Chapter 3 **Light Rail versus Heavy Rail**

The main theme within this chapter is the technical variety in Light Rail systems and the way they can be combined or integrated with (classical) heavy rail systems and urban (street running) tram systems. First, a useful typology of the various existing techniques in infrastructure integration will be presented. Then, vehicle engineering will be treated (using illustrative examples) followed by a section on safety and signalling.

3.1 Arranging Trams, Metros, Light and Heavy Rail

Light Rail systems show a huge technical variation. Actually, out of literature and Internet resources many different definitions and circumscriptions were 'distilled' (see box 3.1). The only resemblance is the aspect of relatively light vehicles (when compared to trains) riding over various sorts of infrastructure. In table 3.1, Light Rail systems and their rolling stock are technically compared to other public transport systems.

Table 3.1 Light Rail compared to other types of public transport

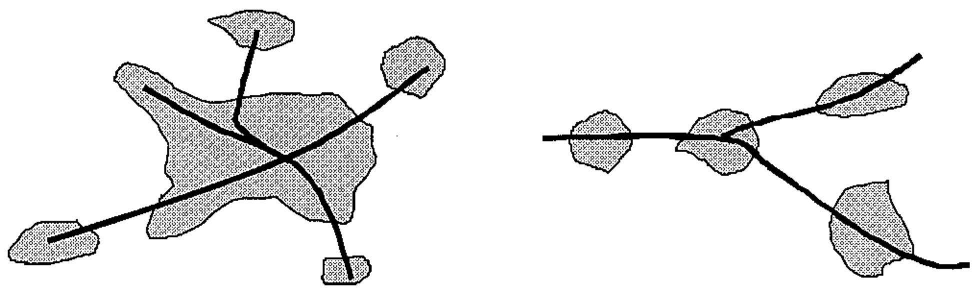
Characteristics	Tram systems	Light Rail systems	Metro and related systems	Heavy rail/ Commuter rail
Typical vehicle car length	10 m	15 m	18 m	26 m
Typical vehicle train length	30 m	25 – 90 m	110 m	52 – 260 m
Typical vehicle width	2.35 m	2.65 m	3.00 m	2.80 m
Typical vehicle floor height	Low or semi-low	Variable	High	High
Platform height	0.15 m	Variable	0.90 m	0.75 m
Dedicated track	Partially	Partially	Completely	Completely
Min. Curve radius	18 m	25 m	150 m	250 m
Voltage/other propulsion	600/750 V	750/1.500 V (or diesel)	750 V	1.500 – 3.000 V (or diesel)
Transfer	Overhead	Overhead	Third rail	Overhead
Security system	None	Partially	Block system	Block system
Brake force	?	Up to 2.6 m/s2	?	Up to 1 m/s^2
Max. speed	70 km/h	80 – 100 km/h	80 km/h	120 – 140
Average speed	15 – 25 km/h	35 – 70 km/h	30 – 35 km/h	60 – 70 km/h
Typical stop distance	0.5 km	0.75 – 3 km	1 – 3 km	5 km
Typical trip distance	3 – 15 km	10 – 40 km	5 – 20 km	15 – 50 km
Frequency per hour	4 – 10	1 – 12	4 – 12	2 – 6

Source: MinV&W (1995), MinV&W (1997), SBO (2000)

In some respects, Light Rail systems rather resemble train systems, in other cases it can be regarded a 'fast tram' system (box 3.1). This hybrid nature becomes also clear in a useful policy concept, used by the Dutch Ministry of Traffic and Water Management. In this concept, there are two main types of systems: urban or metropolitan networks around large cities and regional networks of medium-sized cities and towns. The two types of network are displayed in figure 3.1.

1 The ***Metropolitan Light Rail network*** can be characterised as a network 'growing with the city'. The main target is to extend the (existing) urban network into the surrounding region while largely using existing rail infrastructure. These cities usually have several rail systems but they are working on the accessibility by public transport and the quality of the network.
2 The ***Regional Light Rail network*** is found in less populated regions around medium-sized cities and towns. The main target is maintaining or improving the quality, while cutting costs. Often, these regions are served by conventional heavy rail systems that are very cost-ineffective. With Light Rail these systems can reach more travellers and thus realise a higher patronage and much more cost-effective exploitation[1].

