Upgrading Conventional Streetcar Lines to Light Rail Transit: Case Study from Oslo, Norway

Thor Kaarsberg Haatveit
Oslo Transit Authority
Oslo, Norway

Because of increases in subsidies from the city of Oslo for the transit system, in 1981 it was decided to initiate a comprehensive analysis of the transit system. The analysis was done in two parallel parts, management and network. The network analysis was divided into five projects one of which covered the relationship between operating speed and costs (Figure 1).

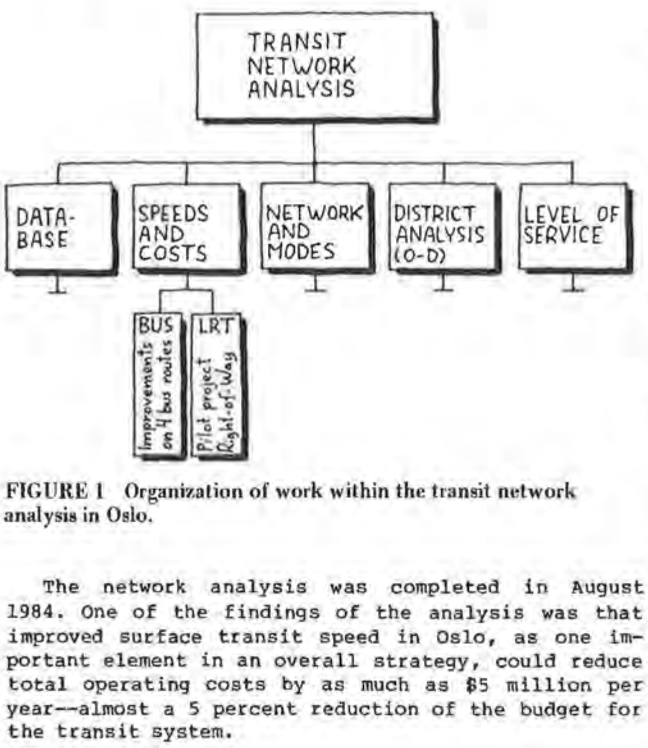


FIGURE 1 Organization of work within the transit network analysis in Oslo.

The network analysis was completed in August 1984. One of the findings of the analysis was that improved surface transit speed in Oslo, as one important element in an overall strategy, could reduce total operating costs by as much as $5 million per year--almost a 5 percent reduction of the budget for the transit system.

STUDY OF TRANSIT SPEEDS AND COSTS

The project within the network analysis that was dedicated to surface transit speeds was divided in two parts: a study of near-term right-of-way improvements for a selected number of bus routes and a more detailed study of a selected streetcar line. The goals, requirements, and findings for the latter study will be discussed.

In the short term the results of both studies are to be implemented gradually in streets and intersections wherever the situation permits. In the long run the results will be incorporated in a strategy to improve the efficiency of the transit system in Oslo.

PROJECT RIGHT-OF-WAY

Goals and Requirements

The goal of Project Right-of-Way (PROW) is to find a cost-effective approach to upgrading a conventional streetcar line into a light rail line so as to increase level of service, reduce operating costs, and cause positive long-range impacts. The line was selected on the basis of the potential for completing the project and because the line was representative of the other four remaining streetcar lines. It should be possible to complete PROW in a construction time of less than 2 years.

The study was required to include an analysis of alternative solutions that increase operating speed by various means. These will ensure improved right-of-way conditions for streetcars, reduce dwell times at signalized intersections, and minimize the number of conflicts with automobiles in general. Further, it was required that the project provide detailed information about results and consequences of the plan for decision makers. Design drawings (scale 1 : 500) were to be developed for the complete line selected for PROW. The plan should, as far as possible, be self-supporting and not involve a lot of red tape.

Finally, PROW should be possible to realize with moderate investments. Operating costs, capital costs included, should be reduced as soon as the project is completed. Increased ridership (and income) is not to be considered even if level of service will improve considerably.

Line Selection

Streetcar Route 11 from Majorstuen to Kjelsås was chosen as PROW. The line is 10.2 km long and is located in regular streets with mixed traffic. No private right-of-way is presently given for the line. The operating speed for the route is 15 km/hr, and reliability during the day is poor.

Total line length for the five streetcar routes in Oslo is 40 km of which 12.5 km or about 30 percent have private right-of-way. The remaining 27.5 km are located in streets with mixed automobile traffic. Route 11 alone covers 37 percent of the total network line length and the other four streetcar routes cover the remaining 17.3 km. Three routes (1, 2, and 7) share 7 km of line with Route 11 (Figure 2).

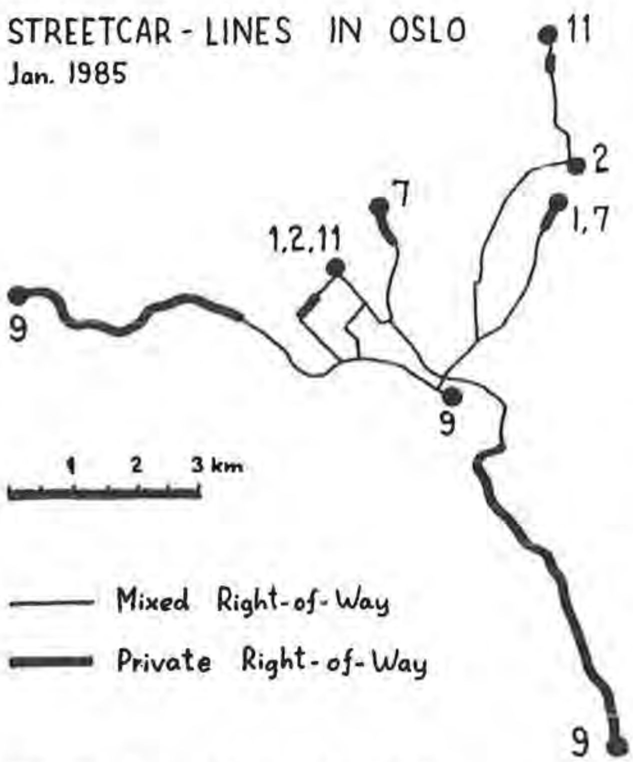


FIGURE 2 Network of streetcar lines in Oslo.

