MELBOURNE AND METROPOLITAN TRAMWAYS BOARD

ENGINEERING DEPARTMENT

PLANNING BRANCH

TRAFFIC OPERATIONS INVESTIGATIONS

ROUTE STUDY METHODOLOGY

NOVEMBER 1975.

CONTENTS.

1. SUMMARY AND RECOMMENDATIONS.

The following report outlines the method to be adopted in carrying out a complete analysis of the performance of any route.

It is recommended that the Route Survey Methodology as outlined be adopted for the analysis of operating characteristics and that a programme be drawn up for systematically covering all of the routes.

It should be noted that the most critical aspect with regard to maintaining a continuous programme is the data collection phase. This will take up to four weeks for each route. With the manpower presently available, it is estimated it will take five years to cover all of the routes.

It is suggested that a preliminary study be made from present information available and that the findings be used as a guide for preparing a report on the optimal allocation of resources.

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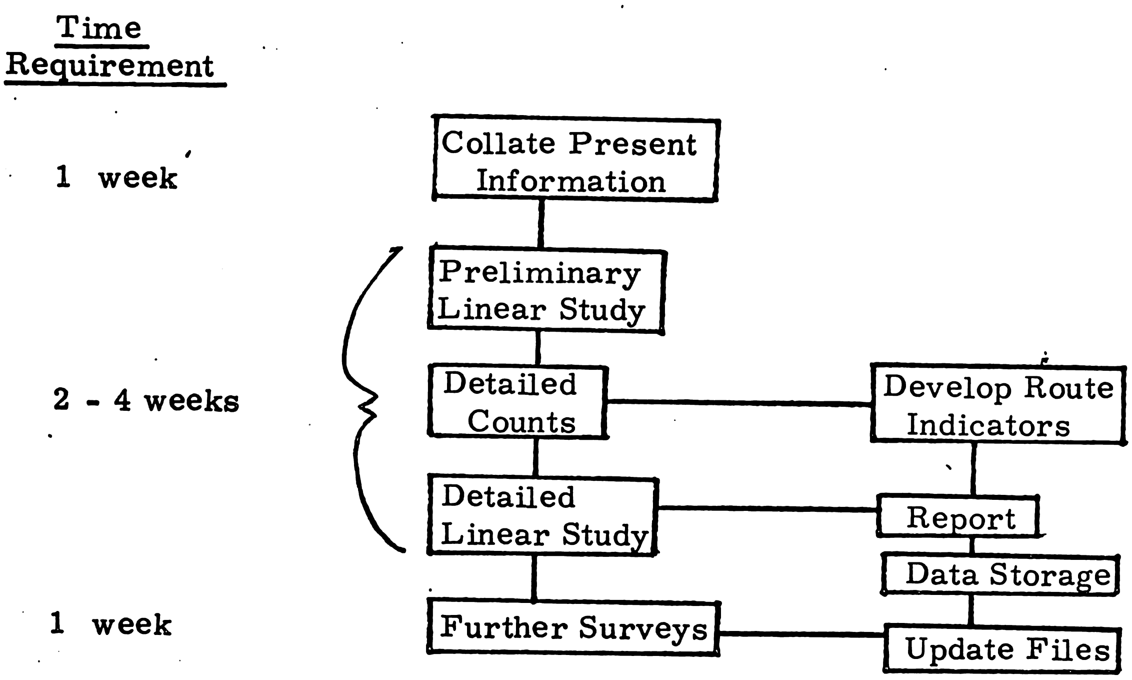
2. INTRODUCTION.

Route Survey Methodology.

The following chart indicates the suggested programme for the complete survey and analysis of any particular route.



Depending on manpower requirements each study could take up to six (6) weeks to complete, with the Data-Collection Phase (up to four (4) weeks) being the most critical.

It is suggested that a complete "scan" of all the routes (tram and bus) be made for A.M. and P.M. peaks. This could be achieved fairly easily by making use of the cordon count information collected over the last few years. It is expected this could tie-up two people for approximately two months and could provide the basis for preparing a report on optimal allocation of resources - (vehicles and crews).

The stratification considered necessary for the complete route analysis is as follows and sampling will be based on these strata.

A) By type of day

i) Monday - Thursday
ii) Friday
iii) Saturday
iv) Sunday

B) By direction of travel

i) UP (towards City)
ii) DOWN (away from City)

C) By time period

i)	Early A.M.	(→ 0729)
ii)	A.M. Peak	(0730 - 0929)
iii)	Off Peak	(0930 - 1559)
iv)	P.M. Peak	(1600 - 1759)
v)	Late P.M.	(1800 →)

NB

Observations made during school holidays, on or around public holidays, during inclement weather, on or around tram or train strikes or directly after fare increases would not be considered normal operating conditions.

