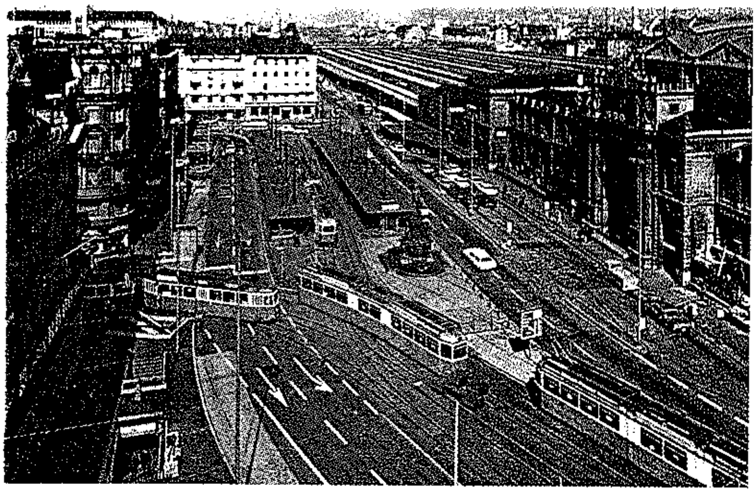


A control system giving priority to trams

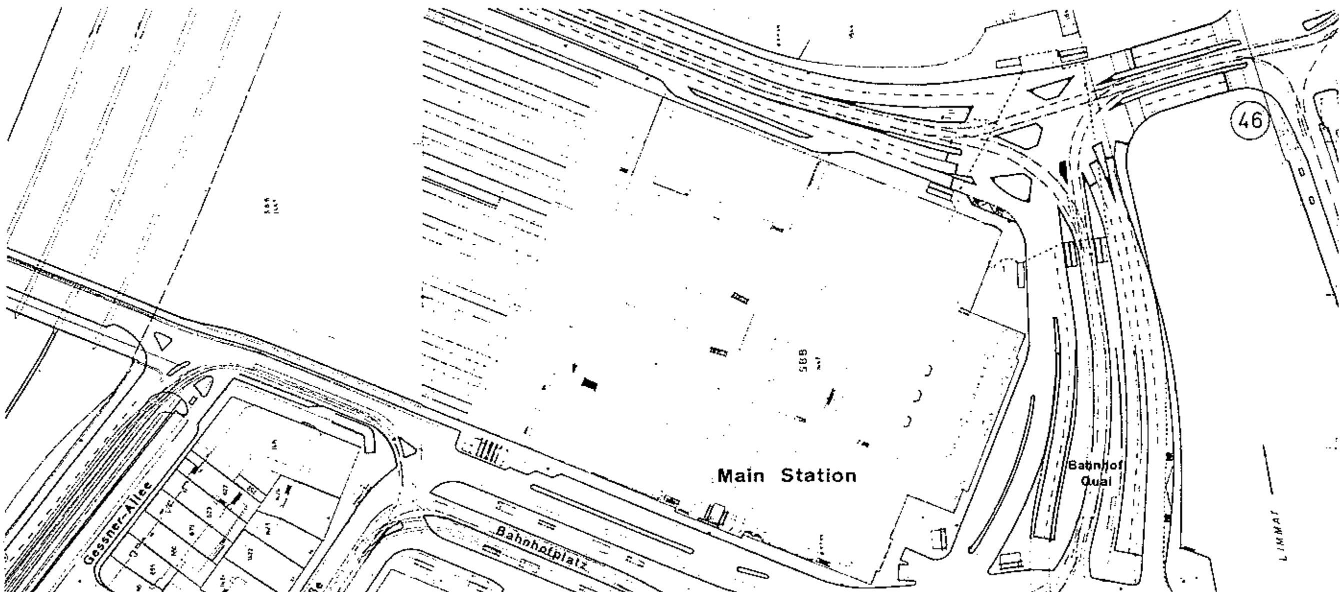
by F. H. MERTENS
GEC-Elliott Traffic Automation, Cologne

