Reversible Lane: Exploring Lane Management Alternatives

Vijay R. Ezapa Arvind, M.S.C.E. and Emelinda M. Parentela, Ph.D., P.E.
California State University, Long Beach.

Abstract. Traffic moves on the roadway in a particular direction depending on time and location. In some cases, traffic lanes are over-utilized in one direction while the opposing lanes are under-utilized. In order to optimize flow and minimize traffic delay, reversible lanes or tidal flow lanes are sometimes implemented to serve traffic in either direction depending on need at various times of day. A reversible lane could be confusing to drivers, which could compromise safety.

This paper evaluates the potential of using various technologies such as in-pavement warning lights, retractable bollards, and electro-luminescent paint as channelizing devices to manage reversible lanes. In-pavement warning lights and retractable bollards have been used as traffic control devices. However, the use of electro-luminescent paint is an idea that the authors propose to explore, assuming technology is available that would make this paint of high quality and durability like those of retro-reflective paints used in pavements. These technologies can provide adequate guidance for drivers to follow the direction of traffic flow and eliminate wrong-way driving, which is a common problem in reversible lanes.

INTRODUCTION

Traffic congestion is a problem in most urban cities, and is progressively getting worse. The widening or construction of new roads to address congestion is a complex problem because of lack of form of funding and right of way, and the short-term impact on traffic flow because of construction activities. Majority of roadways are overbuilt, for a certain hours of a day and there needs to be development of methods and strategies by which the optimum utilization of existing infrastructure can be done.

Reversible lanes are used to mitigate congestion caused by unbalanced directional traffic flow, especially during peak-hour. The outcome of a reversible lane is an improvement in directional flow volume. On a reversible lane, traffic can move in either direction, depending on time of day. Overhead signs are used to inform the direction of traffic flow for motorist. Recently, a new concept known as movable barrier system is being used to reorganize the alignment of roads according to the prevailing traffic demand. As the name suggests, the barriers are realigned by using a moving machine installed on to the truck that moves the heavy barriers from one side to other side. Major drawback of this process is, it takes a considerable amount of time for realignment of lanes.

Reversible lanes take advantage of underutilized lanes by reorienting the direction of traffic flow at certain times of day. It is an interesting concept because reversible lanes can increase the capacity of a roadway significantly without major investments in roadway or control infrastructure. The basic principle of a reversible lane is simple; however, its implementation needs clear planning for safe and efficient operation.

Safety is a major hurdle in the implementation of reversible lanes. Reports suggest an increase of vehicle collisions in areas where reversible lanes are implemented [1][2]. The primary cause of collisions is the driver's limitations of understanding and failure to follow the traffic rules as directed. Limitations of the drivers understanding is reflected in Swedish psychologist Rumar's conclusion that the driver is an "outdated human with stone-age characteristics and performance who is controlling a fast, heavy machine in an environment packed with unnatural, artificial signs and signals." Signs and pavement markings have to convey appropriate information to driver and must not lead to confusion that may result in wrong way driving, as is the case in most reversible lanes. Reversible lanes with enhanced safety features will be very helpful in optimizing directional traffic demand.

The aim of the study is to propose new concepts and strategies to manage directional flows in reversible lanes on both freeways and urban roads, and to make reversible lanes an attractive alternative for solving traffic congestion.

