Directional Flow Improvements on Urban Streets

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This paper discusses methods of improving prime direction flow on individual streets. It is limited to those methods that can be accomplished within existing rights-of-way and with minimum street reconstruction. This means either special lane designations, such as reversible lanes, exclusive use lanes, or specific turning and storage lanes, or reversible one-way operation of the entire street during certain hours of the day. All of the methods described are aimed for the ordinary city street, rather than the expressway or special parkway.

REVERSIBLE LANES

The reversible lane is one of the most efficient methods of providing for increased capacity. It can be employed on any street having three or more moving traffic lanes and directional peak volumes occurring at certain periods each day. The directional traffic volume should be at least 3 or 4 to 1 with existing conditions so congested that average speed decreases 25 percent during peak periods. There must also be adequate capacity at the terminals of any proposed reversible lane system.

The major advantage of such a system is that it can add significant street capacity with minimal initial capital costs. It also permits multi-lane operational efficiencies in the peak direction. These efficiencies are primarily due to the increased ability of faster moving traffic to pass slower or stopped vehicles.

A major disadvantage of a reversible lane system can be the reduced capacity and flexibility in the off-peak direction. It can also be quite hazardous if not adequately designated and signed. Such a system may also prove more costly in the long run if it postpones needed capital improvements or if it runs into costly maintenance and daily change-over expenses.

Methods of designation range from permanent overhead or roadside signs to permanent physical barriers with overhead lane signals. The least expensive method is the permanent roadside sign. Such a sign will give the hours of operation and the expected motorist behavior during those hours. This does not, however, provide any positive indication to the unobservant motorist of the time of operation or the specific lanes in which he is to drive. Hanging such signs directly over the affected lanes is somewhat better, but can still be confusing to the less capable driver.

In Detroit, Grand River Avenue has been operated for many years with four lanes in the peak direction and two lanes in the opposing direction during peak periods. The operation consists of large permanent signs hung over the two center lanes every two blocks with the following alternating messages for the inbound traffic: USE BOTH CENTER LANES—7:00 to 9:00 A.M.—Monday thru Friday and KEEP OFF BOTH CENTER LANES—4:30 to 6:30 P.M.—Monday thru Friday. The outbound signs have the times reversed. Before and after studies found that peak direction travel time was cut and that volume in the peak direction increased 41 percent.

Giving these signs interior illumination or making them of neon tubing will give the motorist a positive indication of the times of operation and will be far less confusing. Since they will not be visible during the off-peak hours, they can be made much more eye-catching during the times that they are used. Placing these signs often enough to be always visible to the motorist can run into considerable expense, however, especially if the wording is long or complex.

Using standard lane control symbols in place of words is the preferred method and will cut down on the size of the illuminated sign considerably. The Manual of Uniform Traffic Control Devices has specified a red X over any lane not meant for travel in that direction and a downward pointing green arrow for lanes in which travel is permitted. These signals are being used more and more frequently, and their meaning is becoming accepted by most motorists. They are very easy to maintain and operate, and provide a positive indication of both lane of travel and time of operation. They do have a rather high initial installation cost, and in commercial areas the overhead lane signals tend to get lost in the background lights. They must also be placed far enough away from signalized intersections to avoid being confused with the regular traffic signals.

Chicago has used overhead lane signals on its Hollywood-Ridge system for almost ten years with very successful results. Both streets are four lanes and provide for three lanes in the peak direction. The lane signals are the recommended red X and downward pointing green arrow. The entire system cost $72,000 and is slightly more than one mile in length. Two-way volume increases of more than 50 percent (from 2250 to 3550 veh/hr during the peak hour) were noted on Ridge Avenue. No significant changes in accident experience were noted, and in more than nine years of operation, there has never been a head-on collision involving any of the reversible lanes. Parking is prohibited on both sides, at all times.