Figure 3.1 A typical metropolitan and a typical regional Light Rail network



Source: BCI/LiRa

With these two possible networks, the typology is outlined. For both of the network types, ***infrastructure integration*** is assessed. In table 2, this is displayed by the columns in the table. To the left, there are the systems that show a less advanced degree of integration with Heavy Rail: ***types 1A and 2A***. These systems have dedicated tracks. To the right, there are the systems that are in some way integrated, e.g. the duo-systems: ***types 1B, 1C and 2B***.

Literature shows that for the LiRa purpose, two more types have to be added. They both have a singular position because of the fact that there is no integration (possible) with existing tram or Heavy Rail infrastructure:

[1] Source: Dutch ministry of Transport and water management (1997)

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Box 3.2

Light Rail systems: network & integration types

Type 1A Full technical integration of infrastructure in tram net; no more classic trains	• Manchester Metrolink • Sheffield Supertram • Various USA systems, e.g. Portland MAX • Nantes
Type 1B Use of heavy rail with extensions onto urban tram system ; Partially also classic trains	• Randstadrail • Rijn-Gouwe lijn • Some lines in Karlsruhe (Bad Herrenalb, Ittersbach, Leopoldshafen) • Köln – Bonn (lines 16/18) • Saarbrücken Saarbahn • San Diego • Zwickau (light trains)
Type 1C Full technical integration of Light Rail and Heavy Rail; full use for classic trains possible	• South Limburg Light Rail • Some lines in Karlsruhe
Type 1D Non-integrated Light Rail with 100% dedicated track	• London Docklands Light Railway (DLR) • Bangkok Sky Train
Type 2A Partial mix with heavy rail; extensions on dedicated track possible	• Kaiserslautern • Dürener Kreisbahn
Type 2B Full mix with heavy rail; requirement of heavier vehicles or separated operation needed	• KAN regional Light Rail • Some lines Köln • Utrecht region Randstadspoor
Type 3 Non-steel-rail rapid transit with 100% dedicated track	• Zuidtangent Haarlem – Schiphol • Caen • Clermont-Ferrand • Utrecht

- Non-integrated Light Rail (e.g. the driver-less London Docklands Light Railway). This kind of system falls within the range of type 1 (urban/metropolitan) but is devised as a separate system running on its own track, which was built especially for this system. It is indicated in the typology as ***type 1D.***
- Non-steel-rail rapid transit (e.g. trams on rubber tyres and buses with a 100% dedicated track, explained in box 3.2). This is a category that can both run in urban/metropolitan areas and in middle-size cities and towns. It is therefore indicated as ***type 3.***

There are some reservations. As already referred to, it turns out very difficult to use technical definitions to make a circumscription of Light Rail systems. In the classification it will probably turn out impossible to make a 100% fitting typology. There will certainly be systems that are hard to enter in this system.

Equally, it has to be noted that systems are made out of different lines. Sometimes the lines do not show much integration. It follows that one Light Rail network can contain several Light Rail ***techniques*** besides (for example) a tramway with street running. Tram systems themselves are deliberately not incorporated in this scheme. However, there can be Light Rail systems where there are conventional trams among the rolling stock.

Nevertheless, it is useful to have an overview showing some of the dimensions of how Light Rail systems can be devised (table 3.2).

Table 3.2 LiRa Quality Rapid Transport system typology

<table>
<tr><th>Type of Light Rail network</th><th colspan="6">Integration with heavy rail
Less integration ← → More integration</th></tr>
<tr><td rowspan="2">1 Urban/metro-politan Light Rail network: Growing with the city</td><td colspan="2">A Take-over of heavy rail: Full technical integration of infrastructure in tram net; no more classic trains</td><td colspan="2">B Use of heavy rail with extensions onto urban tram system; Partially also classic trains</td><td colspan="2">C Full technical integration of Light Rail and Heavy Rail; full use for classic trains possible</td></tr>
<tr><td colspan="6">D Non-integrated Light Rail with 100% dedicated track</td></tr>
<tr><td>2 Regional Light Rail network: cheaper exploitation in middle-sized cities/towns</td><td colspan="3">A Partial mix with heavy rail; extensions on dedicated track possible</td><td colspan="3">B Full mix with heavy rail; requirement of heavier vehicles or separated operation needed</td></tr>
<tr><td colspan="7">3 Non-steel-rail rapid transit with 100% dedicated track</td></tr>
</table>