LITERATURE REVIEW

The American Association of State Highway and Transportation Officials (AASHTO) suggest, “65 percentages or more traffic moving in a particular direction during peak hours justifies the application of reversible lanes” [3]. There are many computational studies done on reversible lanes, which reinforce the claim of adjusting the number of lanes in each direction depending upon traffic demand on hourly basis. However, the problem with the implementation of reversible lanes is the risk of safety of the commuters as there are chances of drivers getting confused leading to a dangerous traffic scenario. The modern advancement of reversible lanes leads to Dynamic Lane Reversal [4]. It is a concept by which the lane directionality is updated quickly and automatically in response to the instantaneous traffic conditions recorded by the traffic sensors. Matthew Hausknecht and his team studied the effectiveness of dynamic lane reversal by comparing the programming formulation of a standard approach and contra flow approach. Using integer linear programming formulation and bi-level programming formulation, they computed an optimum lane reversal configuration that increased the efficiency of the network by 72%. The major drawback in implementation of lane reversal is the method of communication, which informs the drivers about the present traffic scenario. According to a study by Lamberti and Wolshon, drivers tend to use normal-flow lane until it becomes more crowded, and then begin to move into the adjacent and less utilized reverse-flow lane [2]. This shows the confidence levels of drivers pertaining to reversible lanes and its usage. It also suggests most of the drivers are comfortable in tailgating a car, which is already there instead of going alone. These drawbacks have to be overcome in order to pave a way for wider implementation of reversible lanes.

PROPOSED APPROACHES FOR REVERSIBLE LANE MANAGEMENT

Normally, on a traditional roadway, opposing vehicular traffic is separated using the Hines centerline concept that conveys the driver not to cross over the solid yellow line at each and every movement throughout the drive. However, this concept is not appropriate to use while implementing the reversible lane as the centerline has to be changed depending upon traffic demand. The current practice utilizes a combination of broken yellow markings on the pavement and overhead variable message signs. These signs notify the driver initially, but do not bind or remind the driver all the way along the road to follow the unmarked centerline. Therefore, there has to be a method, which can guide the driver throughout the entire segment of the reversible and prevent the driver from occupying the opposing lane. A mechanism is needed to remotely control the reversible lane based on traffic demand and clearly guide the drivers on the direction of traffic flow. The succeeding discussions describe three technologies that can potentially be used to manage reversible lanes. These are the electro-luminescent paint, the in-pavement LED markers, and the fully automated retractable bollards.

<u>Use of Electro-Luminescent Paint:</u> Electro-luminescent paint is a paint that illuminates with the passage of electric current. Its practical implementations are in very early stages, and mostly confined to motorcycle paint industry. This paint can be innovatively used in the transportation field because of its numerous merits. The motivation of using this paint on a reversible lane is to increase visibility of pavement markings to keep the driver aware of the direction of traffic.

Traditional roadways maintain one solid yellow line to separate opposing flows. On reversible lane, our proposed method utilizes three electro-luminescent solid yellow lines, which can be turned on and off depending on traffic demand.

Considering a roadway with four lanes, two in each direction, the scenarios described below and illustrated in Figure 1 are possible.

<u>Scenario 1</u>: When traffic in the westbound direction is flowing heavily compared to the opposing direction, an electro-luminescent solid yellow line separating the inner and outer eastbound lanes will be illuminated to indicate a change in lane usage favoring the direction of heavy traffic flow, thereby attaining a ratio of 1:3 for minor and major traffic lanes.

<u>Scenario 2</u>: When traffic flowing in both the directions is at or near equal ratio, then the solid yellow line partitions the lanes in the ratio 2:2. This indicates two lanes are provided in one direction, and two lanes in the opposite direction. A solid electro-luminescent yellow line in the middle of opposing lanes will be illuminated.

<u>Scenario 3</u>: When the situation discussed in the first scenario is reversed, an electro-luminescent solid yellow line separating the inner and outer westbound lanes will be illuminated to indicate a change in lane usage favoring the direction of heavy traffic flow, thereby attaining a ratio of 3:1 for major and minor traffic lanes.

