*Paper No. 03-2651*

# Implementing Zurich's Transit Priority Program

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**Transit priority is an excellent way of improving transit system productivity and attractiveness although it is often neglected in favor of larger investments. Transit priority techniques and implementation are outlined, Zurich's transit priority program is described, eight transit priority implementation lessons from Zurich are presented, and Zurich's innovative traffic-signal transit priority system is summarized. A longer report that fully describes research results is the basis. Transit priority improvements are relatively low-cost ways to make transit systems work better by speeding up transit vehicles. Specific improvements include four categories: roadway improvements and traffic regulations, traffic signal priority, transit system operations, and separate right-of-way. These improvements may be implemented individually or in a comprehensive program. Comprehensive implementation is optimal but politically and institutionally difficult. Zurich has been successful in implementing a comprehensive transit priority program with impressive results. Implementation lessons from Zurich were identified through interviews and a survey of public officials. Key findings were the importance of support from public and elected officials (and the common underestimation by elected officials of their constituents' transit support), smart implementation techniques (not alienating the public), government organization to deliver projects, careful traffic engineering, simultaneous implementation of complementary programs (such as traffic calming), careful systems-level thinking, and leveraging needed organizational change through capital improvement funding. Zurich's traffic-signal transit priority system is an interesting example of reducing opposition to transit priority through technical innovation. The system provides transit priority without significantly affecting private vehicle traffic by adjusting signal timing and phasing to provide the right amount of green time for transit when needed.**

This paper describes the transit priority program in Zurich, Switzerland. It summarizes a longer research report prepared for San Jose State University's Mineta Transportation Institute—Implementation of Zurich's Transit Priority Program (*1*).

The research objective was to describe transit priority techniques implemented in Zurich and the way Zurich was able to implement its program. Implementation is particularly interesting because although most transit priority improvements are relatively simple and inexpensive, in practice they have proved to be very difficult to implement and sustain.

The research effort consisted of a case study with interviews and a survey. Numerous individuals associated with the development and implementation of Zurich's transit priority program were interviewed and a survey of transportation decision makers in Santa Clara County (California) was completed to evaluate support for transit improvements in a typical U.S. county. The Santa Clara survey was compared with results of a similar survey done in Zurich (*2*) to help understand how elected officials think about transit improvements.

This paper consists of the following sections: outline of transit priority, description of Zurich's transit priority program, information on building public support, description of implementation lessons from Zurich, description of Zurich's innovative traffic signal control program, and brief concluding remarks.

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## TRANSIT PRIORITY

Transit priority improvements are techniques designed to speed up public transit vehicles and improve the transit system's efficiency. They include a wide variety of physical improvements, operating changes, and regulatory changes. Often, the cost of improvements is relatively low. (For more information on transit priority techniques see *Transit Preferential Streets Program: Sourcebook*, City of Portland, Office of Transportation, 1997.)

### Why Is Transit Priority Important?

Transit priority is important because it is an extremely cost-effective way to improve transit service. Transit priority improves customer service by providing faster and more reliable service, and it improves transit's bottom line by enabling it to provide more service with the same resources and by attracting more passengers (since the service is better). By reducing conflicts with private traffic, transit priority improvements also can reduce accidents and driver stress.

Transit priority is especially relevant because the vast majority of transit service today shares right-of-way with other traffic. Whether buses or light rail systems are used, operating transit in mixed traffic leads to delays and unreliable service. Unfortunately, transit priority improvements that could address these problems are often neglected in favor of larger and "sexier" projects such as new rail transit systems.

While new rail systems clearly provide a very attractive and environmentally friendly transit service, they are feasible only in major corridors in which high ridership justifies the large capital investment. Furthermore, it is difficult to find funding for these expensive projects. In contrast, transit priority improvements are less expensive and can be more easily justified by cost–benefit analysis. Therefore transit priority improvements represent a significant opportunity for improving transit service in many American cities (*3*).