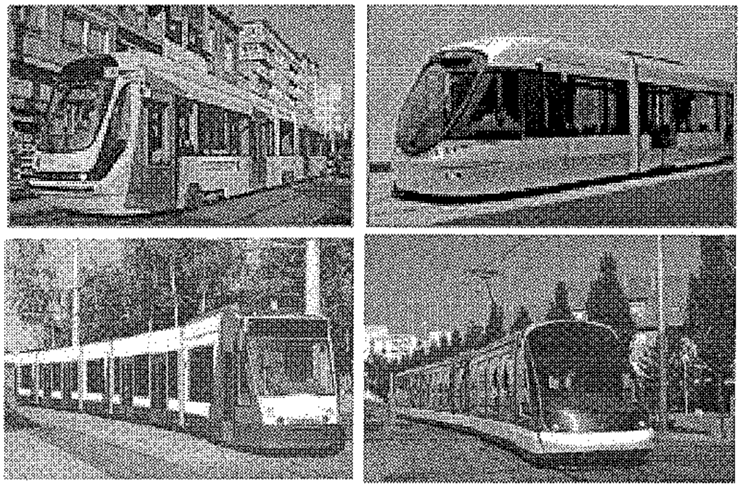
Source: BCI

In box 3.2, some examples for every type are given.

Box 3.3a

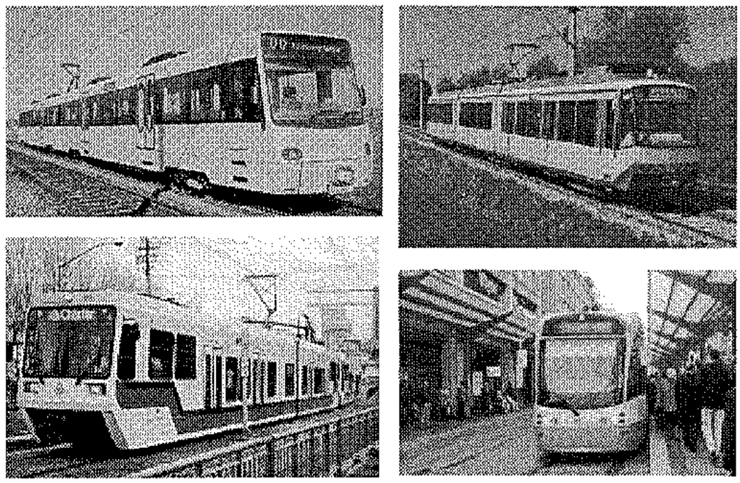
LRV types

Tram (-like) LRVs



Sources:
- Top left: http://www.mivb.irisnet.be/NL/70000N.htm
- Top right: http://www.transportation.bombardier.com/htmen/5_1.htm
- Bottom left: http://usa.siemens.com/Products_and_Services/ProductListing.asp
- Bottom right: http://www.carfree.com/pax_trans.html

Stadtbahn (-like) LRVs



Sources:
- Top left: http://www.railway-technology .com
- Top right: http://www.railway-technology .com
- Bottom left: http://www.trimet.org
- Bottom right: LiRa

3.2 Vehicle engineering between Heavy and Light Rail

This section will give an overview of different kinds of Light Rail Vehicles (LRVs). It has been referred to that Light Rail as a technical device combines the advantages of many different rapid transit systems. Many LRVs were initially designed as (fast) trams. On Light Rail systems 'avant la lettre' ('Interurbans' as e.g. in Los Angeles, and between Delft and Leiden) faster rolling stock was needed. Also, with the extension of street tram systems the typical LRV began to take shape. In other cases, traditional trams ride out of the city; on heavy rail.

In general, the literature points to a range from lighter, semi-tram-like vehicles to heavier, semi-train or semi-metro like vehicles. This is actually in accordance with what was concluded in the introductory chapter (figure 1.4): Light Rail generally has an 'in-between position' between trams, metro systems and full-size heavy rail. However, it cannot prevent that LRVs show the same variety as the different infrastructure systems they ride on.

In general, specialised literature and Internet resources[1] make a division by weight into three 'families': Tram (-like) LRVs, Stadtbahn-like LRVs and light train-like LRVs. Boxes 3.3a and 3.3b give examples.

