TRAMWAY RESERVED TRACKS

– A COMPARATIVE STUDY –

by R.G. Vanselow.

F

INDEX OF CONTENTS

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(2) INTRODUCTION:

(1) SUMMARY:

This project seeks to quantify the travel time and operational savings resulting from the provision of exclusive rights-of-way for passenger tram cars in greater Melbourne, by carrying out extensive delay studies on tram services operating along the adjacent parallel arteries of High Street and Dandenong Road, Windsor.

Trams along High Street use the more common "centre-of-the-road" running, whereas Dandenong Road has a reserve for the exclusive use of trams, together with two four-lane carriageways for motor traffic.

Thus trams in High Street suffer severe interaction with motor traffic during peak periods, whilst both trams and motor traffic flow relatively smoothly in Dandenong Road.

It was found that in peak periods trams along High Street could take up to twice the travel time of those along Dandenong Road, over equivalent distances, and with the same numbers of tram stopping places.

In High Street a far greater proportion of the overall trip time was spent in traffic delays, especially approaching intersections. Only a small portion ~~portion~~ of the overall trip time along Dandenong Road was due to traffic delays, although delays were not uncommon in peak periods.

In High Street, under wet weather conditions, a very significant increase in the trip time (due mainly to traffic congestion) was observed, whilst services in Dandenong Road were only slightly affected - due mainly to the late running of trams as they fed into the reserved trackage from the congested street systems.

Under off-peak conditions the two routes exhibited very similar trip times, although Dandenong Road generally

W 16

(2) INTRODUCTION:

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showed a small time saving over High Street - it being safer (and therefore more common) to operate at higher running speeds along the reserved trackage.

Although it would probably not pay the M&MTB to purchase land and convert their existing "centre-of-the-road" tracks to reserved trackage, it would undoubtedly prove to be a saving to the community as a whole (over a 20 year period) - especially to those using the trams and to the motorists sharing road space with the trams. Furthermore, should the M&MTB again have the opportunity (as it did with Queen's Way) of constructing reserved trackage whilst land was being purchased for a roadway (thus reducing the cost of extra land significantly), not only the community, but also the M&MTB, would benefit considerably.

Furthermore, it has been found that trams using reserved tracks have an accident rate of atleast 30 % less than those sharing the roadway with motor traffic.

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(2) INTRODUCTION:

Of the 201 route miles of the M&MTB's tracks, only 10 route miles are laid in reserves for the exclusive use of trams.

The longest section of reserved track is in Dandenong Road, between St. Kilda Junction and Glenferrie Road; a distance of 2½ miles. (Approximately ½ mile of this has only recently been converted from "centre-of-the-road" running - extending from St. Kilda Road to the east side of Chapel Street.)

Less than ½ mile to the North of Dandenong Road, and running parallel to it, is High Street, Prahran. Here the trams use "centre-of-the-road" running over the entire 2½ miles between Punt Road and Glenferrie Road.

Since both routes are serving very similar areas and are crossed or served by both the Sandringham and Caulfield railway lines, the Clifton Hill - point Ormond bus, and the Chapel Street trams, these two lines offer an excellent means of measuring and estimating the operational advantages in the use of tracks laid in separate tramway reserves, as against the more common "centre-of-the-road" running.

Background:

With the explosion in the volume of road traffic in recent years congestion has led to increased delays to those tram services sharing the roadway with motor traffic, and the disimilar operating characteristics of trams and motor cars has led to significant delays to motorists as well. This has been of growing concern, not only to the M&MTB, but to other authorities and the public alike, as is evident in the following statements taken from the publication "MMTB News"(January 1965):

"Services suffered increased delays, especially in peak hours, when late running in some instances grew to five or

ten minutes more than the previous year..... Trams on ot
routes, especially those which cross Chapel Street, have
suffered delays caused by right hand turning motor vehic

"In the public interest, it is indefensible that trams should be held up short of their stops by motorcars, man of them carrying only the driver, ... so that the tram with its 50 or 60 passengers misses the traffic light cy in order that the motorcar may catch it."

"Street parking continues to be the principal factor i causing delays, directly and indirectly. It takes up traffic lanes which could be well used by moving vehicle particularly in peak periods, forcing or encouraging the to drive on tram tracks, delaying trams.

