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TRANSPORTATION RESEARCH CIRCULAR

Number 161 Subject Area: Highway Design
Traffic Control and Operations
Traffic Flow
Traffic Measurements
Urban Transportation Systems

December 1974

NOTES FROM THE INTERSECTION CAPACITY WORKSHOP

January 20, 1974
Sheraton-Park Hotel
Washington, D. C.

COMMITTEE ACTIVITY

GROUP 3 - OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES
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*As of December 31, 1973

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL NATIONAL ACADEMY OF SCIENCES - NATIONAL ACADEMY OF ENGINEERING
2101 CONSTITUTION AVENUE, N.W. WASHINGTON, D.C. 20418

PREFACE: The Committee on Highway Capacity and Quality of Service has for some time been aware that certain portions of the 1965 Highway Capacity Manual (HCM) are not entirely satisfactory in their application. One such major area includes Chapter 6, At-Grade Intersections, and a task group chaired by Dr. A. D. May, Jr., has been addressing this subject extensively. To focus attention on problems and possible solutions, a workshop was held on the Sunday preceding the TRB's 53rd Annual Meeting.

The morning session was led by James H. Kell and consisted of a review of the current HCM approach. The afternoon session was led by Dr. Donald S. Berry and covered alternatives to the HCM approach, including techniques developed in England and Australia. The notes were originally intended for internal committee distribution only.

Since attendance was restricted by several factors, and since interest in the HCM and its application is so widespread, the committee subsequently decided that publication and distribution of these notes could serve a worthwhile purpose. Chairmen Blumenthal and May will appreciate comments from readers on their experiences, especially if they are in any way different from those reported in these discussions.

ACKNOWLEDGEMENTS: The Board wishes to acknowledge several contributions which helped to make this a successful workshop. The task group and committee members who developed the program included B. D. Greenshields, D. W. Gwynn, Jack E. Leisch, Karl Moskowitz, C. C. Robinson, Joseph Wattleworth, Donald S. Berry, James H. Kell, Arthur A. Carter, Bob Blumenthal, and task group chairman A. D. May, Jr. Major contributions were made by two who traveled far to participate: Dennis Robertson from England, and Alan J. Miller from Australia. Finally, the notes published here are the work of committee secretary Arthur A. Carter for the morning session and William R. McShane for the afternoon session

INTERSECTION CAPACITY WORKSHOP

PROGRAM

9:00	-	9:30 A.M.	Registration
9:30	-	9:40	Opening Remarks - Bob Blumenthal, Chairman, Highway Capacity and Quality of Service Committee
9:40	-	10:00	Objectives and Format of Workshop - Dolf May, Workshop Chairman and Chairman, Intersection Capacity Sub-Committee
10:00	-	12:00	Review of current Highway Capacity Manual Approach - James Kell, Session Moderator
			Presentations by
			Hristaki Sofokidis, Highway Engineer, Office of Traffic Operations, FHWA
			James Sparks, Deputy City Traffic Engineer, City of Phoenix
			Joseph Lam, Senior Traffic Engineer, Roads and Traffic Department, Metropolitan Toronto
			James C. Ray, Traffic Engineer, Sacramento County
			Eugene F. Reilly, Chief, Bureau of Operations Research, New Jersey Department of Transportation
			Panel Discussion
12:00	-	1:30	Lunch
1:30	-	3:00	Alternative Approaches to the HCM Approach - Don Berry, Session Moderator
			Presentations by
			Dennis Robertson, Traffic Engineering Department, Transport and Road Research Laboratory, England
			Alan J. Miller, Commonwealth Scientific and Industrial Research Organization, Australia
			Donald S. Berry, Civil Engineering Department, Northwestern University
3:00	-	3:15	Recess
3:15	-	4:15	Workshop Discussion - Dolf May, Discussion Leader with Panel Members Don Berry, Bob Blumenthal, Jim Kell, Alan Miller, and Dennis Robertson
4:15	-	4:30	Workshop Summary and Closing - Dolf May and Bob Blumenthal

MORNING SESSION

In the Opening Remarks, Chairman Blumenthal reviewed the history of the Committee, now 30 years old, and discussed the intent of the meeting today -- Chapter 6 consideration. A consequence of the meeting will be an executive session of the subcommittee to decide further course recommendations regarding Chapter 6.

Objectives and Format of the Workshop were given by Dr. May. Expansion of Blumenthal's remarks included question of extent of need for a data bank, introduction of subcommittee members, and comment on overseas guests.

Review of Current Highway Capacity Manual Approach - Kell

General introduction of five speakers. Presentation of reports.

1. Hristaki Sofokidis, Office of Traffic Operations, FHWA, Washington, D.C. "Intersection Capacity Analysis Practices, A State-of-the-Art Review"

He first gave the background for the review, which FHWA undertook after encountering insurmountable difficulties in trying to carry out the Highway Capacity Committee's request to conduct a third nationwide data-gathering effort, with delay considered as a new key factor. He next described the purpose of the review, to obtain from all interested parties throughout the country any comments, good and bad, which they might have about HCM Chapter 6--successes with it, problems encountered, innovations they have developed to resolve problems, and the like. He then presented a mid-study status report, briefly summarized as follows:

a. Status

Response to the survey has fallen considerably less than had been hoped and expected. There have been 56 completed responses from 12 States. Nine States expressed no interest at all and there is little hope for much response from rural-oriented States. At the present rate of return and expressed interest, probably 3/4 of all possible contacts have been made. Also, only one response was received to the notice about the review in the November 1973 "Traffic Engineering" magazine.

b. Summary of Findings

(1) Forty-five of the fifty-six respondents use the HCM procedures in one of its three forms; i.e., the charts and formulae; the Jack Leisch nomographs; and the Dolf May computer programs. Four do not conduct any intersection capacity analyses. Four use some rule-of-thumb, usually based on headways. Three use the critical lane method.

(2) Only 15 conduct some crude validation of their computed capacities.

(3) Seventeen do not consider delay and they do not see any need to consider it. Twelve consider delay only for cycle length and G/C ratios, but with very little detail or refinement.

(4) The majority of the respondents encounter problems in determining the various factors (PHF, L.F., population, and location within metropolitan area). Quite often they have to make assumptions based on very little data. Nine respondents find that the HCM procedures result in too high or too low capacities (but they don't say how they know). Seven indicated that approach capacities do not increase linearly as approach widths increase; that is, the curves should be stepped rather than continuous. Five find the HCM procedures too complex and hard to follow, and four indicated that they have difficulties with left-turning volumes.

(5) Of the 29 respondents who expressed an opinion on the need for a new nationwide study, nine see no need, 12 would prefer the effort spent to make specific refinements to the existing procedures and eight feel that a new study would be warranted only if the results would be simpler to apply and more accurate simultaneously. The most prevalent recommendation is to "keep it simple."

Mr. Kell commented on the presentation by observing that the above findings make it obvious that, as before, we need to consider who we're writing the manual for.

2. James Sparks, Deputy City Traffic Engineer, Phoenix, Arizona, (Substituting for C. E. Haley, City Traffic Engineer)--Comments mainly on Chapter 6 but also on HCM generally:

a. Use of current manual

Haven't done any extensive evaluation of present methods; just a few initial satisfactory validation checks when the '65 HCM first came out. Well satisfied with it.

(1) Findings

Flaring of intersections to increase capacity hasn't been successful. Added lane at intersections only is 53 percent effective. It seems like a continuous lane is needed, or at least a longer added lane.

Mathias of Arizona State has reported on left turn movements in Tempe, in HRR 433. He found protected turn lane capacity 33 percent higher than HCM criteria show.

Yellow time has been found more effective than the HCM's handling shows, and no accident problem.

