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Introduction

Subsequent to the first special issue in March 1980 of

"Stadtschnellbahnen und Stadtbahnen"
(Rapid Transit and Light Rail Rapid Transit),

we now discuss this theme in a special Light Rail issue, which deals with the Cologne experience.

We thus continue the coverage already begun in 1964 on the topical field of rapid transit and light rail rapid transit, termed the 'Second Level', from another wider aspect. The reason is that ectraordinary improvements are possible, even at the 'First Level', if a rail transit system is not considered solely in terms of 'Tunnels and Concrete'. Cologne is an example of well-timed pursuance, with sense of proportion, of a light rail rapid transit policy. The utmost has been obtained which could be achieved within the stipulated financial limitations on technical and organizational feasibility.

The contributions cover the current aspects of the 'Cologne Light Rail Rapid Transit'. Further noteworthy Cologne solutions will be presented by us in the journal 'Verkehr und Technik'.

The occasions marked by this special issue are the opening of the tenth section of the underground/light rail rapid transit system in Cologne - the Deutz construction section - on 10th April 1983, the 15 years of operation since 1968 of the first Cologne tunnel section, and the 20th anniversary of the start of underground construction in 1963.

We wish our readers professional enjoyment with this first special light rail rapid transit issue.

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For Instance Cologne Light Rail – the Success of an Idea

Earlier Inadequacies – Construction Standard – Today's Achievement – Resultant Costs – Future Development Requirements

Earlier Inadequacies

In the 1960's the performance of public transit in Cologne could be equated with the inability of the KVB to ensure an attractive supply for the passenger:

- Along the line in Neusser Strasse, which served the northern residential and industrial areas, delays in the tramway service were an everyday matter due to its incorporation into the private transport.

- The service to the residential areas on the right bank of the Rhine, by means of the former suburban railways to Bensberg and Königsforst, resulted in excellent average speeds in the outer areas, but every pedestrian was faster than the rail in the bottleneck of Kalker Hauptstrasse.

- The crossings of the Rhine on the three bridges: Mühlheimer, Deutzer and Severins-Brücke, became a daily ordeal also for the KVB passengers in a "stop-go" progress together with the private transport.

- Breakdowns in the power supply system due to overloading, particularly in the winter months, often demanded considerable patience from the passengers.

- Delays occurred daily on the "Ring" line because of the lack of a north-south connection from Ebert-Platz via Cathedral/Central Station to Neumarkt, despite the provision of a segregated right-of-way on the "Ring" streets and in Cäcilienstrasse.

An enumeration of the inadequacies could be easily continued. Due to the economic boom, these daily problems were superimposed by the disastrous and chronic shortage of personnel in the entire organisation of the KVB, particularly in regard to

Fig. 1: Neusser Strasse and Kalker Hauptstrasse before and after the light rail rapid transit construction

personnel on vehicles, so that the scheduled trains were only rarely fully in service.

It was inevitable, with an average speed throughout the rail network of 19 km/h, that the annual patronage of the KVB fell from 199 million passengers in 1960 to 153 million passengers in 1968.

Then, on 11th October 1968, came the underground, or more exactly, the underground light rail. All Cologne travelled enthusiastically through the first tunnel. It would be presumptuous, however, to declare that, by these 1,3 kilometres of exclusive right-of-way, a return took place to the transit system on the part of the Cologne population. Nevertheless, no further drop in the transportation figures occurred. A distinct improvement in the quality of the transport supply came when the central city underground line was connected with the city areas on the right bank of the Rhine via the "Severinsbrücke" in 1970, and, in 1974, when a connection was made for the first time from the north, too.

Construction Standard

Discussions began in the State of North Rhine-Westphalia in the 1970's on the construction standard for future light rail rapid transit lines. The large cities were to be provided with exclusive right-of-way rapid transit networks as soon as possible. Existing light rail lines, even with segregated right-of-way, were only regarded as "supplementary communal lines". A luxury vehicle, the rapid transit car 'A', was to be the carriage of the future. Critics could not overlook Cologne, because a tunnel system of a different standard was already functioning. The planners of Cologne and the KVB were not spared biting comment. A "mini-underground" or a "would-be underground" are only two examples of the derogatory opinions.

Nevertheless, the mixed system was determinedly pursued, i.e. light rail rapid transit sections in combination with mainly segregated or exclusive right-of-way light rail sections. A light rail rapid transit car, the "Cologne Type" (B) was developed, and by this means, the conceptual aims of the subsidizing authority were met. The current financial situation places restricted limits on grand construction projects. Today, the future belongs to the once-derogated mixed light rail system, not only in the Rhine-Sieg service area, but also in the Rhine-Ruhr area, as well as in many cities of the Federal Republic. The light rail system is today operated with light rail rapid transit cars by authorities in the United States, Canada and Great Britain.

Today's Achievement

Up to 10th April, 1983 a total of ten light rail rapid transit sections have been handed over to the transport operation and the public. Thanks to new exclusive right-of-way sections, the KVB have enjoyed unhindered travel on all three Rhine bridges since 31st August, 1981.

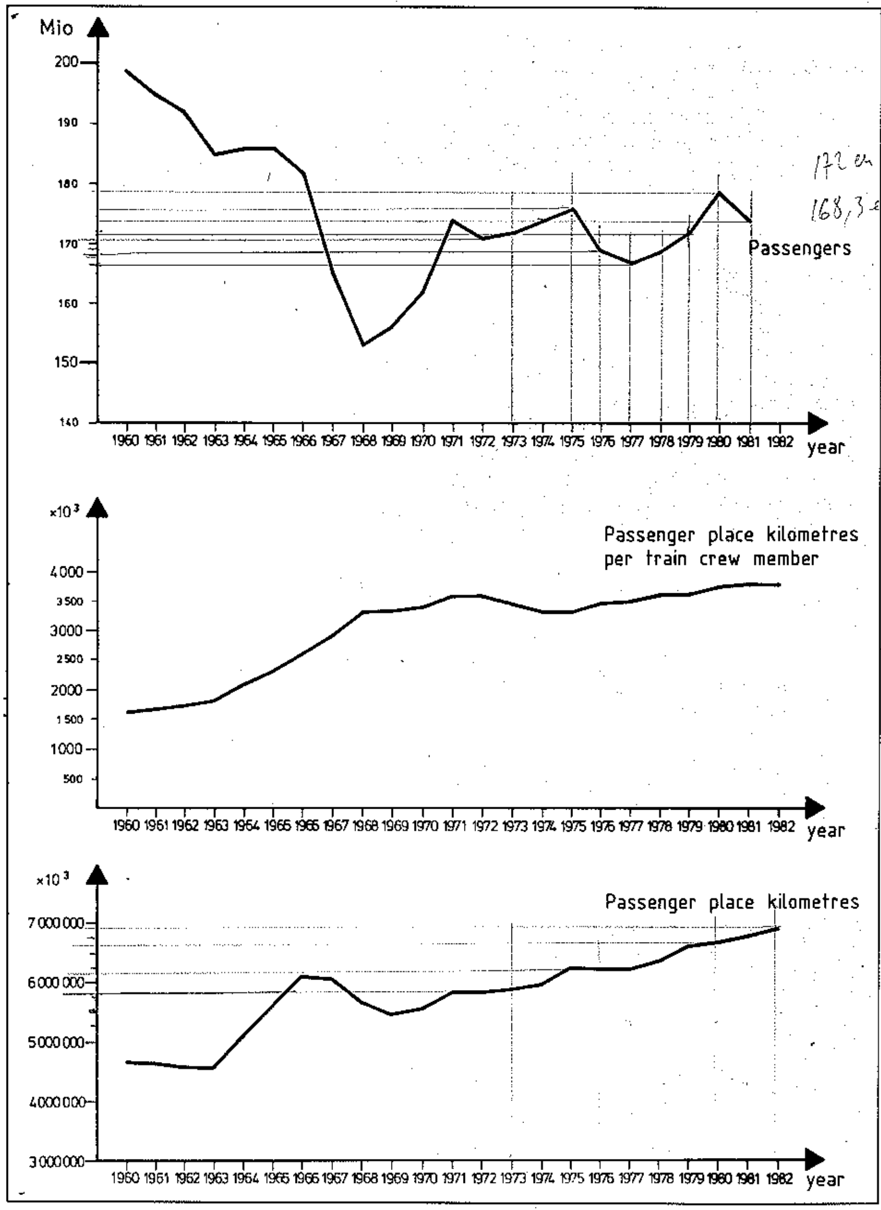

Fig. 2: Development of passenger totals and operational indicators

Since 1978 the longest light rail rapid transit line in Germany, from Cologne-Mülheim to Bonn-Bad Godesberg, utilizing the railway line of the Cologne-Bonn Railways (KBE), has operated at 15 minute headway. The average speed has increased to 23.7 km/h, with the following characteristics of the system (sections of the KBE line which predominantly belong to the service area of Cologne are included):

Fully constructed light rail rapid transit sections	41.6 km (= 27 %)
Remaining sections with exclusive right-of-way (absolute priority, most of the level crossings with technical safety measures)	48.0 km (= 32 %)
Other sections	63.3 km (= 41 %)

Thus, those features of a good transport supply which command a hight value in public transit, according to public opinion polls, have been fulfilled in Cologne:

- high average speed because of separation from private transport
- reliability because of the minimizing of operational breakdowns
- good scheduling together with punctuality
- comfort at stations and in vehicles competitive to that provided by private transport.

The latter aspect is particularly important for the motoring target group. A switch-over trend is already perceptible in Cologne. The park-and-ride (P+R) system under construction is being well utilized.

Some facilities must already be extended in a second construction stage. It is clear that motorists who are accustomed to comfort particularly prefer to use the parking facilities provided at the terminal of a line or a fill-in line. This is understandable, as at these points the comfort of a seat is assured.

Resultant Costs

Recently the discussion on resultant costs for light rail rapid transit measures has at times become heated. With every decision on future light rail construction, the municipal representatives rightly demand clarification on the financial burdens from its operation, maintenance, and renewal for the cities and the transit authorities. To experts it has always been known that underground traffic facilities lead to increased costs. It is, however, of extreme importance that in the consideration of resultant costs not only the cost-increasing aspects, but also the cost-reducing components are clarified. With light rail rapid transit lines the round-trip time is sometimes considerably reduced. thus saving on personnel and rolling stock. In the past, in Cologne, these costs savings have been extensively utilized in order to provide an improved operational schedule. This is no longer necessary in the future. On this basis, full cost equalization is already obtained, for example, in the resultant costs for the next light rail rapid transit section in Venloer Strasse, if a passenger increase of only 10 % is achieved on this line. This could easily be achieved.

Future Development Requirements

In conclusion, two requirements should be formulated which must be fulfilled for the future. One is concerned with the form of organization for public transit in the Rhine-Sieg area, and the other with the associated town development planning.

- Viewing the modal split between private transport and public transit in Cologne, the KVB is considered to be competing with the other metropolitan areas of the Federal Republic. This, however, is a comparison of dissimilarities. The Cologne-Bonn area is the only conurbation in the Federal Republic which still does not have an integrated transport supply in which all public transport operators provide a service to the passenger. The transport association or Rhine-Sieg is lacking. Only if its establishment is intensively pursued by all participants and the formation of an transport association is achieved in 1983, the light rail rapid transit investments will bring about a lasting change in trends to the benefit of the public transit. The supplementation of the communal light rail rapid transit network in Cologne by an effective rapid transit system of the German Federal Railways represents a further prerequisite to this aim.
- In the layout of the surface areas *after* completion of the light rail rapid transit construction works one may notice frequently that the design of the traffic circulation areas for private transport are more extensive than *prior* to the light rail construction. As a minimum requirement, it must be assured, however, that *increased* traffic areas for private transport are not provided, with it being understood that private transport also includes cyclists in addition to motorcars. The light rail system should be supported by accompanying restrictions on road construction planning, in order that more space is assured for a rewarding environment.

D. B.

Economic Utilization of Investment Subsidies in the Cologne "Mixed System"

Principles of the Mixed System – Staged Construction of the Rail Network – Development of Investments and State Grants – Influences on the Choice of Construction Standards – Advantages of Flexibility

1. Principles of the Mixed System

An important principle of the Cologne "Mixed System" is that rail vehicles of differing types can travel *without interruption* on both light rail rapid transit type constructed sections and pure tramway sections. In comparison to the separated operation of a pure rapid transit network and a supplementary tramway network - particularly in consideration of the high density of the rail network of the Kölner Verkehrs-Betriebe AG (KVB, Cologne Transport Co.) - this has a traffic advantage in that a considerably higher number of direct connections can be provided. By this means no extra changing is required, which has a positive influence on the attraction of the overall system.

A further system-related advantage is that limited newly-constructed sections can be incorporated into the existing rail network immediately after completion, by the provision of temporary ramps in the event that differing track levels occur at the junction.

By this means, the high financial investment in the infrastructure can be directed towards a *promt and continuous* level of application.

2. Staged Construction of the Rail Network

With the above objective in mind, the construction of the surface lines often takes place in *two phases:* a section with exclusive right-of-way is first constructed, which after completion generates an operation with major improvement on the earlier average speed and is no longer hindered by private transport. Afterwards, whilst in service, the section will be equipped with train protection systems and other operational installations. An example of this technique is the section *Heumarkt-Deutzer Brücke* which has operated without problems already since 26th October, 1980, on an exclusive right-of-way, whereas the train protection system will be in operation only two-and-a-half years later, on 10th April, 1983, together with the construction of the Deutz section. A similar experience has occurred on the *Severinsbrücke,* where the trains have also travelled on an exclusive right-of-way since the completion of the reconstruction works on 31st August, 1981, and in this manner the advantage gained of unhindered operation can already take full effect. At present, the power transmission system for twin-vehicle-train operation and the train protection system are being installed according to the availability of financing. On completion, which is foreseen for the end of 1984/beginning of 1985, investment in this section will have been utilized over three-and-a-half years to the benefit of the community.

Since the commencement of light rail rapid transit construction in Cologne in 1963, there have been *altogether ten new openings* of fully constructed light rail rapid transit sections in the KVB network, including the putting into service of the Deutz section on 10th April 1983, with lengths of from 600 m (Fuldaer Strasse, 1976) to 12,3 km (Central Area/North, 1974). Also to be included is the completion of the KVB central control on 2nd May 1980, which is an important component - also from the economic aspect - in the operational and traffic monitoring and control of the ever extending network construction with its increasingly complex operational installations.

The development of the right-of-way kilometres in shown in Fig. 1. In addition to the light rail rapid transit sections of the KVB, the *Rheinuferbahn* (Rhine Bank Line) of the Köln-Bonner Eisenbahnen AG (KBE, Cologne-Bonn Railways Co.), opened on 12th