### Types of Transit Priority Improvements

A broad definition of transit priority techniques was adopted for use in this research to allow consideration of improvements that can significantly benefit from simultaneous implementation of multiple transit priority techniques. The best example is transit malls, which

are most effective when implemented with transit system operations improvements such as coordinated scheduling and proof of payment. This research categorizes transit priority improvements into the following four types:

- Roadway improvements and traffic regulations. Minor changes to roadways, relocation or reduction in the number of transit stops, and traffic regulations designed to reduce transit vehicle delays.
- Traffic signal priority. Traffic signals that reduce delays to transit vehicles by providing them with green lights when they approach.
- Transit system operations. Changes to operation of the public transit system designed to reduce delays, including low floor buses, proof of payment, and system control centers.
- Separate right-of-way. Sections of roadway designated for the exclusive use of transit vehicles, allowing transit to bypass congestion.

### Transit Priority Program Implementation Levels

A transit priority program's effectiveness depends on the extent to which the program is implemented. This research categorizes implementation of transit priority programs into the following four levels:

- Limited implementation. Individual transit priority improvements are made in various locations.
- Route-level implementation. Transit priority improvements are made as part of a coordinated program along an entire transit route.
- Areawide implementation. Transit priority improvements are made in a particular area and used by several different transit routes (e.g., transit malls).
- Comprehensive implementation. Transit priority improvements are made on all transit routes, and changes are made to the way the whole system operates (e.g., proof-of-payment fare collection).

Comprehensive implementation is the best way to implement a transit priority program. This is the approach Zurich has used during the past 30 years. A comprehensive program systematically evaluates each aspect of transit operation over the entire network and seeks ways to speed up the service. The improvements identified can be implemented over time.

### Difficulty in Implementing Transit Priority Improvements

In the early 1970s many cities began implementing transit priority programs. While Zurich has continued to expand its transit priority program, many other cities have reduced their interest in transit priority and neglected their existing programs (e.g., lack of enforcement). The difficulty in implementing transit priority improvements and the disinterest are ironic because most transit priority techniques are relatively simple and inexpensive. The key reasons it is difficult to implement transit priority techniques include the following:

- Low technical competence and lack of expertise in transit priority techniques and implementation,
- Lack of support or direct opposition by different agencies or departments,
- Difficulties of coordination between agencies and departments,
- Pressures by automobile users,
- Poor public understanding of the benefits of transit priority, and
- Opposition to changes by businesses and residents.

The difficulty of overcoming these obstacles has led to skepticism and a defeatist attitude in transit agencies and planning departments about implementing transit priority improvements (*3*). Given this situation, the purpose of this research was to learn how Zurich was able to implement its comprehensive transit priority program, in the hope of providing ideas for other cities interested in inexpensive and quick ways to improve existing transit networks.

## TRANSIT PRIORITY IN ZURICH

Zurich's public transit system is easy to use and an attractive way to move about the city because service is fast, frequent, reliable, and inexpensive. Furthermore, the well functioning transit system makes a significant contribution to the city's high quality of life. Critical to Zurich's success is a comprehensive transit priority program implemented during the past 30 years. According to Professor Robert Cervero, "the results of this program have been nothing short of exceptional. Zurich has one of the highest rates of transit usage today, about 560 transit trips per resident per year, almost twice as many as Europe's largest cities" (*4*).

The comprehensive nature of Zurich's transit priority program enables the city's transit system to function as a network. It is fast, easy, and comfortable to travel from Point A to Point B using public transit (in both the city and the region), at almost any time of day, on any day of the year. Although many trips require transfers, that is not a problem because as a result of the systematic implementation of transit priority throughout the transit network, all the lines work well.

### Citizens' Transit Priority Initiative

Zurich's transit priority program was implemented as a result of a 1977 citizens' initiative that provided funding and political support for transit priority improvements. The initiative followed the defeat of two proposals for constructing major underground transit lines in the city (in 1962 and 1973). Citizens proposed the transit priority initiative as an alternative to the 1973 U-Bahn proposal.

While Zurich planners understood the benefits of transit priority and were in fact implementing transit priority programs, passage of the citizens' initiative measure provided the funding and political support for more-comprehensive implementation.

Systematic implementation of the transit priority program in Zurich was faster and less expensive than constructing a new underground rail line, and furthermore allowed the city to improve its entire transit system rather than a single route. Improving a surface transit system by providing transit priority can have many advantages over constructing a new underground system. A surface line can have more stops (providing more accessibility) and does not require people to go underground to access the system. Finally, a surface system is simple to operate and can be designed to fit well into the urban environment.

