its Campusbahn is an example of a failed project due to declining support and the final death blow by the negative outcome of a referendum.

3.2.7 Planning and project organisation

All of the above points need to be settled before the realization of the light rail enterprise can take place. This requires a tailored planning and an executive agency that is responsible for the overall planning and the substantive course of the project, including the practical, technical and financial considerations. This agency i.e. project organisation plays a key role in the process of societal justification, the creation of broad support and the consent of political and administrative decision-making. A naive technocratic attitude in this context is one of the greatest risks for any project, especially for more ambitious light rail projects. It is wiser to view and accept planning as an incremental process; certainly in projects that involve public space (Tillner, 2013).

There are two (extreme) models for the development of an executive agency. The first model represents a radical orientation towards the project itself. This means that for the entire enterprise, one independent project organisation is established, which is responsible for the entire planning and later implementation process of the intended project. The second model focuses on existing organisations of the various stakeholders. The project is then realised within the framework of a partnership. Both models have their pros and cons. In addition, hybrid variants are possible (see e.g. Brandsma et al., 2017). A project organisation is often preferred for public transport projects in which infrastructure is a major component. Many of the projects known to us only really got underway after a joint project organisation had been established. This applies to Luxembourg, but also to Utrecht (Van der Bijl and Alkema, 2008). Both cases, with their years of history and preparation, show that mitigating incremental planning processes is almost inevitable. The Jerusalem case shows how a poor organisation can break up a project and lead to significant delays and cost overruns (Van der Bijl, 2011). In contrast, LuxTram is an example of a socially embedded organisation (a private limited company, the capital of which is in the hands of the government; two-thirds the State and one-third the City of Luxembourg), which is able to effectively link its responsibility for operation (including as commissioner of sub-projects) with the further development of the light rail system in Luxembourg.

3.2.8 Tendering, contract form, concession

Different components of a project can be tendered separately or not, such as the design and construction of infrastructure, or instead a single tender for design and construction (design & construct). A separate tender is

usually held for rolling stock, sometimes including a period of on-site maintenance by the manufacturer. The maintenance of the infrastructure can be part of the regular maintenance of the public space, or possibly integrated into the operating contract. In Europe, it is common practice to use different contracts for designers and builders and to award the operation separately to a public transport company, whereas the maintenance of the road infrastructure is regarded as a public task. Nevertheless, integrated contract forms should not be ruled out in advance, such as DBFMO (design, build, finance, maintain, operate). This certainly applies to light rail projects outside Europe. In contrast to traditional tendering where (pre) financing is predominantly a task of authorities, the DBFMO contract form creates the possibility of private financing. Over the term of the multi-year contract, a private party (usually a consortium) earns back its investment (hopefully with some profit). It is clear that the Luxembourg light rail project opted for a classical approach (see the history of the LuxTram project), while the research into the Groningen RegioTram (Van der Bijl et al., 2018) case shows that the use of DBFMO (including rolling stock) was one of the reasons for the project's demise, while the Stockholm tram project was rescued by switching from the initial integrated contract to a traditional contract (Van der Bijl et al., 2018). Liège represents a history of a DBFM contract (including rolling stock) initially rejected three times by Eurostat (2013–2016). Only after a fourth review by Eurostat (Pagano, et al., 2017) and a second tender (2017–2025), the project could commence. And yet in 2023 the Walloon government had to save the construction company Colas from near bankruptcy by restructuring the contract (Metro Report International, 2023). After much social commotion during construction and major delays, the light rail line was put into service in April 2025. However, for the time being, politicians have decided not to build the planned extensions.

3.2.9 Construction, operation, robustness

Well-known are the anecdotes of new French mayors who would prefer to tear up the rails of the light rail project under construction of their cursed predecessor. The question is how robust light rail systems can remain. This does not only involve radical demolition, but also more subtle interim adjustments. If the concession allows it (or does not provide for it), changes in the operation can affect the actual quality of the service, for better or for worse. In the latter case, the operation turns out to be less robust. In addition, reality can be more stubborn than expected. On paper, in

accordance with the technical and functional specifications of the contract and the concession (see previous point), a high-quality light rail service may be adequately described, but in practice the performance of the service can remain substandard due to obstruction of traffic in the area, or other unexpected hindrance.

