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A SERIES OF SIX DISCUSSIONS

ON

TRANSPORTATION ENGINEERING

BY

R.I. JACKSON B.Sc. (Eng.). M.Sc.

"INCREASING THE CAPACITY OF A ROAD SYSTEM".

May/June 1965.

Forward Planning Branch.
City Engineer's Department.
Johannesburg.

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C O N T E N T S.

1. ORGANISATION.

1.1 Need for Attack on Congestion.

The tremendous growth of urban areas due to population expansion and flow from the rural areas, together with the rapidly increasing ownership and use of motor vehicles is throwing a heavy load on urban roads. Already in South Africa, 60% of the nation's travel miles are driven on 10% of the nation's roads - the 10,000 mile urban system (1).*

Traffic congestion resulting from the overloaded roads is inflicting severe losses in money and amenity on the nation. Manpower and capital are wasted. An excessive number of vehicles is required for transportation and productivity is generally reduced. It has been estimated that traffic congestion cost Britain R500,000,000 in 1963 (2).

It is evident that in the interests of the nation's economy, positive action will be required to alleviate congestion in the future. Every available traffic engineering technique will have to be employed to squeeze the maximum traffic-carrying capacity out of the existing facilities. Then, as the load on the new freeways builds up, advanced techniques will be required to maximise their capacity before they, too, become congested and require huge investments to duplicate them.

1.2 The Three E's.

It is widely recognised that the problems of traffic must be solved by the efforts of appropriate agencies through 3 distinct channels, often referred to as "The Three E's", namely:

1. Engineering.
2. Enforcement.
3. Education.

* Numbers in Parenthesis refer to texts used in reference.

Channel./ ... ...

Channel	Approaches
Engineering	Traffic Engineering Highway Engineering Automotive Engineering
Enforcement	Police Courts Driver Licencing Vehicle Inspection
Education	Schools Adult Education Public Support

1.3 The Traffic Engineering Unit.

The execution of the complex functions of modern traffic engineering can best be achieved by the assignment of responsibility for these functions to appropriate agencies.

The United States President's Highway Safety Conference recommended for cities over 100,000 population (equivalent to 40,000 motor vehicles) the establishment of "a traffic engineering unit, comparable in authority and influence to other major divisions of the department of public works or corresponding organisation" (3).

The purpose of the establishment of such a unit is quoted as:

1. To provide clear-cut lines of authority removing confusion as to who is responsible for what.
2. To consolidate related functions, improving effectiveness in studying traffic engineering problems.

3. To provide an agency staffed to factually study each problem and recommend solutions based on facts instead of opinions.

The success of such a unit depends on the personnel assigned to it. Standards of the National Safety Council (United States) call for the equivalent of 1.5 full time traffic engineers per 100,000 population (corresponds to "per 40,000 motor vehicles") in addition to maintenance, clerical and other personnel (3). It has been recommended (3) that these traffic engineers should have adequate technical training "preferably engineering degrees and some specialised traffic training".

1.4 Functions of the Traffic Engineering Unit.

The Uniform Traffic Ordinance of the League of California Cities contains model provisions for assigning responsibility for traffic engineering functions to an appropriate official.

The California Ordinance states that it is the duty of the City Traffic Engineer:

> "to determine the installation and proper timing and maintenance of traffic control devices and signals, to conduct engineering analyses of traffic accidents and to devise remedial measures, to conduct engineering investigation of traffic conditions and to co-operate with other city officials in the development of ways and means to improve traffic conditions, and to carry out the additional powers and duties imposed by ordinances of this city".

The city of Detroit established a Department of Streets and Traffic. One major division is the Bureau of Streets, responsible for:

Design.
Construction.
Maintenance.

The other, the Bureau of Traffic has 3 divisions:

Traffic Planning.
Traffic Operations.
Parking.

An example of a fairly typical organisation chart for traffic engineering functions is given by the proposed organisation plan for Los Angeles, shown in Figure 1.