3. DESCRIPTION OF METHODOLOGY.

Collate Present Information.

This will be achieved in terms of the collation of any previous work done on the route in question. The cordon count information, M.T.S. predictions for 1985 and any other available sources of information within the Board. The preparation and design of the surveys will in part be based on this information.

Preliminary Linear Study.

The linear study is an "on-vehicle" study with passengers boarding and alighting at each stop recorded. The times passing selected locations are also recorded. The aim of this study, which is done on a few peak trams only, is to estimate the points of maximum load and the points where serious delays occur. The information derived is used in the design of the succeeding surveys.

Detailed Counts.

These will be done at a number of locations along the route to ascertain the load on vehicle passing the points in question and also their times passing this point. It will be done for a continuous time period to include all vehicles in that period.

These counts provide the basic information for developing the route indicators concerned with Headway, Patronage, Speed and Late running (see examples below).

Detailed Linear Study.

Between 25% and 50% of all vehicles are sampled on a systematic basis with randomization of the selection within the first group of vehicles within the time period concerned. An "on-vehicle" study of passengers boarding and alighting is made as indicated previously.

These observations form the basis for estimating indicators for trip length and stop usage.

Further Surveys.

Following preliminary analysis it may be found necessary to do further investigations. The reliability of the primary data is of utmost importance.

Other investigations may also be prompted from these findings. These may include -

- Delay studies (tram, bus or car)
- Vehicle counts
- Pedestrian movements
- Origin-Destination Surveys
- Home interview surveys.

Report.

The report will summarise the present traffic operating characteristics in terms of the route indicators as given below.

Data Storage and Update Files.

Initially this will be done manually however, computer analysis and storage may become necessary.

4. DEVELOPMENT OF ROUTE INDICATORS.

Headway Considerations.

The headway of a Public Transport system is defined as the time intervals between successive arrivals at a particular point. It is commonly known that for any system there is a natural tendency for the vehicles to exhibit "pairing" or "partial-pairing" or "bunching" effects which increase the average waiting time for the intending passenger at any point.

This effect is most evident in Street Public Transport systems where variable traffic conditions prevail. It is the job of the rostering sections to reduce these effects as much as possible by adequate time-tabling to cater for variations in loading and traffic conditions. The measure of the effectiveness of this timetabling is given by the Headway Ratio (HR), which will be defined at a later stage.

Due to irregular delays caused by traffic lights, heavy loading etc., the "pairing" effect once induced will magnify as the trip continues - Due to increased loading for the first vehicle and decreased loading for the second at successive stops. At the point where complete pairing has occurred the two vehicles, which act as one, will only tend to split-up once the first vehicle is fully loaded (or nearly fully loaded) and passengers boarding tend to choose the second of the two vehicles. (In actual fact, the vehicles will travel as a pair until the end of the journey).

This gives rise to the concept of Effective Headway in so far as the passenger is concerned the headway differs considerably from the schedule headway as given in the timetable.

The Effective Headway is defined as twice the average waiting time.

Let h_i = headway between the $(i-1)^{th}$ vehicle and the i^{th} vehicle (mins).

Let a_i = arrival rate of intending passengers during h_i (passengers/min).
(at any particular point)

$\therefore$ The number of passengers waiting at arrival of i^{th} vehicle $= h_i a_i$

and on average each passenger has waited $h_i/2$ minutes.

$\therefore$ Passenger-minutes spent in waiting for i^{th} vehicle $= \frac{h_i^2 a_i}{2}$

and over a period of time T (mins).

Passenger-minutes spent in waiting $= \sum_0^T \frac{h_i^2 a_i}{2}$

Passengers arriving in period $= \sum_{0}^{T} (h_i \; a_i)$

Average waiting time per passenger $= \dfrac{\sum_{0}^{T} h_i^2 \; a_i}{2 \sum_{0}^{T} (h_i \; a_i)}$

OR

Effective Headway $= \dfrac{\sum_{0}^{T} (h_i^2 \; a_i)}{\sum_{0}^{T} (h_i \; a_i)} = \dfrac{\sum_{0}^{T} (h_i \; a_i) \; h_i}{\sum_{0}^{T} (h_i \; a_i)} = \dfrac{\sum_{0}^{T} h_i \; l_i}{\sum_{0}^{T} l_i}$