"It is logical that much more stringent restrictions c or banning of, parking on busy streets must be imposed i the early future."

R. J. Caldwell, B.Ec, AASA:

"The essence of the public transport system is speed.. the less time spent travelling to and from work the more time is available for leisure.

"In Melbourne, trams would be the dominant means of transport within the area up to 6 miles from the city, a should run in reserved ways wherever possible."

In March 1968, work commenced on the Wellington St By - Pass (now known as Queen's Way) as part of the St. Kilda Junction redevelopment project. The work, completed early 1969, resulted in the replacement of over ½ mile of "centre-of-the-r double track in Wellington Street by reserved trackage along th centre of Queen's Way. Consequently, delays to both trams and road traffic have been reduced, and running costs reduced all round, but this has been at the expense of a greater capital outlay on construction of the Way.

(3) LITERATURE SURVEY:

(i) C.A.T.S. Research News (Sept-Oct 1968):

This publication studies the driving times between O'Haire Airport and Downtown Chicago, as a function of the (departure) time of the day. It gives the normal elapsed times, and the deviation from the normal (due to weather, congestion, and (possibly) accidents). It was found that the travel time varied seasonally (in late autumn and early winter - poor weather, short days, high traffic volumes - the travel times are slightly higher than during other seasons). In the summer months, when many people are out of town on vacation, and traffic volumes are low, travel times are consistently shorter than the average throughout the year.

Many of the methods employed in the above travel time study were adopted for this Research Project, but due to the limited time available, seasonal effects have been ignored.

(ii) Transit Record (No.11 - 1968):

This publication gives the financial break-down of the operating expenses of the Chicago Rapid Transit, for the three months ended September 30, 1968:

	Cost	% Total Cost
1) Operating Costs	$ 40.12m.	46.6 %
2) Maintenance of Way&Struct's	$ 14.96m.	17.4 %
3) Maintenance of Equipment	$ 13.50m.	15.7 %
4) Power Costs	$ 9.36m.	10.9 %
5) Injuries & Damages	$ 1.31m.	1.5 %
6) General & "Other" Costs	$ 6.91m.	7.9 %
7) Operating Rentals	$ 0.02m.	0.0 %
TOTAL COST:	$ 86.18m.	100.0 %

(iii) Victorian Year Book (Y/E: 30th. June 1968):

This contains a summary of the Yearly Report of the M&MTB. The following data applies to the tramway system only:

	Cost	Cost per Veh-mile	% Total Cost
1) Traffic Operating Costs	$7.39m.	44.85¢	44.5 %
2) Maintenance of Way	$0.90m.	5.48¢	5.4 %
Electrical Equipment	$0.53m.	3.19¢	3.2 %
Buildings & Grounds	$0.20m.	1.22¢	1.2 %
3) Maintenance of Trams	$2.48m.	15.05¢	14.9 %
4) Power Costs	$0.88m.	5.36¢	5.3 %
5) Claims	$0.19m.	1.15¢	1.1 %
6) "Other" Costs	$2.36m.	14.29¢	14.2 %
Administration & Stores	$0.93m.	5.66¢	5.6 %
Charges	$0.74m.	4.50¢	4.5 %
	$ 16.60m.	100.75¢	100.0 %

Miles run = 16.48m.

Traffic Receipts/Veh-Mile = 93.92¢

Total " " " = 94.83¢

Traffic Receipts/Passenger =12.13¢

Operating Expenses/Veh-Mile=100.75¢

Passengers/Veh-Mile = 7.74

Passengers Carried = 127.575m.