Reconstruction. Zürich, the 'secret capital' of Switzerland, today has more than 0.5m. inhabitants. The main railway station is a terminus with restaurants, Post Office, tourist office and Swissair terminal, and the surrounding streets are therefore a focal point for pedestrians, private cars and public transport. The former street layout south of the station with its simple rail system became inadequate and was changed in 1970 in order to make better use of the available space (Fig 1). A computer-controlled signal system was introduced to optimise traffic flow for a mixture of trams, buses and private transport. An important design objective was to reduce the conflicts between pedestrian and vehicular traffic as much as possible, therefore an attractive underground shopping centre ('shop-ville') was created beneath the critical area, and connected to the surface by means of escalators. The ceiling of this 'shop-ville', i.e. the whole tram-stop area with rails and car lanes, is floated on a bed of rubber, so that the noise induced by running trams is reduced.

The Bahnhofstraße, one of Zürich's most important shopping streets, was made into a pedestrian-only area and the pavements were extended up to the tram rails by the use of large stone flags. The whole area between Löwenstraße and Bahnhofbrücke was changed to an elongated roundabout through which the tram rails were laid. More than a dozen tram routes cross the area and these routes are often in conflict with each other. Unnecessary delays which might be caused, for example, by a left-turning tram in conflict with another tram, holding up a tram going straight ahead which is not in conflict, are avoided by the provision of additional rails. There are at least two lanes for cars everywhere, except for the U-turns in the west, affecting mainly taxis.

Strategically-located detector loops and antennae (used for tram identification) which are required for the

Fig 1. The new street layout south of Zürich's main railway station (see also heading photo above).



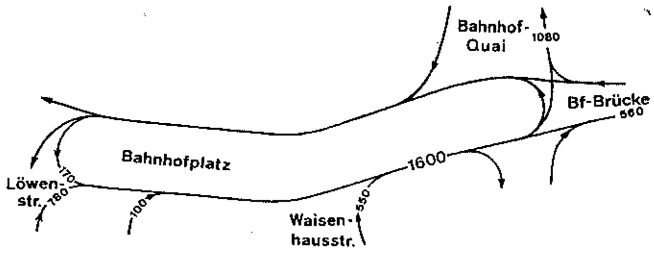


Fig 2. Traffic volumes in veh/h, taken in April and May, 1972, about 16.00 *hours, before congestion arises.*

computer-controlled system were installed during the road construction. By April, 1971, reconstruction had been completed and cars were allowed to enter the area. At this time the electronic traffic signal controllers also started operating but, initially, on a local standby program.

The first impression was that almost no cars wanted to go through the square from choice. Apparently, during the years of reconstruction, drivers had become accustomed to making a detour and were slow to abandon their image of a place broken up by rubble and provisional tram tracks. Gradually, however, the situation has changed and traffic counts (Fig 2) show a steady increase.

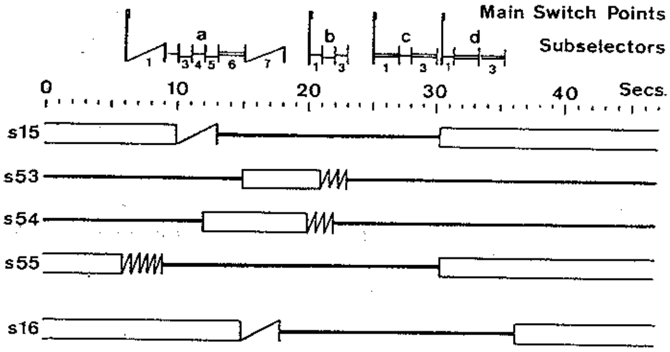
Standby program from local controllers

It was decided to place a tram stop for one tram in Bahnhofstraße right at the edge of Bahnhofplatz, in order to keep the walking distance for interchange passengers short. But this meant that only one tram could enter Bahnhofstraße per cycle, and the relatively high tram frequency here demanded a low-cycle time.