Tram (-like) LRVs

Trams or Tram-based vehicles with tram-like specifications (table 1). These consist of two to five sections and can be equipped with one or two driver cabins (for respectively driving in one or two directions). An innovative aspect is low-floor configuration, which can be constructed partially or integrally (throughout the unit). State-of-the-art examples are Siemens' Combino (100% low floor), ADtranz' Eurotram (the famous 'Strasbourg example') and Bombardier Cityrunner. These vehicles weight up to 35,000 kg and drive up to 70, sometimes 80 km/h. In literature, there is no agreement about all trams being real Light Rail vehicles.

Stadtbahn (like-) LRVs

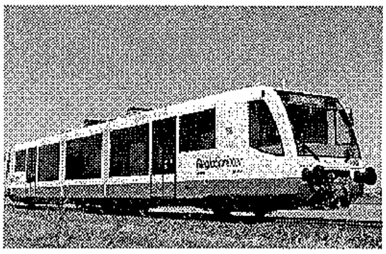
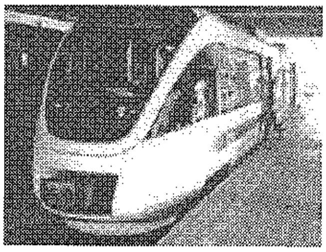
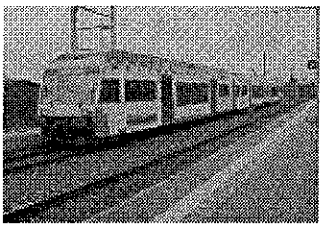
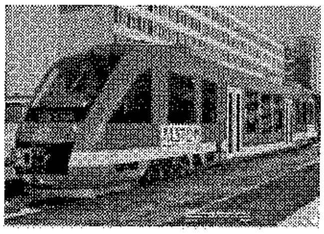
An intermediate category involves the Stadtbahn rolling stock of the often-cited Light Rail projects in Köln, Saarbrücken and Karlsruhe (Light Rail column in table 1). Dimensions and comfort conform more to heavy rail underground rolling stock than trams (MinV&W 1995) but these stock can be regarded a derivative of the tram. Maximum speed is 80-100 km/h and the weight of the units can go up from 35.000 to over 55.000 kg. These types can have low or high floors and according to the platforms where they have to stop. The first unit to

[1] Especially the magazine Tramway and Urban Transit, Internet sites of manufacturers as Adtranz, Bombardier and Siemens; Schenk & Van den Toorn (1999), v/h Hoogerhuijs (1996)

Box 3.3b

LRV types -continued-

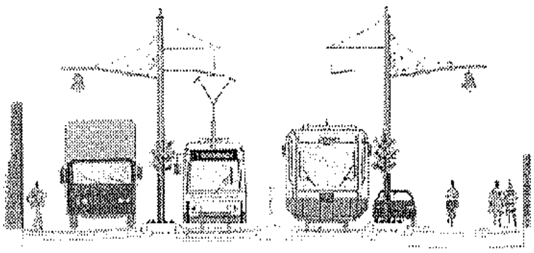
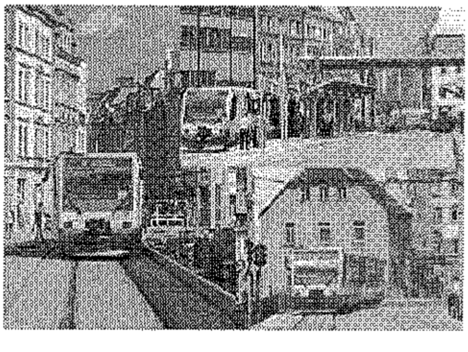
Light Train-like LRVs

Sources:
- Top left: http://www.xs4all.nl/~rajvdb/lra/e_htm/e_2m04.htm
- Top right: http://www.railway-technology .com
- Bottom left: Province of Limburg
- Bottom right: http://www.lrta.org

Box 3.4

Zwickau: tram and train together

At the end of 1999 tram/trolley and train (RegioSprinter, DUEWAG) of the former East German city Zwickau will use a common track between the centre and the south. Two worlds will be merged: tram-based Light Rail and Light Railways. The RegioSprinters of the Vogtlandbahn (regional network on tracks of Deutsche Bahn) are guests on the tramway network. Therefore the RegioSprinters are adapted to the German tramway standards, namely the so-called 'BOStrab-Einrichtungen'. The RegioSprinter is a real Light Rail Vehicle; this LRV possesses much properties of a modern low-floor tram. Entering is comfortable and the interior is spacious. It is even possible to store bikes and there is a restroom.