Route 11 carries 6.4 million passengers per year or about 21,400 passengers on a weekday. Fifty-six percent of the trips are direct (without transfers). Seventy-five percent of transfers are taken at three stops; one is a terminal (Majorstuen) and the others are large stops in downtown. Average stop distance is 350 m. Average trip length for passengers is 3.3 km, which is slightly less than the average for passengers using routes within the center city.

Speeds along the line vary considerably. Station-to-station speeds are as high as 30 km/hr and as low as 8 km/hr. To improve reliability, terminal time in peak hours has been increased to as much as 30 percent of driving time. With an operating speed of 22 km/hr and 15 percent terminal time, the fleet size for the line would be reduced from the present 22 vehicles to 14. At the same time the travel time for a passenger would be reduced by 19.5 hr per year.

Given the potential for Route 11 just described, the choice of this route for PROW was obvious.

PROBLEM ANALYSIS

Existing Situation--Location of Bottlenecks

To obtain information about when and where problems exist for vehicles operating on Route 11, a microcomputer was installed in a vehicle to take automatic and detailed measurements of the traffic problems on 50 to 60 round trips. The trips were later separated in two batches, peak and off peak, for statistical analysis.

The microcomputer had three connections with the vehicle: power (24 V), gearbox, and doors. It was also equipped with a built-in clock and a memory unit with data cassettes. It was therefore possible to measure average speeds along the line (operating, station-to-station, and so forth), number of stops (stopping or passing), dwell time at stops, stop time (red light at intersections and so forth), and frequency of occurrence (number of stops or delays at particular locations along the line). The microcomputer was used on 58 round trips on Route 11, from which 49 were accepted as valid for statistical analysis.

The taking of detailed measurements along the line was accepted by the labor unions because the actual speed (at any point) was not presented. The presentation of the data gave an objective picture of the driving conditions along the line, not information about individual drivers (Figures 3 and 4).

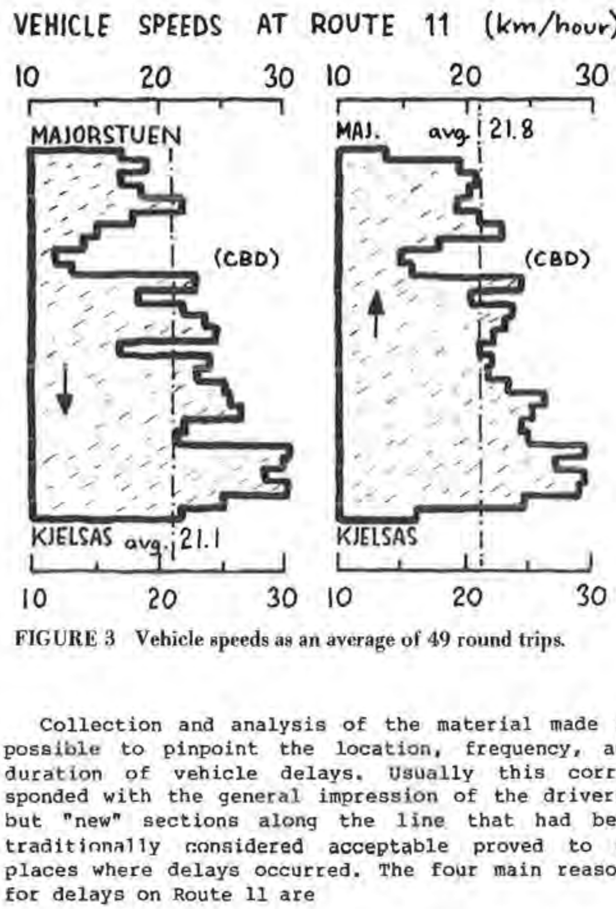


FIGURE 3 Vehicle speeds as an average of 49 round trips.

Collection and analysis of the material made it possible to pinpoint the location, frequency, and duration of vehicle delays. Usually this corresponded with the general impression of the drivers, but "new" sections along the line that had been traditionally considered acceptable proved to be places where delays occurred. The four main reasons for delays on Route 11 are

1. Intercepting traffic (automobiles and pedestrians),
2. Parking and deliveries,
3. Signalized intersections, and
4. Safety in general (rail transit in nonreserved right-of-way is vulnerable to existing or even possible traffic movements next to the line).

Combinations of these problems also decrease the operating speed of transit. The existing situation of every section of the line operated by Route 11 was classified, and this information served as a

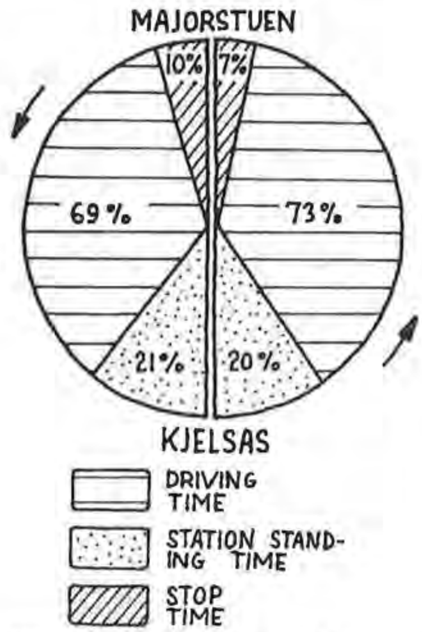


FIGURE 4 Operating time split into driving time, station standing time, and stop time (red lights etc.); driving time for Route 11 is normal for an inner city route, but speed is slow (21.5 km/hr driving speed).

point of reference in evaluating alternative solutions.

Automobile Traffic Pattern

Route 11 shares the right-of-way with automobiles in arterial as well as local streets. Some of the streets within the central business district (CBD) have limited access for automobiles, but none have been reserved exclusively for transit.

The existing traffic pattern is conventional: two-way traffic is allowed in most streets whether or not they have transit, parking, or high volumes of pedestrians. Because of narrow streets, two-way traffic would not be possible if transit were given private right-of-way. A major problem is therefore to upgrade local streets to arterials for through traffic in order to be able to reduce the traffic in streets with transit. Also, the large number of local streets that cross the transit right-of-way should be reduced to improve transit operating speed. The present automobile traffic pattern will therefore have to be changed in the areas where Route 11 is given a separate right-of-way. Even if the policy of the city is to reduce the volume of automobile traffic by improving transit and increasing parking fees, PROW still must maintain the present capacity for automobile traffic.

