INSTITUTE
OF
TRANSPORTATION ENGINEERS

TRANSPORTATION AND TRAFFIC ENGINEERING HANDBOOK

SECOND EDITION

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PRENTICE-HALL, INC., *Englewood Cliffs, New Jersey 07632*

Library of Congress Cataloging in Publication Data

Main entry under title:

Transportation and traffic engineering handbook.

At head of title: INSTITUTE OF TRANSPORTATION ENGINEERS.

Includes bibliographies and index.

1. Traffic engineering. 2. Transportation.
I. Homburger, Wolfgang S. II. Keefer, Louis E.
III. McGrath, William R. (William Restore),
date. IV. Institute of Transportation
Engineers.

HE333.T68 1982 388.3'1 82-340
ISBN 0-13-930362-6 AACR2

Editorial/production supervision
and interior design by Virginia Huebner
Page layout by Gail Collis
Manufacturing buyer: Joyce Levatino
Cover design by Edsal Enterprise

Printed in the United States of America

10 9 8

ISBN 0-13-930362-6

PRENTICE-HALL INTERNATIONAL, INC., *London*
PRENTICE-HALL OF AUSTRALIA PTY. LIMITED, *Sydney*
PRENTICE-HALL OF CANADA, LTD., *Toronto*
PRENTICE-HALL OF INDIA PRIVATE LIMITED, *New Delhi*
PRENTICE-HALL OF JAPAN, INC., *Tokyo*
PRENTICE-HALL OF SOUTHEAST ASIA PTE. LTD., *Singapore*
WHITEHALL BOOKS LIMITED, WELLINGTON, *New Zealand*

$$C_0 = \frac{L + 2.2\sqrt{L/S}}{1 - Y} \qquad (24.11)$$

where L = total lost time

Y = sum of critical flow to saturation flow ratios

S = lowest of saturation flows among the critical movements

Alternatively, the ARRB suggested that the Y value should be less than 0.7 in order to provide a reasonable level of service. A Y value of 0.7 is equivalent to a 65 to 85% probability of queue clearance.

Canadian Manual on Uniform Traffic Control Devices method.[34] By way of contrast, the *Manual on Uniform Traffic Control Devices for Canada* presents a table of phase time, which is the sum of the green and yellow change intervals required to provide a 95% probability that all vehicles arriving at an approach during a complete signal cycle will be able to clear during the next green interval. If the equivalent hourly volume in the heavy direction for each signal phase is known, the required time interval for any phase can be found in Table 24-6 by equating the volume for that phase against the sum of the volumes for all other phases.

TABLE 24–6
Phase-Time Requirements

Sum of the Equivalent Hourly Volume in the Heavy Direction on All Other Phases	Phase Time (s) Required When the Equivalent Hourly Approach Volume Is:											
	50	100	150	200	250	300	350	400	450	500	550	600
200	11	12	13	14	15	16	17	19	21	23	26	29
250	11	12	13	14	16	17	18	20	22	24	27	30
300	11	12	13	14	16	17	19	20	22	24	29	32
350	11	12	13	14	16	17	19	21	23	26	30	34
400	11	12	13	15	16	18	20	22	25	28	32	37
450	11	12	14	15	17	19	21	23	26	30	35	41
500	11	12	14	15	17	19	22	25	28	33	38	45
550	11	12	14	15	17	20	23	26	31	36	42	51
600	11	13	14	16	18	21	24	28	33	39	48	60
650	11	13	14	16	19	23	26	31	37	44	56	73
700	11	13	15	17	20	24	28	34	41	52	68	97
750	11	14	15	17	21	26	31	38	48	63	88	143
800	12	14	16	19	23	28	34	43	57	81	132	—
850	12	14	17	20	25	31	40	52	74	121	—	—
900	12	14	18	22	27	35	47	67	110	—	—	—
950	12	15	19	24	31	42	60	99	—	—	—	—
1000	13	16	20	27	36	53	88	210	—	—	—	—

SOURCE: *Manual on Uniform Traffic Control Devices for Canada*, Metric Ed., copyright Roads and Transportation Association of Canada, 1976.

Yellow change and clearance intervals

At the termination of a green phase, motorists approaching a signalized intersection are advised by a yellow signal indication that the red interval is about to commence[35]. The speed and location of some approaching vehicles will be such that they can stop safely at the stop line; others will have to continue at their speed or even accelerate into or through the intersection. The minimum length of the clearance interval (which may include an all-red interval after the yellow indication) should accommodate both situations and eliminate the possibility of a dilemma zone in which a driver can neither stop safely nor legally proceed into or through the intersection. See Table 24-7.

Gazis et al[36] analyzed this situation as follows. In order to come to a safe halt at the stop line:

$$x = t \cdot v + \frac{v^2}{2a} \qquad (24.12)$$

where x = the distance required for stopping (in ft or m)

t = the perception-reaction time (in s)

v = approach speed (in ft/s or m/s)

a = deceleration rate (in ft/s^2 or m/s^2)

A driver at distance x from the intersection is in the most critical position. This driver can proceed *into* the intersection if the clearance time is at least:

$$\tau_{min} = \frac{x}{v} = t + \frac{v}{2a} \qquad (24.13a)$$

or *through* the intersection if the clearance time is at least:

$$\tau_{min} = \frac{x + w + L}{v} = t + \frac{v}{2a} + \frac{w + L}{v} \qquad (24.13b)$$

where τ_{min} = the minimum clearance interval (in s)

w = the width of the intersection (in ft or m)

L = the length of the vehicle (in ft or m)

In jurisdictions whose vehicle codes permit vehicles to enter the intersection throughout the yellow change interval and clear after the red indication has appeared, equation (24.13a) gives the minimum value for the clearance interval. However, for safety reasons, yellow intervals of less than 3 s are seldom used. Local conditions may require the use of longer intervals, up to the values obtained by equation (24.13b), especially where sight distances at the intersection are poor. Since excessively long yellow indications might encourage driver disrespect, a maximum of about 5 s is used; if a longer clearance period is required, an all-red phase can be inserted to follow the yellow period.