Source: http://www.xs4all.nl/~rajvdb/lra/e_htm/e_2m04.htm (adapted) be developed was the Duewag Stadtbahn U2 for two extended tramlines from the Frankfurt/Main inner city. This type was also built for cities in Canada and the USA (Edmonton, Calgary, San Diego). Later, Duewag came with the Stadtbahn-B which is used between Köln and Bonn (see box). This type became famous for the innovative doorstep construction and is used throughout many cities in Germany. It was also the basis for many derivative stock types throughout Europe, including Bombardier's Tram-train family that now drives in Saarbrücken[1].

In conclusion, it can be stated that this type of rolling stock has been developed bottom-up from the traditional tram.

Light train (like-) LRVs

The last category can be referred to as 'light trains'. Not weighting much heavier than Stadtbahn-stock, these are rather trains, adapted for street running. Further advantages in comparison to heavy rail trains include more flexible and cheap exploitation. Examples are the Duewag Regiosprinter (Düren, Zwickau), the ABB Henschel Regioshuttle, the LHB LINT (Leichte Innovative Nahverkehrs Triebwagen, Light Innovative Regional Train Unit) and the Talbot (now Bombardier) Talent. When compared to trains, this stock is lighter (30.000 to 50.000 kg), has generally a lower maximum speed (100-120 km/h, sometimes 140) but has much better acceleration and deceleration capabilities. The traction can in this category be diesel and electric.

This kind of LRV has been developed 'top-down' from the classic train.

The data on rolling stock are summarised in table 3.3. The specifications of these three types largely lie in line in a range from light/slow to heavier and fast.

Table 3.3 Rolling stock data summarised

	Tram-like stock	Stadtbahn stock	Light Train stock
Max. Speed	80 km/h	80 – 100 km/h	100 – 140 km/h
Weight	Up to 35 tonnes	35 – 55 tonnes	30 – 50 tonnes
Length	20 – 25 m	26 – 30 m	24 – 37 m
Width	2.20 – 2.65 m	2.65 – 2.90 m	2.90 – 3.10 m

Source: MinV&W (1995), van 't Hoogerhuijs (1996), Brochures Bombardier/Saarbahn

Innovative aspects that go for all the rolling stock types include ***modular design.*** This implies that the vehicles are not designed integrally, but in parts, modules: e.g. sections or carriages (cars). The parts can be combined in various ways, e.g. making a 2-car or a 3-car vehicle. This way, flexibility is ensured; operators can order 2-part stock first and extend them later. Furthermore, if practical different modules can be manufactured in different factories this improves production efficiency and reduces costs.