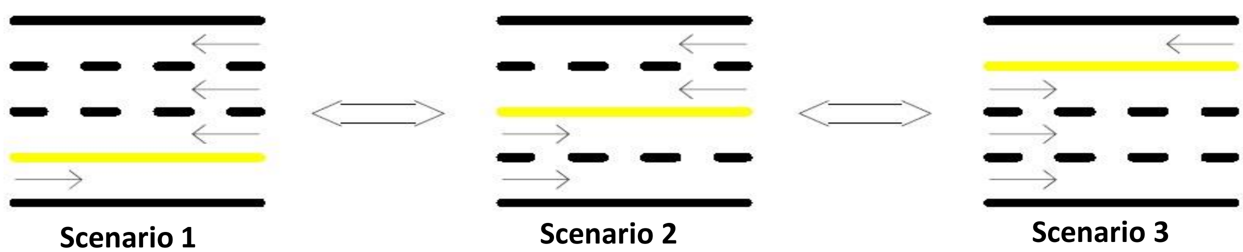

Figure1. Depicting the reversible lanes

As mentioned previously, electro-luminescent paint is in its early stages of implementation, mainly in the motorcycle paint industry. For reversible lane implementation, this paint has to be chemically developed to attain the durability of retro-reflective paints used in the pavement industry, with an additional feature of electro-luminescence. The paint has to be strong enough to withstand the repetitive passes from vehicular traffic, and varying weather conditions. This requires research and participation from various industries to develop this technology fully.

<u>Use of In-Pavement LED Markers:</u> In-pavement Light Emitting Diode (LED) markers are commonly used on smart crosswalks as shown in Figure 2. They are also used for lane delineation and route guidance on ramps, lane curvatures, and pavement edges. The in-pavement LED markers can be used on reversible lanes to separate traffic flowing in opposite directions based on real-time traffic demand. Intelligent features can be added to turn the LED lights on and off depending on the lane that is being delineated. The same procedure discussed for implementing the Electro luminescent paint applies to in-pavement LED markers.

The in-pavement LED markers are readily available. However, practical implementation of this method involves remote, reliable and dynamic control of the in-pavement LED markers, depending on demand. In addition, it needs to be integrated to traffic signal operation at the intersection or beginning of reversible lane segment. During daytime to achieve high intensity light LED markers have to be closely spaced which may result in discomfort for the driver while changing lanes. In addition, Luminance design has to be carefully implemented to increase the visibility of the LED alignments without causing discomfort to the driver's eyes.

Figure2. In-pavement LED markers installed at crosswalk

<u>Use of Fully Automated Retractable Bollards:</u> On freeways, the opposing traffic is typically separated by rigid concrete structures known as dividers. These help prevent high-speed traffic flowing in one direction from entering the opposing lanes. In areas suitable for implementation of reversible lanes, concrete dividers can be replaced by retractable bollards. Bollards are small posts that are used for access control. They can be installed on a fixed location or can be removable. Depending on directional demand, the bollards can be automatically extended or retracted to separate opposing lanes. The retractable bollards such as show in Figure 3 are commonly used in parking areas and in heavily dense pedestrian area as a safety barrier from speeding vehicles. But implementing it for reversible lanes involves modification to its design parameters in order to deal with impacts of high speed cars, ease of extending and retracting multiple bollards, and controlling its operations remotely. Retractable bollards require embedment in pavements.

Figure3. Retractable bollards in a parking lot

The characteristics of the proposed technologies for reversible lanes are summarized in Table 1.

Table1. Comparison of Proposed Reversible Lane Management Applications

	Electro-luminescent paint	**In-pavement LED markers**	**Fully Automated Retractable Bollard**
Areas of Application	Urban Areas (no dividers)	Urban Areas (no dividers)	Freeways (alternate to dividers)
Development	Futuristic	Can be implemented right away	Can be implemented using present technology with major modifications
Cost	Not yet certain, as it requires further research	Best alternative economically	Very expensive as it requires bollards assembly and control mechanisms, and re-paving of roadways
Limitation	Developing this kind of paint to handle wear and tear of roads is a major challenge	To achieve high intensity light LED markers have to be closely spaced which may result in discomfort for the driver while changing lanes.	This requires relaying the pavement to accommodate the retractable bollards so appropriate for new roads