No. of kWH/Tram-Mile = 3.13

Price of Current/kWH = 1.71¢

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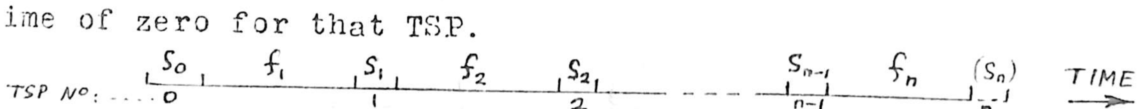
(4) DESCRIPTION OF THEORETICAL ANALYSIS:

Basically, any tram trip can be separated into two portions:

(i) Free running time (f_i) is the time taken to travel to the i^{th} Tram Stopping Place (TSP) from the previous TSP. That is, the time in which the tram is travelling between two TSP's and is not engaged in the loading or unloading of passengers. The tram may in fact be stationary for some part of this time if delayed by the traffic between TSP's. Also, if a tram is stopped at a TSP, the free running time is increased due to the decel\eration up to, and subsequent acceleration away from, that TSP. Hence the minimum free running time between two adjacent TSP's will occur when the tram runs express past both of them, and will be increased if either or both TSP's involves a stop.

(ii) Stationary time (or Stop Time) (s_i) is the time from when the tram arrives at that TSP to when it departs for the next TSP, and may be further broken down into time spent loading/unloading passengers, waiting for traffic lights to change phase, waiting for road traffic to clear, or to a number of other causes (such as waiting for the driver to punch the 'Bundy' time recorder clock, changing points, crew changes, clearing roadway accidents, unwanted stops at TSP's, waiting for other trams to shunt, connecting with trams on other routes, etc..) Obviously an express run past a TSP results in a stationary time of zero for that TSP.



Consequently, the Total Trip Time (T) for a journey from TSP(0) to TSP(n) is (on a stop-stop basis) given by:

$$T = \sum_{i=1}^{n} f_i + \sum_{i=0}^{n-1} s_i = s_0 + \sum_{i=1}^{n-1} (f_i + s_i) + f_n$$

OR $\quad T = F + S \quad$ where F = total free running time

S = total Stop Time.

The total free running time can now be broken down further into three components:

(i) Base time (B):- which depends only on the distance covered and the gradients and curves of the track in that direction. Variations in the power of the tram, and the effects of its loading, will be ignored in this analysis.

It is the sum of the minimum free running times between all pairs of adjacent TSP's, for that direction, and represents the Total Trip Time for a hypo-thetical journey made in the absense of all traffic, traffic lights, passengers and other sources of delay; commencing at the origin TSP and running express to the destination TSP at the normal free 'cruising' speed (being that speed adopted by drivers when free of outside influences).

(ii) Decelleration-Acceleration Time (DA):- due to having to stop at a TSP. For any journey, we assume that the total extra time spent in this deceleration-acceleration stage will be directly proportional to the number (n) of stops made by that tram.

(iii) Intermediate Traffic Delay (ITD):- due to intermediate interference of road traffic between TSP's.

Thus:- $$F = B + (n \times DA) + ITD$$

Now, since we can measure F for each trip, and both B and DA can be estimated from off-peak running times, we are able to calculate the Intermediate Traffic Delay:

$$ITD = F - B - (n \times DA)$$

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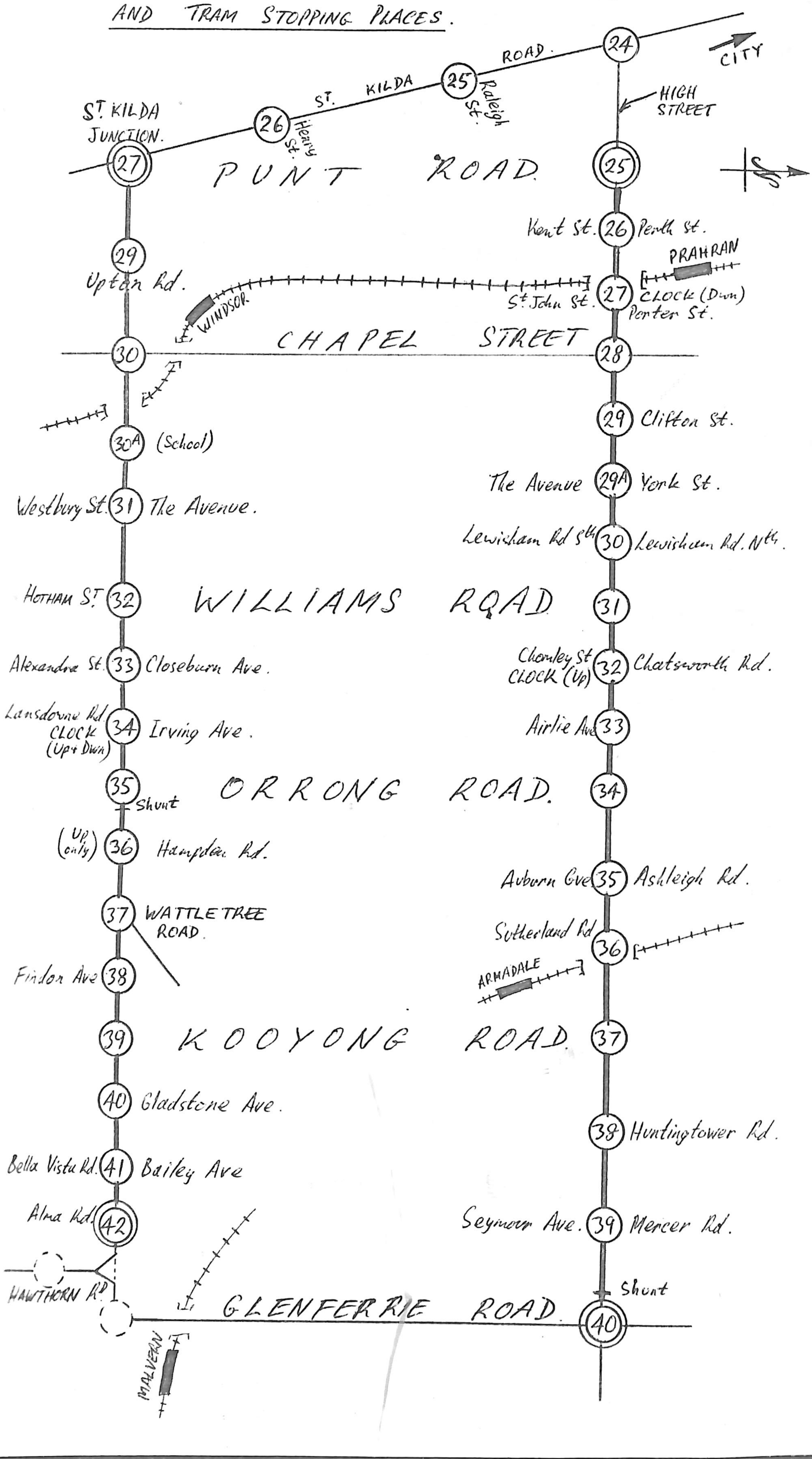
DIAGRAM SHOWING STUDY ROUTES AND TRAM STOPPING PLACES.



(5) DESCRIPTION OF EXPERIMENTAL ARRANGEMENTS:

The experimental side of this project involved an extensive comparative delay study of tram services using "centre-of-the-road" running with those using reserved trackage.

With the use of a Tramways Pass and stop-watch, sixty-four complete (one-way) trips were made over the two chosen routes: 19 trips in each direction along High Street
13 " " " " " Dandenong Road.
... over a period of two weeks (August 1969).

The trips were selected so as to be representative of each day of the week, and for weekdays trips were made during AM peak, mid-day, PM peak, and night time.

(i) Weekdays: For the AM and PM peaks, ten tram journeys were studied (being the same tram journeys each day) on four consecutive days. On three of these days the weather was fine, but on the fourth it rained heavily - this ratio being roughly typical of Melbourne's weather over a full year.

For Mid-day journeys, only one trip in each direction was made over both routes (i.e. a total of four trips), as it was felt that such journeys would be approximately constant in trip time from day to day.