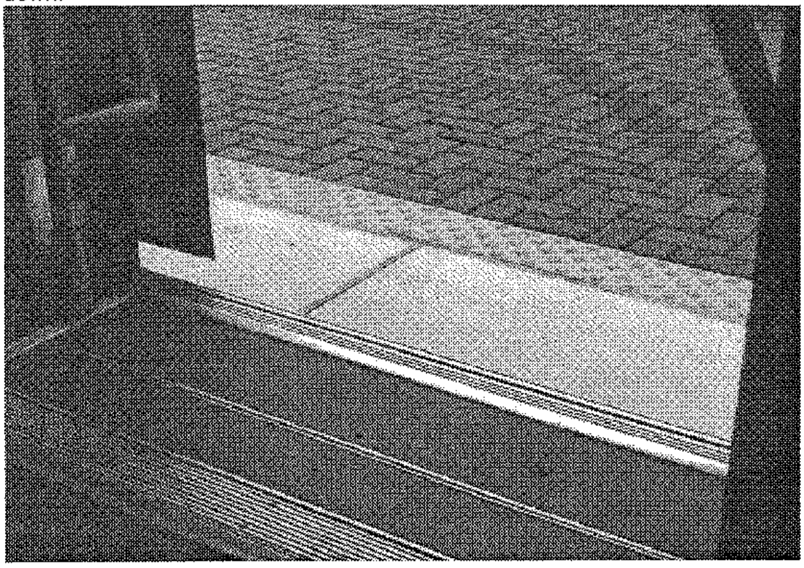
[1] Brochures Bombardier and Saarbahn

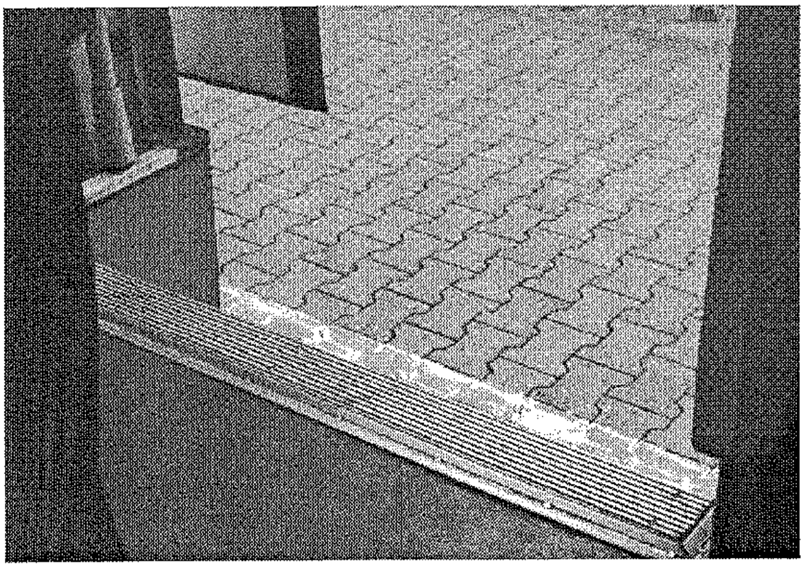
Box 3.5

Köln – Bonn: coping with platforms

The chameleon-like behaviour of line 16 between Köln and Bonn is remarkable. In the medium-sized town of Bonn, the vehicle drives through a metro tunnel with high platforms. This tunnel also has a low platform area for accommodating street trams. Between the two cities, an old heavy railway line is used which still has medium-high platforms. Then, the street tram infrastructure of downtown Köln is used: low (or hardly any) platforms. Toward the main station (Hbf) the vehicles enter a tunnel again.

The pictures show how simple the multi-platform technique works. On top the situation with a high platform. When the vehicle is on a low- or medium-platform station, a part of the floor moves down, becoming a step down.



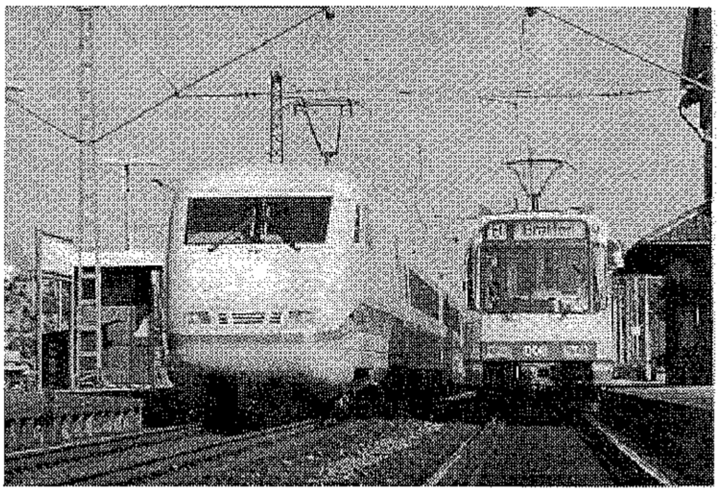


Source: BCI/LiRa

3.3 Technical and organisational implications of integration

The idea of mixed track use (duo-systems) was first put into action in Germany. The story still goes around that a high-speed train driver bringing his ICE train into Karlsruhe Hbf (main station) activated his emergency brake on seeing the Stadtbahn tram on the mainline rails. Still, the idea is very simple. As long as the gauge is the same and special wheels are used, it is relatively simple to design rolling stock or to adapt existing rolling stock that can run on all kinds of rail infrastructure. A technical description of duo-systems in Europe has been made by Karr (1998).