(where l_i = loading on the i^{th} vehicle)

If the arrival rate of intending passengers is assumed to be constant over the period (especially if T is relatively small).

$$\text{Effective Headway,} \quad H_e = \frac{\sum_{0}^{T} h_i^2}{\sum_{0}^{T} h_i}$$

The Scheduled Headway for a particular time period, T, is defined as the magnitude of that period divided by the actual number of vehicles arriving in that period.

$$\text{i.e.} \quad H_s = \frac{T}{n} \cdot = \frac{\sum_{0}^{T} h_i}{n}$$

The Headway Ratio is defined as the ratio of the effective headway to the Scheduled headway.

$$\text{i.e.} \quad HR = \frac{He}{H_s} = \frac{n \sum_{0}^{T} h_i^2}{\left(\sum_{0}^{T} h_i \right)^2}$$

If the vehicles arrive at the point at exactly even headways, the effective headway is equal to the average (scheduled) headway, the headway ratio =1, and the timetabling is fitting the demand for service absolutely perfectly.

However, if pairing occurs and $H_e > H_s$, then headway disruption has occurred and $HR > 1$. The magnitude of this disruption will vary from a very minimal nature $HR \leq 1.2$ (partial pairing) to quite substantial pairing $HR \rightarrow 2$. When $HR = 2$, complete pairing has taken place and the effective headway is twice the scheduled headway.
For $HR > 2$ severe headway disruption has occurred and bunching of more than two vehicles has taken place.
The headway ratio (HR) is thus giving a measure of this headway distortion.

EXAMPLE.

During a quarter hour period the observed arrival times of trams at a particular point were ...

4.44½, .45, .45¾, .49¾, .51, .56¾, .58, .58¾, .59½

i.e Actual headways $h_i = \frac{1}{2}, \frac{3}{4}, 4, 1\frac{1}{4}, 5\frac{3}{4}, 1\frac{1}{4}, \frac{3}{4}, \frac{3}{4}$

$$H_s = \frac{15}{8} = 1.9 \text{ minutes}$$

$$H_e = \frac{\sum_{i=1}^{8} h_i^2}{\sum_{i=1}^{8} h_i} \quad \text{(assuming constant arrival rates)}$$

$$= \frac{54.125}{15}$$

$$= 3.6 \text{ minutes}$$

and $HR = \frac{3.6}{1.9} = 1.89$ (quite severe headway distortion).

In assessing the headway requirements of a Public Transport service the one criteria which could be adopted is that each passenger should have a high probability of obtaining a seat. This probability is obviously at its lowest at the point of maximum loading for the route. For the criteria stated above to be satisfied, the number of passengers passing that point must be equal to or just less than the number of available seats at that point.

Let x_i = load distributions of the i vehicles at a point

$\bar{x}$ = average load passing the point

σ_x = standard deviation about this average

n = number of vehicles passing the point

Criteria

$x_i \leq$ Maximum seated load of the vehicle.

i.e. $x_i \leq 48$ (for Melbourne trams)

or Passengers per tram ≤ 48

i.e. Passengers per hour $\leq 48 \times n$

and Desired Headway (mins) $\leq \frac{48 \times 60}{n\bar{x}}$

Given that the loadings vary randomly about an average, to obtain a probability of at least 0.68 for a new passenger boarding to obtain a seat (at the point of maximum loading) the following formula should be adopted.

$$\underline{\text{Desired Headway}} = \frac{48 \times 60}{n\,\bar{x}} \left(1 - \frac{\sigma_x}{\bar{x}}\right)$$

However, as passenger loads depend on headway conditions we must correct this formula to allow for headway distortion, as the desired headway (indicator) should exhibit no headway distortion.

- This is achieved by dividing $\frac{\sigma_x}{\bar{x}}$ by HR (as previously defined).

i.e.

$$\underline{\text{Desired Headway}} \quad H_d = \frac{48 \times 60}{n\,\bar{x}} \left(1 - \frac{\sigma_x}{\bar{x} \times HR}\right)$$

NB

This formula gives passengers boarding the vehicles at any other point a probability of obtaining a seat greater than that stated above.

The formulation is <u>not</u> designed to give exact headway requirements. The desired headway indicator is independent of any policy decision or limiting physical criteria which may affect any particular service. It should only be used as a relative guide for comparison between different services.

EXAMPLES.

CARNEGIE TRAM SERVICE from A.M. Peak Cordon Count - October, 1975.