Switching the Lane Alignment

The movement of traffic changes in a particular direction depending on time, the lanes has to be re-oriented according to traffic demand. Consider a road segment having two lanes in each direction where traffic is about to increase in one direction. To accommodate this spike in traffic demand, one extra-lane has to be added along the direction with heavy flow. The re-alignment is achieved by moving the solid yellow line from the centre of the segment to the adjacent lane by reducing a lane along the low traffic direction. This transition can be carried out in a phased manner as shown in Figure 4. During the initial phase, the solid centre line and adjacent line are made to flash continuously for a few minutes. Thereby, indicating the drivers on that lane to change to their adjacent lane in their moving direction. After that phase, the solid yellow line on the centre is turned off from illuminating, resulting in a new solid yellow line which partitions the road segment in a 3:1 lane ratio, catering to traffic demand. The reversed process is carried out to meet the heavy traffic demand in the opposite direction.

The majority of process is the same for three approaches, but for the retractable bollards, embedded pavement lights may be mounted on top of the bollards to warn the motorists of an impending lane reversal. During transition, the lights are made to flash for certain amount of time to caution commuters to not get into that particular lane after which, the retractable bollard can be raised. The commuters need to be educated extensively on the operation of the retractable bollards. Care has to be taken during the transition phase by allotting more time for flashing lights, and ensuring that the reversible lane is unccupied.

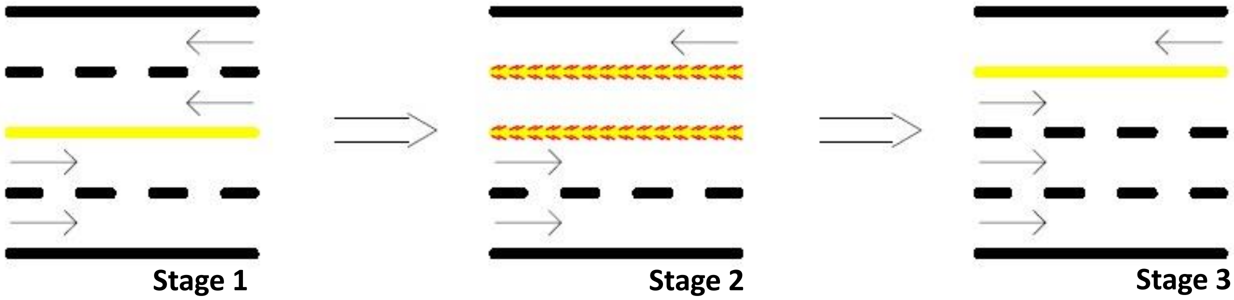

Figure4. Depicting the realignment of lanes

CONCLUSION

The proposed technologies for safe implementation of reversible lanes have been discussed in this paper. However, there are some challenges that need to be overcome in order to make them viable. The investments involved in applying these methodologies vary depending upon the selected technology. Implementation of in-pavement LED markers is mostly efficient and economical in urban areas. It requires LED's to be embedded into the pavement that can be done without any major modifications to the existing road segment. Alternatively, solid yellow line can be replaced with electroluminescent technology, which can be illuminated accordingly to meet the traffic demand. The implementation of reversible lanes on freeways can be done using retractable bollards. However, the implementation of this method may be very expensive. Future research may be needed to address these challenges.

The use of the proposed technologies may improve traffic safety by minimizing driver confusion associated with reversible lanes, and thereby attracting cities around the world to revisit the concepts of reversible lanes as a viable solution of dynamic lane management system. This will also pave the way for looking at innovative ways to optimize the use of existing infrastructure instead of constructing new ones.

REFERENCES

[1] Dey, S., J. Ma and Y. Aden, Reversible Lane Operation for Arterial Roadways: The Washington, DC, USA Experience, ITE Journal, and May 2011.

[2] Laurence, L. and B. Wolshon, Characterization and comparison of traffic flow on reversible roadways, Journal of Advanced Transportation, Volume 44, Issue 2, pages 113–122, April 2010.

[3] American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011.

[4] Hausknecht, M., T. Au, P. Stone, D. Fajardo, and T. Waller, Dynamic lane reversal in traffic management, *Proceedings of IEEE Intelligent Transportation Systems Conference (ITSC)*, October 2011.