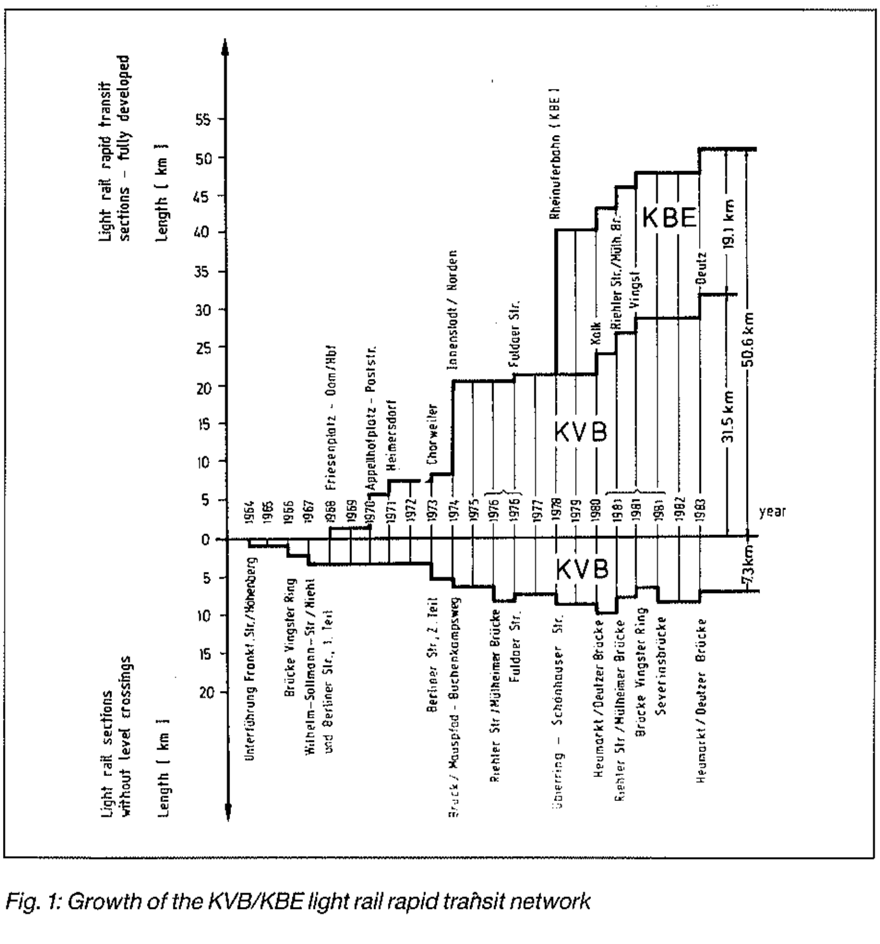

Fig. 1: Growth of the KVB/KBE light rail rapid transit network

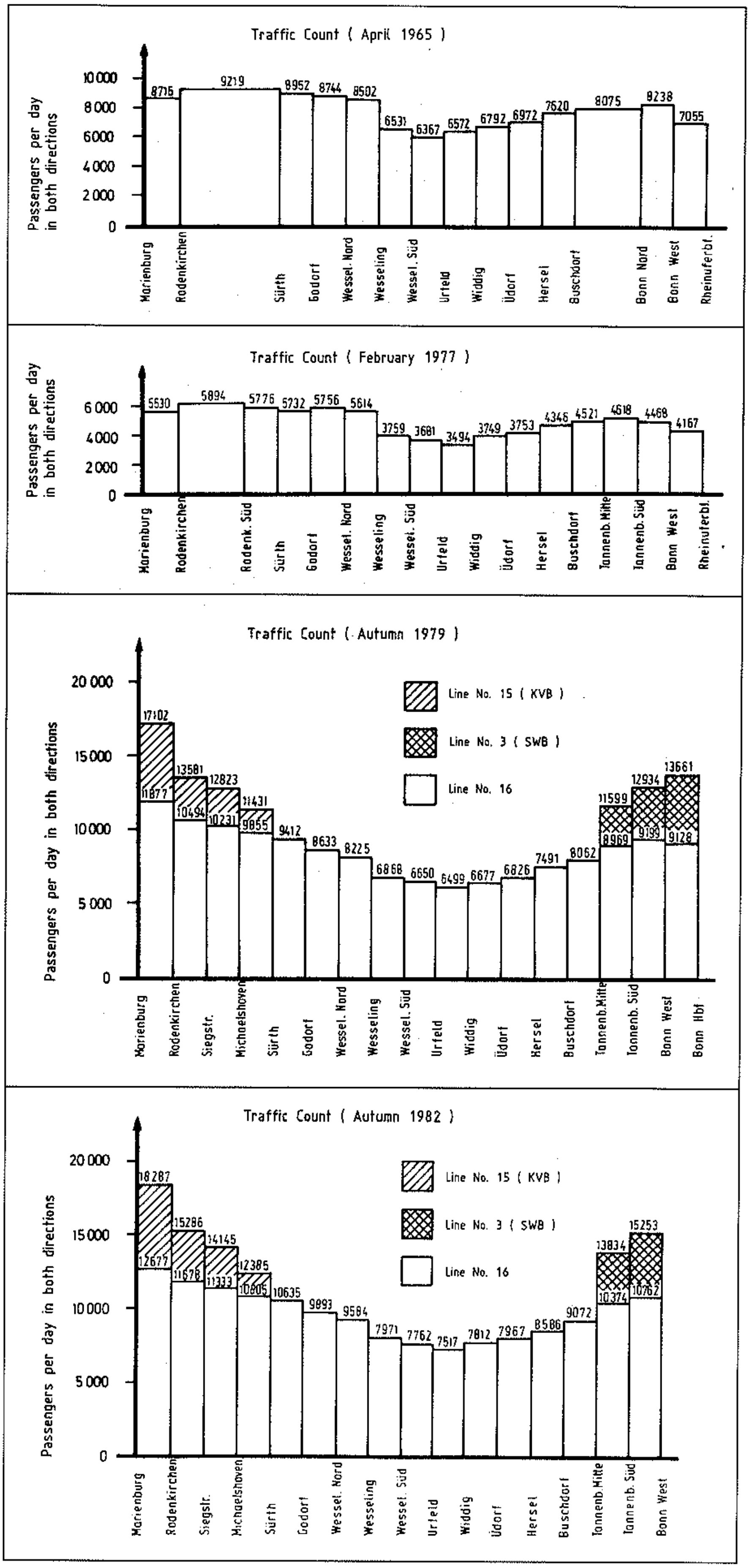

Fig. 2: Development of traffic growth on the KBE Rhine Bank Line

August 1978, is also included, but only for those sections which for a length of at least 1000 metres do not include level crossings for private transport. The Rheinuferbahn runs between Cologne-Marienburg and Bonn as an EBO (Railway Construction and Operation Regulations) main line with a full priority right-of-way throughout, and is fully signalled, but at present still crosses roads with private transport at 13 level crossings with technical security devices.

A right-of-way completely without level crossings is so far not yet available to the Rheinuferbahn. When it is taken into consideration, however, that level crossings no longer exist within many rail sections of considerable length, and if you consider the differences of construction standards for the *stations* from the layout elements which have been established by the State of North Rhine-Westphalia for the design and construction of light rail rapid transit (references 1 and 2), to be not decisive in the final classification, then line sections with a total length of 19.1 km can be considered as part of the fully constructed light rail rapid transit network. Of these 10.1 km belong to the commuting area of Cologne (traffic centre Cologne) and 9.0 km to that of Bonn (traffic centre Bonn). Included from this aspect are also the three light rail rapid transit stations in the area of the town of Wesseling (Wesseling North, Wesseling, Wesseling South), which have been identified with the underground sign (white 'U' on a blue background) after the elimination of the previous level crossings at Flach-Fengler Strasse and Kronenweg.

Furthermore, the Rheinuferbahn is a striking example - with its scope limitations and *comparatively restricted investment* (some 3.7 million D-Mark per km) - of how lasting positive effects on the demand for public transit can be achieved. On the basis of traffic counts made in 1965, 1977, 1979 and 1982 (Fig. 2), the section loadings, as determined for normal working days, clearly show that the sharp reversal in traffic volume between 1965 and 1977 has been converted into a strong and lasting rate of growth by the inception of light rail rapid transit operation and the integration of the line into the city networks of Cologne and Bonn in 1978. Thus the sectional loading (passengers per day in both directions) has increased, for example, by an average of some 114 % north of Sürth Station, and some 241 % north of Bonn-West Station.

Not to be overlooked against the background of this accomplishment, the KBE is endeavouring to achieve the earliest possible reconstruction of their second north-south connection, the 31.9 km long *Vorgebirgsbahn* ("Foothills"-Line). Measures to this effect have already been started in the region of Bonn in 1982. The commencement of construction for the section between Cologne and the northern city limits of Bonn is foreseen for the current year, in consideration of the present status of the preparatory works.

3. Development of Investments and State Grants

The continuous expansion of the light rail component in the track network of KVB and KBE is only possible with extensive support from the Federal and State authorities. The necessary preconditions for this have been especially provided, as the financial volume for the subsidizing of the projects in the course of the years has been considerably increased, and, at the same time, the grant conditions have been improved.

Whereas at the commencement of the construction operations for a communal light rail network in Cologne - up to 31st December 1966 - grants of a level of only 50 % were guaranteed (exclusively contributions from the State of North Rhine-Westphalia), the grant component in the following years, because of statutory measures which also included the Federal authorities in the contribution*), rose to 90 % of the acknowledyed investments (60 % Federal financing, 30 % supplementary State financing). Since 1970 the State of North Rhine-Westphalia has assured a further supplementary contribution of 7 % towards the planning and preparation costs of light rail rapid transit construction (based on the acknowledyed investment sum).

With the support of the high State subsidies, the annual construction volume has today grown to more than double that of 1968 - the starting-up year of the first line section - which was urgently necessary in view of the backlog with which public transit was burdened in comparison to competing private transport. Up to the end of 1982 a total of some *1327* million D-Mark has been invested in the light rail rapid transit construction within the operation network of KVB and KBE (Fig. 3). Of this, some 626 million D-Mark was financed by the Federal Government, and some 398 million D-Mark by the State of North Rhine-Westphalia. The city of cologne and the KVB contributed from their own resources a further 294 million D-Mark, with a further 8 million D-Mark, approximately, coming from the Stadtbahngesellschaft Rhein-Sieg mbH (Rhine-Sieg Light Railway Rapid Transit Ltd.) and the City of Bonn.

In addition to these investments for infrastructural construction, a *further 92.8 million D-Mark* had to be obtained for the provision of new rolling stock particularly adaptable to light rail rapid transit operation. These vehicles have been developed specially for the purpose of mixed operation, with the extensive participation of Cologne engineers, in particular regard to

*) Steueränderungsgesetz, 1966 (Tax Amendment Statute 1966); Gemeindeverkehrsfinanzierungsgesetz 1970 (Communal Transport Financing Act, 1970); Verkehrsfinanzierungsgesetz, 1971 (Traffic Financing Act, 1971).

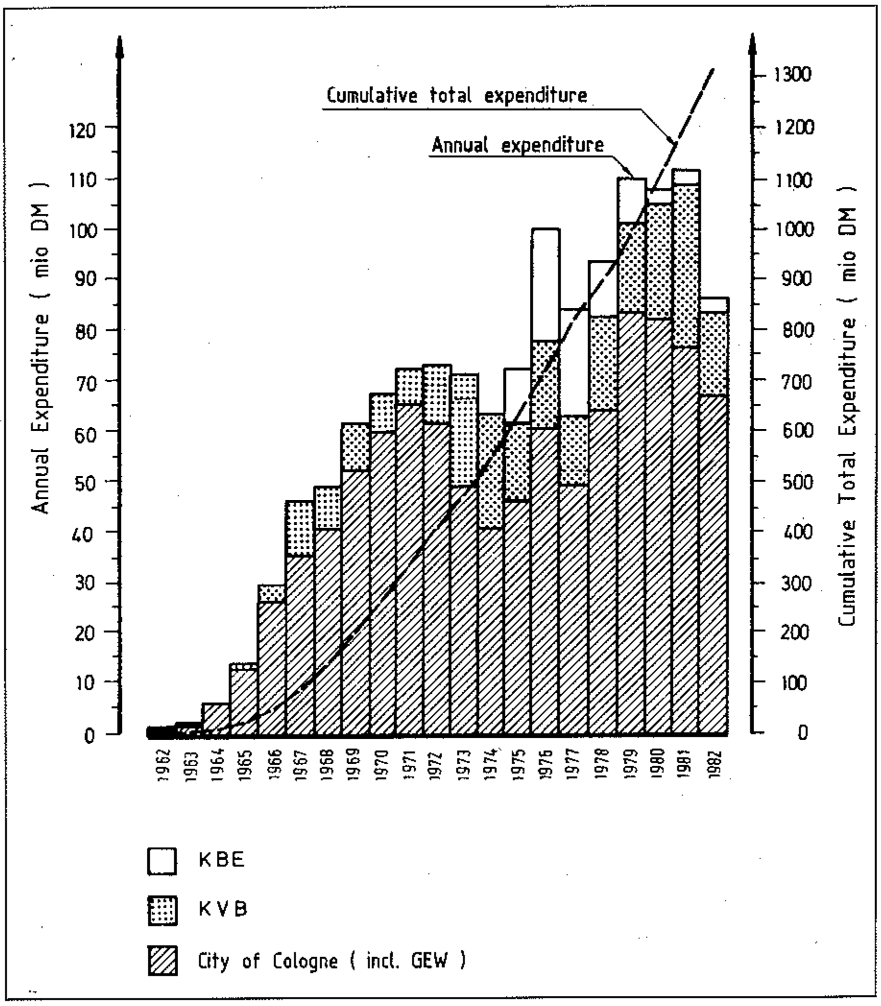

Fig. 3: Nominal expenditure for light rail construction in the KVB/KBE traffic area

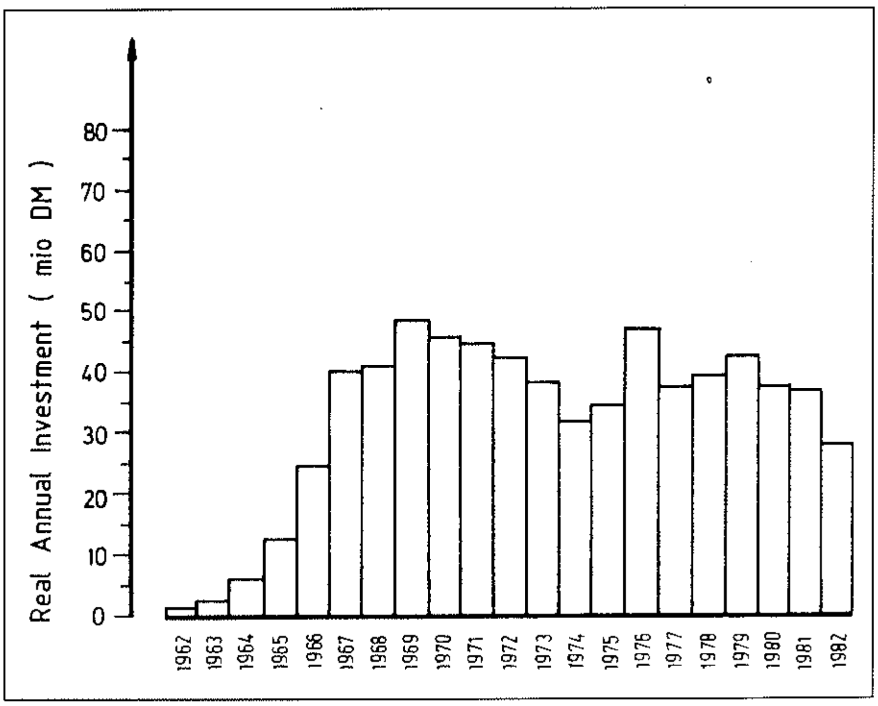

Fig. 4: Real expenditure for light rail construction in the KVB/KBE traffic area

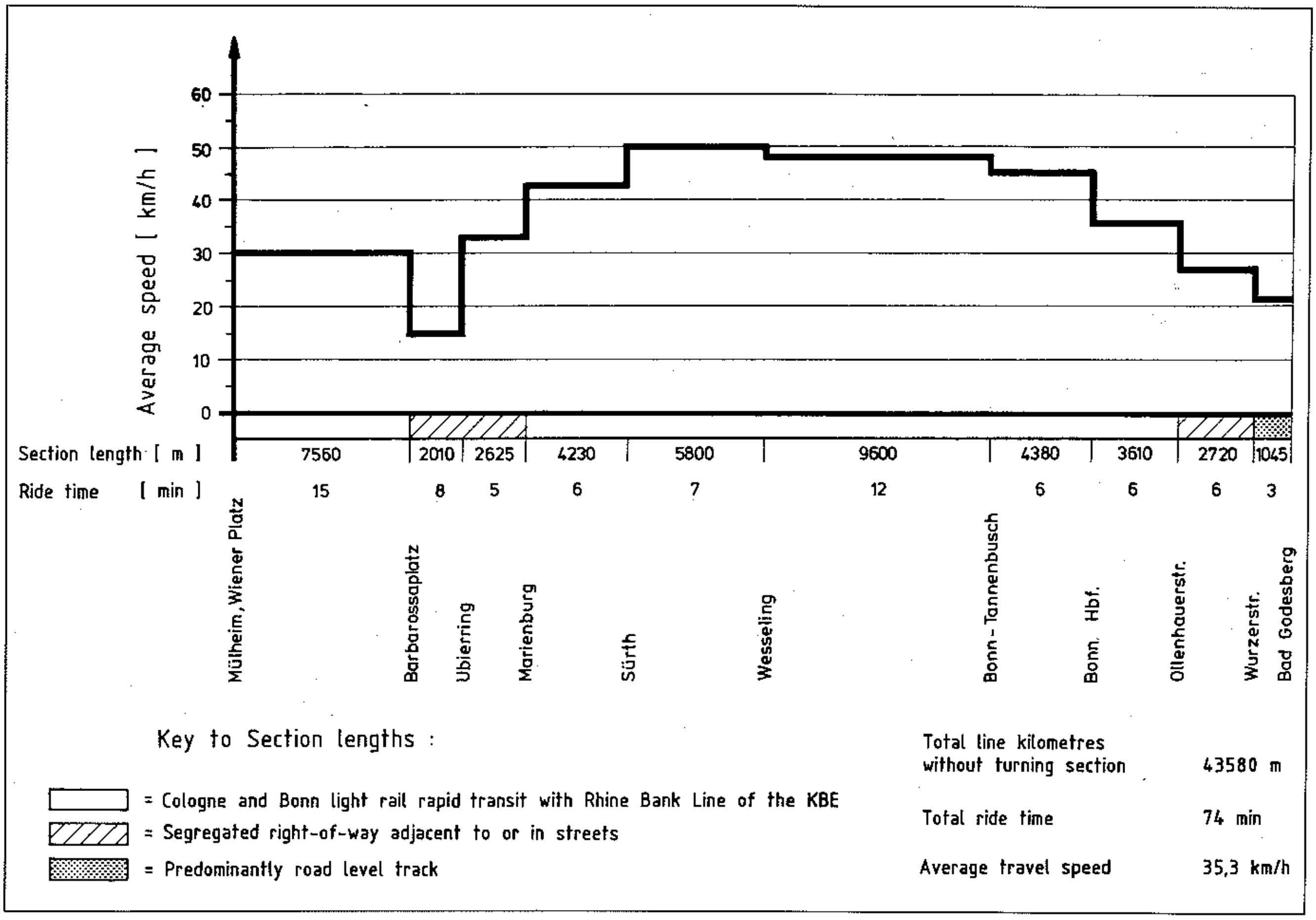

Fig. 5: Average speeds on the light rail rapid transit line Cologne-Wesseling-Bonn

economic aspects, and are known today throughout the world as the "Cologne Type Light Rail Rapid Transit Car". For the provision of the 59 vehicles which are today operating in Cologne (54 with the KVB and 5 with the KBE), the KVB had to provide some 51.2 million D-Mark form their own resources, and the KBE some 8.1 million D-Mark. Some further 33.5 million D-Mark were provided by the State of North Rhine-Westphalia as a grant under the investment assistance program.

The positive development of the nominal investment in the construction of light rail rapid transit lines has, however, been superimposed on a parallel rapid increase in construction costs. The construction price index has risen by some 170 % since 1967, so that the *real investment* for some years has been *falling* (Fig. 4).

The drop in available investment funds has forced a slackening of the place in the further construction of the light rail network. This has led to the consequence that works already commenced must be *extended over a longer period* which, in the town areas affected, has created traffic and economic problems with the cut-and-cover construction methods which have been exclusively employed until now on economic grounds in Cologne.

At present, however, with financial support from the State of North Rhine-Westphalia, strong efforts are being made to alleviate these effects by a *pre-financing* of grants, and to ensure continuity in the completion of well-advanced construction works.

For projects not yet commenced, there is the question whether the planned construction works can be commenced and completed within the envisaged time frame.

This question is at present of particular importance in Cologne for the foreseen *network expanison* which will be connected to the Friesenplatz cross-station, at present under construction, and a section to Hans-Böckler Platz (foreseen completion April 1985). Tunnel sections should be simultaneously constructed here:

- on the one hand, on the line of the traffic-overloaded *Venloer Strasse* through the thickly populated town quarter of Ehrenfeld
- and on the other hand, as the continuation of an existing tunnel section on the line of the *"Ring"-streets* to eliminate the points of conflict with the heavily loaded radial streets.

Both construction sections, which after their completion will make a considerable contribution to increasing the attractiveness of the public transit system in the west of Cologne, will determine the light rail transit achievement in Cologne until long into the 1990's.