### Regional Coordination and Improvements

While the city of Zurich was improving its surface transit system with transit priority, the canton of Zurich led the effort to significantly improve the region's commuter rail network (S-Bahn). As part of the

S-Bahn project the canton organized the Züricher Verkehrsverbund (ZVV), a regional agency responsible for coordinating fares and schedules among the region's 42 different transit operators.

Improvements to the regional S-Bahn and to the city's surface system of trams and buses were mutually reinforcing. The systems were designed to work closely together, making it easy for travelers to move throughout the canton and city with the same ticket in a reasonable amount of time.

One interesting aspect of Zurich's approach is that by making the city's surface transit system run faster (with transit priority) and building a regional S-Bahn with more stops in the city (compared with S-Bahn systems in other cities), the region was able to forgo the need to build an intermediate-level system (such as a center city subway or Metro system). In Zurich the shorter intermediate-length trips can be made on the tram network and the longer intermediate-length trips can be made on the S-Bahn network.

### Transit Priority Program Results

The transit priority program has increased transit ridership and improved transit's mode split in Zurich. The city's per capita transit ridership increased by 22.8% between 1970 and 1980, the major implementation period; ridership increased by approximately 7% between 1990 and 1997 despite a recession that significantly affected the city's economy at the tail end of this period (between 1980 and 1990 the data reporting changed from linked to unlinked trips so comparisons between these years are not readily available) (*5*).

Mode split for work trips for locations in the city increased from 49% in 1970 to 61% in 1990 (*6*). Trips crossing the city border on the regional S-Bahn system increased by 37% between 1989 and 1997, reflecting implementation of the new regional coordination and S-Bahn system.

While these data are impressive, there is a need for more quantitative analysis of transit system performance data (e.g., cost data) to assess the full impact of Zurich's transit priority program. This is clearly an area for additional research; an especially important area for more data collection is the effectiveness of the traffic signal control system.

## BUILDING PUBLIC SUPPORT FOR TRANSIT PRIORITY PROGRAM IMPLEMENTATION

Transit priority is well understood to be an effective way of improving transit service, yet it has not been implemented to the degree it could be and has often been neglected in favor of high-cost transit improvements; in many cases transit priority techniques that have been implemented have been rolled back. The objective of this research is to identify how Zurich was able to overcome the resistance to transit priority and implement a comprehensive transit priority program.

In Zurich a unique set of circumstances coalesced and members of the public pushed transit priority on the transit agency (as the key approach for improving transit) through passage of an initiative ballot measure. An important question is, What happens when that initial public support is not apparent?

The situation can be viewed in two ways. First, it could be said that without strong initial public support, transit priority cannot be implemented. Second, it could be said that public support must be developed and ways of building the necessary support could be considered.

The first point to make concerning these two possibilities is that even in Zurich, public support did not simply materialize for transit priority. Zurich's public transit agency had completed a well-known study on the impact of transit priority improvements on one streetcar line (*7*), and the city was implementing transit priority improvements even while pushing the 1973 U-Bahn proposal. Thus the education process had started, and small-scale examples (as well as more comprehensive transit priority programs in nearby cities such as Bern and Basel) were in place for the public to observe. That brings us to the famous election. While much is made of the rejection of a major transit project in favor of transit priority, what happened is that citizens voted *against* the major transit project in 1973 and then *for* the proposed transit priority program in 1977.

In the 1973 campaign, citizens opposed the U-Bahn proposal for a number of transportation, urban design, and development reasons, and proposed introduction of a comprehensive transit priority program as an alternative. That alternative initiative (written following defeat of the U-Bahn proposal) was drafted based on the transit agency's studies and existing implementation program; it simply called for more comprehensive implementation by providing guaranteed funding and political support. In a sense, Zurich's transit agency helped to build public support for the transit priority initiative, although it did so without knowing that transit priority would be used against the officially approved U-Bahn plan.

To the question of what can be done when initial public support for the program is lacking, this research supports the conclusion that individuals and agencies can build public support through education as well as careful and sensitive implementation of transit priority improvements. In the implementation lessons from Zurich presented below most of the lessons address how Zurich was able to build and maintain public support. Once public support and understanding reach certain levels it may be possible to implement bolder transit priority techniques.