(2) Comments

Minimum R/W standards map--HCM has been useful in creating this.

Phoenix has very dense traffic--must squeeze out every bit of capacity.

TOPICS--much needed; sorry to see end of specific program.

Right turn on red--support it, but doesn't believe it increases capacity. Good for public relations; lets turns move into cross-street progression and delays onset of congestion.

b. Suggestions for future HCM

(1) Modified basid procedures

(a) Condense and simplify procedures (Leisch charts are good example of good move)

(b) Develop conversion charts, giving level-to-level percentage difference.

(c) Incorporate short-cut method (critical lane method).

(2) More consideration of detrimental effect of multiphase on capacity, and on ability to give progression to most drivers (which he feels is key element in preventing congestion).

(3) Flexible lane striping coverage--more coverage of effect of striping, in various forms--widths, reversibles, etc.

(4) More definitive location factor--the current up-to-25 percent differences depending on choice made are bad.

(5) Modified criteria for influence of parking--250' rule-of-thumb not good at Levels D and E. Parking near the intersection here doesn't effect capacity as much as HCM indicates.

(6) Broader scope--cover broader range of transportation systems.

(7) Broader range--Phoenix has one ways wider than covered by HCM. (Maybe HCM doesn't need to change--may be too special case.)

c. Conclusions

Manual has been very valuable in providing national consistency. This value of it shouldn't be changed, and he wouldn't recommend more than fine-tuning. Concluding, "We like the Manual."

3. Joseph Lam, Senior Traffic Engineer, Roads and Traffic Department, Metropolitan Toronto

a. Described their capacity computation program, based on HCM Chapter 6 and Dr. May's programs. They get field data in 15 minute intervals. Output includes an input summary, PHF, peak hour and off-peak average volumes, total volumes (7-9 a.m., 4-6 p.m., 8 hours), AADT estimates, capacity (L.F. = O.7), and running time.

Applications include development of volume and capacity files, quick evaluation of particular locations, signal timing, redesign, and planning studies on short notice.

b. Modifications suggested

(1) Left Turn Capacity

Exclusive lane, exclusive phase - Cap. $= 1500 \times \frac{G}{c}$ (i.e., 2.4 sec./veh.) rather than HCM's $1200 \times \frac{G}{c}$

Study results show headway of 2.0 - 2.5 sec., including lost time effects (same for exclusive right turn lanes).

Exclusive lane, no exclusive phase -
HCM gives: $(1200 \times \frac{G}{c})$ - opposing flow, or 2 per cycle, whichever is greater.

This was found okay for opposing low flows, but it underestimated for opposing flows over 600 vph in 2- and 3-lane flows. Gap acceptance criteria were therefore used instead.

No exclusive lane -
With exclusive phase: Treat as one way (same as HCM)
Without exclusive phase: HCM overestimates, since opposing not considered.

(2) Straight-through capacity

HCM generally underestimates. They verify by field data, and use local adj. factors. They suggest as alternatives

(a) Webster method for delay and queue

(b) Saturation flow, using Australian method.

(c) Field observation of cycle failures, if all else fails.

c. HCM problem areas noted

(1) Lane width vs. number of lanes as basic criterion--number of lanes better, except wide single lanes.

(2) Pedestrian interferences on turns--needs more coverage, particularly of effect of pedestrian volumes.

(3) Load factor definition for field observation--wide variation between observers, depending on interpretation.

(4) Metro location factors--suburban shopping malls are particular problems.

(5) Buses and trucks--adjustments needed for higher volumes than now covered; they have bus volumes well over 120 per hour.

(6) Bus stops in turning lanes--need better coverage.

(7) Parking distance from stop line--Webster's approach probably better.

(8) Left turns against opposing flows--modification as previously suggested.

(9) Left turns on arrow indications--should reflect changed driver response.

(10) Approach gradient--should include this as a factor; they use such a factor.

(11) Relationship with delay, queue, etc.--such a measure needed at least for civic purposes. It's hard to talk to developers, etc., in our "load factor language."

(12) Calibration procedures--would be of value for cities to use in updating HCM individually for their own tailored use.

He closed by stressing the HCM's statement that the factors handle only part of the error and that observed traffic must govern.

4. James C. Ray, Traffic Engineer, Sacramento County, California

Will repeat much of what has already been said, based upon his experience in Sacramento County since 1959.

Needs--Simplify. Traffic engineering is moving out to suburban--rural categories as development spreads. New problems arise.

Uses--Planning, design, operations. Planning estimates may be 100 percent off, so simplified methods are all that are feasible.

Specific points:

G + Y - Promotes, like Moskowitz, use of the total G + Y time in capacity computations.

Left turn lanes - Needs more consideration.

Parker, L.A., feels that special left turn lanes may increase, not decrease capacity, contrary to what others have said. Without them, cross-street capacity blocked by turners.

Oakland, Co., Michigan, also reports it is increasing capacity by reserving left lane on ordinary 2-lane approaches to left turns.

Progression--has feel that it increases capacity.

Lane markings and traffic distribution between lanes -

Montgomery Co., Maryland, using critical lane method; comes up with 1350 veh/hour as critical lane capacity.

Traffic-actuated signals--All in Sacramento County are actuated to some degree; he finds it desirable in maximizing G + Y use. Permits green time as low as 4 sec., and keeps them from getting loaded cycles.

Needs more coverage.

Right turn on red--disagrees with earlier speeker, Sparks; feels it does increase capacity.

5. Eugene F. Reilly, Chief, Bureau of Operations Research, New Jersey Department of Transportation

Advised that he would give his report as planned, though he knew there would be duplication with earlier ones.

He discussed their validation studies, and errors found. Errors of over 20 percent from the HCM were found in 45 percent of the cases. He described raw data problems which complicated the work.

He showed slides showing errors found for various conditions. "Step" problems were shown, resulting from width categories in turn adjustments--to some extent the steps may be true, but New Jersey feels the HCM makes them too pronounced.

Other problems covered by slides included:

Location

Metro area size--big problem in N.J. with many overlapping municipalities within the metro area. They have settled on "Municipality + Adjacent Municipalities," rather than "Individual Municipality" or "Entire Region."

Bus corrections--shouldn't exceed $1.00

Effect of parking (250' rule-of-thumb)-- Thought they had good data, but couldn't get effect value.

Showed errors of:

HCM, unrevised (middle)
HCM, No PHF (worst, though it should best fit true capacity)
HCM, "Revised" (best, generally)

Second approach tried by N.J.--Field data taken to draw curves equivalent to the HCM curves--very unsuccessful so far, with statistical incongruities, etc.

Suggestions:

Don't lean on the manual when you're going to be taking field data anyway. Use.

Kell Wrap-up of Reports - So much of this sounds just like the hours and days of frustration spent trying to create the present methods in the early 1960's. Such things as: G + Y, 250', buses, data variability, etc.

Questions and Answers

(?) to Reilly - Question on the "jumps" in his error charts, depending on turn percentage. Suggested refinement; Reilly agreed, but didn't consider it worth the trouble.

Williams - Given same G/c, what's the effect on capacity of extending cycle length?

Ray responding--Delay extended, but thinks capacity would decrease because probably less saturation flow period. Sparks agreed. Murmurs in audience showed disagreement, and Reilly disagreed also, feeling capacity would increase.

Ray advised that "Traffic Engineering" Magazine, November 1963, has a good article on this--shows short cycles best.

May advised of Moskowitz's new paper on this, "Long Cycles, Short Cycles, and Lost Time at Signalized Intersections." Also suggested Hutter might have comments from his workshops.