4. Influences on the Choice of Construction Standards

The ever-increasing difficulties in the financial situation have led, in the substitution of tunnel constructions to a great extent by a return to *elevated line sections,* as are in operation along the northern "Belt"-streets of Cologne, and, above all, the utilization of *ground level solutions* (Ref. 3). Extremely good conditions are found, particularly in the outer areas, for at grade section alignments. By utilization of the *flexibility* which is provided by the Cologne style of mixed system, fully developed and signalled light rail rapid transit lines can throughout be linked up to tramway lines containing level crossings with private transport; in this case, however, the activation of traffic light systems for obtaining the priority must be considered. In the inner city areas, however, the retention of individual track sections with tramway operating characteristics within the network sections constructed for light rail rapid transit operation is problematical over any *length of time.*

Even with the extensive use of segregated right-of-way, points of conflict easily occur with the private transport - particularly when the priority is not cleared for the rail traffic - which lead to *speed reductions* and breakdowns in the operational system, in consequence of delays, accidents, poor road conditions due to weather conditions, etc. for the private transport. An *example* of this is the 2.5 km long section Barbarossa Platz-Rheinauhafen, operated in tramway mode, a section within the light rail rapid transit line Cologne-Bonn, served by trainline No 16 (Fig. 5), a section which still has 17 crossings with private traffic (of which four represent heavily loaded radial incoming and departing streets, and three exclusively for pedestrians), and where, because of the local factors as well as the limited availability of financing, a substantial portion must be retained at the existing construction standard prior to the completion of the line.

The full construction of light rail rapid transit sections at grade in the inner city areas, however, - with continuous flanking barriers - can create difficulties, as in this manner the line will have a *divisive barrier effect,* and will be regarded as a reversal in town planning and a communications hindrance. In the long term, therefore, the construction of the second level in the inner city areas is indispensable, and the target planning must be directed towards this end.

5. Advantages of Flexibility

In conclusion it remains to state that the mixed system offers excellent possibilities, not only in regard to specialized local, technical and operational factors, but is also compatible to differing financial conditions and design concepts. W. M.

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Ride Times, Average Speeds and Headways – Past and Present

Ride Times – Average Speeds – Headways – Details of Bus Operation – A Further Comparsion

Cologne, although a city of almost 1 million inhabitants, *still has no transport association.* This means that, in contrast to almost all other conurbations, there is still no interconnection between the municipal public transport and the transit services carried on the tracks of the German Federal Railways, and also no integration of the national bus companies with their partner undertakings with whom they operate in common.

The Kölner Verkehrs-Betriebe (KVB) must cope with the inner city traffic practically single-handed, as the Cologne-Bonn Railways (KBE) and the Rhine-Sieg Transport Company, who are both partners within the transport and fares union of Rhine-Sieg (VRS), are only marginally engaged in the transit services of Cologne. A similar minor involvement is also applicable at present to the German Federal Railways, as their commuter rail service is only of benefit to those inhabitants of Cologne who are in the immediate vicinity of the 22 German Federal Railway stations, if they are living there and have another of these stations as their destination.

Without a transport association there is no fare coordination for the required free accessibility in suburban service. As the establishment of the Rhine-Sieg association is in prospect for 1984, the theme of this contribution is applicable at present only to the KVB.

First a word regarding the acceleration of operations by *rapid passenger processing:* the KVB have become fast not least by nineteen years of passenger self-service. Only a bare 4 % of the passengers utilize single trip tickets purchased from the driver. No less than 96 % of the tickets are bought in advance! This fact is to be taken into consideration in the examination of the following comparisons.

Ride Times

For ride times there are two pictures. In a city of on million inhabitants it would be ideal if one could declare:

- "No more than 30 minutes for the city to all destinations in the peak hour!"

Whether it was expected or not: within the city area the KVB have actually achieved this aim on their *rail network,* with ride times of over 30 minutes being exclusively associated with destinations on bus routes (Fig. 1).

For the inner city destinations of *bus feeder lines,* a considerable advancement towards the 30 minute limit would be possible if the Federal Railway lines were incorporated by a common fare system into the overall service. The construction of the Ehrenfeld underground is also a prerequisite for such a service. Not to be overlooked is that a particularly rapid connection is not justified on bus routes with low occupancy rates and correspondingly extended intervals.

Such routes are concerned with connections to residential areas with low population densities.

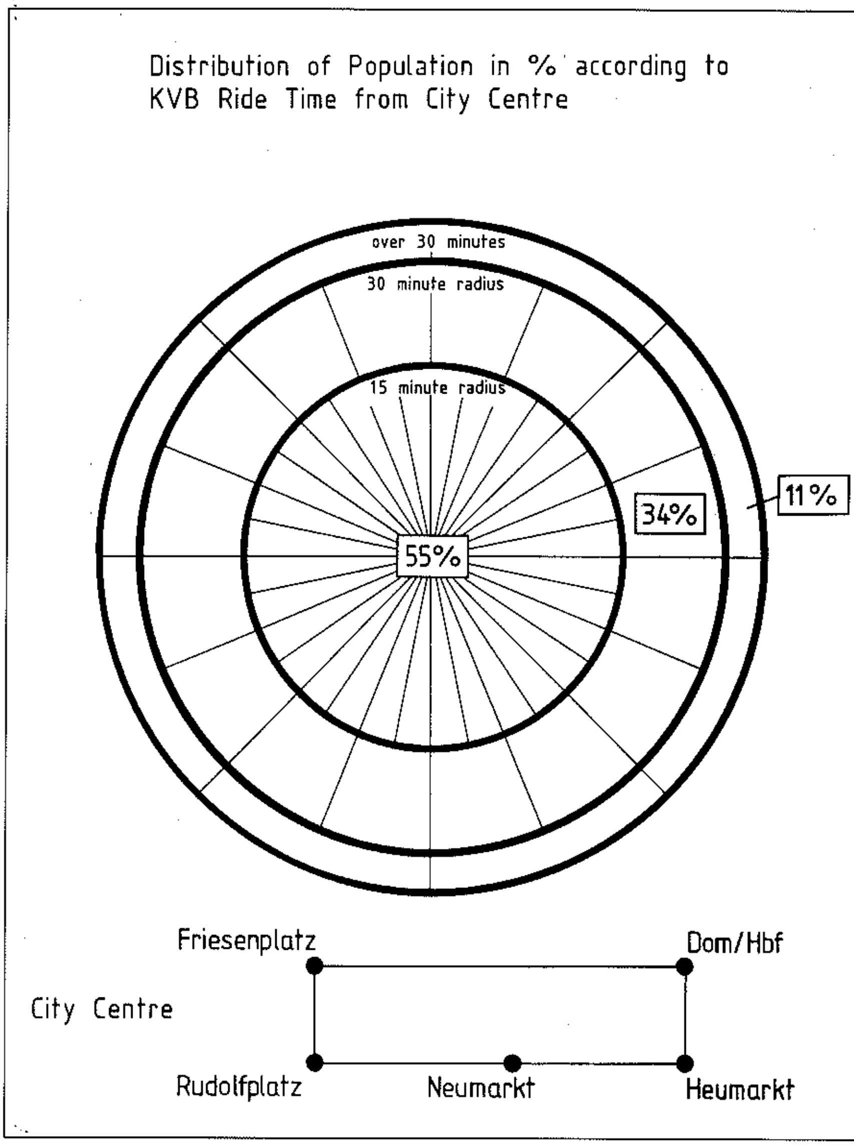

Fig. 1: KVB ride times (by rail and bus) from city centre, for population within the city area, in percent (in 1983)

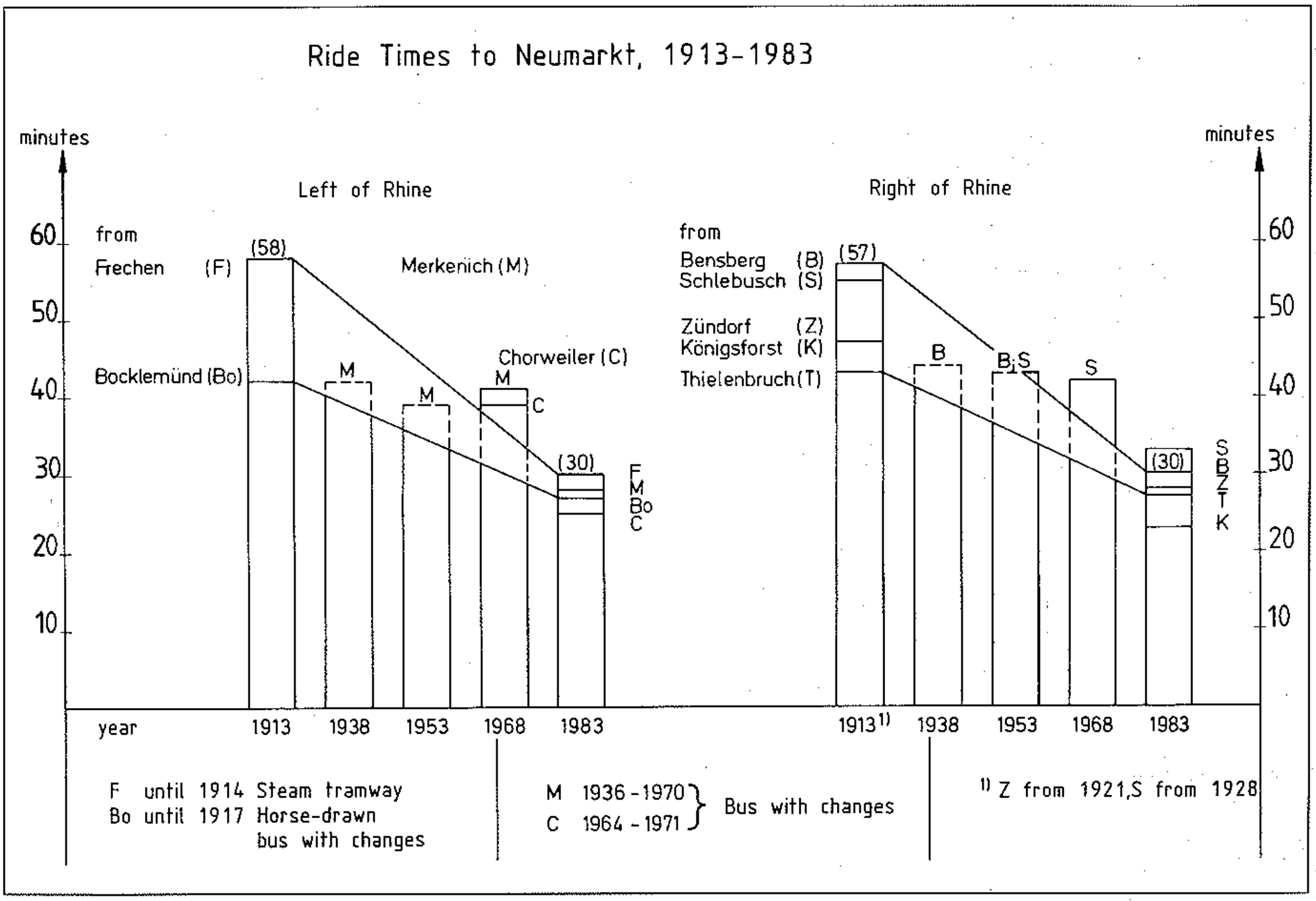

Fig. 2: Past an present ride times to Neumarkt (city centre) from some characteristic terminals of the KVB rail network

The *improvements in ride time* from the past until today are shown in Fig. 2, which displays a fine achievement. On one hand, the *suburban rail lines* with full priority right-of-way are to be thanked, which were put into operation by the KVB founders shortly after the turn of the century, and on the other hand, above all the *underground construction* in modern times, which will have a positive influence also on the Bocklemünd terminal in some years. Not to be overlooked are those sections in which only minor improvements were made during the period from 1913 to the present. These are discussed below with the average speeds.

Highly important to the quality of Cologne public transit is the fact that, in accordance with the general recommendations, all residential areas within the extended inner city zone are situated *within 500 metres* of a KVB station or stop, and *within 600 metres* outside that zone. The extended inner city zone is bounded on the left of the Rhine by the Militärringstraße and by the Frankfurt-Oberhausen Autobahn on the right bank.

Average Speeds

The following review of the average speeds, as of 10th April 1983, exhibits notable differences.

Average Speed to Neumarkt on the Routes from:

Bensberg	32,2 km/h
Königsforst	31,5 km/h
Slabystraße	30,4 km/h
Chorweiler	29,5 km/h
Zündorf	28,4 km/h
Thielenbruch	27,4 km/h
Merkenich	26,2 km/h
Schlebusch	25,3 km/h
Frechen, Mühlengasse	23,7 km/h
Rodenkirchen	23,1 km/h
Ossendorf	19,6 km/h
Südfriedhof (Zollstock)	18,4 km/h
Bocklemünd	18,2 km/h
Junkersdorf	17,5 km/h
Klettenberg	17,2 km/h
Marienburg	17,0 km/h
Sülz	13,4 km/h

The mean value of the above list, which does not include the rapid KBE section Rodenkirchen-Wesseling, is some *23,5 km/h.* Already an average of 20 km/h could be taken as acceptable, which represents 10 km distance in a travel time of half an hour, or 5 km in 15 minutes' travel time.

On seven of the 17 sections this value is not achieved. In the foreseeable future, however, two of these sections will be more highly rated because of their partial replacement by underground: the Bocklemünd and the Ossendorf sections. As *slow sections,* the other five remain, being those from:

– Südfriedhof (Zollstock), Junkersdorf, Klettenberg, Marienburg and Sülz.

It is of some comfort that these terminals are either within the 15 minute travel time zone from the city centre, or are only a few minutes beyond that.

If Zollstock, Marienburg and Sülz are taken into consideration, on these streets the *traditional tramway* ist employed for the greater part. It is true that the N° 6 line (from Marienburg) travels on the segregated right-of-way of the "Ring"-line from Chlodwig-Platz, but this actually *lowers* the speed of all lines, because the average speed is dependent upon the *road traffic signals,* and, for example, between Chlodwigplatz and Barbarossaplatz an average speed of not more than 14 km/h is achieved. This also applies to the otherwise fast light rail rapid transit line N° 16 to Bonn. The odd fact should be noticed that already in 1913, on the sections in operation at that time, an average of 15 km/h was achieved.

The section from *Südfriedhof (Zollstock),* with its long girder rail track up to the Ring, performs rather well.

At the bottom of the table is *Sülz.* Between the University and Neumarkt the corresponding speed slips to below 12 km/h, which is almost that of the horse-drawn tram of the past. The planned underground connection to the University quarter would provide relief. Unfortunately, this still lies in the distant future.

The two remaining slow sections, to *Junkersdorf* and *Klettenberg,* are located on segregated right-of-way in the course of streets. Here it is clear that segregated tracks *without* priority for the rail traffic in street crossings produce scarcely any advantage in the average speed. If one was to provide full priority on both sections, this would be at the cost of the "green light sequence" for the private transport at the main crossing streets (the Ringe, University Strasse, the Gürtel). Thus it would be essential to provide absolute priority for these sections, if not by means of an underground, then with a corresponding signal control system in the interim.

The converse applies to the fast lines to *Bensberg* and *Königsforst,* which lie at the head of the list, and indicate what a full priority right-of-way in the outer areas can achieve. The two sections are connected with the underground network on the right of the Rhine, near the Federal Highway 8, Frankfurter Strasse - thus being connected within the above-mentioned inner city zone. In the outer areas these are located in a full priority right-of-way which, since the time of the former suburban railways, is separated from the arterial roads in the same manner as the railway. The rail crossings are for the main part technically safeguarded.

Not given in the list is the "race track" of the *elevated line* with its 45 km/h over a 7,5 km length between Cologne-Mülheim and Cologne-Ehrenfeld. Fig. 3 gives an impression of its special features.

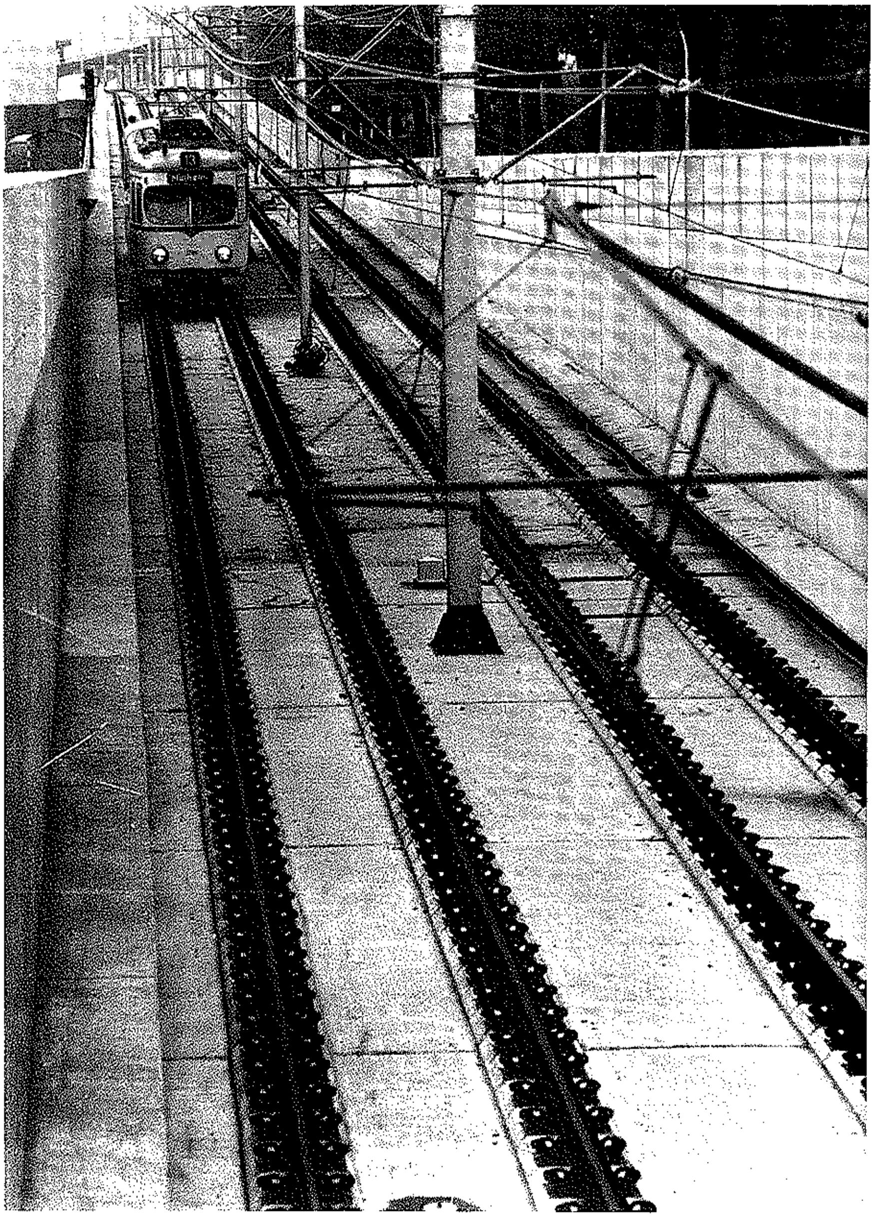

Fig. 3: Not indicated in the list of average speeds: the elevated rail section between Mülheim and Ehrenfeld - illustrated is the ramp form level '+1' to level '–1', west of Geldernstraße/Parkgürtel station

Headways

In the following table the operating frequencies of some of the sections given in the previous list are shown at intervals of 30 and 40 years, with reference to through-service to the terminal in the peak hours.