An important aspect of building public support is leadership from elected officials. However, survey results from Zurich and Santa Clara County found that elected officials often underestimate public support for public transit (*1*). The Zurich survey, done in 1993, compared people's opinions on the degree to which transit should have priority with elected officials' perceptions of what the people thought (*2*). This survey showed that elected officials significantly underestimated the degree to which their constituents supported transit priority. A similar survey done in Santa Clara for this research confirmed that a majority of elected officials believe that their constituents prefer roadway solutions although the elected officials themselves support transit solutions. Given the need for strong support from elected officials to implement transit improvement projects, the fact that elected officials appear to underestimate public support for transit improvements is troubling for the transit industry.

## IMPLEMENTATION LESSONS FROM ZURICH

One of the main objectives of this research was to learn how Zurich was able to implement its comprehensive transit priority program given the difficulty other cities have had implementing similar programs. This section describes some important implementation lessons from Zurich. Lessons from Zurich are transferable because Zurich shares many of the same problems facing other cities:

- Jobs and housing are decentralizing from the center, automobile ownership and traffic congestion are increasing, and employment

is shifting out of traditional industries to service and professional sectors.

- Zurich's elected leaders face the same pressures as politicians in other cities including reducing taxes and improving livability.
- Zurich relies on voter approved local funding (taxes) for major capital projects such as transit system improvements.

One potential difference between Zurich and other cities is that Zurich started with a well-used and highly respected transit system that simply needed to be upgraded. Cities with less developed transit systems might not achieve the same results as quickly, but Zurich's approach, incrementally improving its existing system by implementing transit priority improvements, remains an excellent model.

Finally, it should be emphasized that many of the lessons presented below are not surprising but are common sense. In these cases it is not so much the lesson that is of interest, but rather the specific techniques and strategies Zurich used.

## Lesson 1: Build and Maintain Strong Public Support

Public support is the most critical element of implementing any government program and is particularly important for transit priority since effective programs can create winners (public transit) and losers (other roadway users). A particularly problematic aspect of transit priority programs is that they are most effective when implemented comprehensively, but it takes some time before public support can be generated, and the specific improvements generate immediate criticism from other roadway users.

One way the transit agency helped build public support for the transit priority program was to aggressively publicize the benefits of transit priority. Other ways are outlined in many of the following lessons. It cannot be overemphasized that public support for transit priority does not simply materialize; its development requires education, understanding, and advocacy.

In Zurich, the public, arguably educated by the transit agency, took an active role in forcing the city administration to implement transit priority improvements more comprehensively and more boldly than would have been possible otherwise. Passage of the transit priority initiative provided funding and political support for program implementation. Activists continued to pressure government officials for more comprehensive implementation over the years using traditional tactics such as lobbying, initiative campaigns, and political endorsements.

Transit priority improvements can be implemented by degrees, and strong implementation is better for transit but has more effects on private vehicles. Without continuing support for transit priority from activists, it would have been difficult to overcome the objectives of private vehicle drivers. Zurich's experience clearly shows that strong public support is required to implement and maintain a transit priority program.

## Lesson 2: Enlist Support of Elected Officials

Support of elected officials is required to implement a comprehensive transit priority program. Elected officials force government departments (often overwhelmed with day-to-day responsibilities) to undertake such long-term and challenging citywide programs.

In Zurich almost all elected officials supported the 1973 U-Bahn proposal and most opposed the 1977 transit priority initiative. They hesitated implementing controversial parts of the transit priority program. Slowly, after years of active pressure from citizen groups and as they saw the benefits of the comprehensive transit priority program, elected officials began to support the program. It is still difficult to implement improvements to the optimum degree, but elected officials in Zurich are generally onboard with the program.

Obtaining elected official support is difficult. Surveys in Zurich and in Santa Clara County indicate that elected officials often underestimate the depth of support for transit among the voters and are too timid in their support for transit priority.

## Lesson 3: Use Smart Implementation Techniques

To build and maintain support for transit priority programs, transit agencies must implement programs intelligently. The following are some of the smart implementation techniques used in Zurich:

- Implementing high-impact projects quickly and publicizing their benefits. One lesson from Zurich is that it is beneficial to have good projects on the shelf and ready for implementation.
- Not alienating people unnecessarily. Some transit priority improvements affect private transportation. The lesson from Zurich is that this should be done only where absolutely necessary and that the effects should be minimized. For example, Zurich's traffic signal priority program takes the minimum time necessary for transit priority, which enables it to provide transit priority without hurting traffic circulation.
- Implementing transit priority techniques together with improvements that increase neighborhood livability. In Zurich, transit priority improvements were implemented as part of a more comprehensive program designed to improve city livability. Examples include building bus stops that are pleasant pedestrian spaces and introducing turn restrictions that reduce transit delays and eliminate neighborhood through traffic (see Figure 1).