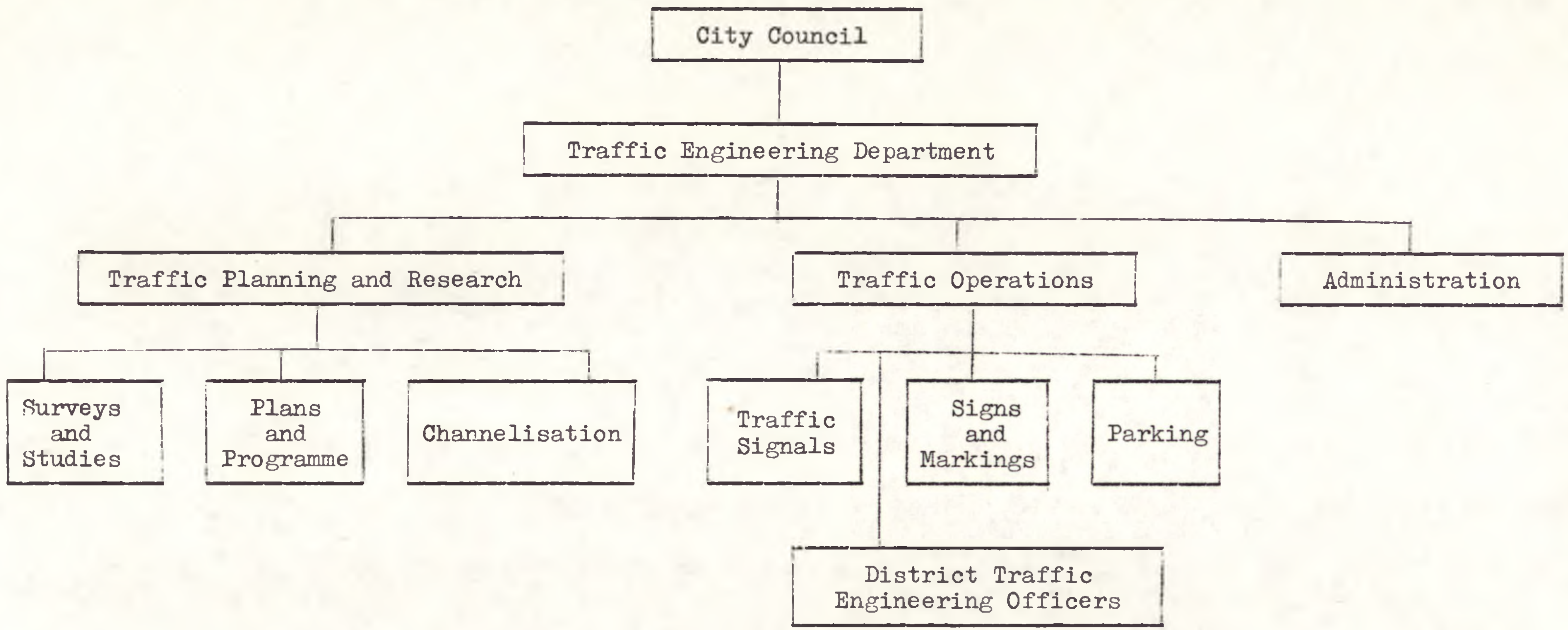

FIGURE 1: Proposed Organisation Plan for Los Angeles Traffic Engineering Department.

2. TRAFFIC CONTROL DEVICES.

2.1 Application of Uniform Traffic Control Devices.

There is a strong relationship between techniques which streamline and control traffic for the purposes of obtaining efficient flow and therefore greater capacity and those employed to increase road safety. However, since the latter will be treated more fully in the discussion on "Road Accidents and Safety" this discussion will omit them.

Traffic control devices can be considered in 4 main groups:

1. Markings (white lines, etc.).
2. Signs.
3. Signals. ('Robots').
4. Islands.

Control devices regulate traffic by:

* Informing motorists of regulations in force, e.g. speed limits, parking restrictions.
* Instructing them to take some action - stop, yield etc.
* Permitting them to make some manoeuvre - U-turns, etc.
* Assigning right of way - signals, through streets, etc.

They also guide traffic by indicating:

* Directions, using destination signs, turn markings, etc.
* Route markings - highway routes, etc.