The second restriction on the cycle time was caused by the itinerary between Bahnhofstraße and Bahnhofquai which required co-ordination in both directions; this means an optimal cycle time of about 47 seconds. The standby program therefore operates at a fixed cycle of 47 seconds and the three controllers are synchronised with each other.

The operating mode is switch-point control, with the main switch points starting subselectors, which can run independently and operate the output contactors either through amplifiers or via bistables. The subselectors which may have up to eight timed stages, can be stopped or deactivated by special control signals. This facility and a general logic board gives considerable flexibility in setting up a structure. A signal program is simply patch wired by means of prepared leads which plug into the rear of the card rack.

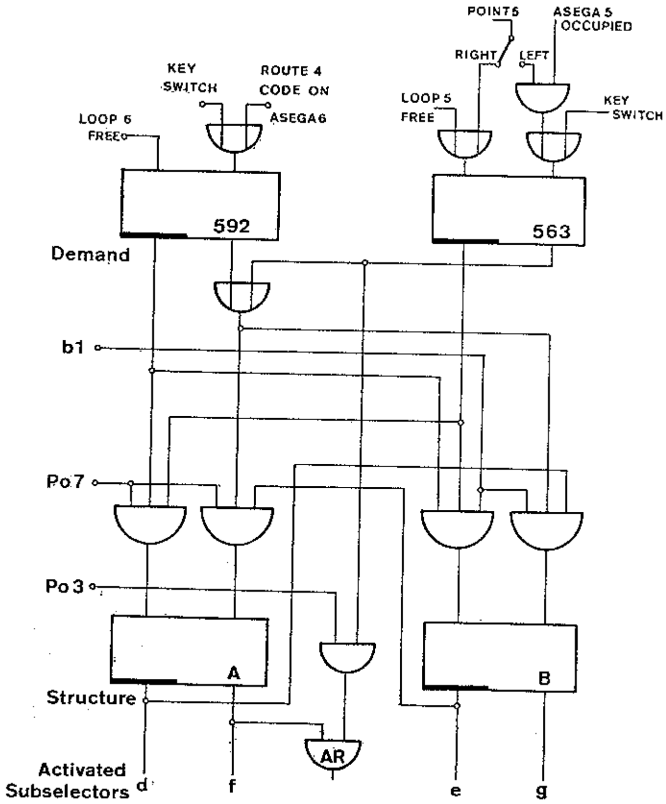
Fig 3. Controller 2, *Bahnhofstraße and Waisenhausstraße.*



The switch points are derived from a motor-driven pulse generator which contacts in turn each of 50 equidistant pins. Patch wires 'extract' the main switching pulses and lead them to a group of diodes functioning as an OR-gate. Figure 3, showing controller 2 (Bahnhofstraße and Waisenhausstraße), is a simple example. The bus phase S69 is brought up only if there is a demand on the detector loop D9 at second 27. In this case the bus will go just prior to the 'green wave' to the bridge.

The cars from Löwenstraße are co-ordinated up to Bahnhofbrücke, and partly to Bahnhofquai too, the phases for trams into Gessnerallee and those for route number 4 between Bahnhofquai and Bahnhofbrücke being included only on demand. The initial idea of including all 'special phases'—i.e. those not necessarily requested every cycle—in the emergency program in a fixed mode was dropped in favour of a faster cycle, otherwise the junction at the bridge would have required a minimum of 66 seconds. Figure 4 shows controller 3 structure switching (northern part of the Bahnhofquai junction). Depending on the instant of arrival of a No. 4 tram, a special structure is introduced for a complete cycle. b1 or Po7 respectively represent the instant where the corresponding position of subselector b or the main selector respectively is being active.

Fig 4. *Controller* 4, *structure switching, northern part of the Bahnhofquai junction.*



The computer concept

A traffic evaluation revealed that flashing ambers gave better results with respect to journey times, especially for trams and buses. A fixed plan was inadequate for both the timetable and for delayed trams. A traffic signal scheme was, however, essential to safety, at least during day time.