## Lesson 4: Organize Government to Effectively Deliver Program

Transit priority improvements by their nature affect many different city departments, and frequently bureaucratic concerns prevent them


FIGURE 1 Traffic calming and transit priority—creating a cul-de-sac on a small neighborhood street reduces through traffic and provides transit priority.

from being implemented effectively. Zurich addressed these issues by creating the following task forces:

- Executive council. Group of elected officials and city department heads that direct city departments to develop transit priority improvements and provide the political support for implementing them.
- Working party. Group of department heads and planners from several departments who collaborate on the development of specific transit priority improvements. An important point is that the working party is a group with changing representation; therefore, many members of city departments have participated on it at one time or another. This has given many people an understanding of transit priority techniques that they use in their other projects.

Although departments work together on developing projects, the traffic police have the sole responsibility for making changes to the roadway system, including signs, traffic signals, painted markings, and road construction. This allows changes to be made quickly and efficiently once a plan has been adopted.


FIGURE 2 Transit priority provided by traffic signal—traffic signal stops private traffic, enabling tram to go first as it moves from separate right-of-way to shared right-of-way.

## Lesson 5: Careful Traffic Engineering and Technology Are Critical

One argument against complex programs such as transit priority is technology. People often say that a particular thing cannot be done. That was the case in Zurich. Government officials said that certain programs could work in smaller, less complex situations but not in a large city with significant traffic such as Zurich. Once Zurich voters approved the transit priority initiative, the city was forced to implement the program. Technical solutions were developed. It was not easy, but it was done. Two main points about Zurich's technology development follow:

- Technology application—careful traffic engineering. The lesson from Zurich is that sophisticated traffic engineering helps reduce opposition to transit priority techniques. Providing transit priority often means taking street space that has been used for mixed traffic and dedicating it to transit. That requires creating new routes for private vehicles. In Zurich sophisticated traffic engineering techniques such as channelization and traffic signal placement enable private vehicles to circulate while still providing transit with priority (see Figure 2). A good example is in Zurich's main squares, many of which are served by seven or eight transit routes and private vehicles; these squares are carefully designed to provide transit priority, but also to allow for efficient traffic movement.
- Technology development—traffic signal system. Existing traffic signal technologies could not achieve the desired degree of transit priority without significantly affecting traffic flows. Therefore, Zurich's traffic police, the department responsible for the traffic signal system, took a fresh look at the problem from a systems approach and developed an entirely new approach (see the following section for more information on the traffic signal system).

## Lesson 6: Implement Complementary Programs to Improve Transit System

Transit priority alone will not create an excellent transit system. The transit system must provide good service as measured by frequency, travel time, and customer attractiveness (e.g., safety). In addition to these basic attributes, there are several complementary programs that cities can implement to further support the transit system. Zurich implemented the following complementary programs:

- Planned land uses that support transit. Zurich worked aggressively to encourage land uses that support transit, through both conventional land use planning techniques such as increasing density with zoning and development agreements, and efforts to make areas best served by transit attractive places to live, work, and visit. Initial efforts focused on improving center city urbanity by reducing parking and traffic and then using the freed space to speed up transit, create pedestrian zones, provide space for public events, and create a lively and entertaining downtown. These improvements helped business, and now the program is being applied to redeveloping areas and new development in the city.
- Traffic volume reduction. Zurich has a long history of implementing measures to restrain and reduce private-vehicle traffic. The city has used three main approaches: traffic calming, roadway capacity reduction, and parking controls. As with other programs, Zurich has taken a comprehensive and thoughtful approach to controlling vehicle traffic.
- Regional transit coordination and S-Bahn system. The canton of Zurich organized the ZVV to coordinate fares and schedules of the region's 42 different transit operators. Today, careful scheduling links the systems, and it is possible to use a single ticket for all journeys. The canton also rebuilt the regional rail system (S-Bahn) to improve mobility and serve as the basis for schedule coordination between different transit operators. Good regional transit has increased ridership on Zurich's city transit system, and good transit in the city has increased ridership on the S-Bahn—a win-win situation for transit.