Hutter - Have had 1000 people at 25 workshops. (Had expected 3 workshops originally; have sold 5000 sets of "Leisch charts.") His views--all-important to go out and look and see how drivers use an intersection. This will tell you how to use the book in many cases (width vs. number of lanes, parking, etc.).

Kell - Uses of manual are many - Hutter's "looks" are fine for one type of application but there are others where looks at existing aren't the key, or where nothing currently exists to look at.

Leisch - (In response to Kell and May requests) - Feels optimistic--though there are many problems, we can solve them if we make clear the two or more types of applications and develop appropriate procedures for both. We should also try to show that apparent complexities really aren't, in many cases.

Suggests a brief working document, with in-depth back-up document. The first would have two parts: Simple, for planning and design and somewhat more detail, for operation, keyed to above. The second would be a more detailed technical back-up document.

Other points: He does not think there's any difference, no matter how we handle yellow--plot will just be at different point on the scale.

He is a proponent of nomographs, but sees that current ones can be simplified, to cover whole intersection of a particular type on one nomograph, rather than going approach by approach.

Kell - Agrees that "entire intersection" should be considered more than it has been.

May - (at Kell's request) - About 600 copies of his computer programs have been distributed.

Petersen - Stressed the need for simplified adaptation to planning, and for more application of v/c as related to level of service. Mentioned requirements being placed on developers to consider not just their developments' roads but neighboring ones.

Kell - Stressed the point that H. Sofokidis made; that the "fire" we thought existed for a new manual around the country doesn't really seem to exist. We must seriously consider who we're writing this for.

AFTERNOON SESSION

1. Dennis Robertson

D. Robertson of the Transport and Road Research Laboratory presented the U.K. Method for traffic capacity computations. He cited Road Research Technical Paper 56 (available for about £1) as the basic reference.

His presentation is best summarized in the set of ten illustrations used in the presentation. These are attached to this report.

Illustration 1 shows a typical arrival pattern. This was presented for background and introduction.

Illustration 2 shows the computation of approach capacity. The determination includes (1) conversion of flow to passenger car units (pcu's) and (2) saturation flow computation based upon the characteristics of the site. It was noted that the formula is in terms of width, not lanes, but that this is not meant to be definitive: lanes may or may not be better. In addition, the grade correction of 3% correction per 1% grade may be too high. Remember for flow indications that the right turn is the turn across on-coming traffic in this method.

Illustration 3 shows the computation of the proportion of time which should be allocated to each phase. The computation is based upon calculation of 'y' values, where:

$$y = \frac{\text{flow}}{\text{saturation flow}}$$

Some numbers are shown for an example: note that on any phase, the greater number governs.

It was clearly pointed out the signal timing is and should be integral to the capacity method.

The % reserve capacity was highly recommended as a measure of intersection service:

$$\%\ \text{reserve capacity} = \frac{Y_p - Y}{Y}$$

Illustration 4 shows a sketch supporting a point that the relationship between flow, delay and intersection service depends on the method of control and settings of the signals.

Illustration 5 reports on the descriptions of intersection load cited in a report from OECD Research Group T-8.

Illustration 6 shows the saturation flows used in various countries for various widths or lanes.

Illustration 7 shows correction factors for composition and grade in various countries.

Illustration 8 shows detail on a correction factor effect for opposing flow, and indicates the weaknesses in it at the bottom of the illustration.

Illustration 9 shows minor flows possible in a gap acceptance scenario for various bi-directional major road flows. The illustration highlights the large differences between relationships derived in the UK, Germany and the Netherlands.

Illustration 10 reports on trends in research work in the United Kingdom:

- Urban Areas
  - Coordinated Fixed Time Plans; development and application of TRANSYT, e.g. to give priority to buses.
  - Development of a traffic responsive coordination method known as 'SCOOT'.
- Non-Urban
  - Mini-Roundabouts (traffic circles)

D. Robertson also indicated that within the U.K. Method, the following points need or are open for discussion: laning, nearside lane use, parking, and grade correction factors.

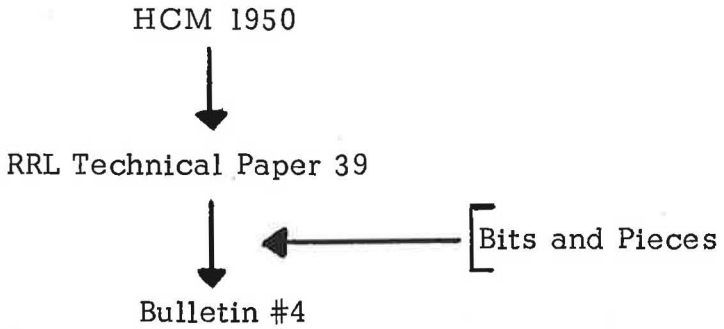
2. Alan Miller

A. Miller presented the Australian Method, citing Australian Road Research Bulletin #4 (1968) as the basic reference. It may be obtained from

Australian Road Research Board
500 Burwood Highway
Vermont, Victoria, Australia 3133

This document is not considered as a design guide. If it were, more emphasis would have been placed on safety to balance it.

The historical context of Bulletin #4 is as follows:



The paragraphs to follow summarize points made in the course of the presentation, highlighting the essential points and differences in the Australian Method.

1. The method relates to number of lanes and not to approach width.

2. The streets are much wider than in Britain. Only six intersections were found with a single lane structure.

3. Truck volume is converted to equivalent number of through car units. The methodology thus uses the actual observed truck volume.

4. Approximately 40% of the passenger cars were European width (4-cylinder size).

5. Parked vehicles within 600 feet downstream inhibits use of curb lane.

6. There is a capacity formula involving opposed turns.

7. In regard to curb lane usage:

   a) 100% usage on 1 or 2 lane approaches
   40-60% usage on approaches with 3 or more lanes (no stopping strictly enforced)

   b) With no parked vehicles downstream but some upstream, it is assumed that one vehicle per 30 feet use the upstream space during the red.

3. D. Berry

D. Berry of Northwestern University presented a technique for capacity computation based upon headways. A version of this appears in Highway Research Record 453. He recommends use of intersection line rather than stop line because of ambiguity/existence or not of latter.

He recommended consideration of weather as a factor, and reported some results on this subject.

He also recommended for consideration:

- a headway or saturated flow approach
- a need for statistics on headway data for loaded cycles
- through car equivalents studies
- left turn median lanes and cycle length studies
- right turn on red effects
- grade effects
- perhaps a return to fewer descriptive levels or characterizing numbers, specifically as in the 1950 HCM.

4. Questions

The meeting was opened to the floor for discussion and questions, addressed to specific speakers or to the group of speakers. Where possible below, individuals are identified. This was not always possible due to the size of the audience or the number involved in the discussion.

1. The first question did not bear on the subject of the talks, but elicited some interesting remarks nonetheless. Q: Freeway/motorway flows very high: up to 3000 vphpl? True?

A: (Dennis Robertson) Yes, high, but not that high in all lanes. Also vehicle length is a factor.

A: (Alan Miller) Yes, 4500 vph observed in 2 lanes in Australia. An observation of 5100 vph was cited for the M-4 Motorway in England, 3400 in the right lane and 1700 in the left lane (truck lane). The driver is the primary factor.

2. J. Lam commented that the Australian Method is better correlated to actual results: He considers it due to similarity of intersection types.

3. Q: How does one get a bicycle through an intersection?

A: (R. Blumenthal) This depends upon volume and policy. The trend in the U.S. is segregation. He noted the lack of pedestrian and bicycle data, and cited this as a subject for Tuesday full Committee meeting.

A: (D. Robertson) 1 bicycle = 1/5 pcu.

4. Q: We need more studies of good pavement markings, pedestrian visibility, pedestrian isolation. Are there references on statistics of such?