Detroit has recently installed a combination sign and signal arrangement over the center lane of Michigan Avenue, a five-lane roadway. The sign can either show a red X with No Left Turn legend, a green arrow with a No Left Turn legend, or no symbol at all with an Only Left Turn legend. This last legend is for off-peak periods and allows the center lane to be used for left turns from either direction. Parking is prohibited at all times. This system has produced volume increases in the peak direction of from 4 to 20 percent in the morning peak period and up to 7 percent in the evening. Travel time during these two periods has decreased 19 and 20 percent, respectively, and average speed is up 23 percent. There has also been an overall accident decrease of 19 percent, although most of this was due to a 93 percent decrease in accidents with parking vehicles brought about by the full-time prohibition of parking. The decrease in non-parking accidents has been 4 percent.

An even more positive designation of reversible lane usage can be obtained through the use of pedestal signs and cones. These signs and cones are manually placed out on the street at the start of each rush period, and are removed when traffic returns to normal. Although there is only a small initial cost outlay, this method involves costly daily maintenance and change-over manpower expense and can be quite hazardous if the cones are not spaced often enough or if a number of consecutive cones gets knocked out of position by passing cars.

Los Angeles was the first city to use reversible lanes during the peak periods, and these lanes are almost completely designated by manually placed signs and cones. The first installation was made in 1928 and there are now approximately thirteen miles of streets using reversible lanes. The total annual operation cost is a little less than $2,000 per lane mile. A study of accident reports reveals in general that the accident rate per million vehicle-miles is much less on these streets than on major streets where lane reversal is not used. Field observations indicate a more satisfactory operation, in terms of smoothness of flow and frequency of stops, and decreased travel times ranging from 1 to 15 min.

Milwaukee used both overhead lane signals and manually placed cones on a six-lane street designated as an interim freeway terminal distributor system. This seven-block stretch of West Clybourn Street was placed in operation in 1963 and has handled two-way traffic volumes of 55,000 veh/day, with as many as 4,000 veh/hr in the peak direction. The data from these five cities are summarized in Table 1. Other successful systems have been installed in Cleveland, Louisville, Memphis, Cincinnati, Arlington, and New York City, where the five-lane Queensborough Bridge uses overhead red and green lane signals.

Permanent physical barriers give the best indication of proper lane usage, but are not usually applicable to normal city streets. On bridges and viaducts, however, where there is no entering or crossing traffic to contend with, this method can be quite useful.

TABLE 1

EXAMPLES OF REVERSIBLE LANES

City	Street	No. of Lanes	Type of Installation	Reported Results
Detroit	Grand River Ave.	6	Overhead signs	Travel time cut. Peak-direction volumes up 41%.
Chicago	Hollywood-Ridge	4	Overhead signals	Two-way volumes up 50%. No increase in accidents.
Detroit	Michigan Ave.	5	Overhead signs and signals	Peak-direction volumes up 4-20%. Travel times down 19-20%. Average speed up 23%. Overall accidents down 19%. Non-parking accidents down 4%.
Los Angeles	13 miles of streets	Varies	Manually placed cones and signs	Accident rate less than streets without lane reversal. Travel times decreased 1-15 min.
Milwaukee	W. Clybourn St.	6	Overhead signals	Interim freeway terminal distributor. Peak direction volumes as high as 4,000 vph.

This usually takes the form of reversible lanes in the center separated from the regular lanes on either side by small curbs or barriers with appropriate signing and channelization at each end. This method is very easy and inexpensive to maintain and operate, but it can be costly to install and is, by its very nature, a much more permanent type of control.

New York City's eight-lane George Washington Bridge with its two-lane physically separated reversible center roadway is an excellent example of this reversible lane technique. Chicago's eight-lane Lake Shore Drive with its three sets of hydraulically operated divider fins is another specialized reversible lane technique that will probably not be applicable to most situations.

SPECIAL LANE DESIGNATIONS

Other special lane designations are left-turn only and right-turn only lanes. These special uses of lanes are quite common, and their efficiency and safety are well established. The most common deficiencies of these types of lane designations are inadequate tapers (should be 20 to 1 on most city streets) and failure to line up through lanes across intersections. Allowing paint markings to deteriorate to the point where they are no longer visible is another deficiency. This has become a common type of improvement, with additional information readily available in the traffic literature.