Headways in Minutes	1913	1953	1983
Bensberg	30	20	8
Königsforst	30	10	6-7
Chorweiler	-[1]	-[1]	6-7
Zündorf (Porz)	(15)	30 (15)	4-5
Thielenbruch via Deutz	30	10	7-8
Merkenich	-[1]	-[2]	6-7
Schlebusch (Dünnwald)	(30)	20	7-8
Frechen	30[3]	30[4]	12-15
Bocklemünd	-[5]	20	3-4
Junkersdorf	30	20	4

[1]) not yet in service

[2]) bus service 32 times daily with change to tramway

[3]) from 1914 - previously 15 times daily with steam tramway service

[4]) with three trains additionally

[5]) seven times daily by horse-drawn bus with change to tramway

This review shows an astounding development. The services offered on the *outer sections* in 1983 can be scarcely surpassed.

A further comparison rounds out the picture: the average intervals within the KVB network for the differing sectors:

Sector	in the peak period	in the normal period
Rail	6 (VHW)	9,5
Inner City Bus	7	11,5
Suburban Bus	15	22

"VHW" is something special: the *„Visible Headway"* which is possible on some straight sections. The passenger waits at the stop and looks to the right in the direction of travel: he sees a departing train already at the next stop. He now looks to the left: he sees at the preceding stop that the next train is coming. The "visible headway" amounts to 4 to 6 minutes. At peak hour with service intervals of 4 minutes - for example to Junkersdorf on a straight section - the "visible headway" is almost an everyday affair. It assists the passenger to have the contented feeling that he is being well-served and that it is not necessary to chase after a service. The VHW is also completely possible with a service interval of 6 minutes, thus at the average interval in the peak hours. Truly, a super service!

Details of Bus Operation

Here a word on *bus services,* which fulfil an important feeder function for the rail sections, and partially provide cross connections:

27 % of the KVB passengers consist of bus passengers, which corresponds approximately to the percentage of inhabitants whose residential areas are only connected by bus lines into the KVB network. Of the 33 bus lines only six still travel into the city centre and a further three approach it.

A Further Comparison

In conclusion, another comparison. If the east-west line Junkersdorf-Bensberg, the present *Line N° 1* of 22 km length, had been operated *in 1913* at today's headways with the same passenger capacity, then in the peak hours the utilization of *180 cars and 225 staff* would have been required. Each unit consisted of four cars with 1 driver and 4 conductors.

In *1953,* with 3 car units, it would have still required 102 cars with 136 staff. Today, in 1983, it has only *28 cars,* without conductors, and *28 drivers.*

It that - together with the data given in the Tables - is not an increase in service with limited expenditure . . .? E. S.

□

Use of Vehicles in Mixed Tramway/Underground/Railway Operations

Mixed Operation before the Opening of the Underground – 1968: the Underground Arrives – Since 1973: Universally Adaptable Light Rail Transit Cars – Operation of the Cologne-Type Cars – Acquisition Program for further Light Rail Cars.

Mixed Operation before the Opening of the Underground

The rail network of the KVB has been burdened from the beginning with the peculiarities of a mixed system, with, on one hand, *the railway lines* - namely the Rheinuferbahn) (Rhine Bank Line) and the Vorgebirgsbahn ("Foothill"-Line) of the Köln-Bonner Eisenbahnen AG (KBE) and the Köln-Frechen-Benzelrather Eisenbahn (KFBE) of the Kölner Verkehrs-Betriebe AG (KVB) - having direct connections and vehicle transfers, whereas, on the other hand, the earlier so-called *suburban lines* of the KVB on the right of the Rhine, although certainly an integrated component in the network, were leading a separate existence to a certain extent.

This was exhibited in the variety of the vehicle stock. Not only did the KBE-owned stock travel on the inner city light rail lines, but also the "Frechener line" and the suburban lines had special types of vehicles, which from the technical aspect had to be suitable for mixed operation. *Compatibility* demanded special wheel set configurations and dimensions. In addition, at an early date, special standards were enforced regarding vehicle width and length, and also the travel comfort (Fig. 1).

In the actual KVB area, including the KFBE line, which is owned by KVB, the above differences were finally eliminated in 1969. The "Frechener line" and the suburban rail lines were now travelled uniformly by tramway vehicles. Only the KBE used specialized railway type units when changing to the KVB network.

1968: The Underground Arrives

In the meantime the first section of the Cologne underground was put into service in 1968. It had been decided that the underground sections to be constructed would be connected with the existing tramway network, and that they would be operated with the technically unchanged rail vehicles which were available at the time. A new form of mixed service came into being, namely a mixed *tramway and underground* system (Fig. 2).

It should be mentioned here that the standards laid down for the underground sections did not permit that the vehicles of the KBE should travel on these new lines. Thus, should the two lines of the Rhine Bank Line and the Vorgebirgsbahn ("Foothill"-Line) run into the inner city from their terminals on the outskirts, a *new type of vehicle* must be developed for this purpose and supplied either by KBE or KVB.

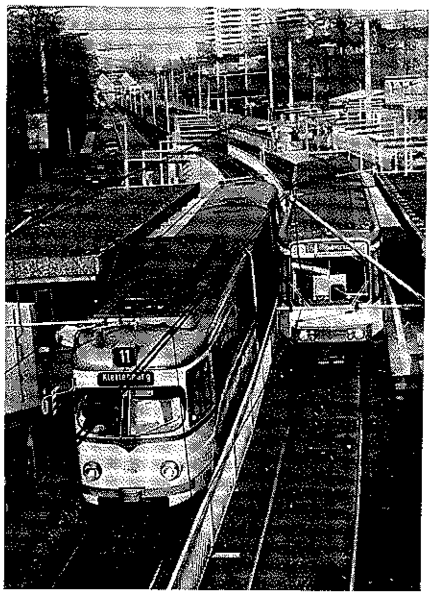

Fig. 2: Tramcar and ligth rail rapid transit train operating simultaneously on the open section of the underground at the station for the zoo

Since 1973: Universally Adaptable Light Rail Rapid Transit Cars

The above situation arose almost simultaneously with the official commencement of light rail rapid transit construction by the State of North Rhine-Westphalia. A component in the light rail program was a new

Fig. 1: Suburban line train of the former Line F, now Line No. 2, at Frechen Station of the KFBE, where the entire track installations are bustling with goods traffic activity

light rail rapid transit car, which, in a modified form for the requirements of through operation between the cities of Cologne and Bonn by the incorporation of the KBE connecting sections, first completed its trial runs in 1973. Universal application on the inner city rail networks in Cologne and Bonn, which still retain tramway characteristics at times, as well as on the railway sections of the KBE, was the salient feature. Furthermore, a rapid transportation means was required, with due regard to starting, maximum speeds and breaking performance. Good running characteristics, soft suspension, high sound insulation and passenger comfort would also provide more attraction than the tramway vehicles of the last generation. As the light rail rapid transit cars, in contrast to the streetcars, would again be *bi-directional vehicles,* with drivers' cabins at both ends and doors on both sides, this very closely corresponded to the requirements of the State for a pure underground vehicle, besides fulfilling the necessity in Cologne and Bonn of ending the trip on a dead-end track, i.e. without any turning loops.

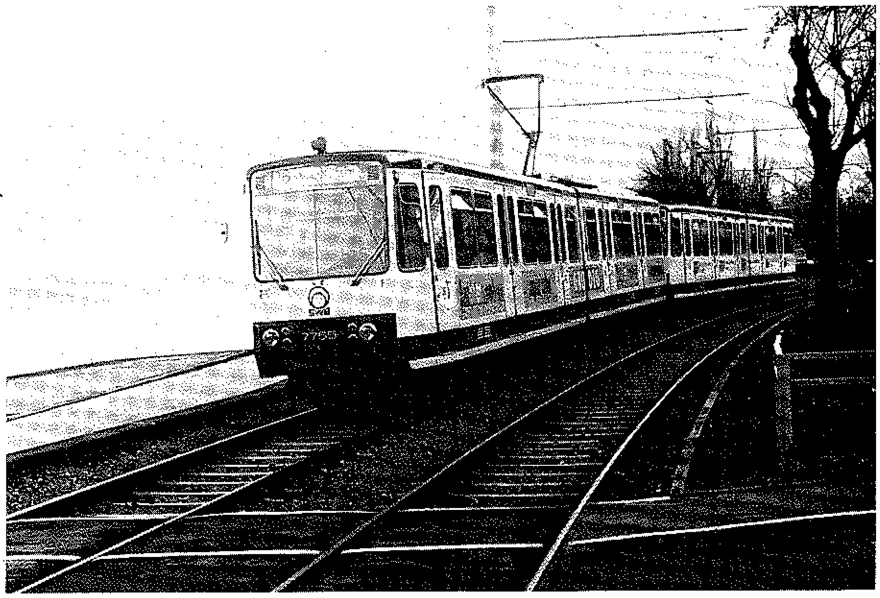

Fig. 3: Light rail train of Line 16, made up from two Bonn authority units (SWB), on the Rhine Bank Line in Cologne

Operation of the Cologne-Type Cars

In the interim, *99 units* of this type of car have been acquired by the transport authorities in Cologne and Bonn, with which *trains of double length* - with two units - are made up for the more heavily loaded routes. These have occurred primarily on the city connecting line between Cologne and Bonn on the Rhine Bank Line - which has the special feature of being jointly operated by the transport undertakings of Cologne and Bonn - and have also been introduced on the supplementary extensions to this line in Cologne and Bonn. In addition, they are also operated on the Cologne-Frechen and Bonn-Siegburg routes. Mixed operation, or better expressed: the working together of differing vehicle types, is now an everyday sight and presents *no problems* from the operational aspects (Fig. 3, 4 and 5).

It may be maintainded with justification that after the revival of the bi-directional vehicle, with the precondition that suitable track installations in the form of turning tracks or track connections are available, the light rail rapid transit car has been proved to be more adaptable both in the event of disruptions and in the choice of intermediate end stations. Furthermore, the possibility to accommodate changing traffic developments by making up trains without the need for additional train crew personnel cannot be too highly evaluated. An operation utilizing only single units, moreover, is noticeably hindered in its efficiency by bottleneck sections.

That special precautions must be taken in regard to the routes, to be able to utilize

Fig. 4: Streetcar and railway unit of the Vorgebirgsbahn of the KBE (line 18) on the jointly use section along Luxemburger Straße in Cologne

Fig. 5: Light rail unit of the Line 16 at Wesseling Station of the KBE, where goods trains travel on the tracks of the light rail rapid transit section between Cologne and Bonn

those sections which are operated in conjunction with standard railway vehicles is only noted in passing at this point.

Acquisition Program for Further Light Rail Cars

The light rail rapid transit car is not only purely and simply *the vehicle* for the further expansion of the current light rail networks in accordance with the aims of the State of North Rhine-Westphalia. It has proved itself in Cologne and displayed its suitability. To the extent that vehicles must be replaced and, even more, as reconstructed or newly constructed sections are taken into service, it will be further acquired. For Cologne, therefore, there is a vehicle acquisition program which is orientated towards the *following projects:*

1. Preparation of the Vorgebirgsbahn of the KBE (Cologne-Brühl-Bonn) for light rail rapid transit operation on the model of the Rheinuferbahn.

2. Underground construction along the Venloer Strasse to Bickendorf and Bocklemünd. Here centre platforms will be constructed for the first time within the Cologne network, which with double-track right-hand operation will necessitate doors on the left side.

3. New construction of a terminal in a tunnel in Bensberg with bus connections, which will have a dead-end track.

Should it one day occur that the approximately 200 eight-axle articulated tramway cars at present in use be replaced by light rail rapid transit cars, the mixed operation of vehicles serving passenger transport will cease to exist. All that will remain are the special features of the switches on those rail sections which are travelled in conjunction with the railway.

H. Bg.

No Level Crossings or Absolute Priority on 59% of Cologne Light Rail Network

Level of Independance – Mixed Networks – Street Level Track and Segregated Right-of-Way – Influence of Traffic Signal Installations – Right-of-Way with Full Priority and without Level Crossings – Minimum Lengths – Proceed Signals and Train Protection Systems as Characteristics – The Cologne Findings

1. Level of Independance

The level of independance from road traffic has a particular importance for the operational efficiency of a public rail transit system.

The most dependent are "rail-operations in the streets", the classic tramways whose tracks are flush-laid at street level in traffic or pedestrian areas. Networks are hardly found today whose routes exclusively consist of such *tramway lines in the narrowest sense.* Due to the differing rail bed constructions it is advisable to identify those section lenghts in the network of this level, or other levels of "road independence" as described below, both absolutely and percentually, and from this compilation to establish the level of independence of the entire network.

The absolute opposite to tramways in the pure sense is the *underground* whose tracks are fully separated from road traffic and are furthermore equipped with *train protection systems,* i.e. the tracks are occupied neither by parallel-running nor by crossing street traffic, and this maximum degree of independence from road traffic is fully utilized with the aid of train protection systems to obtain a high operational efficiency.

2. Mixed Networks

As the entire track network is uniformly independent in the "classic" underground, efforts keep being made to establish a similar uniform characteristic for mixed networks. What is correct in regard to technical requirements of vehicles - i.e. a classification according to rail systems by those whose vehicles must operate together with road traffic somewhere in the network, and those which are nowhere required to do so - is incorrect, however, due to the variations which occur along the travelled *routes.* In the revised draft of the BO Strab (German Construction and Operating Regulations for Light Rail Transit Systems) a three-tier classification is now foreseen of *street level track, segregated right-of-way* and *exclusive right-of-way.* Without disturbing this classification, two sub-classifications for the segregated right-of-way and the exclusive right-of-way are given in the following, which, for example, aid in the designation of those sections of *underground* which are within a mixed network. The concept of an "underground" can apply also to a correspondingly constructed *section* of a network. Only for classic underground systems this concept is equally valid throughout the entire network, because of the 100% distribution of such sections.

3. Street Level Track and Segregated Right-of-Way

In the consideration of individual sections within a large mixed network, a number of intermediate stages are found between the extremes of "tramway lines in the purest sense" and "underground". The former can be immediately taken as equivalent to the *street level track* as given in the draft for the new "BOStrab".

The next level, the *segregated right-of way,* relates to a location between the roadways of public streets in the draft of the new regulation. Such a track bed can ensure independence from parallel-running road traffic throughout, as thanks to its *open superstructure* on sleepers and ballast it is plainly impassable to road vehicles.

By that, it is certainly not guaranteed that there are *no level crossings,* as Fig. 1 indicates in an exceptional extreme form. If a segregated right-of-way along the side of a road with houses create this type of problems, it is best if its "segregation" aspect is dispensed with, as has already been done by the KVB for some decades in this particular case, with the closure of this single-track section in Leverkusen-Schlebusch.

On the other hand, there are segregated rights-of-way with a *covered superstructure,* which are only separated from the adjoining traffic lanes by fixed side kerbs. With "Stuttgart" thesholds, kerb stones and guard rails some transit authorities have rapidly increased their sections with segregated right-of-way some years ago, without the complete exclusion of joint usage by parallel-running road traffic. At times, this is intended for exclusive *sharing by buses* of the same undertaking, in other cases occasional usage by private traffic is not excluded, e.g. with heavy peak traffic or after traffic accidents on a constrained carriageway, even under the direction of the police. In any case the rail operation will be hindered, and this will increase with a higher traffic density.

Fig. 1: Once upon a time this was a "segregated right-of-way". It was truly free of crossings - from one dustbin to the next!

Because of its disadvantages for the operational efficiency of the rail transit, the segregated right-of-way with a covered superstructure is separated in the following from that with an open construction. Together, the two represent the segregated right-of way approximating the intention of the draft for the revision of the "BOStrab".

4. Influence of Traffic Signal Installations

With the normal *median location* of a segregated right-of-way in the street, the entrances and accesses to the properties,

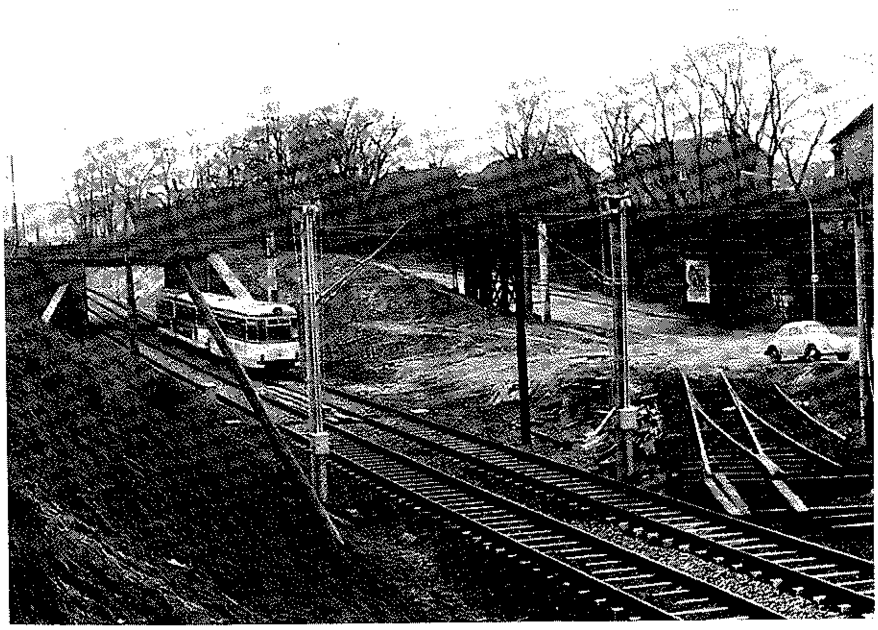

Fig. 2: The tramway already abandoned the road before any underground construction: a rail section free of level crossings in Cologne-Dünnwald, put into operation in 1967

in contrast to Fig. 1, generally have no influence on the rail operation. A more frequent hindrance, however, are *street crossings* with time-controlled traffic signal installations. In the preceding article on ride times and average speeds, the example of an average speed of only 14 km/h on a segregated right-of-way in the south of the inner city of Cologne was mentioned.