Parking and Deliveries

About 50 percent (5 km) of the line length of Route 11 is in typical shopping streets with a variety of businesses. Along the line there are more than 200 parking places (with meters) most of which are on the western side of the city and in the CBD. In addition, there are more than 400 nonregulated curb parking places. The latter are mostly used for 2-hr off-peak parking, although overnight residential parking is also allowed. With few exceptions, automobiles park next to the right-of-way for streetcars. Streetcars are therefore delayed daily by automobiles that are parked too close to the rails.

In general there are no regulated parking places for delivery vehicles along the line. Vans and trucks frequently have difficulties when loading or unloading, and double parking in the middle of the rail tracks is not uncommon.

Originally, deliveries were included as a separate issue in PROW. However, it was later decided to also include parking in the analysis because PROW should be planned to avoid any substantial loss of presently available parking places.

DEVELOPMENT AND EVALUATION OF ALTERNATIVES

Definitions

Right-of-way (ROW) can be classified (1,p.650) in three categories:

- Category A. Fully controlled ROW without grade crossings or any legal access by other vehicles or persons; also called grade-separated, private, or exclusive ROW. Such ROW can be underground, aerial, or at grade level.
- Category B. ROW that is physically separated longitudinally (by curbs, barriers, or grade separation) from other traffic but with grade crossings, including regular street intersections, for vehicles and pedestrians.
- Category C. Surface streets with mixed traffic. Transit may receive preferential treatment, such as reserved but not physically separated lanes, or it may travel with other traffic.

For the purpose of PROW, two type of preferential treatment of transit at signalized intersections were defined:

- Active transit priority. Transit approaching an intersection is given a green light. A signalized intersection with active transit priority will automatically detect and prepare for fast passage of transit vehicles. When transit vehicles are not present, all available green time is given to automobiles and pedestrians.
- Passive transit priority. The available green time for transit is expanded to a maximum within the fixed cycle time. Transit thus receives more frequent or longer green time, or both, but still must wait for a green light. Passive transit priority is common in streets with high volumes of transit traffic.

Development of Alternatives

Three alternatives with different right-of-way characteristics were developed in order to find an approach to an optimal solution:

- Alternative 1 allows two-way automobile traffic on most streets. The tracks are placed on each side of the street. Curb parking is prohibited (Figure 5). Transit is given priority in signalized intersections but operates with mixed automobile traffic (ROW Category C).
- Alternative 2 requires one-way traffic on most streets where Route 11 operates. The tracks are placed on one side of the street and are largely separated from automobile traffic. Curb parking for automobiles and delivery trucks is allowed as long as it is not next to the transit ROW (Figure 6).

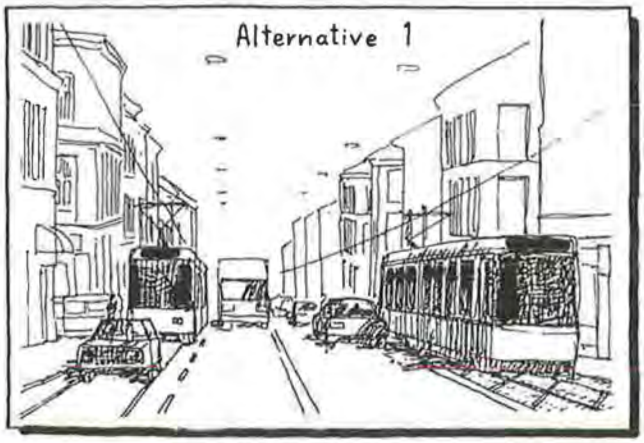


FIGURE 5 Alternative 1 with right-of-way Category C; delays for streetcars are slightly less than at present because there is no parking along the curbs.

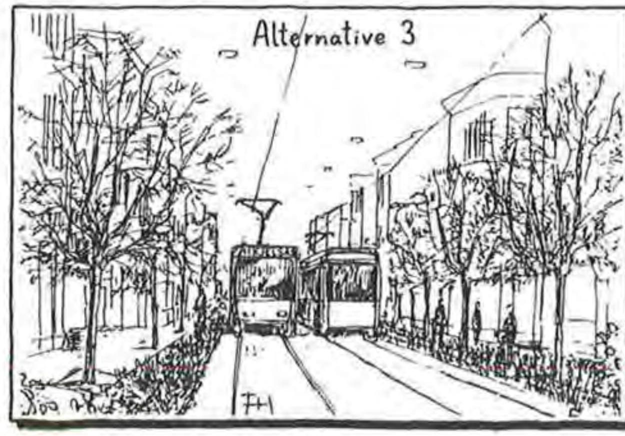


FIGURE 7 Alternative 3 with right-of-way Category B; private right-of-way ensures high operating speed with improved safety.

FIGURE 6 Alternative 2 with right-of-way Categories C-B; automobiles do not interfere with the LRT operation except in intersections.

FIGURE 8 Alternative 3B: three intersections with heavy traffic are grade separated.

A subalternative (2B) explores the effects of longitudinal physical separation between transit right-of-way and automobiles and pedestrians (ROW Category B). Transit is given full priority at all signalized intersections.

Alternative 3 requires private right-of-way for the complete line. No automobile traffic, except delivery trucks, is allowed on streets on which Route 11 operates. The number of intersections is reduced by making several local streets dead-end at the transit right-of-way (ROW Category B). Signalization at the remaining intersections gives full priority to transit (Figure 7).

A subalternative (3B) illuminates the effects of building grade-separated intersections for the three busiest crossing arterials. The right-of-way standard is thus considerably improved for shorter sections (ROW Categories A and B) at higher, but still "reasonable," cost (Figure 8).

Evaluation and Selection

A detailed analysis of operating speed, automobile traffic, and costs was done for all three alternatives.

Alternative 1 gave some improvements in travel speed but at considerable cost. This alternative is not suitable for upgrading to Alternative 2 or 3 and cannot be recommended.

Alternative 2 gave satisfactory improvements in travel speed with limited investment costs. This alternative can be upgraded to Alternatives 2B and 3 whenever this can be justified on a cost-benefit basis.

Alternative 3 gave the best operating speed and the highest reductions in operating costs. Investment costs are considerable and involve more than the right-of-way for Route 11 because considerable changes in the automobile traffic pattern will follow the completion of Alternative 3. These changes will require investments for arterial as well as local streets.