Arrival Time (At St. Kilda Jun)	Headway mins.	Load (xi)
8.04½	5	54
8.09½	5¾	52
8.15¼	4¾	98
8.20	7	59
8.27	5½	83
8.32½	4½	85
8.37	14	39
8.51	1	101
8.52		29
	$\Sigma h_i = 47.5$	$\Sigma x_i = 600$

$\Sigma x_i = 600$

$n = 9$

$\bar{x} = 66.7$

$\sigma_x = 25.9$

$H_e = \frac{377.1}{47.5} = 7.9$ mins

$H_s = \frac{47.5}{8} = 5.9$ mins

$HR = 1.34$

$H_d = \frac{48 \times 60}{600} (1 - 0.29)$

$H_d = 3.4$ mins.

CAMBERWELL TRAM SERVICE from A.M. Peak Cordon Count - October, 197

Arrival Time (At St. Kilda Road)	Headway mins.	Load (xi)
8.06½	3¾	74
8.10¼	9½	43
8.19¾	¼	67
8.25½	5½	45
8.26	½	26
8.42½	16½	78
8.45¼	2¾	59
8.46½	1¼	32
8.51½	5	30
	$\Sigma h_i = 45$	$\Sigma x_i = 500$

$\Sigma x_i = 500$

$n = 10$

$\bar{x} = 50$

$\sigma_x = 18.6$

$H_e = \frac{441.25}{45} = 9.8$ min

$H_s = \frac{45}{9} = 5$ min

HR = 1.96

$H_d = \frac{48 \times 60}{500}(1 - 0.19)$

$H_d = 4.7$ mins.

SOUTH MELBOURNE BEACH TRAM SERVICE from A.M. Peak Cordon Count - October, 1975.

Arrival Time (At St. Kilda Rd)	Headway mins.	Load (xi)
8.03	8	37
8.11	3½	36
8.14½	8	33
8.22½	5½	49
8.28	6	35
8.34	3½	41
8.37½	8	42
8.45½	3½	46
8.49	7	30
8.56		36
	$\Sigma h_i = 53$	$\Sigma x_i = 385$

$\Sigma x_i = 385$

$n = 10$

$\bar{x} = 38.5$

$\sigma_x = 5.9$

$H_e = \frac{344}{53} = 6.5$ mins

$H_s = \frac{53}{9} = 5.9$ mins

HR = 1.10

$H_d = \frac{48 \times 60}{385}(1 - 0.14)$

$H_d = 6.4$ mins.

This would tend to indicate that the route is possibly overserved

SUMMARY OF EXAMPLES - A. M. Peak Cordon Count - October, 1975.

ROUTE	Average Load	Scheduled Headway	Effective Headway	Headway Ratio	Desired Headway
CARNEGIE	66.7	5.9 mins	7.9 mins	1.34	3.4 mins
CAMBERWELL	50	5.0 mins	9.8 mins	1.96	4.7 mins
STH. MELBOURNE	38.5	5.9 mins	6.5 mins	1.10	6.4 mins

Other Route Indicators.

Patronage.

From Point and/or Linear surveys the Patronage of the route will be examined in terms of -

i) Passengers per tram
ii) Passengers per hour.

Average Speed.

From Point and/or Linear surveys the Average Speed will be examined between selected points.

Late Running.

From Point and/or Linear surveys the Running time relative to schedule will be examined. The basic unit being the % of trams running late.

Trip Length.

From linear surveys the average trip length will be estimated in terms of stops travelled.

Stop Usage.

From linear surveys the passengers boarding and alighting at each stop will be compared. An estimated usage will be made for a 12 hour period.

5. PROGRAMME FOR ROUTE ANALYSIS.

1) Toorak
2) West Coburg
3) Carnegie
4) Camberwell
5) East Preston
6) Doncaster - City
7) North Coburg
8) Mont Albert
9) North Balwyn
10) Burwood
11) East Coburg/South Melbourne Beach
12) Moreland/St. Kilda Beach
13) South Melbourne and St. Kilda Beach
14) Essendon Aerodrome
15) North Fitzroy
16) Clifton Hill/Elsternwick
17) Prahran and North Richmond/St. Kilda Beach
18) Glen Iris
19) East Brighton
20) East Malvern (Darling Road)
21) Malvern (Burke Road)
22) West Maribyrnong
23) Footscray/Moonee Ponds
24) West Preston
25) Wattle Park
26) North Richmond
27) Kew/Cotham Road and St. Kilda Beach
28) West Heidelberg
29) Garden City/Fishermen's Bend
30) Footscray/City and Sunshine/City