Briefly: even the median location of a segregated right-of-way does not always provide an advantage to operational efficiency, whether it is passable for parallel-running road traffic or not, if the *crossing* *road traffic* has a strong influence; reference is made to the data on those slow sections with segregated right-of-way to Junkersdorf and Klettenberg in the previous article.

Fig. 3: A further example of earlier crossing-free sections - the so-called Ford Line in Cologne-Niehl

The conditions indicated here - examples for the activity of some road traffic lobby - have led to the KVB not introducing segregated rights-of-way with a covered superstructure to any significant extent, and, too, to be less eager to extend constructions of segregated rights-of-way with an open superstructure if located *in streets.* The KVB - which, amongst the major European mixed rail systems, has been since long one of the leaders with its high proportion of tracks not flush-laid with the road surface - prefers those types of right-of-way which will truly achieve something in the improvement of operations, namely those *free from level crossings* or which provide *absolute priority* for the rail traffic. (Fig. 2 and 3).

5. Right-of-Way with Full Priority and without Level Crossings

The draft revision of the "BOStrab" regards all track beds *outside* streets and roads as being "independant" form road and street-traffic.

With this are equated those *sections with level crossings* as well as those which are crossing-free. Even when subsequent development of the technical safety measures at level crossings results in scarcely any reduction in the maximum speeds in comparison with sections free of crossings, delays on the crossings cannot be entirely excluded, on either technical grounds or caused by road traffic users.

Thus a differentiation is made below between *rights-of-way with full priority* which are identified by warning crosses and technically secured level crossings*), and track beds *without level crossings,* i.e. exclusive rights-of-way in the narrow sense. The two taken together represent the "independant" or exclusive right-of-way within the meaning of the draft for the new "BOStrab" if it is understood that sufficiently long sections free of crossings or with full priority form this type of route also when they are located between the roadways of roads or streets.

6. Minimum Lengths

The segregated right-of-way in Fig. 1 is free of crossings at about every 10 m. It is clear that a sensible minimum length must be established for continuous sections of rights-of-way with full priority or without level crossings.

In Cologne the principle was established that the prerequisite for a crossing-free section - or more exactly, the physical separation from both the parallel-running and the crossing street traffic - must be at least continuous between two stops or over a 1 km long section. A general correspondence is also valid for the minimum length of a right-of-way with full priority with the provision that shorter sections may also be included when they are arranged as the *connection to a section without level crossings,* see also the details given in the notes to the Table in Fig. 4.

7. Proceed Signals and Train Protection Systems as Characteristics

A rail bed completely separated from the road traffic must not necessarily be equipped with proceed signals or train protection systems. Conversely, these can have their advantages for sections *not* free of crossings, as is demonstrated on every railway line. Train protection systems also appear on segregated rights-of-way which are *shorter* than the minimum length for rights-of-way with full priority or without level crossings, e.g. in the case of crossing other railway-lines. On *single-track-sections* at least proceed signals are required, also in conjunction with a street level track.

The features of "proceed signals" and "train protection systems" are thus to be considered separately from the characteristic of independence from road traffic. This is best understood from a *bi-axial presentation* of the types of rail routes (as is

*) On the rights-of-way with full priority of the light rail system of Cologne, with the exception of pure goods train sections, not less than 70 level crossings have been technically safeguarded.

shown below with the Cologne values): *by the line* according to the type of rail bed, *in columns* as double-track sections with or without train protection systems and single-track rail beds.

Single-track lines for present-day public transit is only rarely justified. In these cases the differences between their necessary proceed signals, and whatever train protection systems are provided, have no significance.

8. The Cologne Findings

The Table in Fig. 4 covers, in addition to the public transit network of the KVB, that of the Rhine Bank Line of the KBE which is integrated into the Cologne light rail network, insofar as it runs mainly within the *commuting area of the centre of Cologne* (including Wesseling South). Not included, therefore, is that proportion of the Rhine Bank Line which is associated with the centre of Bonn, nor the entire Vorgebirgsbahn, the second KBE route to Bonn, which has not yet been converted to light rail operation. Both KBE lines - and, in addition, the not inconsiderable goods traffic sections of the KVB and KBE - are operated by the integrated management of the jointly administrated KVB/KBE.

The value of 45.5 km given *under 1.A* in the Table is some 3.9 km greater than the value given in a preceding first article, as a section of the KVB line to Frechen is included (KFBE, not yet fully developed for light rail rapid transit operation).

The value given *under 1.B* in the Table, 8.9 km, is some 1.6 km more than the value of 7.3 km mentioned in the preceding second article, Figure 1, as two unsubsidized sections of the suburban lines of the KVB, existing since long, have been included. (On the other hand, the mentioned figure 1 includes that proportion of the *entire* Rhine Bank Line which is fully developed for light rapid transit rail operation).

Attention is to be drawn to the following totals:

- Field 1: Right-of-way lengths free of level crossings represent 36 % of the total.
- Field 1-2: Exclusive right-of-way lengths (within the meaning of the draft for the new BOStrab) represent 59 % of the total.
- Field 1-4: Segregated right-of-way lengths, within the meaning of BOStrab of 1965, represent 82 % of the total.
- Field 1-5A: Double-track sections with train protection systems comprise 32 % of the total.

The percentages gain an added significance when the high *absoute values* are taken into consideration. For example, the value given under 1A of 45.5 km of right-of-way lengths without level crossings, with double track and with train protection systems, would seem a good achievement even in the field of recent pure underground networks. H. Br.

Operational sections (km) of public transit according to levels of independance

Network: Light rail network of Cologne (KVB + Rhine Bank Line of the KBE within the commuting zone of Cologne). Status on 10th April, 1983. Percentages based on total network length of 152,9 km.

Line No.	Level of independance	Double track sections with train protection systems	Double track sections without train protection systems	Single track sections	Cross totals	Notes No.
1	Right-of-way without level crossings *site propre*	1A: 45,5=30%	1B: 8,9=6%	1C: —	1: 54,4=36%	①
2	Right-of-way with full priority	2A: 3,2=2%	2B: 29,5=19%	2C: 2,5=2%	2: 35,2=23%	2.1, 2.2
3	Segregated right-of-way with an open superstructure	3A: 0,3=0%	3B: 33,3=22%	3C: —	3: 33,6=22%	③
4	Segregated right-of-way with a covered superstructure	4A: —	4B: 1,6=1%	4C: —	4: 1,6=1%	④
5	Street level track *site banal*	5A: —	5B: 26,8=17%	5C: 1,3=1%	5: 28,1=18%	⑤
6	Total 1-2 Exclusive right-of-way	1-2A: 48,7=32%	1-2B: 38,4=25%	1-2C: 2,5=2%	1-2: 89,6=59%	⑥
7	Total 3-4 Segregated right-of-way	3-4A: 0,3=0%	3-4B: 34,9=23%	3-4C: —	3-4: 35,2=23%	⑦
8	Total 1-4 Segregated right-of-way within the meaning of BOStrab of 1965	1-4A: 49,0=32%	1-4B: 73,3=48%	1-4C: 2,5=2%	1-4: 124,8=82%	
9	Network totals	1-5A: 49,0=32%	1-5B: 100,1=65%	1-5C: 3,8=3%	1-5: 152,9=100%	

Notes:

① minimum length for 1A: full distance between two stops or at least 1 km.
minimum length for 1B: as 1A, but optional lengths when connecting to 1A.
minimum length for 1C: as 1A, but optional lengths when connecting to 1A or 1B.

(2.1) minimum length for 2A: as 1A, but optional lengths when connecting to 1A, 1B or 1C.
minimum length for 2B: as 1A, but optional lengths when connecting to 1A, 1B, 1C or 2A.
minimum length for 2C: as 1A, but optional lengths when connecting to 1A, 1B, 1C, 2A or 2B.

(2.2) Absolute priority, with warning crosses and technical safety measures in specified cases.

③ Track bed with open superstructure, which does not fulfil the requirements of Lines 1 and 2.

④ As 3, but with covered superstructure, and separated from the general road traffic.

⑤ Track bed embedded in carriageways or pedestrian areas.

⑥ Exclusive ("independant") in the sense of the draft revision to the BOStrab.

⑦ Corresponding to ③ and ④ not always located between the roadways of streets.

Fig. 4: Independence Levels of the Cologne Light Rail Network

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Antworten auf diese und viele andere Fragen gibt dieser umfassende Bericht. Er ist – 10 Jahre nach der Stockholmer UN-Konferenz vorgelegt – das Ergebnis internationaler Zusammenarbeit. Er gibt einen Überblick über die Umweltveränderungen, beleuchtet die Probleme, bewertet kritisch, aber vorsichtig erzielte Lösungen – dies alles auf der Grundlage einer ungeheuren Fülle von Fakten und Zahlenmaterial.
Die in dem Bericht enthaltenen Informationen, Daten, Überlegungen dürfen und werden international und national nicht ohne Einfluß bleiben.

Der **OECD**-*Expertenbericht*

Wirtschaft und Umwelt

Die Verflechtung von Ökonomie und Ökologie

Expertenbericht über besondere Umwelt- und Ressourcenprobleme für die Organisation für wirtschaftliche Zusammenarbeit und Entwicklung – OECD

94 Seiten, DIN A 5, kartoniert, DM 24,–, ISBN 3 503 02351 8
Beiträge zur Umweltgestaltung, Heft A 92

Wie kann am besten die ökologische Basis eines stabilen Wirtschaftswachstums gewährleistet werden, lautet eine Frage, die immer mehr in den Industrie- und Entwicklungsländern besorgt gestellt wird. Dies ist auch das Hauptthema des Expertenberichts über die wichtigsten globalen Umwelt- und Ressourcenprobleme, dessen deutschsprachige Übersetzung soeben erschienen ist! Zum ersten Mal werden die politischen Maßnahmen ergründet, die dazu beitragen können und zwar sowohl ihre Hindernisse als auch Möglichkeiten auf nationaler und internationaler Ebene.
Knapper und prägnanter lassen sich diese alle bewegenden Fragen und Zielvorstellungen kaum darstellen und beantworten als in dem jetzt vorliegenden Bericht.

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VERÖFFENTLICHUNG DES UMWELTBUNDESAMTES

Umweltforschungskatalog 1983 (UFOKAT '83)

Informations- und Dokumentationssystem Umwelt (UMPLIS)
Herausgegeben vom Umweltbundesamt

5. Ausgabe, XIII, 1480 Seiten, DIN A 4, kartoniert, DM 72,–, ISBN 3 503 02463 8

Der UFOKAT '83 enthält die Kurzdarstellungen von ca. 4100 umweltbezogenen Forschungs- und Entwicklungsvorhaben, die nach dem 1.1.1982 beginnen oder enden.
Zur Veröffentlichung im vorliegenden Katalog wurden dabei Vorhaben ausgewählt, deren Ergebnisse für die auf den Gebieten der Umweltforschung, Umweltplanung und Umweltpolitik Tätigen wichtig sind oder sein können.
Zu jedem F + E-Vorhaben sind neben der ausführenden Stelle das Projektthema mit Kurzbeschreibung, der Projektleiter, Auftraggeber bzw. Zuwendungsgeber, Laufzeit, Kosten und Veröffentlichungen zum Projekt aufgeführt.
Die Daten des UFOKAT '83 sind mit Stand Ende 1983 wiedergegeben.

Auch der UFOKAT '83 wird wie seine Vorgänger den mit Umwelproblemen befaßten Personen in Politik und Verwaltung, in Wirtschaft und Wissenschaft ein nützliches Instrument für ihre Arbeit sein.

Erich Schmidt Verlag
Berlin

NEUERSCHEINGUNG DES UMWELTBUNDESAMTES

Daten zur Umwelt 1984

Herausgegeben vom Umweltbundesamt

2. aktualisierte Auflage,
IV, 399 Seiten, DIN A 4, kartoniert, DM 16,–
ISBN 3 503 02472 7

Als einen ersten Schritt in Richtung auf eine umfassende Darstellung der Lage der Umwelt in der Bundesrepublik Deutschland hat das Umweltbundesamt die „Daten zur Umwelt 1984" vorgelegt. Dabei liegt der Schwerpunkt auf Daten, die eine Aussage für das Gebiet der Bundesrepublik Deutschland insgesamt ermöglichen. Im wesentlichen lassen sich die in 10 Sach-Kapiteln gegliederten Daten folgenden Kategorien zuordnen:

– Informationen über den Zustand der Umwelt: u.a. Angaben über die Qualität der Luft, des Grundwassers und der Gewässer, des Bodens, über den Zustand der Biotope, der Landschaft und der Nahrungsmittel
– Informationen über die Emissionen und deren Verursacher: u.a. Abfallaufkommen, Lärmwerte stationärer Anlagen wie Flugplätze, Müllverbrennungsanlagen
– Informationen über Umweltschutzmaßnahmen: Daten zu Überwachungseinrichtungen wie Gewässer- und Luftmeßnetze, Daten zu Investitionen und Krediten für Umweltschutzanlagen, Ausgaben für Forschung und Entwicklung.

Der Bericht beruht u.a. auf Daten, die nach dem Umweltstatistikgesetz vom 15. August 1974 erhoben werden. Es ist geplant, diesen Bericht 1986 fortzuschreiben.

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Berlin

Development of Train Protection Technology in the Joint Network of KVB and KBE

Developments until 1974 – Underground Interlocking Cabin Ebertplatz – Central Interlocking Tower at Wesseling of the KBE – Central Control of the KVB – Detailed Developments

In the course of the amalgamation of the intercity routes of the Cologne-Bonn Railways (KBE) with the inner city network of Cologne Transport (KVB), in addition to the solutions for guidance, vehicle technology and power supply, a *standard* of train protection technology had to be developed, which would enable the through-operation of the Cologne-type light rail rapid transit car. Also to be considered were the differing concessional and operational rights of the KBE (in accordance with the State Railway Act) and those of the KVB (according to the Passenger Transport Act).

Developments until 1974

Train protection technology was introduced in the inner city network of the KVB in 1968, for the first underground section between the stations Cathedral/Central Railway Station and Friesenplatz. At this time is was decided to equip all vehicles *with magnetic train stopping device* and *inductive wayside control.* This basic system decision was a decisive parameter in all further train protection technique construction measures.

Whilst in the first interlocking cabins of the stations Cathedral/Central Railway Station, Appellhofplatz and Poststrasse it was considered sufficient to install wayside control and *automatic route setting* only at *points fo conflict* (at the joining or branching of tracks), operational difficulties, created not least by the density of trains in the inner city, led to the *supplementary installation* of train stopping devices and speed check points even at block signals, and eventually to a modified route setting adapted to different operational conditions. It was realized that the information capacity of the inductive transfer system from train to track, with its 45 items of data, was not sufficient for the solution of the operational requirements for route setting, nor for the inclusion of specific scheduling data. With the acquisition of the light rail rapid transit cars this led to an expansion of the inductive communications system based upon four-figure train numbers. Methods were discussed for the route setting, how a more rapid working out of the trains could be achieved at points of conflict by foresighted traffic flow coordination.

The further requirement was also to be fulfilled that the driver must no longer change his train number due to alteration of the route in case of disruption. Improved optimization in freedom of operation was to be achieved from the central control in route and line coordination.

Underground Interlocking Cabin Ebert Platz

The considerations about a modified route setting led to one of the first *computerized route setting systems* with the construction of the interlocking cabin at Ebert Platz, which went into operation in 1974. The twin computer installation at Ebert Platz consists basically of a monitoring, a controlling and an operational level. At the *monitoring level* are performed the train indentification, the train running tracking, and the recording of specific operational activities and disturbances. The *control level* sets the routes, the active destinaton signs and contains the route plan. Because of the flexible operational handling which goes on simultaneously with the processing, data from the computer can be requested at the computer operating console, data can be corrected and in the event of disruption routes can be allocated to other vehicles.

The *process computing control* at Ebert Platz has shown itself to be of great advantage in its conception for the later construction of the central control. All train running data, without intermediate switching, can be transmitted from the remote control systems via a direct link to the digital computer.

The data comparison by the central computer with the two route setting computers at Ebert Platz is made by means of two computer links. The data exchange is only performed with the operating route setting computer. On the other hand, the central computer hands over data to both route setting computers. The *twin computer installation,* and the system of data transfer, have proved to be o invaluable assistance in the event of maintenance or clearing of

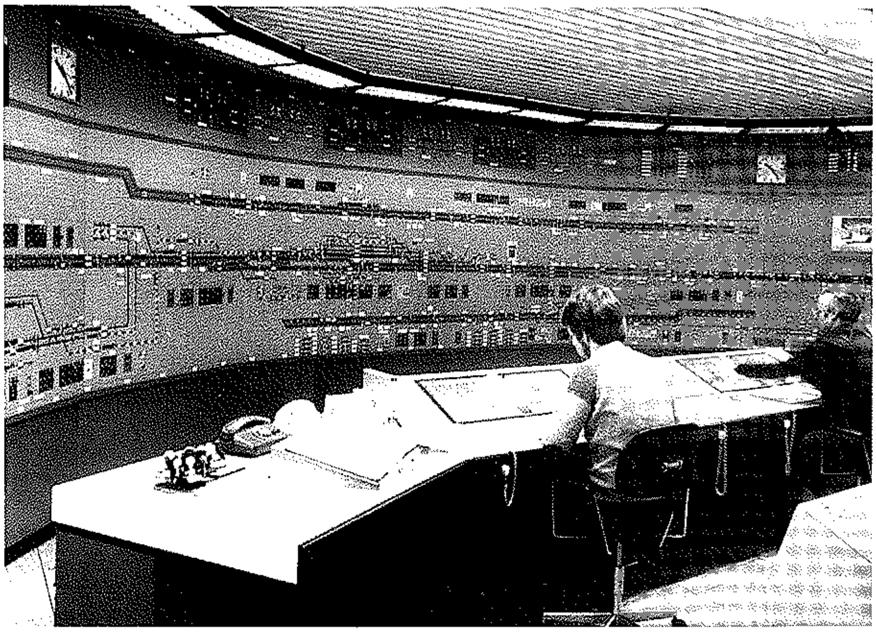

Fig. 1: Central interlocking tower at Wesseling showing track diagram panel and operating console

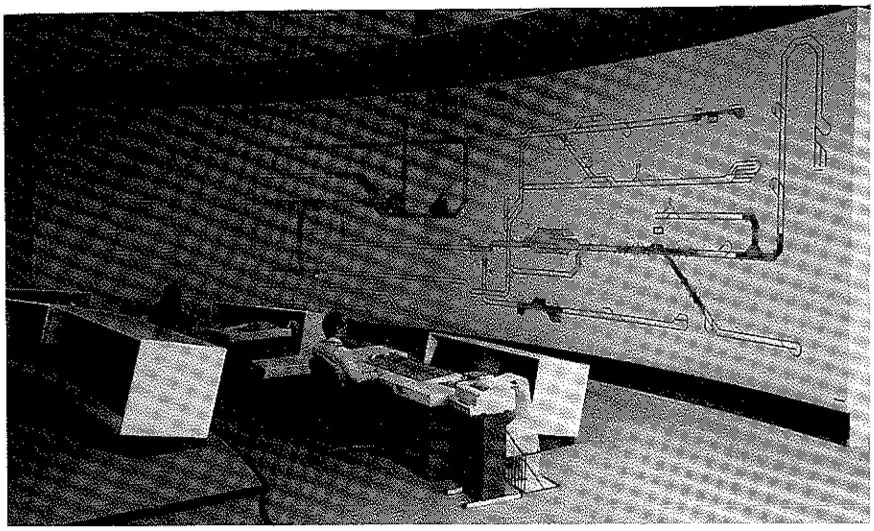

Fig. 2: Partial view of the control centre of the KVB with track diagram panel, operating consoles and graphic data display stations

the installations, as faults can be eliminated, software can be tested, and maintenance works performed on the *idled* computer without interfering with the normal operation.