Comparison of the alternatives shows that Alternative 3B gives the best results in terms of operating speed and costs if capital costs are excluded. It capital costs are included, Alternative 3B is not better than Alternative 2B. If only operating costs are considered, Alternative 3 is the best. However, because this alternative requires work on the surrounding street network, additional costs may be incurred (Table 1, Figures 9 and 10).

TABLE 1 Investments and Reductions in Costs and Operating Times for Different ROW Alternatives

Alternative	Investments (millions)		Savings per year (millions)		Round-Trip Travel Time (min)	Reduction		Operating Speed (km/hr)
	$US	NOK	$US	NOK		Minutes	Percentage	
Today	–	–	–	–	80.7	–	–	15.0
1	2.0	19.2	0.2	2.0	72.0	8.7	10.9	16.8
2	2.4	22.9	0.4	3.9	70.3	10.4	12.9	17.2
2B	2.7	25.3	0.4	3.9	66.3	14.1	17.6	18.2
3	3.9	37.2	0.6	5.8	61.4	19.3	24.0	19.7
3B	6.9	65.2	0.6	5.8	53.7	27.0	33.5	22.5

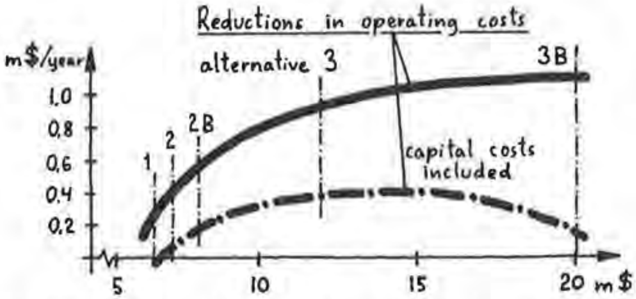


FIGURE 9 Relationship between investments and reductions in operating costs for each of the alternatives; the lower curve shows annual reduction if capital costs are included in operating costs.

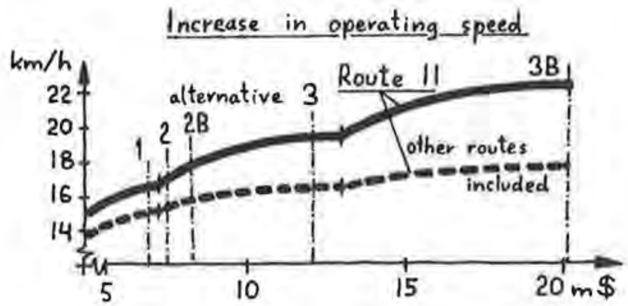


FIGURE 10 Relationship between investments and increases in operating speed. ROW improvements for Route 11 also influence the other routes. The lower curve shows the increase in operating speed for the complete streetcar network after implementation of the different alternatives.

Neither of the alternatives in its present form is desirable for achieving an optimal solution. It was subsequently decided to develop a composite of Alternatives 2B and 3. The following elements should, if possible, be included in the alternative:

- Construction costs lower than for Alternative 3,
- Operating speed higher than for Alternative 2B,
- Automobile traffic pattern principally as in Alternative 2B but with dead-end local streets as in Alternative 3.

The alternative should be defined in terms of general criteria for design. Thereafter the design for the complete line can be developed.

CRITERIA FOR RIGHT-OF-WAY STANDARD

A set of design elements that includes the most important geometric issues for the project was developed. The establishment of these guidelines was important for two reasons. First, it serves as an initial reference, subject to updating, in the process of making plans for the actual line design. Second, when adjusted and approved, it may be a future design standard that can be applied and enforced in all construction work that involves the right-of-way for light rail transit (LRT).

Definition of Design Elements

Design elements for PROW are as follows:

1. The right-of-way for light rail transit in both directions is preferably located in the same street.
2. The track sets are preferably parallel to each other.
3. If the street has three or more lanes, two are reserved for LRT. If the street has two lanes, mixed traffic may exceptionally be allowed in one lane.
4. Only local automobile traffic, if any, is allowed in the lane for LRT. Through traffic is not allowed in streets with LRT unless separate lanes are provided.
5. Parking next to the LRT right-of-way is prohibited.
6. Signalized intersections are to be designed with minimum waiting time for LRT.
7. The LRT right-of-way is, wherever possible, to be physically separated from automobile traffic.
8. The street surface for LRT shall be unsuitable, but in emergencies possible, to use for automobile traffic.
9. There are to be fences between the LRT right-of-way and the sidewalk.
10. Passenger entry and exit are not allowed to or from an adjacent (to the LRT ROW) automobile lane in the street. Three alternative solutions for design of stops are to be used: (a) The stop is located on the sidewalk wherever the location of tracks allows. (b) In streets with an automobile lane next to the LRT ROW at the right side, the sidewalk is extended out to the tracks at the stop. The automobile lane shares the LRT ROW in front of transit stops. (c) In streets wide enough for more than one automobile lane to the right side of the LRT ROW, the transit stop is placed on an island.

PROPOSAL FOR PILOT PROJECT RIGHT-OF-WAY

The design of right-of-way for PROW was done for the complete line with 21 drawings (scale 1 : 500). The drafts were colored and presented in a report in which all sections of the line were discussed in terms of existing situations and problems and recommended solutions and actions. Each block and crossing street was included in the discussion in order to give a complete picture of PROW. Some examples from the presentation are given in this section.

Design of Right-of-Way

Using the design criteria described earlier, the different right-of-way alternatives that have been applied in PROW may be classified in three categories:

- Category 1 (narrow streets, Figure 11). LRT ROW is exclusive in one or both directions. Automobile traffic, if allowed at all, is restricted to local traffic or access to properties. All parking is prohibited.