REVERSIBLE ONE-WAY ROADWAYS

Occasionally, special lane designations or even reversible lanes are not adequate to handle the rush hour traffic in the peak direction. In some situations it may be possible to make the entire street one-way in the peak direction during certain periods of the day. Such an installation has all the advantages of reversible lanes, without the confusion or hazard of opposing lanes of traffic on the same street. However, it does not provide for the off-peak direction at all and can be quite complicated and confusing at the terminals and at intersecting streets.

There are two basic situations where this type of improvement can be applied. The most common is at a specific bottleneck where a reversal of a short street segment of bridge, or the creation of a short reversible roadway segment with no intersecting roadways between the two terminals, will handle the necessary volumes. In either case, some facilities must be available for traffic flowing in the opposite direction. This can be a nearby bridge or a paralleling street or any other logical and convenient traffic rerouting plan. This will require careful planning at the segment terminal and may require expenses for daily maintenance and change-over manpower.

An example of this type of reversible roadway is a two-lane turning roadway in effect at the intersection of Sheridan and Devon in Chicago. The roadway is approximately 300 ft in length and handles a heavy left-turn movement in the morning and the reverse right-turn movement in the evening. It is used in conjunction with a reversible lane system on Sheridan Road, and is designated by cones, pedestal signs and two internally illuminated signs. During non-rush hours it is used as a right-turn only lane. This roadway was installed to handle peak hour turning demands of over 2000 veh/hr and has resulted in a very smooth and improved method of operation.

The other application of the reversible one-way roadway is the reversal of an entire street for a number of blocks during certain parts of the day. Again, provision must be made for the opposing flow on adjacent streets, and the terminals must be adequately signed and channelized. In addition, particular care must be exercised at intersecting streets to prevent motorists from using the street in the wrong direction during times of one-way operation. This can be done with special one-way and turn prohibition signs listing the hours during which they are in effect or with internally illuminated or neon signs that are lit only during the appropriate hours. The regular signs can be quite confusing to the unitiated or less capable driver, while the illuminated signs are considerably more expensive.

One of the best examples of this type of operation is the reversal of 13th Street in Washington, D.C., during the rush hours. This four-lane street, normally a two-way street, is made one-way inbound during the morning rush and one-way outbound in the evening. Blank out neon one-way arrows are used on all cross streets along 13th Street. These radio-controlled flashing red arrows indicate to approaching motorists the direction of travel on 13th Street during the a.m. and p.m. rush hours. At all other times the arrows are dark, thereby indicating two-way operation. This street has been successfully operating as a reversible one-way street for over two decades. It is an excellent example of squeezing out maximum capacity on a relatively narrow and otherwise inadequate city street.

CONCLUSIONS

It is possible to improve prime direction flow on individual city streets without major reconstruction or right-of-way acquisition. The reversible lane can be a very efficient method of providing increased capacity with minimal initial capital costs on any street having three or more moving traffic lanes and directional peak volumes occurring at certain periods each day. However, the use of reversible lanes will reduce capacity and flexibility in the off-peak direction, can run into costly daily maintenance costs, and can be quite hazardous if not properly executed. Most applications of reversible lanes have proved quite successful with sizable increases in traffic volumes, significant decreases in travel time, and no adverse accident experiences.

Where reversible lanes are not capable of handling the rush-hour traffic, it is sometimes possible to make the entire street one-way in the peak direction during certain periods of the day. This avoids the hazard of having opposing lanes of traffic on the same street, but it does increase the confusion at the terminals and intermediate street intersections and drastically affects the off-peak direction traffic capacity.

REFERENCES

1. Dorsey, R. I. The Use of the Off Center Lane Movement in Los Angeles. Traffic Quarterly, Eno Foundation, Vol. 2, p. 291, 1948.
2. Todd, Mansfield M. Reversing Flow in Center Lane of Three Lane Roads. Proc. ITE, 20th Annual Meeting, 1949.
3. Todd, Mansfield M. Effects of Reversible Lane Movement Signalization of Three Lane Highways. HRB Proc., Vol. 30, pp. 346-354, 1950.
4. Watkins, W. F. New Plans for Some Old Streets. Traffic Quarterly, Eno Foundation, Vol. 4, 1950.
5. Traffic Engineering Handbook. ITE, 2nd Ed., pp. 326-329, 1950. (Also 1965 Ed., pp. 559-565.)