As the tram service in Switzerland is highly valued, a specific requirement of the City Police was to favour public transport rather than private traffic. In addition, the mutual interference at peak hours of public and private vehicles should be minimised. By too long occupancy of queue detectors, the approach signals should be switched to RED in order to prevent queueing across tram tracks. On the other hand, approaching trams should only be given GO if

The standard paper tape station comprises tape reader and punch and an on-line control typewriter. The processor is fitted with 16K × 18 bits core store, with a store cycle time of 1.2 μs, of which, however, only 9K words are used.

The output from the electronic interface is fed to the controllers via relays which provide electrical separation, the digital display unit being driven directly from the electronic interface.

The system is fitted with a watchdog unit which sets off an audio-visual alarm when not reset at regular intervals. Suitable software is provided to reset the watchdog; however, before this is done a thorough monitoring of the software functions is made by the program. If a fault condition is found, the system watchdog will not be reset: the alarm will be actuated, and all controllers will be switched to their fixed-cycle standby program. If the program is functioning correctly, the alarm unit will be retained in its NORMAL state. All signal groups are directly controlled by the computer, including amber times, and the rest of the controllers' electronic circuits are inoperative.

The facility has been provided for the computer to switch any individual local controller to its standby program in response to an operator demand. In this case, the computer synchronises its signal program with the controller running under its standby plan.

Each group of junctions can be switched over from colour sequences to flashing ambers by means of hand-switches in the street or a time clock common to all controllers. The facility is provided for special (emergency) cases and night operation, but flashing amber can also be commanded (selected) via the teleprinter by typing the order and the number of the controller affected.

The controllers are able to work in different modes independently. All transitions are regular, i.e. bumpless. A change from flashing amber to red must go via steady amber.

The use of special tram detectors is based on the fact that all trams are equipped with HF-transmitters, radiating coded signals in the form of a single-sideband modulated 138kHz carrier. Initially these signals were given when the driver pressed a button in order to change the position of the next point. This facility with the 'point-code' is still in use, but today a '3 out of 6' code, without the pushbutton being pressed, is transmitted continuously for route identification plus two further side-bands indicating the length of the tram.

For the indication of presence, loop detectors are used both for vehicles and trams. Usually a tram is counted into or out of a block on departure from the loop detector at the corresponding signal. If the respective loop detector is reported to be faulty, then the computer will rely on ASEGA receivers and the relevant signal being at green. On the other hand, counting is possible with loop detectors and the contacts giving the position of the points, but without, of course, knowledge of the tram's length. However, it was noticed that because of the proximity of permanent iron in the form of rails and heavy reinforcement, long trams frequently gave more than one presence signal, as the loop inductance is first increased with the approach of a tram bogey.

Results with computer control

Since significant work had been put into the standby program (at the bridge alone six detector-actuated structures were available) it was suspected that little improvement would be possible. In the event the computer principle proved definitely superior. Observers stated that the performance under computer control was noticeably different, and it was obvious that, except in peak hours, scarcely any trams were left in the blocks, because they were accepted by precision micro-control, whereas they would have been kept waiting by the standby program. This led to some confusion with pedestrians and U-turners crossing the rails, because the trams now appeared at irregular intervals.

Initially the tram drivers who had entered 'block 8' very late dashed towards their outgoing signal at high speed, as they knew from experience of the standby program, when their green time would have been over. They had not yet recognised that a special counter—starting with their tram leaving Bahnhofstraße—would lead them across the Bahnhofplatz and guarantee them a green even when driving according to regulations.

Some tram drivers adjusted to the new facilities very quickly, and it was noticeable that the trams from the bridge on route No. 4 (Fig 6) hardly had to brake now, when they were given their special phase immediately. The opposing trams of route No. 4 had quicker access to their turning phase too. The two policemen who had been 'cutting' the slowly-moving queues every afternoon discovered that cars would stop anyway just as they were about to raise their arms: the computer having given RED because of congestion. Some special features of the program, however, were not so obvious. After only one day's operation of the standby program, it seemed to take several weeks to re-establish confidence in the control system.