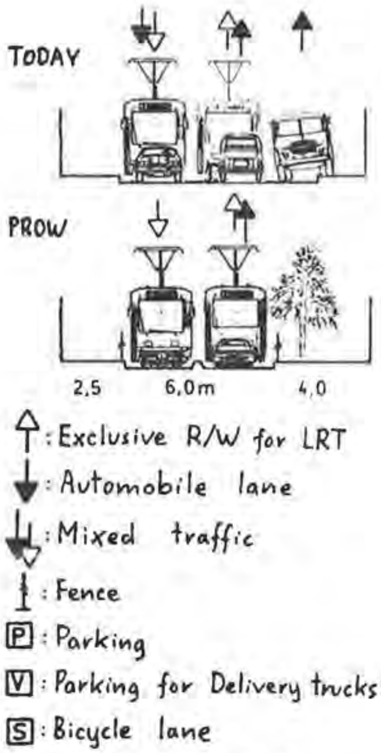


FIGURE 11 Present situation compared with the solution (Category 1) with partial separation (ROW C) in narrow streets. (Note: Commas should be understood as decimal points.)

- Category 2 (narrow and wide streets, Figure 12). LRT ROW is exclusive in both directions. One-way automobile traffic is allowed in a separate lane next to the LRT ROW. If there is sufficient space, parking is allowed between the automobile lane and the sidewalk.
- Category 3 (wide streets, Figure 13). LRT ROW is placed in a separated median with automobile lanes on both sides. If there is sufficient space, parking is allowed between the automobile lanes and the sidewalks.

The geometric street design used in PROW can be described with reference to

- Right-of-way separation,
- Intersections,
- Deliveries and parking, and
- Pedestrian areas and sidewalks.

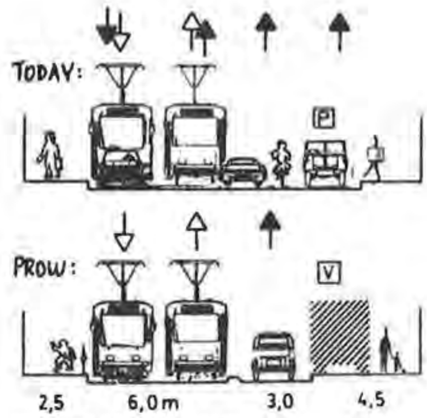


FIGURE 12 Present situation compared with the solution (Category 2) with full separation (ROW B) from other traffic in narrow to medium-wide streets. (Note: Commas should be understood as decimal points.)

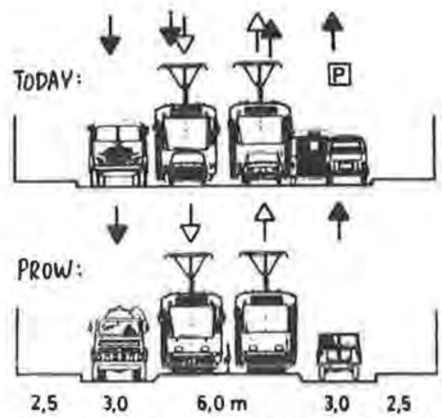


FIGURE 13 Present situation compared with the solution (Category 3) with full separation (ROW B) from other traffic in wide streets. (Note: Commas should be understood as decimal points.)

Separation of Right-of-Way

Longitudinal separation of the LRT ROW can be achieved by either physical or nonphysical measures. The most effective separation is obtained by physical enforcement. Three common types of physical enforcement are curbs, fences, and grade separation (e.g., between street level and sidewalk). Examples of nonphysical separation are traffic signs, street markings (e.g., painted transverse lines), and different types of pavement surfaces. Physical enforcement has been widely used in PROW. Nonphysical separation has only been used when physical separation has not been feasible.

Intersections

In PROW the design of intersections has been developed with particular attention to the relationships among traffic movements, volumes, and safety. Turn controls have been applied extensively, and left-turn movements crossing tracks have been reduced to a minimum. In general, PROW aims to simplify intersections as shown in Figure 14. At the same time, other

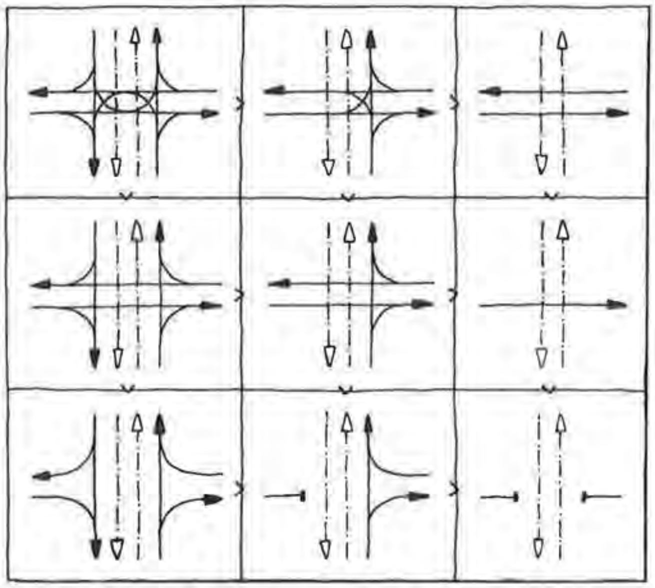


FIGURE 14 Step-by-step simplification of intersections as applied in PROW. Worst: heavy traffic in all directions (upper left corner). Best: full priority for transit with light automobile traffic in dead-end streets (lower right corner).

actions in addition to the longitudinal right-of-way separation are taken. A combination of physical and nonphysical elements that discriminate between automobile volumes has been applied. Although major streets may cross the LRT ROW at grade level (Figure 15, A-A), smaller streets may cross the ROW on ramps (Figure 15, B-B) or even be made dead ends by barriers (Figure 15, C-C). Combined with traffic signs and signalization, these relatively simple measures give satisfactory results in terms of implementation, cost, and increased operating speed for LRT.

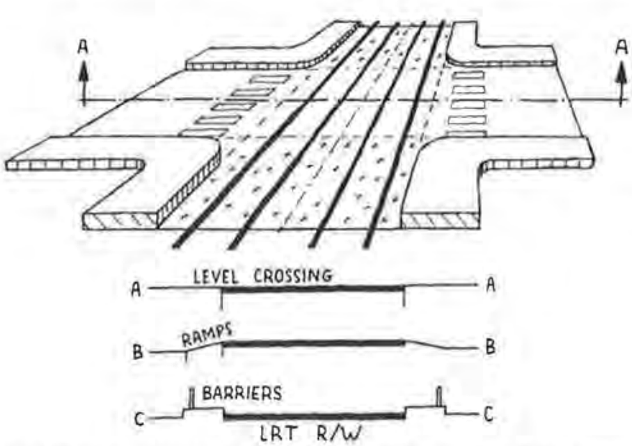


FIGURE 15 Intersection design according to automobile volumes; high volumes may require at-level crossings; light volumes can justify ramps or barriers; the physical design is combined with adequate signalization.