A: (R. Blumenthal) TOPICS may be a source of such information in before/after situations.

A: (A. May) Edwards and Kelsey study - NCHRP Report #113, "Optimizing Flow on Existing Street Networks"; HUFFSAM publications on safety.

A: (D. Berry) UVC changes in 1968.

A: (J. Hess) SRI study on intersection accidents and other FHWA work.

5. Q: Effect of dual left turn lane?

A: (D. Berry) M.S. student did some work on this topic: some capacity for each.

A: (A. Miller) Double and triple in Australia: Same capacity for each.

A: (A. May) San Francisco has cases of both good and bad design of such, and design is a factor.

6. Q: When an exclusive right turn lane exists, what is its free-flow capacity:

A: (A. Miller) The saturation flow of right turners is reduced by a factor of (1 +5/R), where R is the radius of the turning circle in feet. This factor is with no pedestrian traffic.

7. Q: Right turn on red: Can't see but how approach capacity increased. Agree?

A: Must look at total intersection, for movements may get in each other's way.

A: (D. Berry) Data on right turn at a stop sign--which we have--could be used.

8. The Committee Chairman, R. Blumenthal, tried to obtain a consensus of the meeting of which technique is favored. The ensuing discussion complicated the poll to the point where a group poll was inefficient (design vs. analysis etc.).

9. Q: Is the Bellis method (morning session) used extensively in New Jersey for operations

A: (E. Reilly, morning speaker) Yes.

Note: This method is in H.R. Bulletin 271.

10. Statement: HCM is too cumbersome for planning, needing rapid, quick estimation. However, detailed design uses HCM almost exclusively.

11. Statement: A planning rule-of-thumb is that no spot in the intersection may have more than 1500 vph traverse it, total. This agrees with the 1650 vph of Montgomery County if their factors are taken into account. We need more definitive resolution of this planning approach, however.

A. Miller and D. Robertson note that the Webster method yields the equivalent, with refinements.

D. Robertson noted that more generally, there is not much fundamentally different between the Webster and HCM approaches.

12. Statement: It was recommended that a basic approach (elemental?) be selected, and that within the formulated methodology needs be addressed.

- planning
- design
- operations

13. Who do we represent? There was some discussion of the operations/design/planning split of the attendees.

14. Q: (A. May) From a planning point of view, what should the subcommittee do?

Opinion 1: Does not see that the three approaches (HCM, U.K., Australia) should be different. Further, notes that the attendees--by their presence--recognize the need for some changes. Suggests that the subcommittee would be best qualified to indicate direction.

Opinion 2: A public official wants to know how much delay his constituents will suffer. A new HCM should address this.

Opinion 3: Body of knowledge has expanded. Should be incorporated. Re-working Chapter 6 should be broken down so that it is useful to all three interests: planning, design, operations.

15. Statement: Data collection--the consistency thereof. We have used a shotgun approach in the past. We should be more careful in collecting data and in designing basic experiment.

16. Statement: Many of the planners' needs relate to conditions that do not yet exist. "Can they (this or that) be done?" is the basic question. Answer must be intelligible to the local planning boards, and must not require excessive data.

17. Statement: Planners' concern is also over consistency of results (actually, reasonableness). HCM is apparently deficient here.

18. Statement: Another need is for sizing whether effect of a given change is worth the effort.

19. Statement: Operations people know existing situation. Probable effect of alternate improvements is what is of interest (as stated in (17)).

20. Q: (A. Miller) Would U.S. HCC be willing to provide new Chapter 6 without new data?

A: (A. May) Present intent is to figure out what data is needed first. But we do need new data.

A: (J. Kell) With a charge to do so, we could remove inconsistencies in a rewrite but would not really be doing more than that.

21. Statement: There are a few things that could be better treated in a rewrite. For instance, "Metropolitan Area," "Location with Metropolitan Area." Recommend periodic updating of HCM as is done for MUTCD (e.g. circulars).

A: (J. Kell) Cites judgement discussion noted in HCM re: Metropolitan Area classification. Cites fact that information does not exist from which to make updates (e.g., pedestrian activity), and that such updates would be subjective. On second thought, he said this may not be bad, for it would cause reactions which would bring data out.

22. Statement: (D. Robertson) Recommend that the same team be used for any data-taking for consistency.

5. Conclusion

The chairman of the committee made concluding remarks, thanking the subcommittee and the speakers. He considered the day quite successful and thanked the attendees for their participation and interest. A meeting of the subcommittee was to be held following the meeting.