6. Dorsey, R. I. Off Center Aids a City Solution. Proc. ITE, 22nd Annual Meeting, 1951.
7. Lyman, E. C. Lane Directing Signals Aid in Solving Traffic Problems. Municipal Signal Engineer, Vol. 16, 1951.
8. Zimmerman, T. W. Reversible Sign Technique. Traffic Engineering Magazine, pp. 415-416, August 1954.
9. Matson, T. M., Smith, W. S., and Hurd, F. W. Traffic Engineering, McGraw-Hill Book Company, pp. 302-303, 403, 1955.
10. Rice, T. T. Unbalanced Traffic Flow on Three and Four Lane Streets. Traffic Quarterly, Eno Foundation, Vol. 10, pp. 137, 153, Jan. 1956.
11. AASHO. A Policy on Arterial Highways in Urban Areas. Pp. 208, 229-230, 280, 282, 285, 353-354, and 434, 1957.
12. Bugge, W. A. The Seattle Freeway. Traffic Quarterly, Eno Foundation, pp. 69-79, Jan. 1958.
13. Here's How to Handle Rush-Hour Traffic. Engineering News-Record, Vol. 161, No. 6, pp. 30-34, Aug. 14, 1958.
14. Technical Committee 3F, ITE. A Survey of Off Center Reversible Lane Operational Techniques. Traffic Engineering Magazine, pp. 43-48, Oct. 1958.
15. Technical Committee 3F, ITE. Off Center Lane Movements. Traffic Engineering Magazine, pp. 43-49, Nov. 1958.
16. Forbes, T. W., Gervais, E., and Allen, T. M. Effectiveness of Symbols for Lane Control Signals. HRB Bull. 244, pp. 16-29, 1959.
17. Eason, S. D. Reversible Lanes on the Seattle Freeway. Washington State Highways Dept., 1959.
18. Bugge, W. A. Planning for the Seattle Freeway. ASCE, Los Angeles Meeting, Feb. 1959.
19. Radio Control for Reversible Flow. Traffic Engineering, Vol. 29, No. 5, pp. 16-17, Feb. 1959.
20. Exnicios, T. F. Report on Unbalanced Traffic Flow Operations. ITE, 30th Annual Meeting, Chicago, Illinois, Sept. 1960.
21. McGarthy, D. A Reversible Roadway. Highway Highlights, pp. 8-9, April 1961.
22. May, A. D., Jr. Squirrel Hill Tunnel Operations Study. Ramo-Wooldridge, Aug. 1961.
23. "Zipper" Funnels Expressway Traffic. Street Engineering, Vol. 6, No. 12, pp. 16-17, Dec. 1961.
24. Hoose, H. T. Peak-Hour Parking Restrictions and Reversible Lanes in CBD. Proc. ITE, 1961.
25. Morse, R. W. Reversible Roadway for Seattle Freeway. N.Y. American Society of Civil Engineers, Proc., 1964.
26. Armored Train "Zippers" Guard Reversible Lanes. Highway Highlights, pp. 12-13, Jan. 1962.
27. Still, R. C. Four and One-Half Miles of Lane Control Signals. Municipal Signal Engineer, Vol. 27, No. 2, pp. 22-24, March-April 1962.
28. Still, R. C. Continuous Signal Controlled Reversible Lanes. Traffic Engineering and Control, Vol. 3, No. 12, April 1962.
29. Bartelsmeyer, R. R. Reversible Freeway Lanes on the Northwest Expressway in Chicago. Traffic Quarterly, Eno Foundation, Vol. 16, No. 2, pp. 155-172, April 1962.
30. Reversible Lanes Speed Expressway Traffic. American City, Vol. 77, No. 5, pp. 98-100, May 1962.
31. Cottingham, K. E. A Proposed Surveillance System on the Seattle Freeway. Traffic Engineering, Vol. 32, No. 9, pp. 21-24, June 1962.
32. Arnold, S. R. Tidal Flow Traffic. Traffic Engineering and Control, Vol. 4, No. 8, pp. 452-454, 456, Dec. 1962.
33. May, A. D., Jr., and Fielder, D. Squirrel Hill Tunnel Operations Study. HRB Bull. 324, pp. 12-37, 1962.
34. Greenberg, J. Preliminary Analysis of the Lincoln Tunnel Changeover Problem. Report of The Port of New York Authority, Tunnels and Bridges Dept., April 1963.