Deliveries and Parking

Three principles have been applied to deliveries in streets with transit. Curb parking next to the LRT ROW is occasionally allowed in narrow streets where other access to shops and businesses is not adequate. However, curb parking for delivery trucks is recommended wherever an automobile lane exists between parked trucks and the LRT ROW (Figure 16, A). If suitable, curb parking in side streets (Figure 16, B) is allowed. Finally, where a local street dead-ends at the LRT ROW, a separate parking area may be defined for deliveries (Figure 16, C). The same guidelines apply for parking of private automobiles.

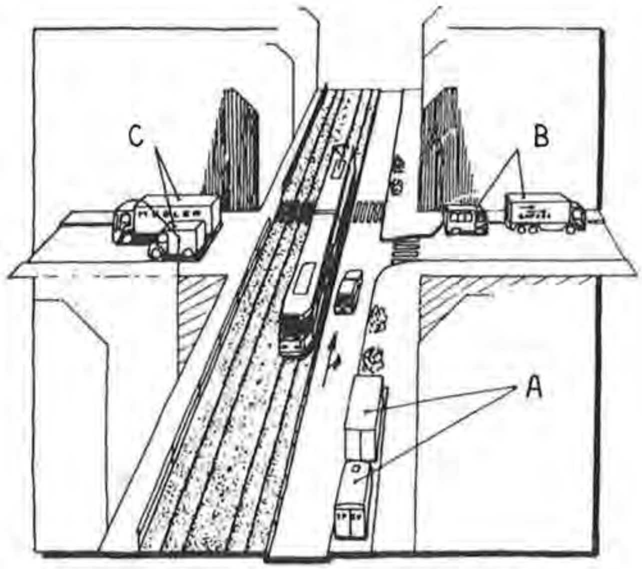


FIGURE 16 Three parking principles applied in PROW.

Pedestrian Areas and Sidewalks

In PROW private automobiles have been discriminated against in favor of pedestrians and transit. In some streets pedestrian areas have been considerably expanded at the expense of automobile parking. Reactions of property and business owners may be mixed. In shopping districts both pedestrian areas and parking are desirable. Trade-offs between these two elements have to be made. In PROW an attempt has been made, on a small scale, to create separate areas for parking and pedestrians. Obviously, the question of which group is to be favored must be addressed. Figures 17 and 18 illustrate the problem.

Signalization

PROW makes extensive use of active as well as passive priority for transit. Active priority gives

FIGURE 17 Maximizing parking spaces in available areas next to ROW for transit.

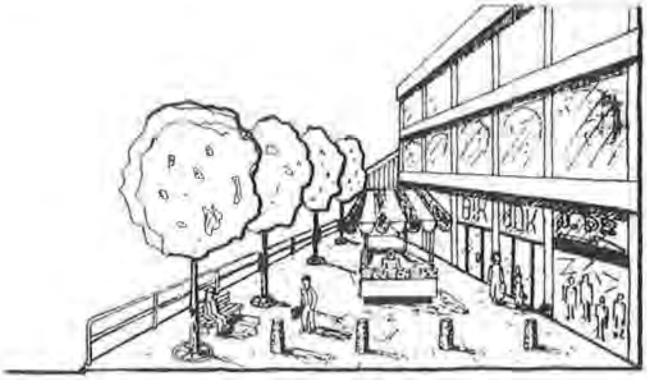


FIGURE 18 Maximizing areas for pedestrians and shopping while improving ROW for transit.

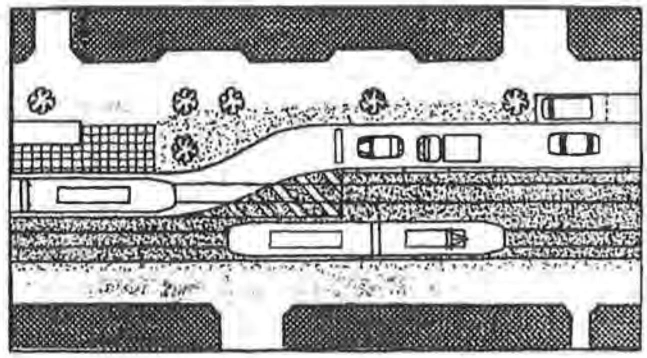


FIGURE 19 "Extended" transit stop (curb is extended to the ROW for LRT); automobiles bypass in the LRT lane; a stop line with signalization (LRT activated) ensures that no automobiles enter the areas in front of the stop when an LRV is approaching.

LRVs a "flying start" across intersections, and passive priority gives an excess of green time (at regular intervals) for transit when it dominates the traffic flow in an intersection. The distribution of green time may thus be influenced by the number of persons rather than the number of vehicles.

PROW has focused on how to solve present problems with active priority. A requirement for successful operation with active priority is early detection of transit vehicles. For transit vehicle drivers, an acknowledgment of detection is important in order to maintain transit vehicle speed when approaching the intersection. Even if acknowledgment of early detection is a rather trivial matter, practical problems can make it difficult to achieve a fully satisfactory solution. Commonly, insufficient block lengths reduce the required detection distance. Therefore, transit stops have been relocated and side streets have been closed when necessary and acceptable.

Design of Transit Stops and Terminals

In PROW two kinds of stops have been used: stops by curbs and stops at islands. Regular stops by curbs require no special design. The stop itself is equipped according to a recently completed design that calls for weather protection, information, and seating. Stops by extended curbs, where the automobile lane in front of the stop shares right-of-way with LRT, require special design. A signal is placed ahead of the transition zone between the automobile lane and the LRT ROW in order to stop automobiles whenever an LRV is approaching the stop. The transition zone and the mixed lane for automobile bypass in front of the stop may have a different surface texture (e.g., concrete tiles) than the LRT ROW (rough cobblestones). Signs, markings, and general layout will thus ensure that satisfactory safety is achieved. The design itself is an example of the discrimination against automobile traffic in favor of transit and pedestrians (Figures 19 and 20).

Stops on islands have been designed where space considerations and need for high-capacity streets for automobiles have made them necessary. The design may vary according to passenger and automobile volumes. Examples of designs are shown in Figure 21.