Traffic can be streamlined by confining movements to definite predictable paths as in channelisation.

An important condition for the successful application of control devices is UNIFORMITY.

Uniform MEANING is essential for driver compliance. For example, if a solid white line means a barrier line which must not be crossed, it must always mean this. If such a line is taken across an intersection so that the motorist is permitted to cross it, it is difficult to expect him not to cross it in another instance.

Uniform/ ... ...

Uniform DESIGN is necessary for instant recognition.

Uniform APPLICATION promotes confidence and respect. If devices are applied without sufficient warrant, motorists lose respect and disobey them even when they are necessary.

Uniform LOCATION reduces the possibility of the device not being seen.

2.2 Markings.

The highest return for investment in traffic engineering is obtained from the WHITE LINE.

Lane markings are as an essential a part of a road as the road surface itself, and they should form part of the engineering design and construction of the road.

The standard lane marking agreed upon by the United States National Joint Committee on Uniform Traffic Control Devices is a broken white line 4" to 6" wide with a 3:5 ratio of length of stripe to length of gap. On high-speed urban roads and on rural roads the stripe length is specified as 15 feet with a 25 feet gap (7). On lower speed urban roads a shorter stripe length is permitted, but the 3:5 line to gap ratio must be maintained. Most big cities use the full 15 feet stripe and rarely is the stripe length reduced below 9 feet.

Machines are capable of painting 3 lines simultaneously and can use two different colours. This means a yellow no-parking line at the edge can be sprayed simultaneously with a broken lane line in the centre of a carriageway, as well as a solid centre line for a 4 lane road (or an edgeline for a divided highway). These 3 lines can be applied at a speed of 4 to 8 miles per hour. Flood-lights are provided for night striping. Quick drying paints can allow traffic on the road within minutes.

Precise cost studies made by the Traffic Engineer of Nashville, Tennessee, showed that the cost of striping was 3.58 cents (United States) per foot of stripe, including operating and paint costs (4).

The/ ... ...

The important effect of lane driving is to streamline and discipline the traffic. Great capacity increases can be achieved by implementing lane driving. This requires an engineering programme to stripe the lanes, followed by an education programme to promote their use, together with an enforcement programme to enforce their use.

THE BARRIER LINE.

In the United States of America a solid yellow line is a barrier line which may not be crossed. It is therefore used to indicate a "no passing zone", in a similar way to our solid white line. The yellow line is more effective than a white line for this purpose, since its contrast provides more emphasis and compels more respect.

If the solid white line is enforced as a barrier line, it can have more uses than just the safety use for no-passing.

It can be applied to increase capacity by prohibiting mid-block right turns. Applied in a main road across an intersection it would, as a barrier line:

1. Prohibit right turns from the main road.
2. Prohibit right turns from the side road.
3. Prohibit side road traffic crossing the main road.
4. Permit only left turns onto or off of the main road.

Other important markings are:

Turning arrows, painted islands, stop-lines, pedestrian crossings, parking space limits, parking restrictions and highway edge-lines.

2.3 Signs.

Signs to inform, advise, guide and regulate traffic can increase traffic capacity by removing hesitation, prohibiting manoeuvres which obstruct other vehicles and assisting motorists to use the facilities in the manner provided for in the design.

Fuller treatment of signs will be given in a later paper. Briefly they must follow all the principles of uniformity outlined for Traffic Control Devices.

2.4 Signals.

At intersections it is necessary to separate conflicting streams of traffic. Overpasses do this by separating them in space. Signals separate the streams in time, by assigning the right of way to each stream in turn while blockading the others. The blockade, however, obviously reduces the capacity of the approach.

The capacity of a signalised approach depends on the proportion of effective green time assigned to it. To maximise the capacity of an intersection as a whole, it is clear that each approach or each movement (e.g. north-south through traffic, left turns, etc.) should receive only enough green to pass the traffic accumulated during the cycle. If the green is longer, then valuable time is wasted as no movement occurs on the intersection and vehicles on other approaches are delayed for no reason. Maximum capacity is obtained when the green time is proportioned to keep all approaches at the saturation flows.