Central Interlocking Tower at Wesseling of the KBE

Whilst the original *push-button signalling technique* was retained in the underground interlocking cabins of the KVB for the essential safety levels, a new requirement for train protection technology was introduced with the integration of the Rhine Bank Line of the KBE into the light rail rapid transit networks of Cologne and Bonn in 1978. The joint operation of passenger and goods transport, the railway construction and operating regulations, the condition of the old signal boxes on the Rhine Bank Line, together with the long distances between them, demanded a complete *new design* of the train protection measures. The necessary control of movable frogs in the switches required for the guidance could not be installed in the existing signal boxes, and furthermore, light rail rapid transit operation with *closely spaced trains* could not be achieved with the existing signalling system. Along the section were located seven signal boxes, some still of the construction type E 12 from 1927.

For the construction of the new interlocking cabins in Wesseling and Sürth there was no alternative to installing *track layout interlocking technology* (SpDrS 60). The interlocking cabin at Hersel was already a push-button installation, and required only some supplementation for light rail rapid transit operation. In order to assure a sensible operational arrangement, the interlocking cabins at Sürth and Hersel were connected by remote control to the tower at Wesseling, which is approximately mid-way between Cologne and Bonn. By this means, Wesseling provides the *central interlocking tower* (Fig. 1).

The systems of inductive signal transmission, train description and route setting were adapted to the light railway rapid transit operations, and could be connected into the track layout interlocking system without problems. By contrast, it was more difficult to connect the *magnetic train stopping device* and *speed monitoring equipment* into the track layout interlokking technique, as these had been developed in accordance with the electronic technology for the undergrund track layout interlocking system, and had to be adapted to the conditions of mixed operation and the track layout technique of the 1960's, compounded by a signalling range of 6.5 km.

The measures undertaken on the Rhine Bank Line brought not only operational and economic benefits, but also raised the safety for the *passenger* and the *speeding-up of private traffic at level-crossings.*

Central Control of the KVB

After the completion of further interlocking cabins in the inner city rail network the KVB central control was put into operation in May 1980. With this installation it first became plain what advantage was provided by the integrated availability of important operational data, which could then be applied to the benefit of the passengers and the operations (Fig. 2).

Before the central control was put into operation, there had been three control and monitoring stations which operated independently of each other, which did not permit of any satisfactory arrangement at that time due to their physical separation and the lack of information on normal operational conditions.

For the first time, the rapid and complete provision of all required data *in one room* became possible with the bringing together of the train protection system, the

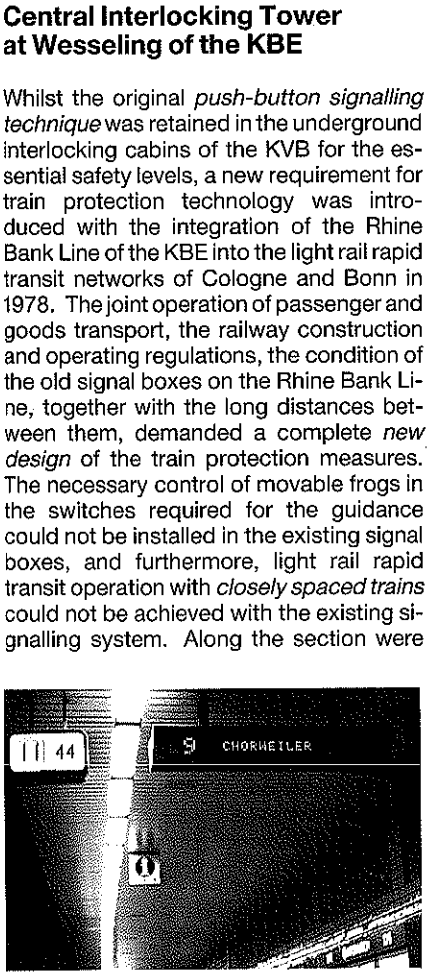

Fig. 3: Train destination indicator with diode element at Kalk Kapelle Station

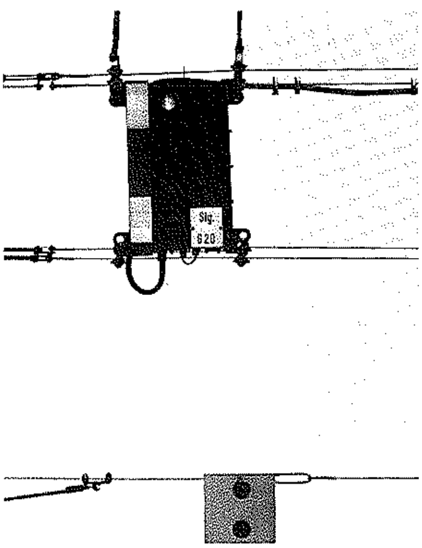

Fig. 4: Signal above the power catenary bracing on the Mülheimer Brücke, crossing the Rhine

Fig. 5: Signal with platform, safety barrier and mounting for signal telephone set on the Deutzer Brücke on the Rhine

power supply, the wireless service, the centralized loudspeaker installations, the video monitoring, the signal telephone equipment and the station monitoring.

The *track diagram panel* could thus, for example, not only serve for train protection and assist the chief signalman in effecting his control orders, but also all other members of the staff could follow the operational procedure by means of the panel display, and undertake the necessary measures from their side in the case of disruption. Long enquiries into the occurrence of a fault were unnecessary, as everyone had seen the operational situation as it developed.

The operator could also obtain further details of any interlocking cabin-district through the *graphic display station*, which, amongst other things, provided him with more information on the disposition status.

The installation of the equipment in the control centre is arranged *modularly*, so that further interlocking cabins can be connected in, without disturbing the functioning of those already in operation.

Detailed Developments

Together with the major projects of the interlocking cabins and the central control there was also a series of individual developments, which were necessary due to constructional factors or economic considerations.

The underground station of Kalk Kapelle was the first to be equipped with a *train destination indicator* with a diode display and no mechanical parts (Fig. 3).

This fully electronic unit, with semiconductor illuminating diodes, and the correspondingly adapted filter plate, is free of maintenance. It can display 32 alphanumerical announcements, and the unit permits of many variations. Apart from the underground stations in the inner city, it will also be installed in the new underground section of Deutz.

The *setting process* for the train destination indicator deserves mention. For the data source the available cyclically operating remote control system for the transmission of train numbers to the central control is incorporated. By this means, a *very economic solution* could be found, and costly directing systems were not required.

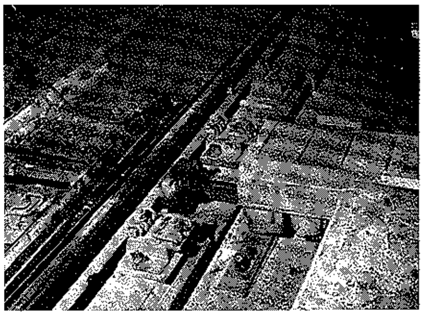

Fig. 6: Shortened form of switch mechanism in Cologne type of ballast-free track

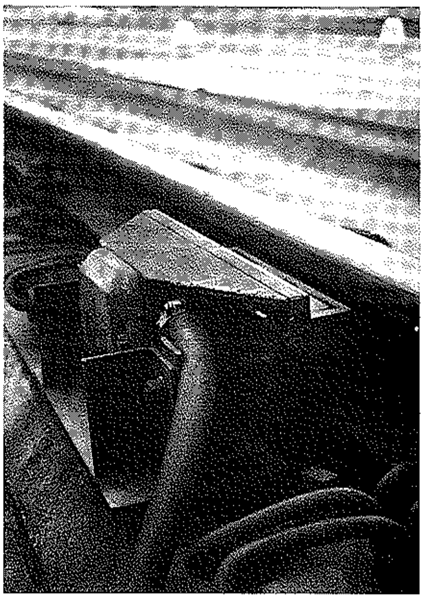

Fig. 7: Magnetic rail contact adapted to ballast-free track construction

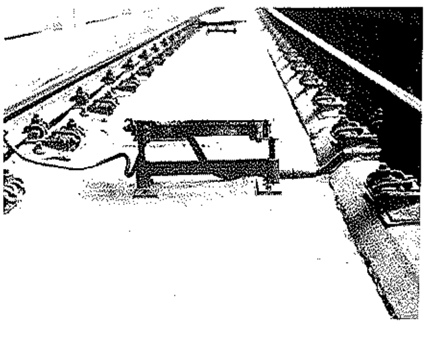

Fig. 8: Fastening for coupling coil on ballast-free track section

The ever-present structural variations, such as the change to ballast-free track, the dropping of switch recesses in tunnels, and the adaption of signaling equipment to restricted space conditions, led to the *self-development* by KVB of *components* such as complete signal units, switch mechanisms of shorter construction, new construction concepts for magnetic rail contacts, and special fastenings for coupling coils and magnetic train stopping devices.

Special conditions had to be taken into consideration for the *signals* in the case of parallel-running private transport. In Fig. 4 is shown a signal *above* the power catenary bracing on a bridge, the Mülheimer Brücke. The signal in Fig. 5, with its stable platform and safety barrier, was installed on another bridge, the Deutzer Brücke, and has been adapted to the space restrictions at this location.

With the construction of *switches with shorter installation width*, as shown in Fig. 6, switch recesses or cut-outs can be avoided in tunnel construction. The switch mechanism itself is additonally secured to the tunnel floor by a holding device.

Cut-outs in the concrete beams of the ballast-free track for the installation of *rail contacts* are certainly possible and would present no problems in Cologne. Subsequent changes and supplementary requierements, however, scarcely can be realized. Because of this, a fastening has been developed for the magnetic rail contacts, which takes the restricted installation height between the concrete beam and the foot o the rail into consideration (Fig. 7).

The manufacturers of coupling coils and magnetic train *stopping devices* specify very fine installation tolerances. In order to always maintain these limits on ballast-free track and also in superelevated sections, a continuous adjustable fastening device is provided, as shown in Fig. 8, which regulates the height by spindles and after installation of the coupling coil or train stopping device can no longer be displaced. The holding unit itself is fastened to the tunnel floor.

H. A.

Reconstruction of Three Rhine Bridges for Exclusive Right-of-Way

Reconstruction of three bridges across the river Rhine: the Mülheimer Brücke – the Deutzer Brücke – the Severinsbrücke – Conclusion

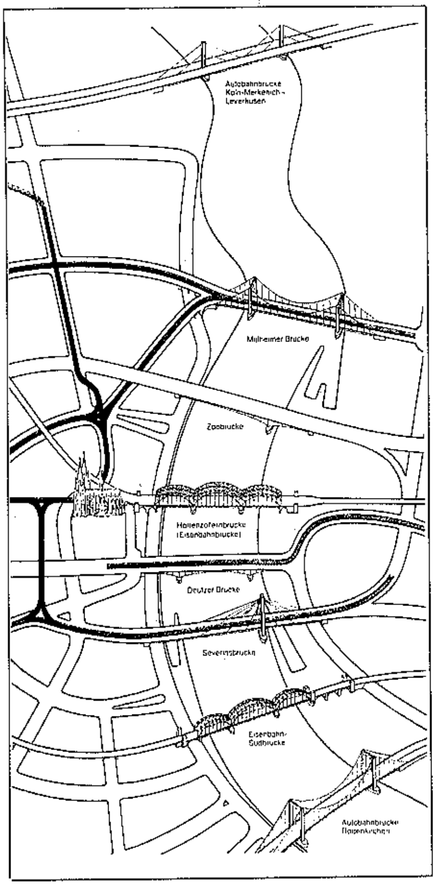

Fig. 1: The Rhine bridges of Cologne

The Rhine bridges form essential connections between the rail networks of the Kölner Verkehrs-Betriebe on the left and right banks of the Rhine. They have determined from the begin the network layout and the alignment of the tramway routes. With the construction of the Severinsbrücke, which became the third Rhine crossing in 1959, came the established line system, which has left a lasting mark on the light rail network of today.

All three Rhine bridges originally had girder rail tracks which were bedded in the road surface. With the advancement of the light rail rapid transit construction, an urgent need developed for the installation of exclusive right-of-way sections which would also permit train protection systems for fast rail operation. The *Mülheimer Brücke* connects the north-south inner city route and the Gürtel route - both already light rail rapid transit lines - with Mülheim on the right bank of the Rhine. The *Severinsbrücke* connects Deutz from the south to the underground inner city route, and the *Deutzer Brücke* is an essential component in the east-west light rail rapid transit route (Fig. 1).

Reconstruction of the Mülheimer Brücke

The Mülheimer Brücke, with main spans of 91 m, 315 m and 91 m, was reconstructed in 1951 as a true suspension bridge to replace the braced suspension bridge destroyed by air raids on 14th October 1944. With a road width of 17,2 m, each of the six traffic lanes was some 2,87 m wide. The two inner lanes were utilized by the tramway. After completion of the Gürtel route (1974) two light rail rapid transit lines met at the start of the bridge on the left bank, together with the route between the inner city and Mülheim. It was therefore decided to provide an *exclusive right-of-way* with train protection systems, separated from the private transport by dividing barriers.

Because of the *limited space conditions* on the bridge ist was not possible to construct a full light rail rapid transit cross-section. The special safety strips inside the dividing barriers had therefore to be dispensed with. The new road construction, with an overall width of 19.25 m, is divided between the light rail construction width of 6.25 m, and the two dual-carriageway unidirectional traffic lanes, each 6.50 m wide

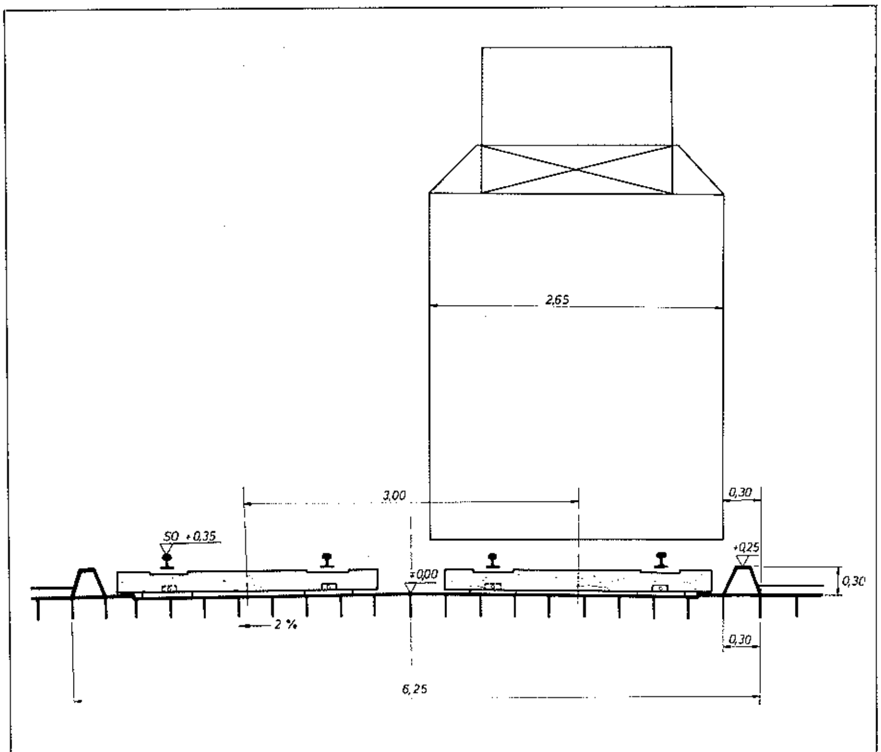

Fig. 2: Light rail cross-section on the Mülheimer Brücke

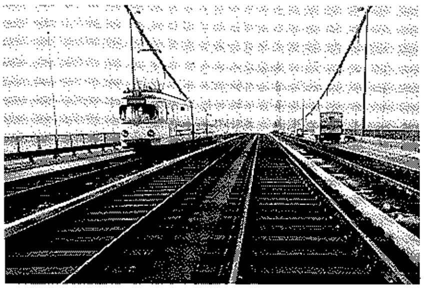

Fig. 3: The 'four-track' Mülheimer Brücke during construction

(Fig. 2). As the overall width of the bridge could not be increased, cycle and pedestrian paths wer made narrower in the course of a long reconstruction process. The width of only 3.0 m between the bridge hangers and parapets was accepted, because only relatively light pedestrian and cycle traffic occurs on the Mülheimer Brükke.

In the area of the light rail cross-section, in which the steel bridge decking was now exposed, special reinforcing and conservation measures were necessary. The 15 cm high *dividing barriers* for the roads and carriageways are in steel.

There existed no precedent for the construction of a *rapid transit permanent way* on a true suspension bridge without double decking. As the bridge had to remain in service during the reconstruction period, and was consequently subject to vibrations, the construction of a tie-less superstructure on the steel bridge, with the fastening points concreted in or welded, would have involved too many unknowns. The KVB therefore decided on a construction method modelled on the *bridge superstructure system Ioarb 106* of the Federal German Railways, with open wooden ties. Because of the high deflection factors in a pure suspension bridge, which take the form of exceptional longitudinal forces being exerted on the rail fastenings, *extra expansion joints* had to be arranged at every 120 m.