Route 11 has two terminals, one at the north end of the line and one at the west. Three other streetcar routes terminate at the western terminal, and two bus routes and four rapid transit routes bypass the terminal. The terminal area has therefore been designed for easy transfers: passengers generally do

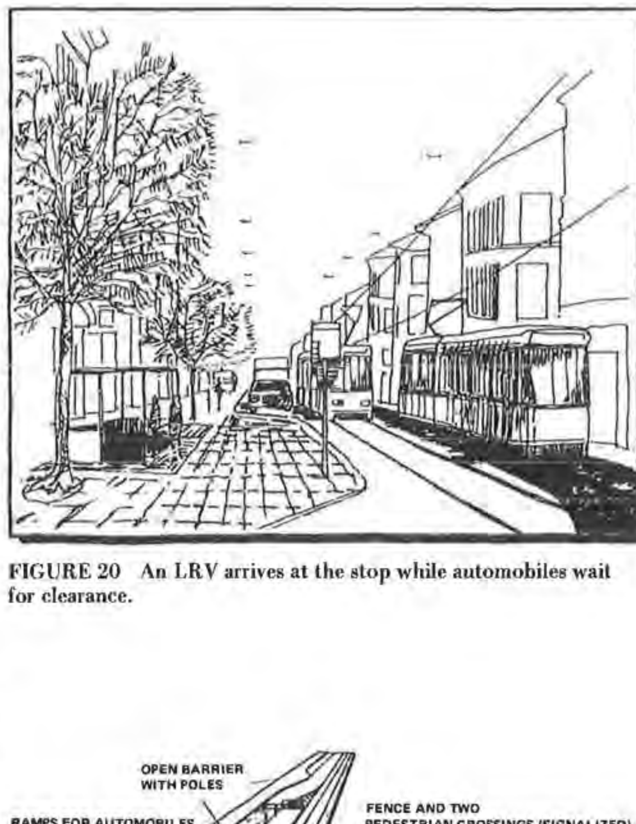


FIGURE 20 An LRV arrives at the stop while automobiles wait for clearance.

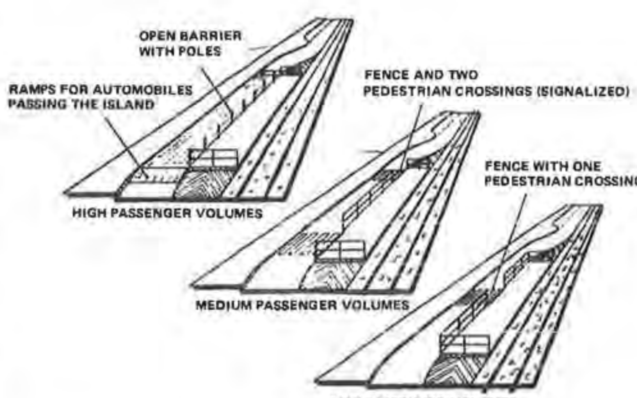


FIGURE 21 Alternative designs of islands according to passenger and automobile-lane volumes.

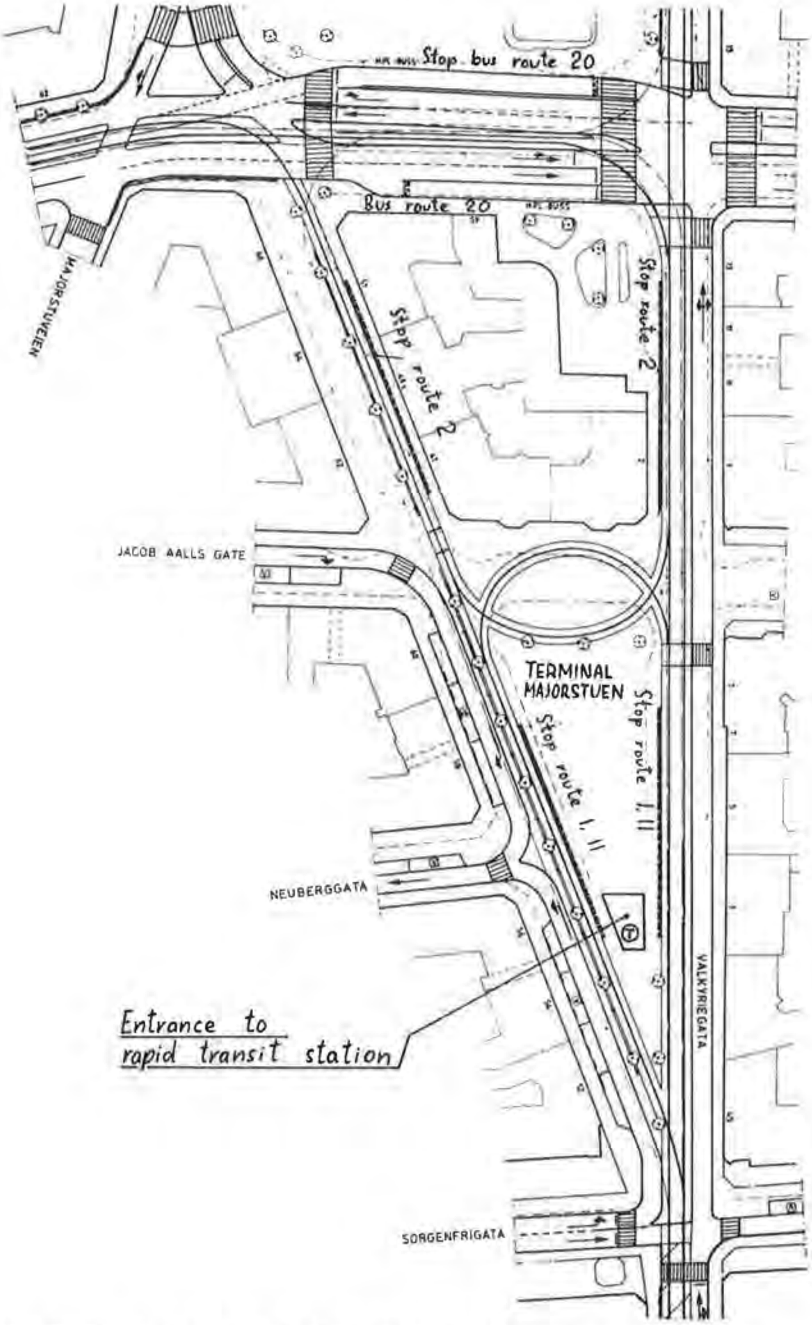


FIGURE 22 Design drawing of the terminal area at Majorstuen; the design makes easy transfers possible between LRT, rapid transit, and bus.

not have to cross streets. The design of the terminal is shown in Figure 22.