After the green appears, the first 5 cars take 3.4 seconds longer to cross the stop line than any subsequent 5. Hence the more cycles occurring per hour, the more time is lost per hour.

The optimum settings have been shown to be a delicate balance between the proportion of green time to the various phases, the approach volumes and the cycle time.

Since volumes are fluctuating throughout the day, it is obvious that fixed time signals reduce capacity and cause unnecessary delay.

Hence traffic actuated signals are widely used today. Radar or sonic detectors detect approaching vehicles and alter the signal timing. For example, a main road would hold green until a vehicle on the side road was detected. Then, the signal controller would wait for a pre-set gap in the main road traffic (say 3 seconds) to switch the green to the side road.

When/ ... ...

When traffic has been disciplined to drive in lanes, signal heads can be suspended over each lane and each lane can be separately controlled. For two-way operation of roads, right-turn traffic can be accommodated by suspending a signal head with a turning arrow over the right hand lane for each direction. This lane can employ a separate phase with a leading or lagging green for the right-turn movements only.

In downtown areas, where signals are placed at regular intervals, the green times can be synchronised to allow platoons to progress through at some definite speed. However, with short blocks, vehicles turning onto the synchronised road from side roads, are stopped on red, ahead of the platoon approaching in the synchronised "green band" and hence destroy the progression. Moreover, if the road is operated on a two-way basis, right-turning vehicles in the platoon have to stop at intersections to await gaps in the opposing through-traffic. This, ofcourse, also destroys the progression. Under these circumstances the simultaneous system is generally best.

2.5 Islands.

Intersections at grade can employ channelising islands to separate movements, store right-turning vehicles and provide refuge for pedestrian traffic. Development of channelising principles is, however, outside of the scope of this paper.

3. TRAFFIC ENGINEERING TECHNIQUES.

3.1 One-Way System.

The conversion of a street to one-way travel increases the capacity by eliminating the hold-up caused by right-turning traffic waiting for gaps in the opposing through-traffic.

In Denver, Colorado, every street in the downtown area is a one-way street. Denver has a grid-iron layout complicated by the fact that one sector of the town has its grid at 45^{o} to the rest of the town.

New York city has almost completed converting the entire Manhattan system to one-way operation. Most east-west streets have been converted, while Fifth and Madison Avenues are the only major

north-south/ ... ...

north-south arteries operating on a two-way basis (5). The Traffic Department reports "slashing delays caused by stops by 46 per cent". Studies showed that travel time on a certain section of the Avenue of the Americas was 18½ minutes with 18 stops before conversion. After conversion the travel time was 6¾ minutes with only one stop on an average.

Between August and October 1963, 35 miles of streets in Brooklyn were incorporated into a system of 10 parallel one-way arteries.

Another study showed that the capacity of a pair of 60 feet roads, would have an increased capacity of 26%, operating on a one-way basis.

3.2 Exclusive Bus Lanes.

The extra capacity obtained from one-way operation makes it possible to provide exclusive bus lanes on selected routes. Surveys in New York City's Brooklyn and Staten Island showed a reduction of 21 per cent in bus trip time making it possible to schedule an additional 22 trips by the existing number of buses during rush hour on each of the routes using exclusive bus lanes (5).

3.3 Location of Bus Stops.

When parking is prohibited, the location of a bus stop on the near side of an intersection can reduce the capacity by 10% more than if the stop were located on the far side and by 15% more than if there were no bus stop at all (3).

Where possible off-street bus stops and terminals should be provided. Special bus bays cut into the kerb line assist road capacity.

3.4 Parking Regulations.

Parking reguoltions have a significant effect on road capacity. Not only does the presence of parked cars eliminate the use of a complete lane (i.e. reduce capacity by 1,000 cars per hour of green) but the interference caused by parking and unparking reduces the capacity of the lane alongside the parking cars.

The/ ... ...

The development of double parking alongside the parking lane causes further loss of capacity, delays, frustration and a serious breakdown in traffic discipline. This lack of discipline leads to further loss of respect for traffic regulations and control devices with further capacity loss and traffic hazard.