In Luxembourg, the first line was built in phases (2017–2025), so that experience could be gained step by step, the operation adjusted where necessary and measures taken to raise the robustness of the operation to a sufficient level.



4. Conclusions

In this chapter, it is explained what can be understood by light rail and how projects and associated investments can be justified. Finally, a checklist is presented what is involved in getting light rail projects off the ground and ultimately operating them successfully. In conclusion, it should be emphasised that light rail should never be considered as a panacea for every mobility challenge. After all, light rail is part of the available and necessary mix of transport modes. As a predominantly urban and urban-regional rail-based form of public transport, light rail is part of a palette in which metro (subway) and train (heavy rail) also deserve a place. It should be noted that light rail, based on the strict tram domain, can also be partly operational on metro and train infrastructure. Moreover, the importance of the bus mode, both as a local service and high level service such as Bus Rapid Transit (BRT) or Buses with High Level of Service (BHLS), must be emphasised, since the bus as a road-based form of public transport in many forms is also part of the aforementioned palette. In addition, in every transport system aiming at sustainable, space-efficient and affordable goals, walking and the (shared) (e-)bike should get a serious role. In connection with light rail, walking and (shared) bicycles could offer an important role as first mile (see e.g. [Kager et al. 2016](#); [Shelat et al. 2018](#); [Van Mil et al., 2021](#)) or last mile (see e.g. [Bachand-Marleau et al., 2012](#); [Montes et al., 2023](#); [Mbugua et al., 2025](#)), thereby offering an alternative for car transport ([Nello-Deakin and te Brommelstroet, 2021](#)).

Despite the distinctive functional and technical characteristics of light rail, metro, train and bus, the choice between these transport modes is by no means always clear. After all, the final preference for a particular transport mode always depends on the historical, social and local context,

including desired or expected quality with associated performance. In many cases, these performances (such as required capacity) strongly and clearly point to the need for a particular mode of transport, but a grey area remains where the choice is less clear. In many of the discussed cases, the choice appears to be strongly dependent on the spatial and urban development situation in combination with the ambitions and desired elaboration of high quality, such as the quality level of equipment, comfort, appearance or spatial environment. In short, the choice between light rail, metro, train and bus can imply a grey area, in which the final choice is not only determined by the technical-functional specifications and performances, but also by local wishes or local chance, by the ambitions on site, or last but not least the available organisational and financial resources.

Having said that, the discussion should be opened that light rail is unfortunately often underestimated and not taken seriously in the final assessment and choice of a certain mode of transport. In particular, it is observed worldwide that there are cities where the decision-making process is already pre-sorted in advance towards bus or metro. There are plenty of striking examples to be found. Let us suffice to mention, by way of example, most medium-sized and even larger cities in the UK, such as Leeds and Liverpool, where the bus is (still) used, while in comparable cities throughout Europe the choice has been made for light rail in recent decades (or the tram has been retained and modernised). Or take India, where in recent years many cities have been working ambitiously on the creation of a metro, but light rail has never been taken seriously (the project in the city of Srinagar is indeed referred to as light rail transit, but it concerns two 'elevated corridors', i.e. metro). On the other hand in China, for example, many major cities have received a new metro, but light rail services have also been newly installed in many places (as well as high-quality buses, by the way).

The final conclusion is that light rail deserves its place on the palette of high-quality public transport. For circumstantial evidence and inspiration, France and Australia are good examples. A number of French cities have had a new generation of tram since the 1980s – Nantes was the first. But there have also been cities that consciously opted for a high-quality bus (BHNS) – Metz is a striking example. In the Paris metropolis (Île-de-France) the public transport palette proves to be balanced and well-filled. Here tram and bus play their role and are being expanded, but the same applies to the metro and the regional train. And in Australia, although the renewal and expansion of urban public transport started later than in

France, the various cities together illustrate a conscious choice from the palette, such as for new light rail (Goldcoast), metro and tram (Sidney), regional train (Perth) and high-quality bus (Brisbane).

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