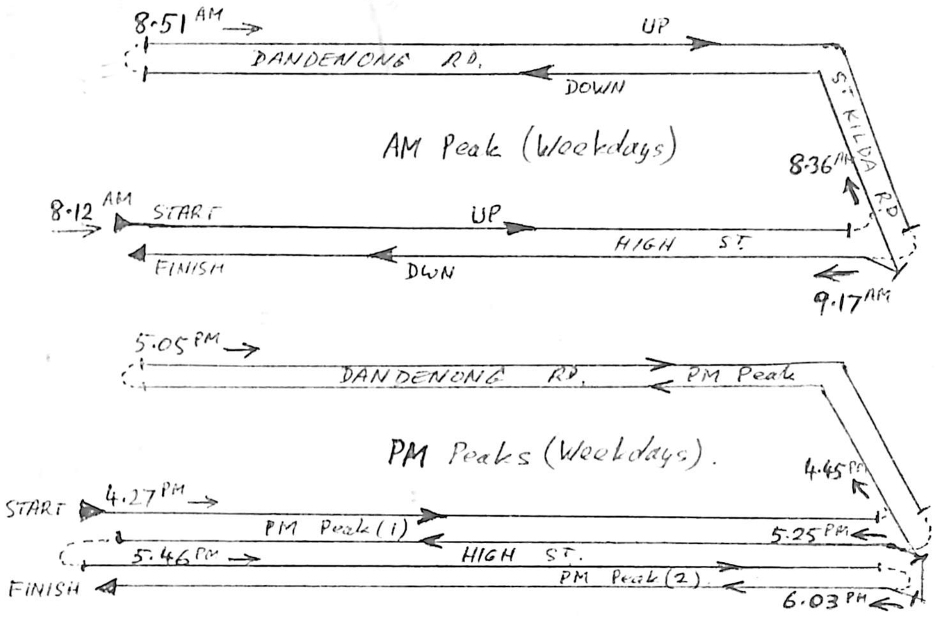
Similarly, only four trips were made at night.

(ii) Saturday: Only one Saturday was studied, but six complete trips were made along High Street, and two along Dandenong Road. (The larger number made along High Street being to assess the effect of the closing down of shops and other commercial activities around mid-day.)

(iii) Sunday: Two consecutive Sundays were studied, again with the minimum of four trips each day. The same journeys were made on both days - in the early afternoon.

Selection of time of day:

(i) Weekdays: It was important for AM and PM peak trips that the same tram journey was studied each day, in order that a reliable comparison could be made of that journey on different weekdays. Since four trips were to be made in each AM peak period, and six in each PM peak, a close study of tram headways was necessary (see App. 'C', pp. 36-41), and schedules drawn up as follows:



Mid-day trips were selected to lie within the steady 12-minute service period, and night time trips to lie within the 15-minute service period.

(ii) Saturday: Trips were made around mid-day, as this was thought to be the busiest time of day, with a mixture of business and recreational traffic. Off-peak trips were assumed to be as for Sunday services.

(iii) Sunday: Early afternoon was thought to be typical of Sunday travel, which is largely recreational (with only one or two passengers loading/unloading at nearly every TSP, but with very little delay due to motor traffic).

Recording of Times and Other Data:

Each of the sixty-four trips was fully recorded on a Running Sheet (see p. 12.) which contained all the necessary details of that trip, and formed the basis for all following computations.

At the departure stop (the Origin TSP) the actual time of day of departure is recorded, together with the weather conditions, tram's Run No., car no., and the number of passengers ("Pass.") aboard the tram upon arrival at the departure stop.

No 63

DANDENONG ROAD — HIGH STREET — UP / DWN — FRI 15 AUG '69 — TIME: SCHED / ACT. 8.36 — RUN: GH 29 / CAR: 584 — WEATHER: Fine

<!>	TS	STP	ELØ	ETR	ELI	ØTH	CØM	WHY	ØN	ØFF
1	2401	0 01	0 05	0 16			0 16		1	5
2	2501	0 45	0 48				0 48		–	1
3	2601	1 * 55					1 * 55	99	–	–
4	2701	2 20	2 23				2 23		1	–
5	2711	2 * 35					2 * 35	99	–	–
6	2901	3 * 25					3 * 25	99	–	–
7	3001	4 24	4 27				4 27		2	2
8	3051	5 * 07					5 * 07	99	–	–
9	3101	5 * 27					5 * 27	99	–	–
10	3201	6 10	6 12		6 57		6 57		1	–
11	3301	6 * 30					6 * 30	99	–	–
12	3401	8 05	8 06			8 27	8 27	98	1	–
13	3501	9 09	9 19		9 50		9 50		7	1
14	3601	9 * 31					9 * 31	99	–	–
15	3701	9 52	9 54			11 10	11 10	97	1	–
16	3801	10 * 53					10 * 53	99	–	–
17	3901	12 14			12 54		12 54		–	–
18	4001	13 * 25					13 * 25	99	–	–
19	4101	13 * 41					13 * 41	99	–	–
20	4201	14 06 //							(1)	(3)

Pass
(10
6

12.