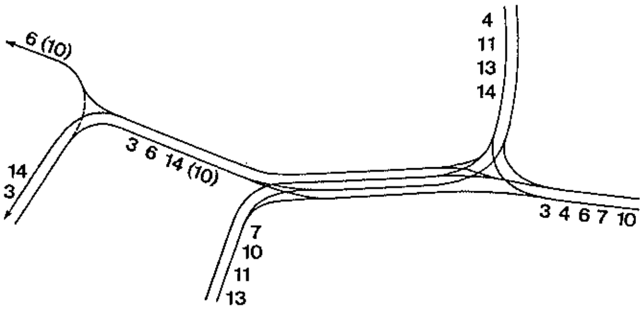


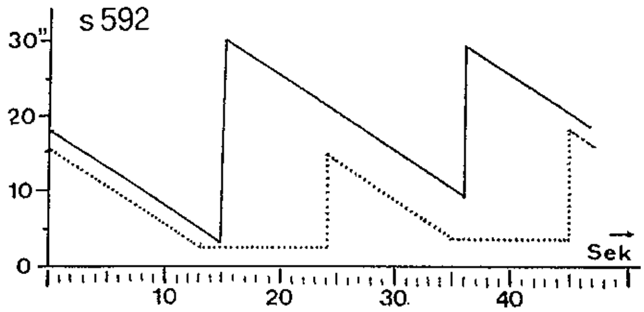
Fig 6. Tram route numbers at the Bahnhofplatz.

Under computer control not only the straight-ahead movements and the S-shaped tram movement between Bahnhofstraße and Bahnhofquai are co-ordinated, but also route Nos. 7 and 10 between Bahnhofstraße and the bridge (Figs 1 and 6). Route No. 14 from Bahnhofplatz receives a green extension of up to 16 seconds, provided it moves out in time. For many of the corresponding control equations information from the block supervision is used, e.g. route number, number of trams in the block and current count of block-occupancy time. Obviously priorities had been defined for the various movements to be co-ordinated.

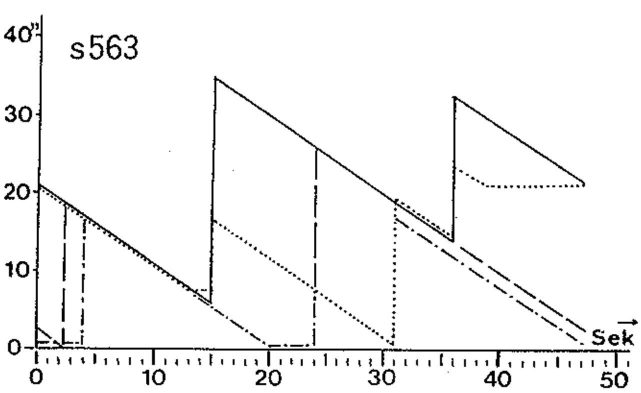
The goal had been clearly defined, i.e. to reduce the transit time of trams, even if this meant penalising car drivers. Although a quantitative evaluation of the degree of success cannot be easily achieved, it can be stated that during off-peak hours the flexible program reduces waiting times considerably as a result of detector actuation, whilst at peak hours the queue control and block supervision is clearly effective, as mutual obstruction is noticeably reduced.

Each tram of route Nos. 7 or 10 saves approximately nine seconds in crossing Bahnhofplatz and trams of route No. 14 save up to 25 seconds compared with the standby program. The improvements in accessing special phases can only be estimated in the absence of long-term records, as the 'cycle time' is variable under computer control. But even when comparing both types of control assuming a cycle of 47.5 seconds, the average waiting time for special phase s592 (route No. 4 from the bridge) is reduced by more than 50 per cent. (6.46 seconds against 15.89 seconds), Fig 7a. For the other direction of route No. 4 (s563) the result is 12.63 seconds against 21.47 seconds, Fig 7b. In both cases an average delay time of 0.5 second, resulting from the computation interval when under computer control, is taken into account.