These complementary programs have helped build ridership and public approval for Zurich's transit system, translating into public support for the transit priority program.

## Lesson 7: Use Capital Investments to Leverage Institutional Change

One of the most interesting lessons identified in this research is how the Zurich region used the need for a large capital investment to bring about institutional change. As part of the project to rebuild the

regional S-Bahn system, the canton of Zurich required that transit fares and schedules for all 42 different transit operators be coordinated. The canton agreed to fund the major S-Bahn investment only if a new agency was created to bring about regional coordination. The canton's funding provided the leverage necessary to bring the different public and private transit operators to the table to develop a coordinated regional transit system.

### Lesson 8: Think Carefully at the Systems Level

Many cities have three-level transit systems, a surface system (buses and streetcars) for short trips, an exclusive right-of-way system (e.g., subway) for medium-distance trips, and a regional rail system (e.g., S-Bahn) for longer trips. Zurich's transit priority program, combined with construction of a denser network than usual of S-Bahn stations in the city, enabled the city to eliminate the need for an expensive subway system, because the shorter medium-distance trips can be made on the surface system (since transit priority makes it faster and more reliable than other surface systems), while the longer medium-distance trips can be made by S-Bahn.

A two-level system similar to Zurich's might be an excellent choice for many cities, especially given development patterns in many modern cities (namely, relative medium density centers and large surrounding areas), since this system has significant cost savings and transit service benefits (it reduces transfers) over a three-level system. Carefully considering systems-level choices before choosing a planning approach for improving a transit system is a good lesson to learn from Zurich.

## ZURICH'S TRAFFIC SIGNAL TRANSIT PRIORITY PROGRAM

This section outlines one of the most interesting aspects of Zurich's transit priority program, the traffic signal control system.

### Traffic Signal Progression

Traffic signal progression enables vehicles to go (progress) through a series of traffic signals without stopping. In the most basic type of signal progression, traffic signals are set to turn green as a platoon of vehicles moves at constant speed through a series of intersections without stopping. This is called a "static" system because it is based on repeating patterns of signal cycles at a series of connected traffic signals.

When a transit vehicle is allowed to interrupt the regular pattern of traffic signal cycles in a static system, a queue will build up at the affected intersection and traffic signals downstream will have wasted green time. The affected intersection's queue of vehicles also means that there will be more vehicles to be processed in the next cycle; this queue, when added to the next platoon of vehicles, may be too great for the cycle to accommodate, and then the system becomes overloaded. Much of the traffic engineering literature on transit priority addresses that issue (*8*).

### Zurich's Approach

In the early 1970s, Zurich experimented with a static traffic signal control system but found that it did not provide effective transit priority and also created traffic problems. Zurich's traffic police (the system operators and planners) initially believed that transit operators were not cooperating or were "too dumb" to operate the system, so they learned to drive buses and trams as part of their efforts to research the problem. Then they learned the real problem—it is hard to drive a transit vehicle and there is little time to do anything else. System planners then decided to address these problems by reconsidering the entire philosophy behind the operation of traffic signal systems.

The starting point for this new approach was an idea from industrial production: to maximize assembly line efficiency, there should be intermediate storage for semiprocessed materials. One reason for taking that approach was that system planners were trained in operations research rather than traffic engineering. In an assembly line, if there is a production interruption at one machine, machines downstream can still be used efficiently. In a traffic signal system, that approach means creating places where queues of vehicles are allowed to develop so that green time at downstream intersections is fully utilized. In the standard static (green wave) traffic signal progression, traffic signals are set to turn green as a platoon of vehicles moves from signal to signal. In contrast, Zurich's system provides a green wave for a group of traffic signals and then the platoon is stopped.

Although this sounds inefficient, for networks with many traffic flow discontinuities it actually enables more efficient use of the overall system by ensuring that green time at intersections downstream from the discontinuity is not wasted.

In Zurich's system roadway sensors communicate traffic volume information to central computers, where these data are combined with information from the rest of the street network to determine the most efficient traffic signal operation (timing and phasing) in real time. This type of system is called "dynamic," because rather than repeating, it changes based on traffic conditions (*9*).

Another way of thinking about Zurich's approach is that giving transit vehicles priority adds only 5 to 8 s (the time it takes the transit vehicle to get through the intersection) of green time to a phase if the green time can be added at the right point in the cycle. The dynamic nature of traffic signal timing in Zurich enables the green time to be added to signal cycles at maximum efficiency, thus reducing impact on other users of the roadway system. This is done by adjusting the cycle phasing pattern and the timing.