The clearance intervals computed by equation (24.13b) should usually be used in those jurisdictions whose laws require vehicle to have crossed the intersection before the red indication appears.

Traffic signal system timing for arterial routes

A signal system is defined as having two or more individual signal installations which are linked together for co-

[34] "Traffic Control Signal Timing," *Manual on Uniform Traffic Control Devices for Canada*, Metric Ed., Apr. 1978.

[35] In Great Britain it is the practice to use the yellow clearance interval before the beginning of green as well as before the beginning of red. This is not permitted in the *Manual on Uniform Traffic Control Devices*.

[36] D. GAZIS, R. HERMAN, AND A. MARADUDIN, "The Problem of the Amber Signal Light Traffic Flow." *Oper. Res.* 8(1), 112–132, (1960).

TABLE 24–7
Minimum Theoretical Clearance Intervals* for Different Approach Speeds, Vehicle Lengths, and Cross Street Widths

Approach Speed mph	τ_{min} to Enter Intersection Formula (24.13a)	τ_{min} to Clear Intersection for Combined Vehicle Length and Crossing Street Width ($w + L$) Formula (24.13b)				
		60 ft	80 ft	100 ft	120 ft	140 ft
20	3.0†	4.5	5.2	5.9	6.6	7.2
30	3.2	4.6	5.0	5.5	5.9	6.4
40	3.9	5.0	5.3	5.6	6.0	6.3
50	4.7	5.5	5.8	6.0	6.3	6.6
60	5.4	6.1	6.3	6.5	6.8	7.0

*In seconds; assumed value of $t = 1$ s, of $a = 10$ ft/s^2.
†Minimum interval considered safe.

Note: 1 mph = 1.61 km/h; 1 ft = 0.305 m.

ordination purposes. To obtain system coordination all signals must operate with the same (common) cycle length, although in rare instances some intersections within the system may operate at double or one-half the cycle length of the system. The usual practice for actuated signals within a coordinated system is to provide a common cycle length as a background cycle with an appropriate main street offset. Although at individual intersections, the intervals (red, green, and yellow) may vary according to traffic conditions, it is desirable that the arterial for which coordination is being provided have a green plus yellow interval equivalent to at least 50% of the cycle length. Two intersecting systems form an open network whenever they have only one intersection in common (see Figure 24.11, upper left), and three or more systems form a closed network whenever they have three or more common intersections (see Figure 24.11, upper right).

Advantages

Some of the advantages of providing coordination among signals are:

1. A higher level of traffic service is provided in terms of higher overall speed and reduced number of stops.
2. Traffic should flow more smoothly, often with an improvement in capacity and decrease in energy consumption.
3. Vehicle speeds should be more uniform because there will be no incentive to travel at excessively high speed to reach a signalized intersection before the start of the green interval, yet slower drivers will be encouraged to speed up to avoid having to stop for a red light.
4. There should be fewer accidents because platoons of vehicles will arrive at each signal when it is green, thereby reducing the possibility of red-signal violations or rear-end collisions. Naturally, if there are fewer red intervals displayed to the majority of motorists, there is less likely to be trouble because of driver inattention, brake failure, slippery pavement, and so on.
5. Greater obedience to the signal commands should be obtained from both motorists and pedestrians because the motorist will try to keep within the green interval, and the pedestrian will stay at the curb because the vehicles will be closer spaced.
6. Through traffic will tend to stay on the arterial street instead of on parallel minor streets.

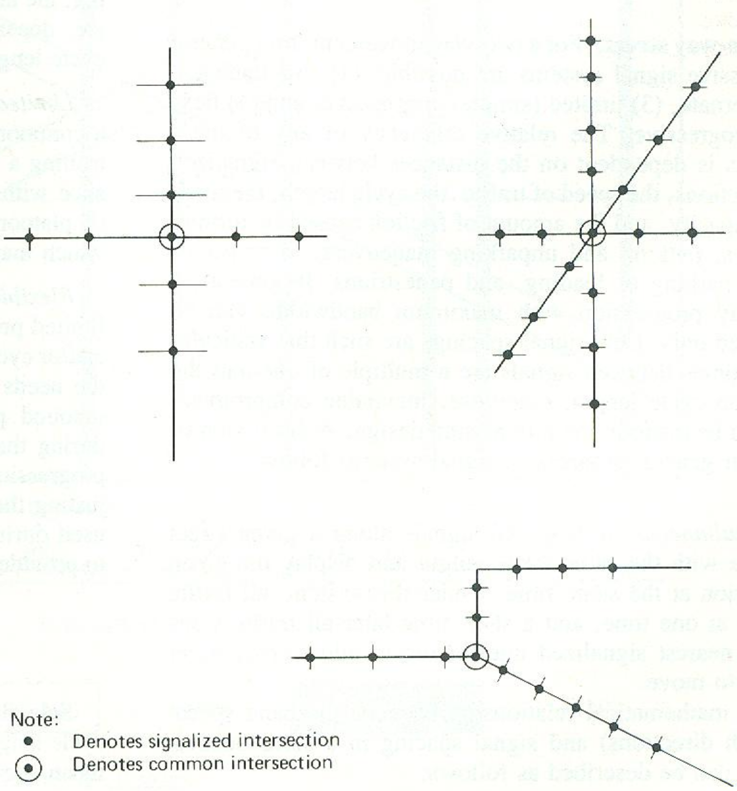

Figure 24.11. Examples of open networks.