35. Hoose, H. T. Planning Effective Reversible Lane Control. Traffic Quarterly, Eno Foundation, Vol. 17, No. 3, pp. 408-413, July 1963.
36. Wake, A. G. Reversible Lanes Reduce Congestion at Little Cost. Traffic Engineering, Vol. 34, No. 8, pp. 39-40, May 1964.
37. Hutchison, A. L. Reversible Lane Operation. International Road Safety and Traffic Review, Vol. 12, No. 3, pp. 29-32, Summer 1964.
38. Jennings, S. W. Tidal Flow Working on Albert Bridge. Traffic Engineering and Control, Vol. 6, No. 8, pp. 401-505, Dec. 1964.
39. Gazis, D. C. Optimum Assignment of a Reversible Lane in an Oversaturated Two-Way Traffic Link. IBM Watson Research Center, June 1965.
40. Thorpe, J. D. Off-Centre Street Operation in Melbourne. Traffic Engineering, Vol. 36, No. 11, pp. 26-30, Aug. 1966.
41. Traffic Engineering Handbook. ITE, 1966.
42. DeRose, Frank, Jr. Reversible Center-Lane Traffic System—Directional and Left-Turn Usage. Highway Research Record 151, pp. 1-17, 1966.
43. Mitton, John. Effect and Advantages of the Use of Reversible Street Practices. Proc. ITE, pp. 86-89, 1946.
44. Fencl, R. G. Jackson Boulevard Analysis of Traffic Operations. HRB Proc., Vol. 30, pp. 297-313, 1950.
45. First Aluminum Traffic Control Arches. Civil Engineering, p. 365, June 1951.
46. Traffic Improvement Plan for the Central Business District, Philadelphia, Pennsylvania. Wilbur Smith and Associates, pp. 65-71, 91, 1957.
47. Manual on Uniform Traffic Control Devices. June 1961, pp. 225-228.
48. Bruening, M. E. 6-Lane Street...8-Lane Performance. Traffic Engineering, pp. 16-18, June 1964.
49. Benefit Analysis of Olympic Boulevard Reverse Lane Control. Los Angeles Bureau of Traffic Research Staff Report, June 3, 1965.

Addendum

On 13th Street, N.W., in Washington, D.C., the signs shown in Figure 1 were found to be confusing.

The local police precincts indicated on several occasions that the black and yellow multi-message signs were difficult to read and confusing. When the signing was converted to blank-out type neon indications this confusion was eliminated immediately. A sample of these flashing neon one-way messages with a reversible arrow is shown in Figure 2.

This part-time one-way operation is in effect on 13th Street, N.W., southbound only between 7:00 and 9:30 a.m. and northbound only between 4:00 and 6:30 p.m., Monday through Friday. The balance of the time 13th Street operates as a two-way roadway.

Connecticut Avenue, N.W., is a 60-ft wide roadway with parking normally permitted on both sides of the street. However, during the morning and evening rush hours, Monday through Friday, this major arterial street operates four lanes in the predominant direction of traffic flow and two lanes in the opposite direction. Parking is prohibited during the rush hours on both sides of the street.

The only notification given to motorists concerning this reversible lane operation is a regulatory sign mounted at the curb at the beginning of each block. This black on white rectangular sign merely states "4 Lanes—7-9:30 a.m., 2 Lanes—4-6:30 p.m. Monday through Friday." These signs are over 30 ft to the right of a motorist in the center lane and often times are obscured by buses or trucks in the curb lane.

The pavement markings on this street are a solid white centerline and white stripe lane lines. This arrangement leaves much to be desired during the hours of reversible lane flow. Although exact figures are not available, a number of rush hour traffic

Figure 1.

Figure 2.

surveillance people, and also the police accident investigation units, have reported mishaps relating to this 4 to 2 lane rush-hour operation. Fortunately, records do indicate that no fatalities have occurred in connection with this little publicized unbalanced rush-hour lane operation. The real answer to this problem, of course, is the use of overhead lane control signals which have not been accepted to date.