Figure 3.2 ICE and Stadtbahn: creative use of existing infrastructure (Karlsruhe)



Source: http://www.xs4all.nl/~rajvdb/lrа/n_html/n_d03.htm

Legally and organisationally, things are more difficult. National railways were traditionally operated by large national railway companies. With railway deregulation, the management of capacity and security is transferred to task organisations that become part of the national administration. Co-ordination with these task organisations is needed to be able to integrate light and Heavy Rail. But because of the national (top-down) perspective and orientation of these organisations, this can be slow and difficult and therefore (time) costly. In many cases, it takes a long time to get things done. In general, the literature suggests that aspects of public transport should be managed at the same the regional level. This means that matters of regional public transport should be organised at the regional administrative level[1]. This can clash with the way things are organised on the national level.

[1] MinV&W (1998)

Box 3.6

Köln – Frechen; tram on heavy rail in semi-duo-system

The modern street trams of Köln of line 2 take a radial route out of the centre of the German city. At the western edge of the Cologne agglomeration (Dürener Strasse) the trams turn left onto a seldom-used freight railway line and accelerate to about 70 km/h. A few stops further on, the town of Frechen is reached. At the old station of Frechen, the tramline gets off the heavy rail again and continues along Kölner Strasse throughout the town. This way, with only a very limited length of new infrastructure both the relations from Frechen to Köln take benefit but also the local Frechen traffic can profit.

Source: BCI/LiRa

On the current duo-systems, LRVs are usually equipped with double-current systems and/or double electricity transfer systems (e.g. both pantographs and a third rail system). Also, when it comes to safety regulations and signalling usually a 'double' system is used. As is the case with double traction system: technically there is hardly a problem but this can be costly. LRVs get the train influence systems and communication that is standard on heavy rail trains. These double equipment fittings are required when the Heavy Rail part is also used by (heavy) trains, as in the duo system cases of Karlsruhe and Saarbrücken.

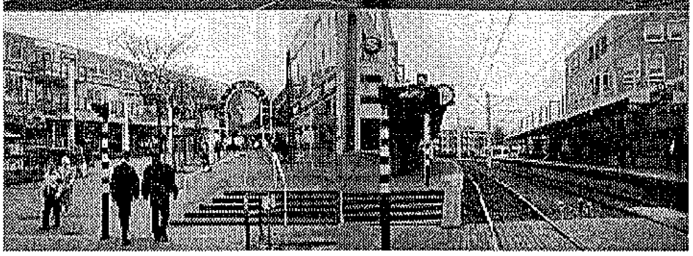
The innovative nature of Light Rail of course points in another direction. LRVs do not need all the security that Heavy Rail Vehicles (trains) need. Essentially, it is enough to devise a tram-like (or metro-like) system for lower speed and lighter vehicles. This can be equipped with devices that count axles. A solution is of course to ban the trains and have a dedicated Light Rail infrastructure. But in some cases, trains are still needed, for example freight trains. Separated operation can then be an option; LRVs use the line in the daytime and freight trains at night. An example can be found on the Köln – Frechen tram line (see box 3.6). The difference in structural strength between the heavy freight trains and the trams is so big that they are not allowed to use the infrastructure at the same time; in case of a collision the risk would be too large.

An important conclusion is that technically there are no big problems; technical innovation will solve most of them. An example is that it is easy, though costly to equip vehicles with double security systems. Legal and institutional problems are more difficult and can be a barrier to Light Rail development. Because of these problems, Light Rail might very well lose the flexibility that makes it such an interesting concept.

Box 3.1

Sneltram Utrecht – Nieuwegein/IJsselstein: light or heavy?

The 'sneltram' (fast tram) system between the Dutch city Utrecht and its suburban towns Nieuwegein and IJsselstein was first meant to be a heavy rail system. After a relatively late decision to incorporate some more stops in Utrecht itself, the Dutch railways (who were responsible for the design) used Heavy Rail technology (in which they had experience) as a basis for the infrastructure. The result was that the 'sneltrams' use tracks that rather look like heavy tracks; though they have the looks of LRVs. Very high platforms were used (with 100% wheelchair access), which could not easily be integrated in the urban environment. The level crossings that were made possible as a part of the compromise cause a lot of waiting time at traffic lights for other traffic (especially in peak hours). It's actually quite logical that when it was time to choose a new rapid transit system, the choice was not made in favour of the sneltram but in favour of a bus lane system. Still, this urban rail system offers convenient and reliable transport since 1983.



Source photos: http://www.xs4all.nl/~rajvdb/rail/n_html/n_kt.htm