During the reconstruction of the girder rail track in open superstructure, a lane was available on both sides for a provisional track. So, for some time, the Mülheimer Brücke had the appearance of a four-track railway bridge (Fig. 3). The reconstruction of the bridge over a total length of 1.1 km was carried out between 1974 and 1977, and cost 28.4 Mio D-Mark. When completed, its tramway past was hardly detectable (Fig. 4).

Reconstruction of the Deutzer Brücke

The Deutzer Brücke was the first of the Rhine bridges of Cologne destroyed during the war to be reconstructed still before the currency reform of 1948. It is a steel box girder structure with a varying hight of the girder web. The bridge piers and access ramps of the previous braced chain suspension bridge, with a main span of 184 m, had to be reused. Thus, the bridge achieved an impressive slimness of form for that time, with its sharply limited construction height, which, however, was only obtained at the cost of special tramway rails with bolted fastenings requiring extensive maintainance.

Due to the steel shortage at the time, the occupying authorities would only approve a utilizable bridge width of 20.60 m. The carriageway could therefore be only 11.50 m wide, with twin traffic lanes in both directions. This represented only 2.87 m per lane, with the streetcar track having to occupy the inner lanes (Fig. 5). The Deutzer Bridge was so constructed at that time that it would be possible to add a hollow box beam on each side later to widen the roadway to 18.0 m.

An *exclusive right-of-way* of 8.90 m width became necessary on the bridge with the construction of the light rail rapid transit line to Bensberg. With two-lane carriageways in both directions, each of 6.50 m, the required road width was therefore 21.90 m. Because of the increasing rate of traffic growth, both on the bridge and on the river, a condition was imposed that with a widening of the bridge there must not ensue any curtailment of the tramway, highway and river traffic. Thus, the plans of 1948 for the widening of the bridge on both sides were not realizable.

It was therefore decided to build a *second additional bridge-superstructure* of 16.30 m width to the south side of the

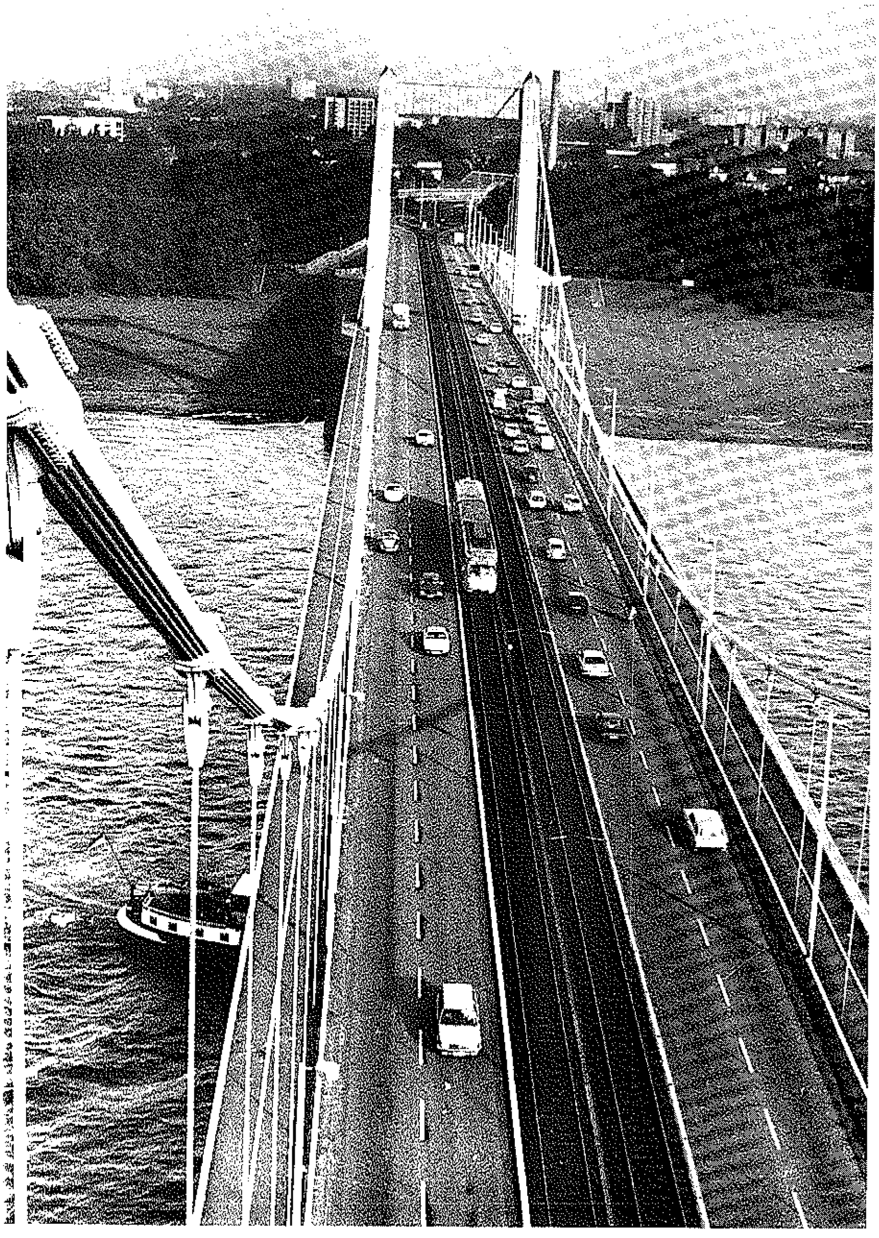

Fig. 4: The Mülheimer Brücke after completion

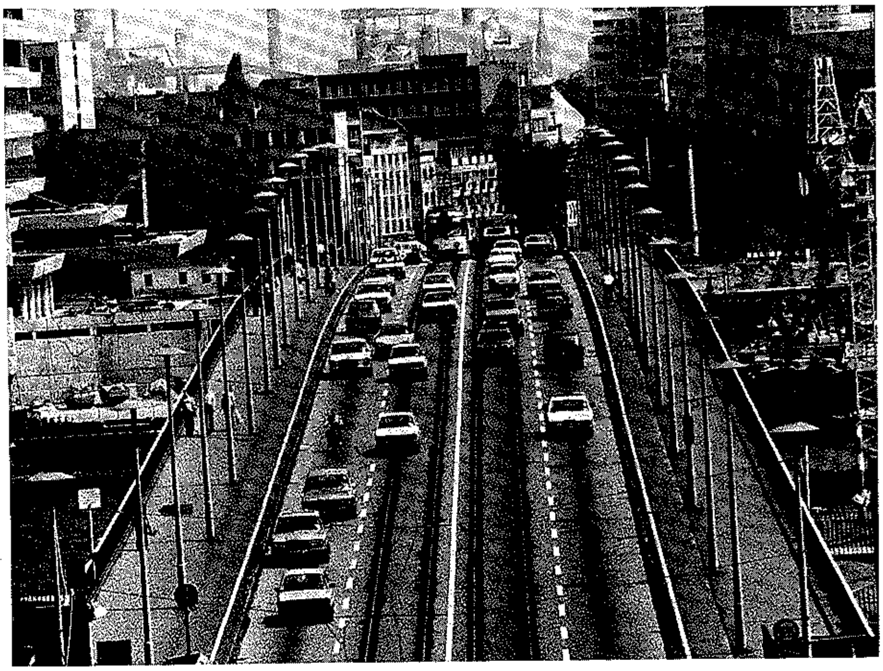

Fig. 5: The Deutzer Brücke before reconstruction - road traffic occupying the tramway tracks

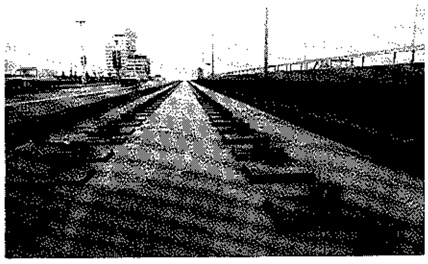

Fig. 6: The track towards Deutz (on right) already in service on the new Deutzer Brücke, the track towards Cologne (centre) in construction. It adjoins the old track towards Cologne (left of white line) which is still in operation on the old steel bridge (mid-October 1979)

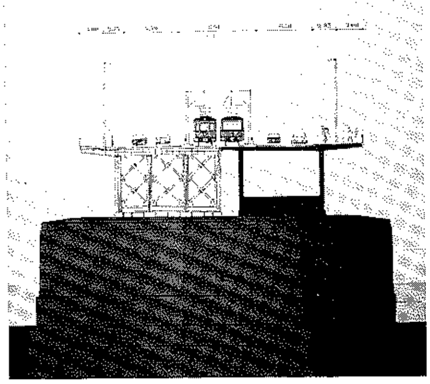

Fig. 7: Cross-section of the Deutzer Brücke after reconstruction

bridge. For this purpose the river piers had to be extended by 10.50 m upstream. After the demolition of the upstream (or south) cycle and pedestrian paths on the old bridge, the new structure would then be *slid into place.* During these demolition works, the road traffic in the direction of Deutz could already utilize the new bridge structure. In this manner it was achieved that the tramway and road traffic could pass over the bridge almost uninterruptedly during the intire reconstruction period. The Rhine river traffic was also unaffected by the bridge construction.

Preliminary investigations indicated that a new bridge-superstructure need not be a steel construction, but could also be executed in *prestressed concrete.*

The external form of the new bridge had to correspond in any case to that of the existing structure, in order that the two separate structures would form an optical entity. With the new distribution of carriageways, the light rail rapid transit track in the direction of Cologne occupied the southern edge of the old bridge, and that in the direction of Deutz the northern edge of the new structure.

The tender offers gave lower construction costs, by some *2 million D-Mark,* for the new structure in prestressed concrete. By today's technical standards in prestressed concrete construction the bridge is again an exceptionally slim structure.

After the southern footpaths had been demolished on the steel bridge, the completed concrete superstructure could be slid over the required 5.30 m to the north on 31st August 1979, in the course of which a small celebration took place. After almost five hours the placement operation was completed.

Next came the installation of the track in the direction of Deutz on the concrete superstructure, so that the rail service could already utilize the new bridge.

After the removal of the upstream cycle and pedestrian path on the south side of the *steel structure,* the light rail track was constructed along the south edge of the bridge and the northern cycle and pedestrian paths were reconstructed.

The reconstruction of the *approach ramps* presented considerable difficulties due to the requirement that the road and rail traffic must be maintained.

The 8.90 m wide track bed comprises the following:

1. two 0.50 m wide outer borders alongside the traffic carriageways,
2. two 0.20 m wide and 0.60 m high dividing barriers in prefabricated elements of exposed aggregate concrete with mounted steel barrier rails,
3. two 0.70 m wide safety strips,
4. the track area of 6.10 m width. It has the similar basic form as the superstructure on the Mülheimer Bridge.

Fig. 7 gives an *overall view* of the new full cross-section.

The reconstruction and new construction costs of the Deutzer Bridge, with a con-

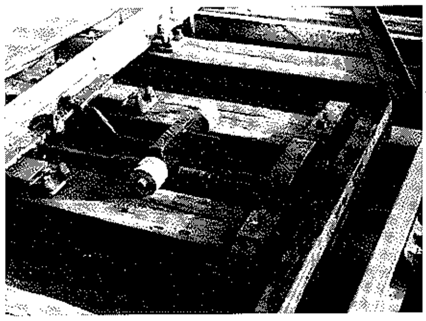

Fig. 8: Bracing of the slide rod of a temporary switch on the Severinsbrücke (with roller skate wheels)

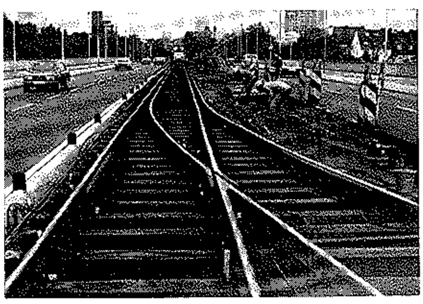

Fig. 9: One of the exceptionally long sections of interlaced track on the Severinsbrücke - no more switch failures

struction length of 615 m, totalled 47.5 Mio D-Mark. The construction works were completed in 1980 excepted the connection of the new light rail rapid transit section in Deutz. Since *10th April 1983,* having been equipped with train protection installations in the meantime, the bridge has been totally incorporated into the Cologne light rail rapid transit network.

Reconstruction of the Severinsbrücke

The time for the installation of an exclusive right-of-way on the Severin Bridge, from 1979 to 1981, was determined, amongst other things, by the fact that otherwise an immediate costly renewal of the special girder rails of the existing road level track bed would have become necessary.

In contrast to the Mülheimer Brücke, no traffic lane for a provisional track would be available during the reconstruction. Thus it was necessary, despite considerable operational difficulties, to work with sections of *single-track operation.*

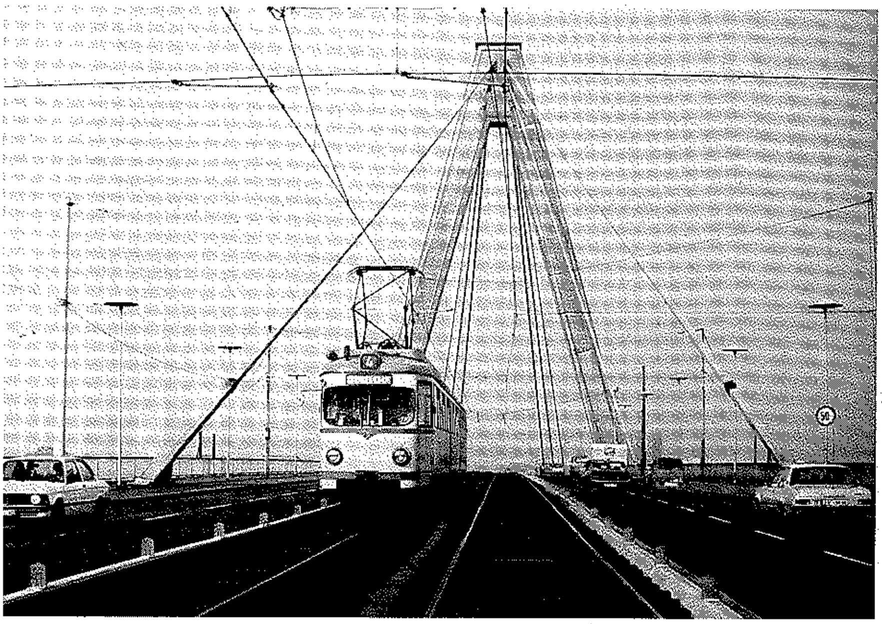

Fig. 10: Severinsbrücke after completion (1981)

With the installation of railway-type *switches* unforeseen problems arose due to the effects of major deflections, this time on a cable-stayed bridge. The locking of the ordinary railway switches was not equal to the vibrations and thrusts which occurred, so that operational interruptions occurred repeatedly. A bracing of the slide rods did not lead to definite improvement (Fig. 8). In this critical situation, the KVB resorted to a radical measure in accordance with a proposal of Theodor *Lück.* The single-track section being utilized was briefly converted into an interlaced double track (Fig. 9). The problem was then eliminated.

The cross-section of the track bed is similar to that on the Mülheimer Brücke. As a large overall road width of 19.0 m was available, two traffic lanes in each direction could be retained without any reduction of the cycle and pedestrian paths. Constructional changes to the main beams, to make it possible to retain three traffic lanes, would have not been possible without the closure of the bridge, apart from the greatly increased costs.

The reconstruction works, over a length of 1.0 km, were completed in summer 1981 (Fig. 10). The costs amounted to 17.8 Mio D-Mark.

Conclusion

Three major Rhine bridges in Cologne have been reconstructed to provide exclusive right-of-way whilst the road and rail traffic was maintained.

This was achieved on each of the three bridges in a special manner. That the Rhine river could be crossed at three points with installations suitable for light rail rapid transit traffic, without expensive tunnel construction or the complete reconstruction of the bridges, has set a standard for *economic light rail rapid transit* construction. W. L./F. J. E./H. Br.

25 Kilometres of Track on Rubber and Concrete save 0,75 Mio D-Mark per year

Cologne Construction Methods – Construction Performance – Improvements – Decisive Advantages – Economy

The ballast-free permanent way, the track on "rubber and concrete", is no longer a sensation in Cologne. The first ramp approach section without ties and ballast had already been constructed in 1970.

The aim to work with utmost accuracy and, at the same time, to achieve economies in construction, has been primarily achieved with the special *Cologne installation system.*

In the form of an *mobile construction site,* the individual operations are carried out in *ten construction stages,* from the cleaning of the tunnel floor and the laying of the rails, up to the removal of the formwork from the completed longitudinal concrete beams.

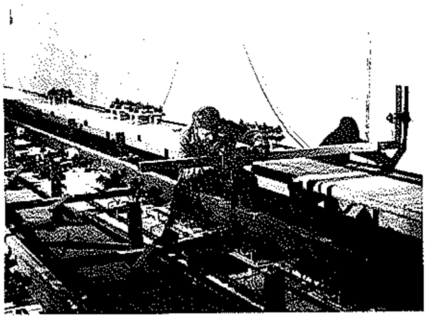

Fig. 1: Line and level are transferred with millimetre accuracy from the control points in the tunnel

The rails are blocked, welded and bolted to U-profiled *subties,* which are steel channel sections with accurately-gauged welded-on ribbed plates.