The only effective solution found overseas is the technique of towing vehicles away. In most United States cities towing is very efficient and on important routes violators are certain of being towed. The deterrent is very effective.

The effective prohibition of parking on a two-way, 60 feet wide, downtown street has been found to increase the capacity by 52%, while the combined effect of parking prohibition and removal of bus stops would increase capacity by 78%.

3.5 Pedestrian Controls.

Effective control of pedestrians at intersections achieves considerable capacity improvement. In the United States pedestrians are controlled by special signals. The illuminated signals display the definite instructions "Walk" in green and "Don't Walk" in red.

The use of the actual words has a strong psychological effect.

3.6 Surveillance.

A strong relationship exists between speed and capacity. On Detroit's John C. Lodge Freeway, the speed limit displayed on overhead signs can be altered from the control room in which television screens provide surveillance of the freeway. As traffic volume increases the speed limit is varied to operate the road at the optimum speed for the capacity required. To prevent speed being reduced below a tolerable standard the ramps entering the freeway can be closed off from time to time from the control room.

3.7 Summary - Capacity Increases.

A study to find the influence of various techniques to increase intersection capacity has been summarised as follows:

INTERSECTION/ ... ...

INTERSECTION CAPACITY INCREASE.
(Pair of 60 feet wide Parallel Downtown Streets).

A C T I O N	Percent Increase
Prohibit right turns	8%
Prohibit left and right turns	14%
Prohibit parking	52%
Prohibit parking and remove bus stop	78%
Widen 20% (to 72 feet)	22%
Change to one-way	26%

3.8 Enforcement and Education.

Enforcement and Education techniques will be discussed in a later paper. However, it cannot be over-emphasised that no matter how extensively and efficiently the engineering functions of traffic are executed, little success can be achieved without a determined and continuous enforcement programme. Both the engineering and enforcement programmes start with severe handicaps without vigorous, continuous and creative education ranging from schools to the adult public.

4. THE WISCONSIN AVENUE STUDY.

The Bureau of Public Roads undertook a study in Washington D.C. to demonstrate the effectiveness of various known methods of increasing capacity when used in combination (6). This study has become known as the Wisconsin Avenue Study and has become an important precedent in the approach to capacity improvement.

The study considered 3 phases of improvement, at different levels of cost.

Phase 1. This phase required no widening, channelisation or physical changes but developed the efficient use of the existing street width at little cost, without appreciable construction.

Briefly/ ... ...

Briefly, the steps were:

1. Encourage turning signals well in advance.
2. Prohibit turning at certain intersections.
3. Change parking regulations. Eliminate parking at all times on sections narrower than 50 feet. Prohibit rush-hour parking on all sections. Enforce prohibition of double parking.
4. Establish pedestrian controls.
5. Instal lane markings.
6. Enforce U-turn prohibition.
7. Control mid-block turning movements.

<u>Phase 2</u>. This phase involved limited construction and installation of signals. The steps were:

1. Widen certain sections to provide a minimum of 4 lanes with a 44 feet road width.
2. Instal a modern, flexible progressive signal system.
3. Channelise several major at-grade intersections.
4. Resurface entire street between existing kerbs.
5. Mark certain sections over 56 feet wide for reversible (3-2) lane operation.
6. Provide bus bays at bus stops.
7. Instal a modern lighting system.

<u>Phase 3</u>.

1. Reconstruct certain intersections.
2. Construct grade separations at certain intersections.
3. Construct additional widenings, including median islands.

The following table summarises the capacity increases for each phase over 3 sections of the road:

WISCONSIN AVENUE STUDY CONCLUSIONS.

LOCATION	Percent Increase Above Current Capacity		
	Phase 1	Phase 2	Phase 3
Lower Georgetown	50	92	117
Upper Georgetown	30-60	110	140
North of Massachusetts Avenue	39-70	126	213

R E F E R E N C E S.

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(6) Berman, J. and Carter, A. - "Increasing the Traffic-Carrying Capacity of Urban Arterial Streets": H.R.B. Bulletin No. 271.

(7) National Joint Committee on Uniform Traffic Control Devices - "Manual on Uniform Traffic Control Devices for Streets and Highways"

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