FLOW DURING GREEN TIME

ILLUSTRATION 1

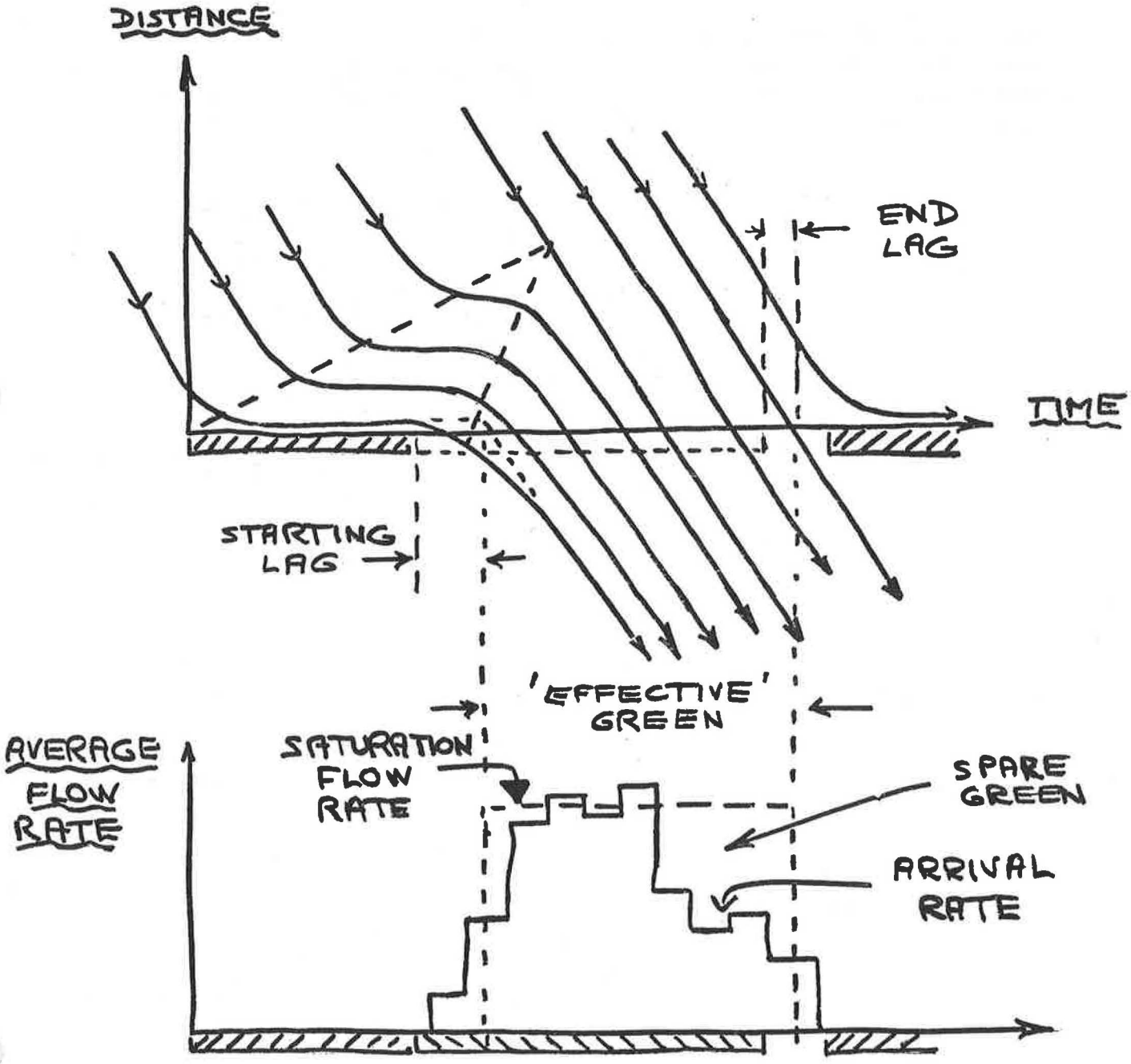
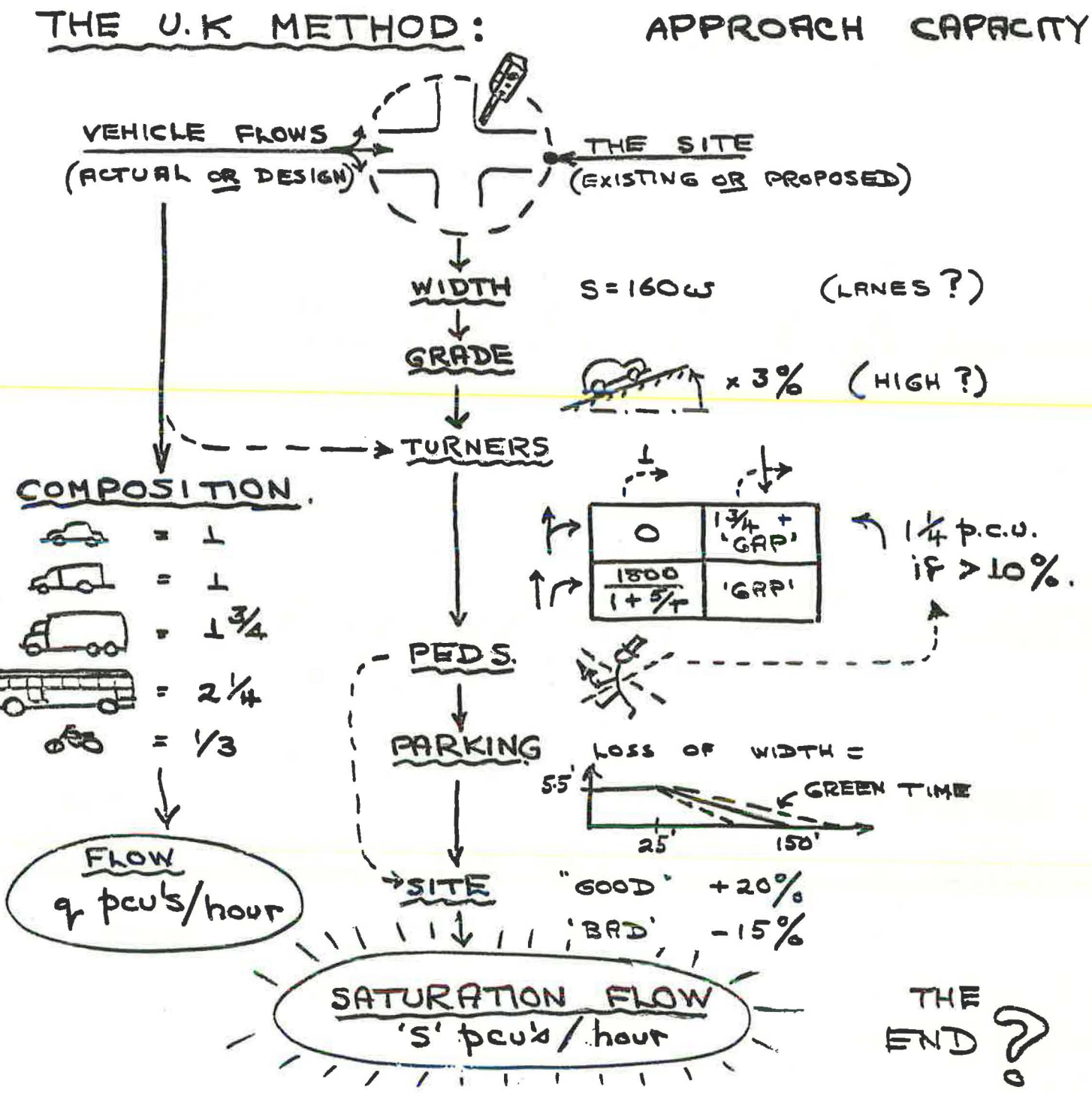
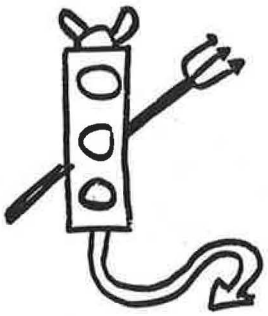


ILLUSTRATION 2

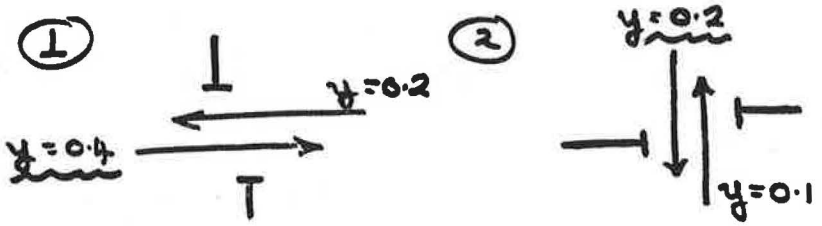


INTERSECTION CAPACITY

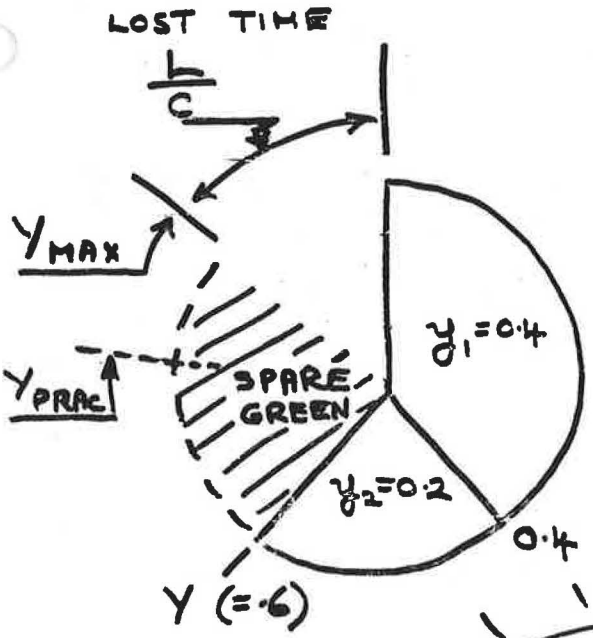


PER APPROACH:

$$y = \frac{\text{FLOW}}{\text{SATURATION FLOW}}$$



$$\therefore Y = \Sigma y \; (= 0.6)$$

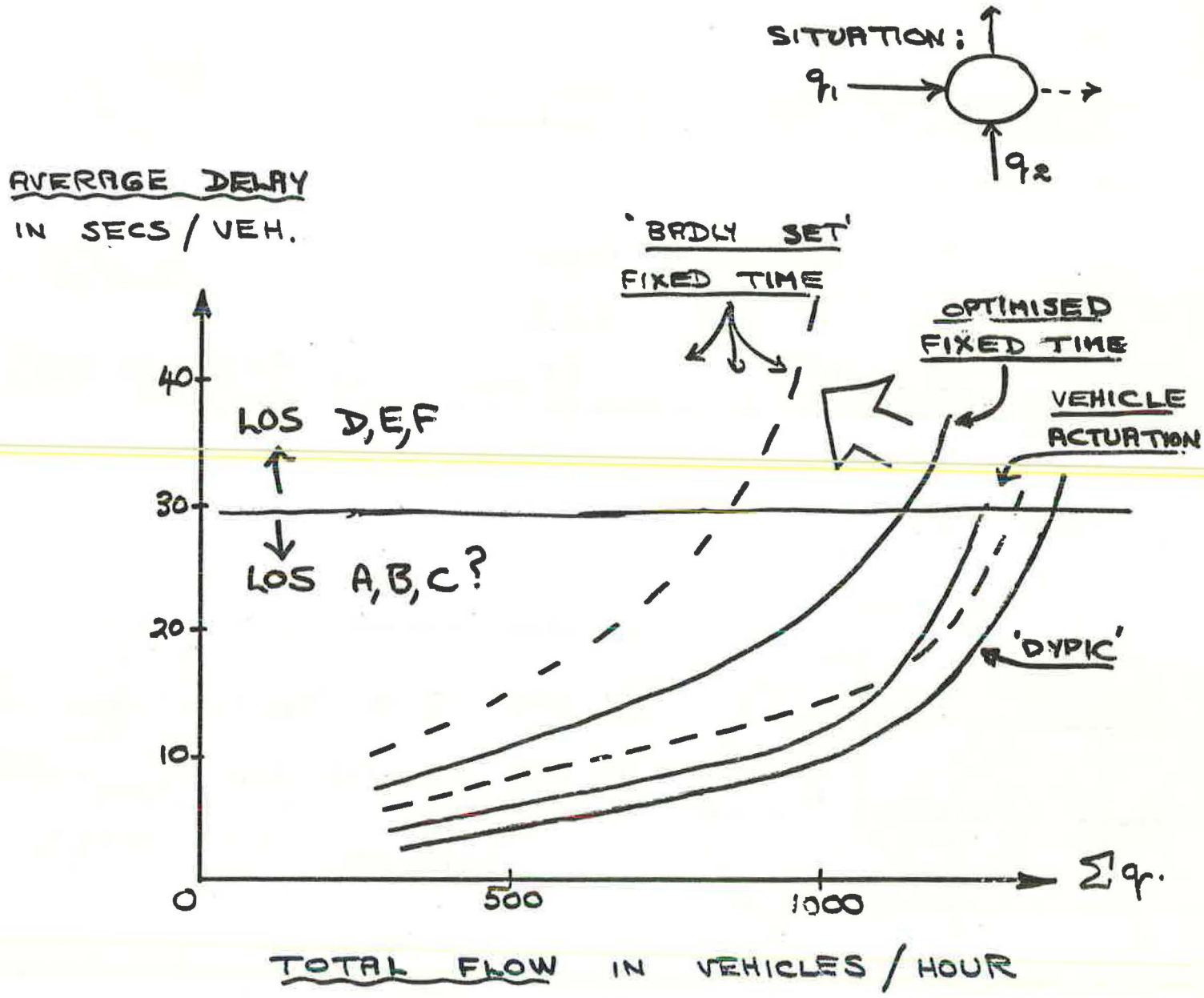


* MIN. CYCLE, $C_m = \frac{L}{1-Y}$
* MAX Y IS $Y_M = 1 - \frac{L}{C_m}$
* FOR $C_m = 120$ AND $Y_{PRAC} = 0.9\,Y_m$

$$Y_{PRACTICAL} = 0.9 - .0075L.$$

SO,

$$\%\ \text{RESERVE CAPACITY} = 100\left(\frac{Y_p - Y}{Y}\right)$$



THE DELAY CAUSED BY FOUR SIGNAL CONTROL POLICIES

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ILLUSTRATION 5

OECD RESEARCH GROUP T-8

DESCRIPTIONS OF INTERSECTION LOAD:

LEVEL OF SERVICE	DESCRIPTION		DELAY IN SECS/VEH	LOAD FACTOR	RESERVE CAPACITY	FLOW/CAPACITY
	FLOW	DELAY				
A	FREE	NONE		0	OVER 600	< 0·7
B	STABLE	VERY LITTLE	< 30	0 TO 0·1	251 TO 600	0·7 TO 0·8
C	STABLE	LITTLE		0·1 TO 0·3	176 TO 250	0·8 TO 0·9
D	NEAR UNSTABLE	MODERATE	30 TO 360	0·3 TO 0·7	126 TO 175	0·9 TO 0·95
E	UNSTABLE	APPRECIABLE		0·7 TO 1·0	76 TO 125	0·95 TO 1·0
F	FORCED	EXCESSIVE	OVER 360	OVER 1·0	0 TO 75	—