At double the support point spacing stable mounting supports are fastened into the tunnel floor. After the *compact support system* - that is the rail supports together with their fastening dowels - has been attached to the rails and bolted tight, the entire assembly is adjusted (Fig. 1) and rigidly attached to the mounting supports (Fig. 2). The reinforcing bars are installed and sheet steel shuttering is placed for the concreting of the beams. At this stage, the track is checked by surveying methods for its correspondence to the requirements for the fi-

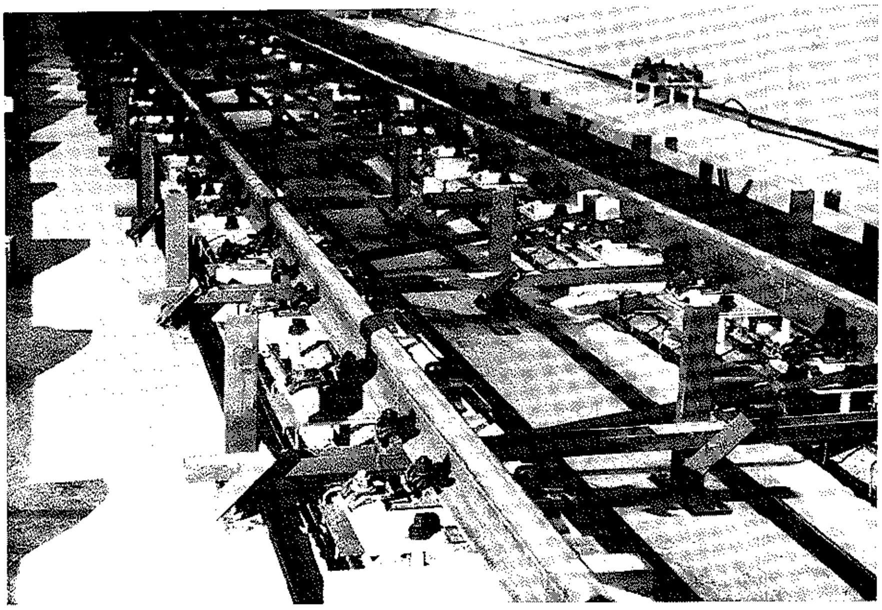

Fig. 2: Ballast-free track before concreting. The track is precisely lined and fastened (1981)

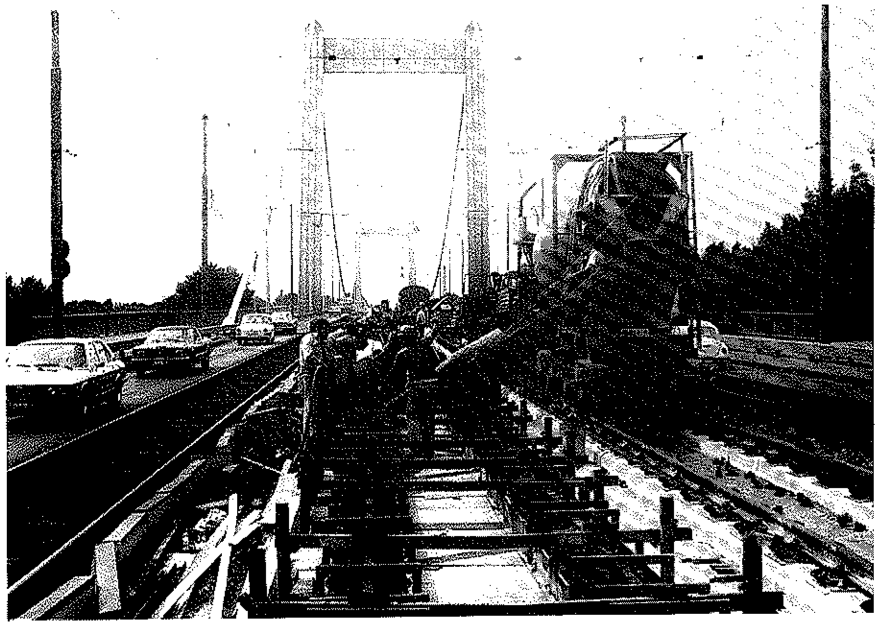

Fig. 3: Concreting of the tracks on the eastern approach ramp to the Mülheimer Brücke (1976 - still with upper ties)

Fig. 4: Junction of the Gürtel section (left) with the western ramp of the Mülheimer Brücke, with a switching section at 500 m radius (1974)

nished track regarding line, level and super-elevation.

The *construction performance*, the daily section length, and thus the overall length of the mobile construction site, are dependent upon the continuous track length to be constructed and the equipment and personel provided. For the now completed underground section of Deutz the daily section lenght was 54 m. The mobile construction site was thus, with 10 working stages, 540 m long.

Naturally, in the course of 12 years experience with tracks on "rubber and concrete", a considerable series of *improvements* and refinements in the construction procedure have been developed. Decisive were the omission of the so-called upper ties (Fig. 3) - which until that time had required an extra working stage - and refinement of the concrete shuttering.

Many improvements developed from suggestions by those engaged on site in the construction work, and also from the critical thinking and creative actions of the craftsmen, technicians and engineers of the KVB and their contractors. The Cologne installation method, with its *progressive construction process* and the chosen construction elements, offers decisive advantages over other installation systems:

- Work reduction:
  Innumberable holes for the fastening bolts do not need to be drilled in the hard concrete, thus avoiding the risk of striking reinforcement steel.
- Long-lasting accuracy of the track installations:
  The required geometric conditions are established with the construction *of the track itself*. The otherwise problematical installation of *switches and crossings* also becomes a routine procedure (Figs. 4 and 5).

Deviations which are found are immediately corrected; *the tolerance value is ± 1 mm.* Nevertheless, a later compensation in elevation due to any subsidence which may occur - for example, in individual tunnel sections - is possible to a substantial extent. From experience, any subsequent lateral adjustment is totally unnecessary.

For the following concreting a *concrete mixer on rails* of special construction is employed. From the adjoining transportation track the two longitudinal beams are simultaneously cast, together with the dowels of the support system (Fig. 3). This thus provides:

- a method of working *from top to bottom*, which appears unusual, but optimally fulfills the high requirements of accuracy.
- good attenuation of ground-borne sound is obtained by the choice of proved support systems of the type 1403/b, and, for higher requirements, 1403/c - the newly-developed "Cologne Egg".
- good elasticity, with 1,5 mm settlement at maximum speed with full loading.
- universal application - without significant alterations - in tunnels, on elevated track sections (Fig. 6), on reinforced concrete bridges, on access ramps (Fig. 3) and on a soil subgrade with a bearing slab (Fig. 7).
- High economy with the minimum wear and tear over a long track life.

The aspect of *economy* is decisive in the selection of an construction system and for its execution according to a specific method, particularly as financing becomes more restricted.

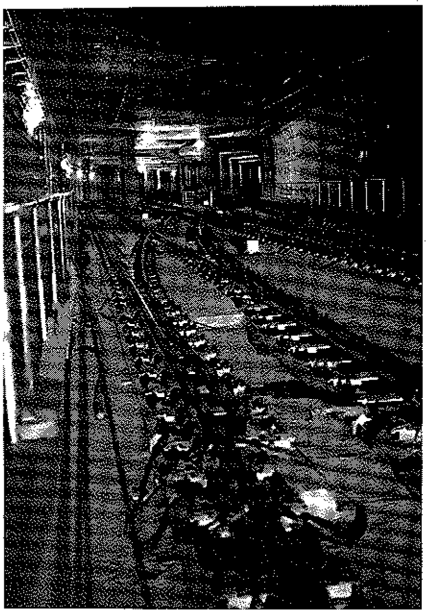

Fig. 5: Switches at west end of track siding at Deutz (1983)

With the usual drainage works required during tunneling, tunnel section with tracks on concrete *are not more expensive* in their execution than those with a ballast and ties superstructure. The higher individual costs as against ballasted construction are already compensated, as the *height of the tunnel* with ballast-free tracks can be redu-

Fig. 6: Elevated rail section in construction (1972). Daily rate of completion: 54 m of track, mobile construction site some 600 m long (with 11 work stages)

ced by some 25 to 30 cm, which has been done since the beginning in Cologne.

The decisive cost advantage, however, is determined by the *track maintenance*.

For the ballast-free sections with, until now, a track life of up to 12 years, *no specific routine costs* have arisen. General works on the rails, such as the grinding of rail corrugations and rail replacement, are required to a less extent by comparison with ballasted tracks. A later reneval of the rubber plates, the only specific works to be foreseen after 30 years, do not involve any great expenditure.

By contrast, in tunnel sections with high traffic loads, routine works for an alternative ballasted rail bed are required, on average, every two-and-a-half year. The comparatively high costs for an underground ballasted track primarily arise because the tamping and re-lining can only be carried out at night during the approximately three-hour suspension of operations.

Fig. 7: The first German double-track section on a bearing slab with earth foundation, some 1200 m of track at Cologne-Höhenhaus, early morning on 31st October, 1973, two months after the start of the construction

According to the price of 1982, a cost saving of *750000 D-Mark per year* is obtained, according to projections for the 25 km of track put into operation after the opening of the Deutz section.

Fig. 8: Commermorative plaque in the new underground station of Deutz-Kalker Bad, marking the completion of 25 km of ballast-free track

In addition to the other mentioned advantages of ballast-free track construction, this cost situation confirms the soundness of the decision taken, some years ago, to install only tracks on "rubber and concrete" in the tunnel sections in Cologne.

W. H./K. B./T. S.

Protection from Ground-Borne Noise for the Public: The First Mass-Spring-System; the 'Cologne Egg'; Novel Under Ballast Mats

Special installations have been provided in the light rail network in Cologne since the beginning of 1968 for the protection of the neighbouring residents from the noise emissions of the underground tunnels. This is concerned with the possible disturbance from so-colled *ground-borne sound* which is transmitted through the ground to a building and is then radiated from the house walls or ceilings as a dull rumbling noise.

The First Mass-Spring-System

The first remedy was at the same time the most expensive, which, due to its costs, was only used in those extreme situations when buildings were located immediately above an underground tunnel. Such a case occurred along the underground alignment in the vicinity of *Appellhofplatz* Station. When this section was designed in 1964-65, there existed no experience with ground-born attenuation methods in other cities. Therefore, new technical territory had to be explored.

In collaboration with the *Uderstädt* Consulting Engineers and the *Clouth* Rubber Factory, a leading Cologne manufacturer, the *city of Cologne* introduced the first spring-cushioned track bearing slab, or the so-called mass-spring-system. The spring element consisted at that time of two tapered elements connected in tandem which could only be relatively lightly loaded. Therefore, for a ballast double-track bearing slab, three rows of spring units, with a relatively small spacing per row, had to be utilized (Fig. 1).

For a second underground section, at *Neumarkt,* the loading capacity of the spring elements, now with only one tapered element each in the cylindrical casings, could be raised to double the previous value, i.e. up to 20 tons per element. In this manner the number of units could be reduced.

The underground section of Appellhofplatz was tested in 1968, and went into operation, together with that at Neumarkt, *in 1969.* The length of the sound-protected section amounted to a total of 131 m of twin-track tunnel.

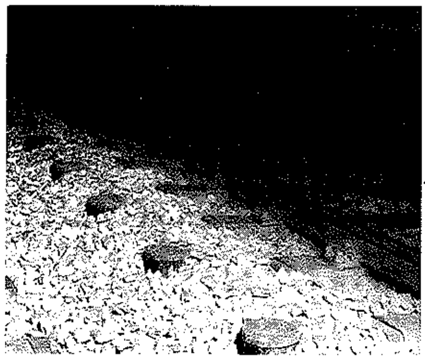

Fig. 1: Mass-spring-system of Uderstädt/ Clouth with ballast bed. In unobstructed operation since 1969

A *ballast-free alternative* of the Uderstädt/ Clouth mass-spring-system was represented by the design in 1974-79 for the underground sections in *Cologne-Kalk* and *Cologne-Vingst,* with a total of some 800 m of single-track or some 400 m of doubletrack (Fig. 2). These were put into operation in 1981 and 1982.

Both versions of the spring-cushioned track bearing slabs have completely fulfilled expectations. *Sound tests* by the Hannover Technical University and the Technical Control Association of the Rhineland confirmed, the excellent quality of the ground-borne sound attenuation. The increase in air-borne sound in the tunnel found elsewhere with a later mass-spring-system has not been observed in Cologne. The most important consequence, however, has been the satisfaction of residents along the underground, on whose behalf the system was introduced.

The "Cologne Egg"

In those cases where possible disturbance from the transmission of ground-borne sound need not necessarily be combatted

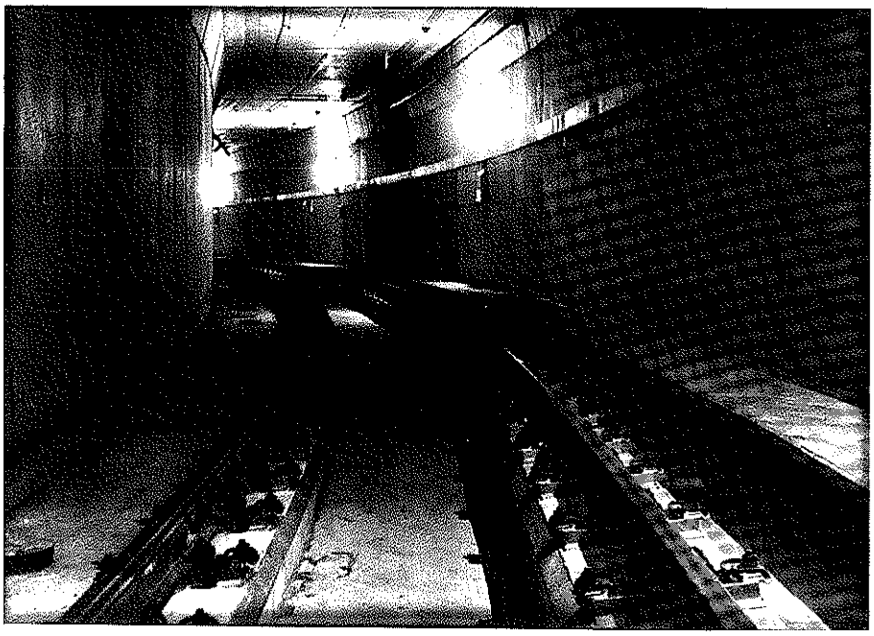

Fig. 2: Non-ballasted version of the Mass-spring-system of Uderstädt/Clouth at Cologne-Kalk, with single track construction. The greater spacing of the spring elements can be observed.

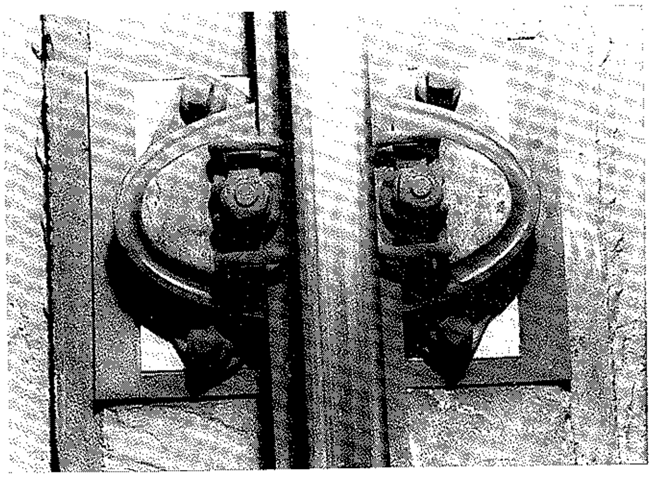

Fig. 3: Top view of the 'Cologne Egg': the oval ribbed plate is suspended in a rubber collar vulcanized in place

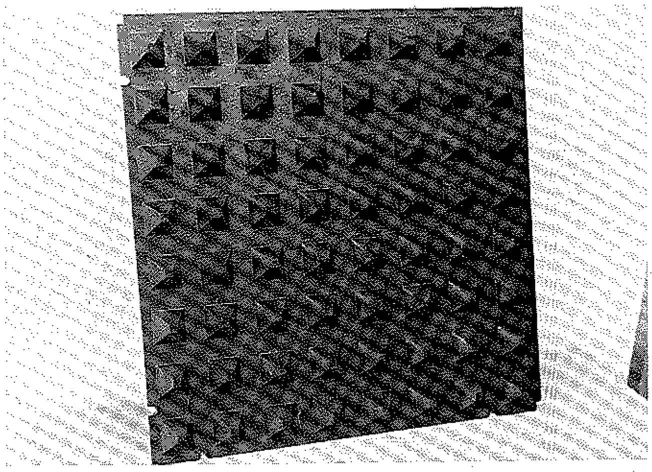

Fig. 4: Underside of the Cologne-type of sub-ballast mat - nicknamed the 'Cologne Egg-box' (although it is, naturally, made of rubber). The reinforcing steel plate is totally enclosed by the vulcanised-on rubber

with the extreme measure of a mass-spring-system, but where, however, protection over a *considerable length* is desirable, or where it is even possible to readily provide a subsequent improvement, a particularly elastic rail fastening was developed by the KVB, which because of its oval shape gained the name of the "Cologne Egg" (Fig. 3).

In contrast to the mass-spring-system, it required no particular preplanning in the design of tunnels, and above all demanded no increase in the normal tunnel height. The special feature of the "Cologne Egg", apart from the comparatively low cost, is the mounting of the rails on a plate which is not supported by, but is enclosed in a rubber collar vulcanised in place, in which it is freely suspended. In this manner, an exceptional degree of ground-borne sound attenuation is obtained at low cost. The "Cologne Egg", officially termed "Superstructure Element 1403/c", with its German and French designations as *"Kölner Ei"* and *"L'Oeuf de Cologne"* has spread the name of the ancient city of Cologne throughout the world in a new context, namely in association with environmental protection. As the development has been extensively reported in this Journal ("Verkehr und Technik" V+T, issues 7, 8, 10 and 12, 1979, and 11 and 12, 1981), it need only be added here that this construction is already installed in a part of the new light rail tunnel in Cologne-Deutz, in consideration of the Municipal Services Headquarters which is still to be constructed, namely in the western section of the *Bahnhof Deutz/Messe Station,* and in the adjoining tunnel section.

New Sub-ballast Mats

These profiled rubber mats, reinforces with a *steel plate,* are used to improve the attenuation of body-born sound created by ballasted tracks in tunnels and on bridges (Fig. 4). They have also been developed in Cologne, and because of their peculiar form, have been termed "Cologne Egg-Boxes". The reason for their development was the disturbance to residents in the vicinity of the underground station at *Post Strasse.* As the later installation of sub-ballast mats under operating tracks is costly, a reinforced form was produced, which would have an *increased life* over older types of similar mats. At the same time, however, the Cologne mat counts as one of the *most effective* measure for ground-borne sound attenuation. The residents near the Post Strasse station have had no further grounds for complaint.

This brief description of the mat will suffice, as details have already been reported in this Journal (V+T No 7/1982).

Further Developments

The "Cologne Egg" can also be used for subsequent improvements in the ground-borne sound characteristics of *ballasted tracks,* when extraction of the bedding ballast is to be avoided. Corresponding trials are in progress for the elimination of rumbling on *steel bridges* and elsewhere.

The next development under consideration is for the purpose of improving the ground-borne sound attenuation of *girder rail tracks* for tramway operation, which are being newly installed and must presumably remain for a long period in the traffic carriageways of the roads.

E. W./H. Br.