Vehicles

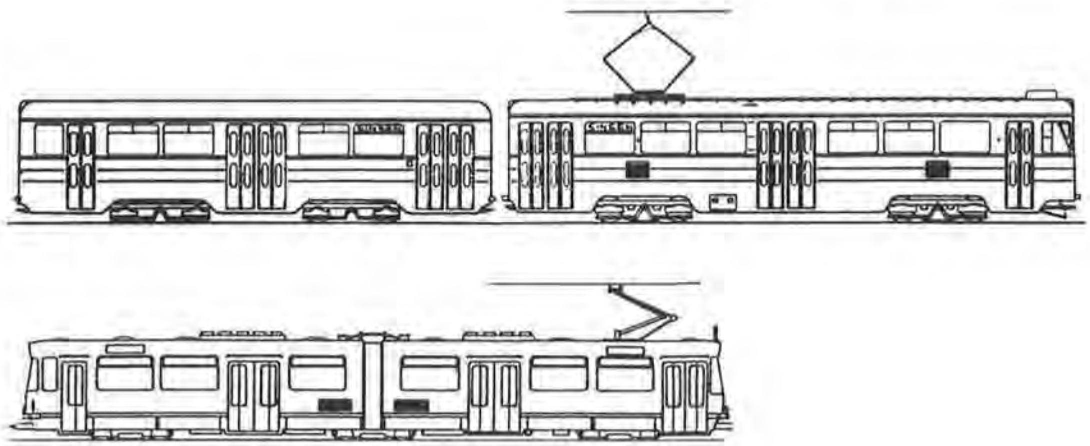
The PROW design accommodates use of the two existing types of streetcars and light rail vehicles in Oslo. The first type is a four-axle vehicle with a four-axle trailer giving a total capacity of 200 passengers. Total transit unit length is 27.5 m. The other type is a six-axle single articulated vehicle with a capacity of 140 passengers. This vehicle may be coupled in two-car trains that are 45 m long. Both vehicles are 2.5 m wide. Maximum speed is 60 and 80 km/hr, respectively. The vehicles are shown in Figure 23.

Operating Speed and Costs

PROW will give an increase in operating speed of from 15 to 19 or 20 km/hr. Further increments of up to 22 to 23 km/hr can be expected if the line for Route 11 is upgraded (Alternatives 3 and 3B).

The round-trip time (terminal time excluded) is reduced by PROW from the present 80 min to 65 min. The fleet size for Route 11 may be reduced by three vehicles. Improved reliability, which reduces terminal time by 40 to 60 percent, is more significant than are reductions in operating speed.

Including the savings for other routes that share the line with Route 11, the total annual reduction in operating costs will be close to $0.8 million. If capital costs are included, operating costs will be reduced by $0.3 million per year.



Vehicle data	Streetcar	Trailer	LRV 6-axle	
Length	14.700	12.000	22.180	mm
Width	2.500	2.500	2.500	mm
Height	3.110	3.130	3.411	mm
Weight	16.900	11.580	32.800	kp
Truck type	Höka	Höka	Duewag	
Axle distance	1.800	1.800	1.800	mm
Truck center dist.	7.600	4.900	7.700	mm
Seats	36	34	70	
Standees	80	50	70	
Total capacity	116	84	140	

FIGURE 23 Vehicles. (Note: Decimal points should be understood as commas.)

IMPACTS AND POTENTIALS

Short-Term Impacts

Along the line for Route 11, PROW will make changes in the travel pattern for automobiles. The changes range from making local streets into arterials, to increasing the number of one-way and dead-end streets, to reducing or removing established parking. Property owners and businesses are most concerned by these changes but will probably not find them dramatic. Even if a transition period between the existing situation and the completed PROW may be unwelcome, the "new" streets in PROW will have considerable benefits. Reductions in travel time and operating costs are among the immediate effects.

Long-Range Potential

PROW will, if completed as a project, bring the streetcar network in Oslo up to the same standard as those of most other European cities. Gothenburg, Sweden; Zurich, Switzerland; and Düsseldorf, Federal Republic of Germany, have characteristics similar to the LRT ROW standard proposed in PROW. These cities all have a mode split in favor of public transit with strong transit corridors leading to a flourishing downtown. Automobiles have access to the central districts but with various restrictions.

The long-range potential of PROW, with a possible later upgraded streetcar network in Oslo, will thus be determined by the negative effects of changes in automobile usage. In PROW these effects have been minimized, and it is reasonable to assume that the positive elements in the plan far outnumber the negative effects. The most attractive areas in Oslo are already served by high-standard rail lines. When the streetcar network is upgraded to light rail, it may give another boost to the revitalization that already has started in several old districts of the city.

Carefully designed use of central streets for transit and pedestrians and improved conditions for automobiles in other areas have, in a number of cities, proved to be a successful approach to a better functioning city. In PROW this has been attempted on a low-cost basis.

CONCLUSIONS

Three alternatives, two of them with a subalternative, have been developed and evaluated for improving the right-of-way standard for the streetcar lines in Oslo. Alternative 3B gives the best improvement and is recommended in the long run, but it has considerable investment costs and requires extensive changes in the automobile traffic pattern. For "Pilot Project Right-of-Way," a solution with lower construction costs and fewer impacts on automobile traffic was desirable. PROW minimizes these problems, which is necessary to gain political approval at the start of the project. An optimal alternative has therefore been developed to give satisfactory improvements in operating speed with limited construction costs and moderate changes in the automobile traffic pattern. The alternative may easily be upgraded to Alternative 3 or 3B in the future. The planning procedure that was used in PROW can also be used when constructing new lines. PROW is a concept with few ambitions in the beginning of the project, which represents considerable savings. At the same time it is easily adaptable to changes in the streets. The recommendation of PROW is based on moderate investments with enough flexibility for future improvements and expansions.

REFERENCE

1. V.R. Vuchic. Urban Public Transportation. Prentice-Hall, Inc., New York, 1981.