At each tram stop the arrival (or Stopping) time (" STP ") is recorded. (NOTE: that the stopping time at the first TSP is always recorded as 00-01 rather than 00-00 as expected. This is to facilitate later computer analysis, and does not introduce a significant error.)

If any passengers are loaded/unloaded they are counted and recorded as ØN and ØFF, respectively, and the time at completion of loading/unloading (" ELØ ") is recorded.

If the tram is delayed at a stop by road traffic, the time at completion of the traffic delay (" ETR ") is recorded.

Similarly, any delay due to traffic control signals is recorded (End Lights ... " ELI ")

Many other less common causes may delay the progress of a tram, so these are recorded as " ØTH " (being the time at the end of that particular delay), and a code number entered in the column headed " WHY " as an explanation of that delay.

If no activity corresponding to ELØ, ETR, ELI, or ØTH (and WHY) takes place, then that column is left blank.

The departure (or Commencing) time from each TSP is recorded as " CØM ", and corresponds to the latest time in any of the preceeding columns for that TSP. When the tram runs express through a TSP, the Commencing time will correspond to the Stopping time, and the code number 99 entered in the WHY column to clarify this.

At the last stop (the Destination TSP), only the Stopping time is recorded, since the overall measurement of trip-time is on the stop-stop basis.

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(5) (cont'd) METHODS OF ANALYSIS:

Travel Time and Delay Analysis:

Stage I: In some cases, particularly early in the experimental stage, some times had been omitted - simply because of difficulty in observing the location of TSP's from a fast moving crowded tram. In order to prepare the information on the Running Sheets for further computer analysis, it was necessary to ensure that a time was entered for every TSP, regardless of whether the tram had actually stopped there or not.

Consequently, a rough table of inter-stop travel times (see App.'F', p. 44) was drawn up for each route (Up and Down), and by means of rough arithmetic interpolation between two known times at adjacent TSP's, the approximate time at that TSP was determined.

Stage II: When every Running Sheet had been so up-dated, 65 decks of computer data cards (22 cards per deck) were punched out for use in the following program. Each deck consisted of one identification card, one giving the number of passengers aboard upon arrival of the tram at the Origin TSP, thence one card per TSP ... giving all the data contained on the Running Sheet.

Stage III: Conversion of times recorded in minutes and seconds, to times in seconds only, and print-out in order to check the data cards for possible errors.

Stage IV: Calculation, for each TSP, of time spent loading/unloading (TLØ) passengers, waiting for road traffic to clear (TTR), waiting for traffic lights (TLI), waiting for "Other" causes of delay (TØT), the number of passengers carried to that TSP from the previous TSP (PAS), the Stop-to-Stop time (SST) (being the time from arrival at the previous TSP, to arrival at that TSP), the number of Passenger-Seconds (PSST) (being the product of PAS and SST, and representing the number of man-hours spent by

passengers on that tram journey), the Free Running time (RUNT) up to that TSP from the previous TSP (that is, the time from departure at the previous TSP, to arrival at that TSP), and the Stopped time at that TSP (being the total stationary time spent at that TSP).

Stage V: Summation of the above values for all TSP's between Punt Road and Glenferrie/Hawthorn Roads, for each trip. This gives, for each trip, the Total Loading Time, Total Traffic Time, Total Lights Time, Total Other Time, Total Passenger-Seconds, the Total Free Running Time, as well as the total numbers of passengers boarding (SUMØN) and alighting (SUMØF).

Stage VI: Collation of the results into groups of equivalent trips on consecutive or corresponding days of the week (i.e. into ' time-slots ').

Stage VII: Calculation of the mean and standard deviation for each set of results, for each 'Total' listed above in Stage V.

Stage VIII: Use of the theoretical analysis given in Section (4), to determine how much of the Total Free Running Time was due to traffic delays between TSP's.

Stage IX: Summation of traffic delays (at, and between, TSP's), traffic light delays, and other delays, to obtain the Total Delay for each trip, or time-slot.