### Traffic Signal Control System Description

Zurich's traffic signal control system works by providing the central computers with information about the position of individual transit vehicles; the computers then incorporate expected transit vehicle arrival data into their calculations for optimal traffic signal timing and phasing.

The system consists of transit vehicle and traffic volume detectors on the streets, transmitters on transit vehicles, and 16 computers in the central control center. Transit vehicle transmitters send a signal to the street detectors, generally located about 300 m before the intersection, 100 m before the intersection, and just after the intersection stop line. The computers use the first detector's signal to develop an initial estimate of transit vehicle intersection arrival time; the second detector's signal is used to revise the estimate; and the third signal tells the computer that the vehicle has passed through the intersection. The computers use this information to adjust traffic signal phases and timing to optimize passage of the transit vehicle through the intersection.

At the intersection level, traffic signal timing is determined in a central computer based on the intersection geometry, predetermined safety parameters (such as minimum pedestrian times), real-time traffic volume data provided by detectors, and transit vehicle location information provided by the detectors. Similar information from the other intersections in the area (the group of signals is called a microcell) is used to determine a coordinated pattern for the group. The street segments at the boundaries between microcells are used as storage areas to make the dynamic system work efficiently.

The system employs six full-time computer programmers to adjust and refine operations. Most of the equipment is custom-designed for Zurich. According to the system operators, despite its uniqueness, the system is not more expensive than other traffic signal systems (*1*).

### Effectiveness of Traffic Signal Transit Priority System

Zurich's traffic signal control system is designed to provide transit priority with minimum effect on traffic flow. According to the Zurich traffic police, intersection traffic volumes with transit priority are similar to those before introduction of the system (*1*). In other words, the traffic signal control system has helped transit without significantly affecting traffic flows.

In addition to providing transit priority, Zurich's traffic signal control system is used to maintain below-capacity traffic volumes on center city streets by metering traffic entering various parts of the city on the basis of congestion levels. Reducing center city gridlock helps keep transit and other vehicles moving and improves Zurich's livability (*10*).

The system has been designed to avoid wasting green time. That is important for two reasons: first, to keep traffic flowing smoothly; and, second, more interesting, to maintain good public relations. If a traffic signal turns green and 30 s later a transit vehicle goes by, people complain; in contrast, if a transit vehicle goes by immediately after the signal changes and then the signal changes again people are less likely to complain. The system's manager believes that Zurich's system is so efficient that many people do not even realize that transit vehicles have priority at traffic signals.

An important area for further research is collecting and analyzing data on the operation of Zurich's traffic signal system. The information collected in the interviews carried out for this research focused on how the system worked rather than on the collection of quantitative data on its effectiveness. More quantitative data would help provide a better assessment of the system and transit priority program.

## CONCLUSIONS

Zurich is one of the most livable cities in the world, and one reason is the high quality of its transit system. The transit system is efficient and extremely attractive to passengers. It is possible to travel easily and quickly throughout the city and region using transit.

Zurich created its excellent transit system by implementing a comprehensive transit priority program designed to speed up transit and increase its efficiency throughout the city. This low-cost approach was chosen over proposals for expensive new underground rail networks. The transit priority program has created a more appropriate transit system for Zurich, and its cost is significantly lower than the cost of a new rail system. Other cities can learn a great deal from this approach and the transit priority techniques used in Zurich when considering how to improve their own transit systems.

Zurich transportation consultant Willi Hüsler put it best when he said, "Zurich is proof that a conventional tram and bus system, omnipresent in the most attractive streets and squares of the city and supported by a high-tech operation and control system, is an extraordinarily effective combination. A combination that is more cost effective than an underground system in a city like Zurich."

## ACKNOWLEDGMENTS

This research project was completed for the Mineta Transportation Institute at San Jose State University. It was financially sponsored by the U.S. Department of Transportation's Research and Special Programs Administration and by the California Department of Transportation. The author gratefully acknowledges the Swiss Federal Institute of Technology (Zurich) Institute for Transportation Planning and Heinrich Braendli for their support while the field research was completed.

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*Publication of this paper sponsored by Committee on Public Transportation Planning and Development.*