(*a*) *The continuous line shows the standby program, the dotted line computer control.*



(*b*) *The dashed line is if the phase had been conditioned by an opposing tram, the dot-dashed line the same with computer control.*



(*c*)

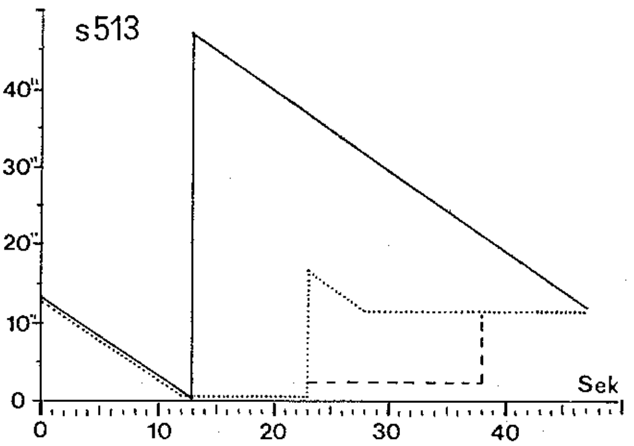


Fig 7. Waiting times for special phases, dependent on Sek of demand within the cycle.

Sometimes, however, trams from the opposing direction condition a special phase, with the result that access times are shorter. For the special phase into Gessnerallee (west of Bahnhofplatz), the computer control has similar convincing advantages, as the diagrams show (Fig 7c).

The unusual idea of having the cycle time influenced principally by trams proved very successful. Certain tram phases which are provided around the start of a (new) cycle are brought forward by reducing the running cycle. If such a phase is needed later than anticipated, because a tram is late, extending the cycle will perform this automatically, whereas in a fixed cycle the phase would be completed and the tram would have to wait almost a full cycle. Naturally in many cases there is a demand (to cut the cycle) even before the minimum cycle time has elapsed, but in general practise shows that this unusual method is most suitable for tram traffic (Fig 8).

It did not appear economic to check all interactions of the control equations for incompatibilities since there were too many random variables. Although the controller would avoid very coarse (and obvious) mistakes such as conflicting greens, how were clearance violations to be checked? Only the computer itself could do this, i.e. make a self-supervision. The software was extended so that individual green, amber and red time counters are used for each signal group, as well as an array containing all defined clearance times. Before a signal is switched to green, the computer will check for all conflicting signals the clearance times expired, comparing them with the design values in the array. The green is suppressed until all the defined clearance times have been obeyed, but violations of minimum green or intergreen times—which could be specified by the control equations—are logged on the teleprinter.

With this feature, the system alarm being then in the alarm position, we had the chance to test the control program without sending erroneous information to the street, for at the same time the local controllers could run on their standby program. With the print-outs received, any incompatibilities could be identified and corrected far quicker than would have been possible with a Monte Carlo approach.

On the other hand, one could afford considerably to simplify certain control equations, relying on the correction action of the respective 'filter' program. For example, 'If special phase n is brought up, also switch signal p to green' —signal p will then turn to green only after all clearance times have been correctly inserted.

Experience of the first months showed that giving preference to public transport can be exaggerated. Route No. 4 by the bridge may cut the other movements so frequently that the capacity of the whole junction suffers. Therefore current practice is to group two trams of route No. 4 whenever possible, even if the first to arrive must be delayed for a few seconds.

The scheme described here is traffic dependent, but the program does not use a 100 per cent program generation technique: the sequence of the most important stages is predefined by the BASIC plan. Thus it may happen that a tram must wait because a conflicting signal is at green even though, in fact, no tram is using the other green. The parallel case is of less importance for cars, because they run in platoons and 'green waves'.

Nevertheless, the Zürich City Police have started to develop the available software in order to implement full signal plan generation. The core store and the speed of the GEC 905 computer is adequate to do this, but certainly a number of additional detectors will have to be installed before this can be achieved.

Fig 8. Frequency of the various cycle times—the broken line shows average values for two seconds each.