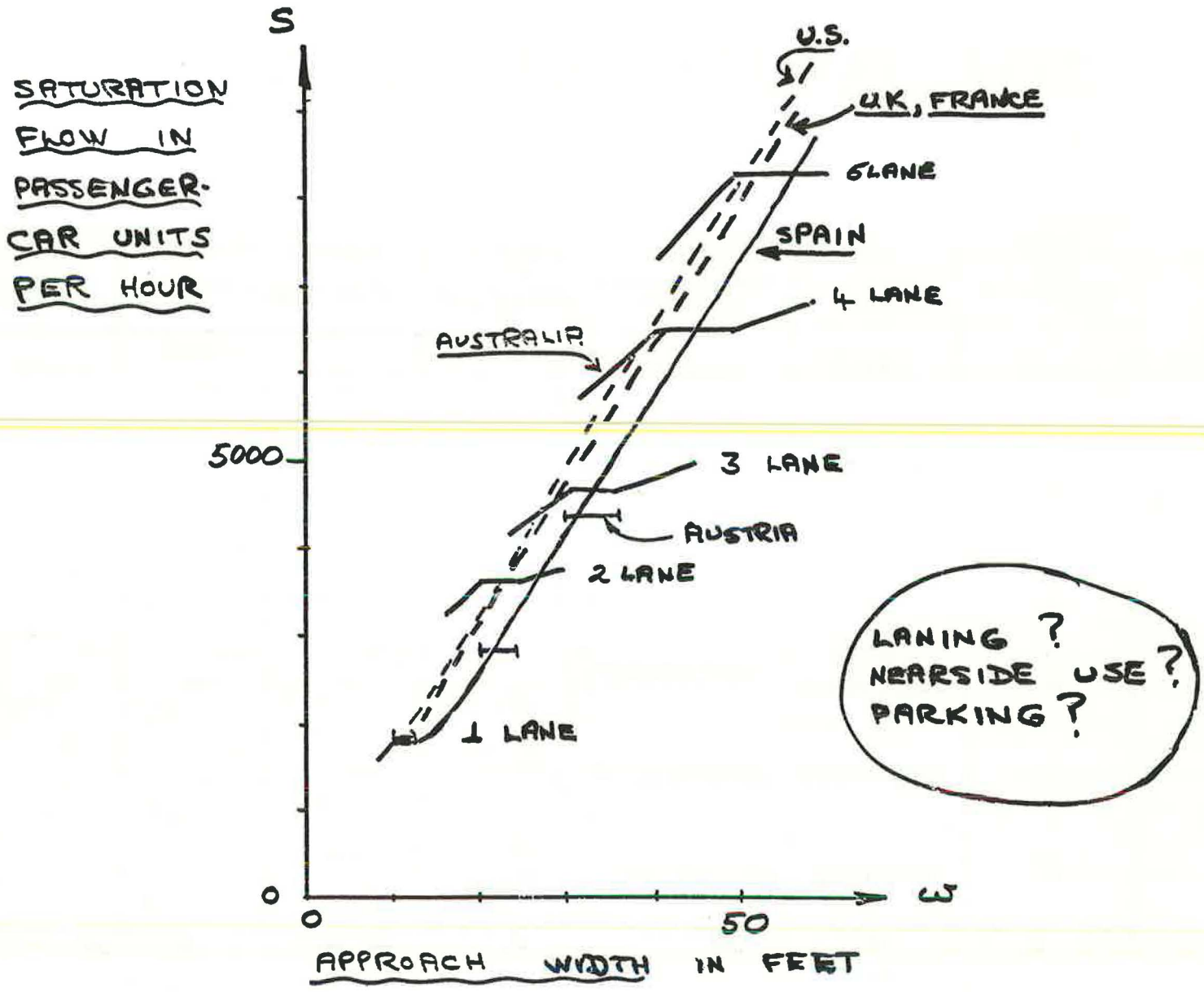
QUALITATIVE ONLY

DEPENDS ON SIGNAL CONTROL POLICY

RELATED MEASURES

GERMAN METHOD USING P.C.U's / HOUR OF CRITICAL STREAM

ILLUSTRATION 6



SATURATION FLOW v APPROACH WIDTH

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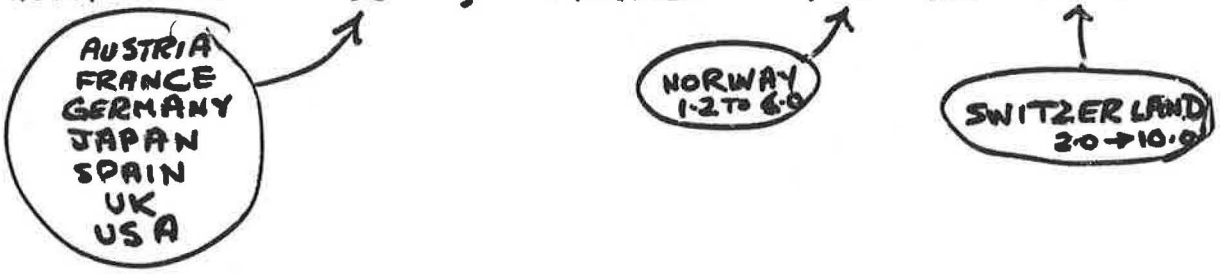
ILLUSTRATION 7

P.C.U. CORRECTION FACTORS :

COMPOSITION

P.C.U. EQUIVALENT FOR H.G.V AND BUSES:

NORMALLY = 2 ; RANGE 1·2 TO 10·0



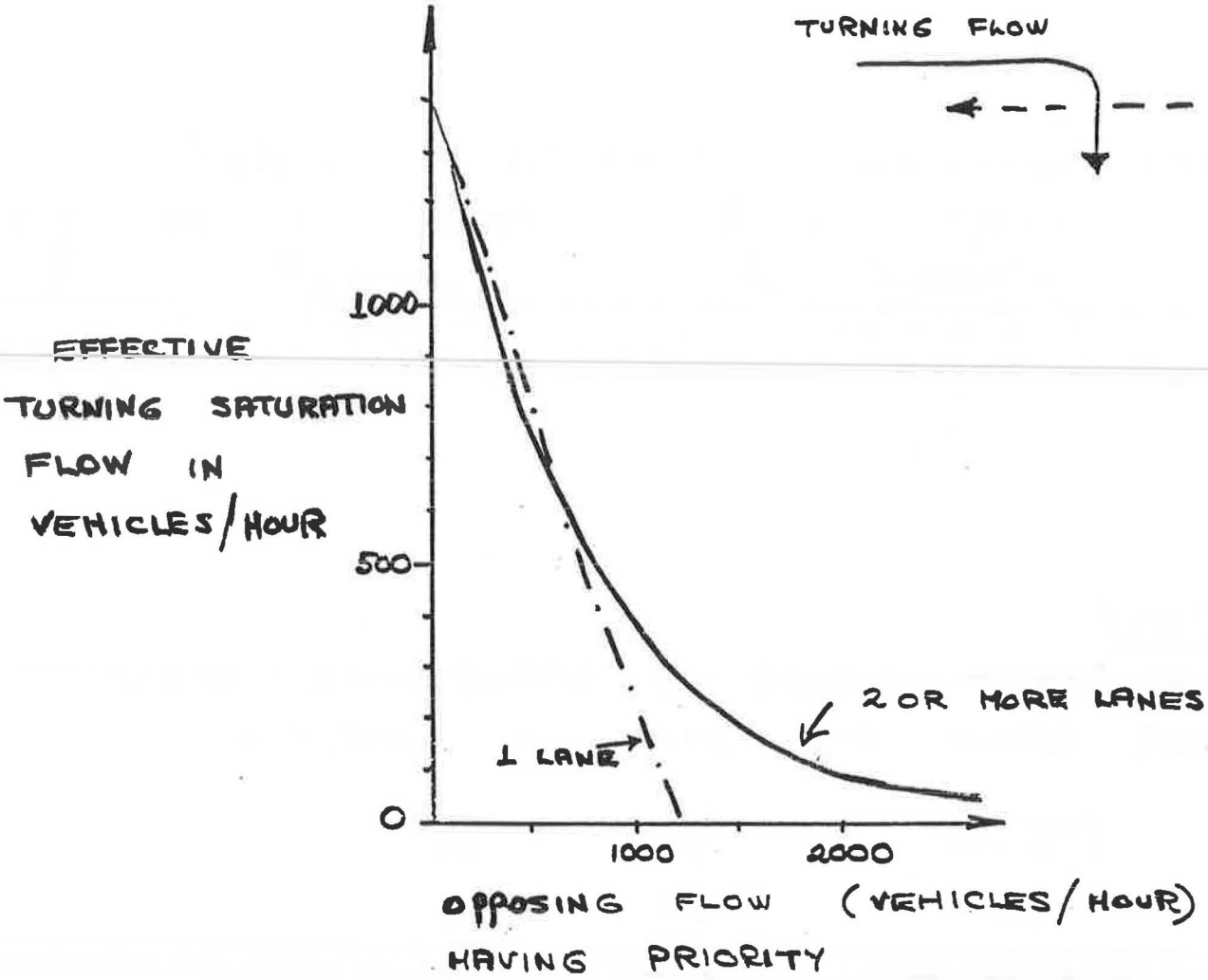
GRADE

PER CENT CHANGE IN SATURATION FLOW FOR EACH PER CENT OF GRADE:

COUNTRY	DOWN	UP	
UK	+3	-3	
AUSTRALIA	+½	-½	
GERMANY	+5	-10	
FRANCE	+1½	-1½	(VARIES)
USA	0	0	

ILLUSTRATION 8

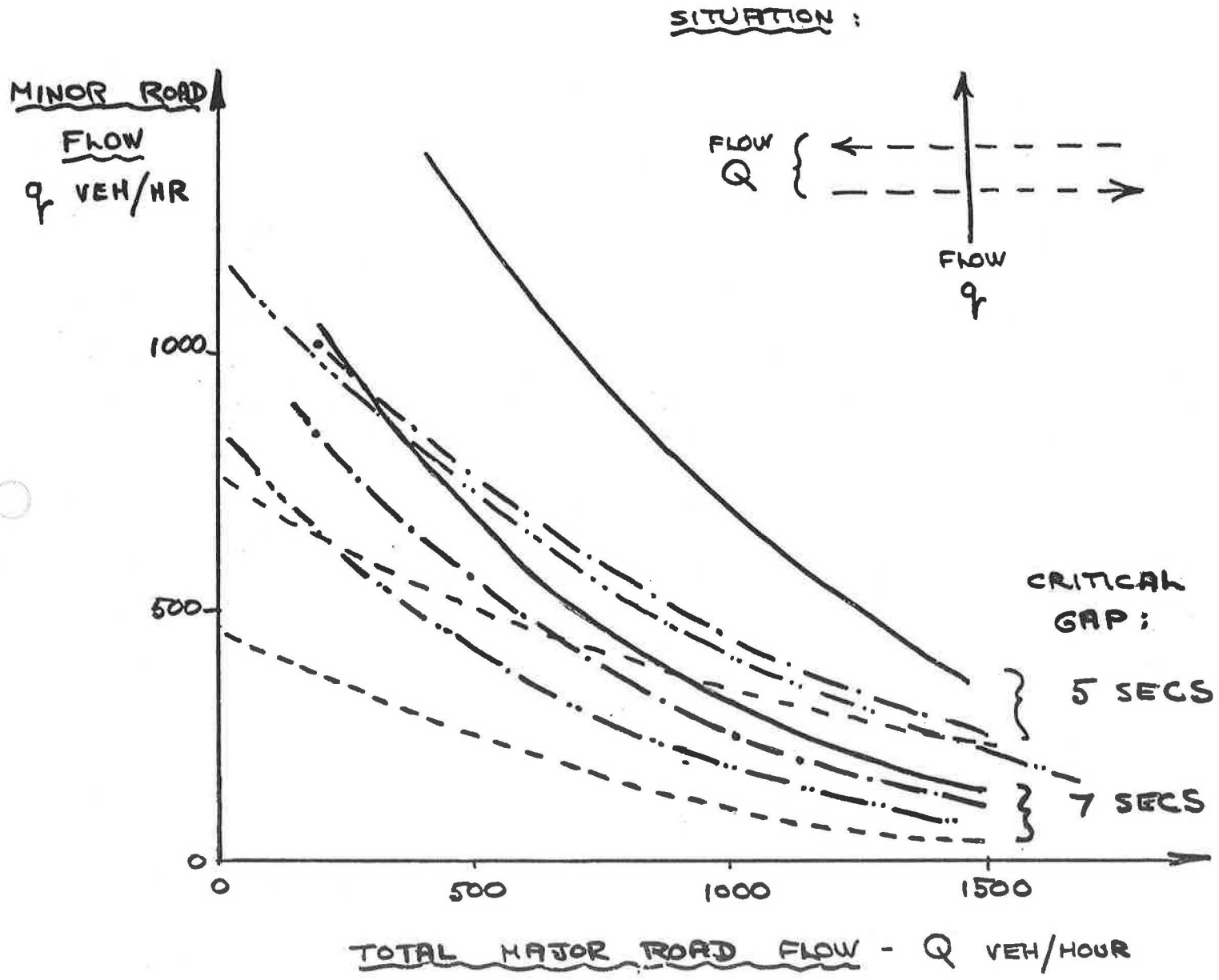
OPPOSED TURNING TRAFFIC:



* LIMITED VALIDATION
* LIMITED USE
* VARYING FLOW IN GREEN ?

TRRL DIR

ILLUSTRATION 9



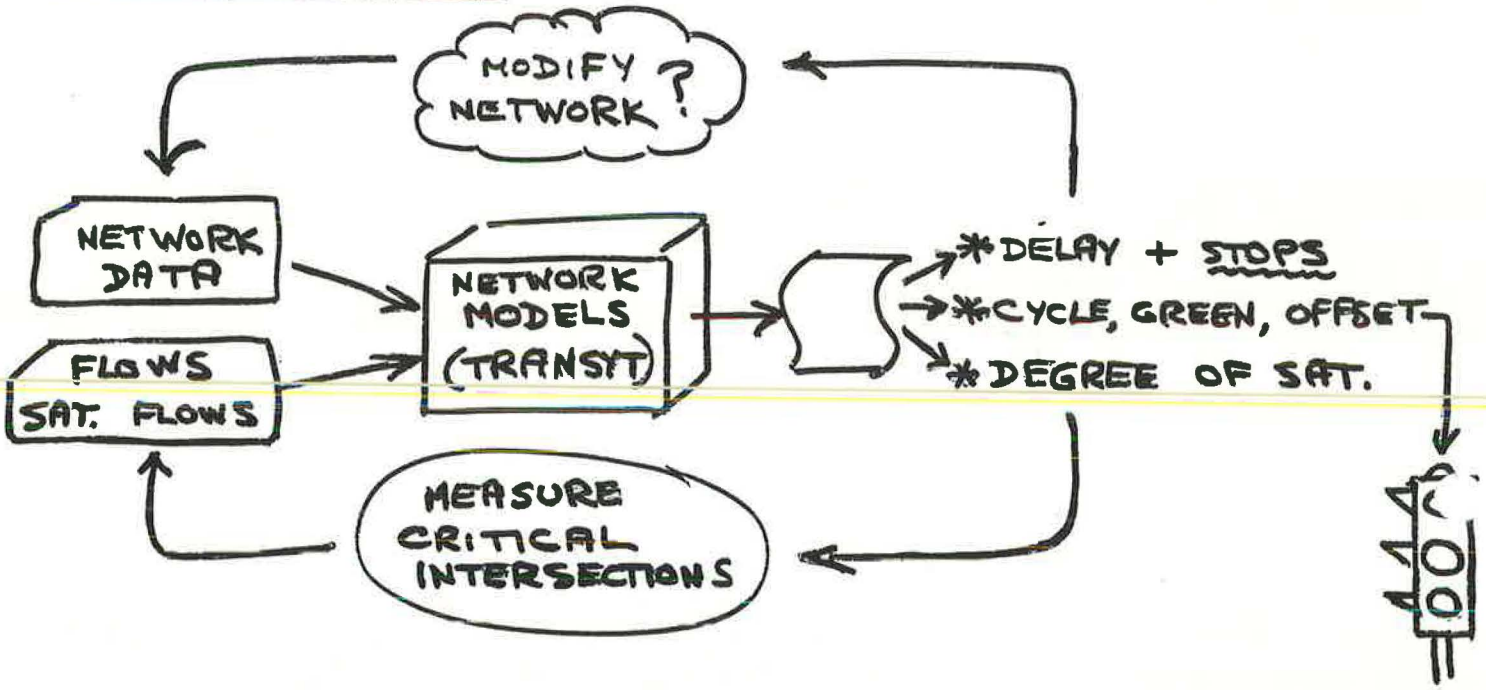
GAP ACCEPTANCE IN U.K., GERMANY AND NETHERLANDS.

TRRL.

ILLUSTRATION 10

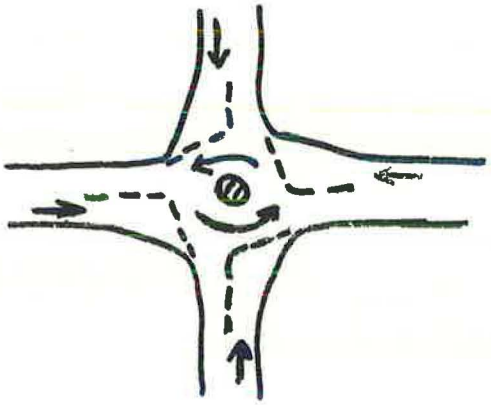
UK TRENDS:

1. URBAN AREAS ~ COORDINATED FIXED TIME PLANS



2. NON-URBAN.

MINI-ROUNDABOUT



DESIGN, CAPACITY, SAFETY

* FLARED APPROACHES
* OFFSIDE PRIORITY
* SMALL CENTRE ISLAND

MULTI-MINIS ?

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Yagar, Sam
Yu, Jason C.