Stage X: Calculation of the trip " Service Time ", being the time that trip would take if there were no delays (and includes the deceleration-acceleration times and loading times, for stops made on that trip):

i.e. " Service Time " = B + (n X DA) + LØAD

Stage XI; Check that the observed Total Trip Time agrees with the theotetical (= B + n.DA + LØAD + Total Delay)

Stage XII: Calculation of the number of man-hours expended by passengers on that trip (from the number of Pass-Seconds).

Stage XIII: Calculation of the percentage of Total Trip Time wasted in delays.

Stage XIV: Calculation of the number of passenger man-hours lost in delays on that trip:

= (Total Man-hrs.)X(% Total Travel Time lost in delay)

Stage XV: Comparison of passenger man-hours lost in delays, for both routes during these time-slots:

SAT.

SUN.

AM Peak (Weekday)

Mid-day "

PM Peak "

Night. "

Stage XVI: Estimation of appropriate " Multiplication Factors " (see App.'D', p.41) to allow for the number of trams providing the service during each of the above time-slots (by perusal of the current Public Time Tables... see App.'C', pp. 36-37).

Stage XVII: Calculation of the Total Time Savings in Delays (per week) due to the use of reserved trackage in preference to " centre-of-the-road " running (per route mile).

# indicates analysis by Computer (see App.'H', pp. 46-54).

Comparison of Costs:

This analysis is by no means complete, but sets out those cost items thought to be most significant, and gives some indication of the relative merits of the two systems.

(b) RESULTS OF DELAY STUDY: (MINUTES/TRAM-MILE)

TIME-SLOT	Direction	Route	"SERVICE TIME"	DELAYS DUE TO: Traffic	Traffic Lights	Other Causes	TOTAL DELAY	TOTAL TRIP TIME
SAT.	UP	DANDE. RD.	3.13	0.29	.45	.59	1.33	4.47
		HIGH ST.	3.42	0.64	.81	.73	2.18	5.60
	DWN	DANDE. RD	3.48	0.10	.16	.11	0.37	3.83
		HIGH ST	4.02	0.79	.39	.13	1.31	5.25
SUN.	UP	DANDE. RD.	3.06	.43	.41	.31	1.15	4.22
		HIGH ST	3.50	.43	.39	.63	1.45	4.95
	DWN	DANDE. RD.	3.50	.20	.19	.95	1.34	4.72
		HIGH ST.	3.28	.67	.27	.08	1.03	4.31
AM Peak	UP	DANDE. RD	3.60	.23	.43	.19	0.85	4.45
		HIGH ST.	4.28	1.43	.49	.10	2.02	6.29
	DWN	DANDE. RD	3.48	.32	.59	.33	1.23	4.67
		HIGH ST.	3.17	.57	.25	.05	0.86	3.17
MID-DAY	UP	DANDE. RD.	3.42	.54	.06	.23	0.83	4.26
		HIGH ST.	3.78	.47	.43	.29	1.19	4.97
	DWN	DANDE. RD.	3.40	.21	.14	.61	0.96	4.37
		HIGH ST.	3.52	.33	.71	.09	1.13	4.65
PM Peak(1)	UP	DANDE. RD.	3.10	.63	.54	.31	1.48	4.59
		HIGH ST.	3.28	.75	.59	.21	1.55	4.82
	DWN	DANDE. RD.	4.07	.37	.39	.17	0.93	5.02
		HIGH ST.	3.68	1.35	.77	.03	2.16	5.77
PM Peak(2)	UP	DANDE. RD	—	—	—	—	—	—
		HIGH ST	3.33	.41	.58	.35	1.33	4.60
	DWN	DANDE. RD.	—	—	—	—	—	—
		HIGH ST.	3.76	.61	.61	.05	1.27	5.02
NIGHT	UP	DANDE. RD.	2.94	.34	.73	.17	1.23	4.18
		HIGH ST.	2.89	.88	.13	.13	1.13	4.03
	DWN	DANDE. RD.	3.20	.00	.31	.79	1.10	4.31
		HIGH ST.	2.98	.37	.31	.09	0.76	3.74

"SERVICE TIME" — TIME SPENT SERVING PASSENGERS (NO DELAYS)