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A Review Of Determination Of Lag Acceptance And Effects For Leftturning Movements At Intersections

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Abstract: This review presents a through survey of academic work on the analysis and application of determination of lag acceptance and effects for left turning movements at intersections. There are many objectives for designing and building the intersections but the most important are to reduce the severity of potential conflicts between motor vehicles, pedestrians, and facilities while facilitating the convenience, ease, and comfort of people traversing the intersection. The incident happens when a drivers change the traffic lane, merges with or crosses a traffic stream. Probably it takes place most frequently when priority control is used to resolve vehicular conflicts at highway intersections. Current critical issues are discussed about some parameters that has a influence on left turn movement that they are Left turn on red movement, lane configuration, cross street lane merge characteristics, type of intersections, islands, common right turn treatments, merging parameters (driving characteristics at intersections ,pedestrian characteristics, headway and ,acceleration characteristics, acceptable right turn gaps), acceptable left turn gaps ,lag acceptance in the freeway merging process, application of lag studies, safety of intersection design elements. The determination of lag acceptance for turning movements at priority junctions and comparisons of lag acceptance during day time and hours of darkness is very important in the performance evaluation of priority junctions and in maintaining the safety of vehicular traffic flow.

Key words: Lag acceptance, intersection, delay time, turning movement, Delay time

INTRODUCTION

Intersection has the significant role in the urban and highway flow. Drivers use it for different aspects such as changing the direction to left or right or keep moving in the straight direction and because of these turning there are some laws and rules that run in the intersections and drivers and pedestrian have to obey them for preventing from accident and fatalities. Most urban arterials and intersections weren't originally designed to accommodate today's heavy traffic. Instead, they've evolved as urban and suburban traffic has increased and because of that delay happened in the urban areas and the aim of the transport engineer is that to find the solution for this problem (Shokri *et al*. 2009a, Ismail 2013a). This study tries to identify the problems and different factors that they are contributed to crashes on specific urban roads and then how to develop and apply appropriate measures to reduce the crashes, based on what types of crashes are occurring at which specific locations (Wang & Abdel 2008). Merging time in major roads is very important because if the drivers can't find appropriate time to merge they will make congestion in the intersection and it's a cause of delay in the intersection. When drivers arrive to the intersection they will face to the different gaps which they should make decision to turn but they will accept only one and they will reject others, so this time is very important because if this gap time is not sufficient for them to turn they will stop in the intersection and it makes congestion and delay in the intersection and the designer should consider this problem in designing the intersection (Cassidy *et al*. 1995; shokri 2012b). Thus the behavior of the drivers which approach to the intersection is very important and the average time which they accept for merging is very significant. The drivers should able to estimate the enough time for themselves to merge and its very important because if they estimate wrongly it will cause of the accident with the cars in opposite approach.(Shokri *et al*. 2012a; Schroeder & Rouphail 2011)

Studies of lags and lag acceptance are useful in evaluating the capacity and level of service of unsignalized intersections. Driveway openings, and unprotected left turns, among other applications. Time headway or gap between vehicles measured from the arrival of the front ends of successive vehicles. The frequent occurrence of lags of adequate duration is necessary in many conflict situations (Troutbeck & Brilon 2002, Ismail 2013b). The frequency of adequate lags is also used in warrants traffic officer protection at school crossings and for traffic controls at other pedestrian crossings. Lags are measured with the aid of timing devices (Chen *et al*. 2008). Complete records of the time of arrival of vehicles may be utilized in order to obtain lags. Stopwatches may also be used in order to measure individual lags. A lag is the time from a random instant until the arrival of the next vehicle. When two traffic streams conflict. It is often necessary to observe the lags in the stream with the right

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of way accepted and rejected by the minor stream. This involves the measurement of lag duration and to determine the driver acceptance or rejection of the gap. There are several possible measures used to describe this behavior. In overall, the critical lag is the minimum size lag that a particular driver will accept. Most studies using lags to examine capacity assume that each driver has a constant critical lag (Asano *et al*. 2011m, Ismail 2012).

Left Turn On Red Movement:

By the late 1970s, the individual states in the United States had each adopted a left turn on red (LTOR) policy whereby left-turn movements were permitted after the driver stopped unless specifically prohibited by a sign. Several studies have shown that LTOR increased the frequency of left-turning crashes at signalized intersections, especially crashes involving pedestrians and bicyclists (Sun *et al*. 2003). When a left-turn movement at a signalized intersection is shadowed" by a protected right-turn signal on the cross street, LTOR movements can be completed successfully without any concern for cross street gaps in traffic. Since LTOR drivers are required to come to a stop before making the turn, the driver must incur delay as a result of this enforced stop condition. Right-turn vehicles often use shared lanes where the vehicles may occupy the same lane as vehicles turning left or progressing straight through the intersection. The use of shared lanes will often impede the LTOR movement. Narrow or sharp roadway geometry may also be counterproductive to the LTOR movement. Lin determined that a small increase in the approach width of an intersection would drastically raise the rate of LTOR use (Mahmassani & Sheffi 1981). The Highway Capacity Manual (2000) identifies seven factors that influence optimal use of LTOR movements as:

- Approach lane (shared or exclusive)
- Demand (generally based on hourly volumes)
- Sight distance at the intersection approach
- Degree of saturation (elevated conflicting movements)
- Left-turn signal phasing on conflicting street
- Conflicts with pedestrians.

These six items not only offer understanding on how well a LTOR movement may function, but generally are factors that should influence which type of left-turn treatment should be considered. It is important to note the sixth influence identified above refers to pedestrian conflicts. As previously stated, this item should be extended to bicycle traffic if appropriate for the candidate site (Kludt 2006).

Lane Configuration:

Often the left-turn movement must occupy a lane shared with vehicles that are right-turn or through movement vehicles. Clearly, the likelihood for a left-turn vehicle to proceed through the intersection unimpeded after the driver stops and perceives an acceptable gap is directly dependent upon where the driver's vehicle occurs in the traffic queue and what vehicles (straight or right-turning) are positioned between the driver and the intersection. Often an exclusive left-turn lane may be warranted to minimize the delays incurred due to vehicles on the same intersection approach. Left-turn lane warrants are:

- Volume of right turns;
- History of left-turning rear-end crashes;
- Speed of the highway; and
- Land-use availability.

The taper and lane-length design are also based on deceleration, storage, or both. Lin (2002) Concurs with these warrants and also suggests that the ability of an auxiliary right-turn lane to reduce vehicle delays also depends on the LTOR policy, type of signal control and signal timing settings, and the pedestrian flows their guidelines suggest appropriate thresholds for left-turn lanes based on the design hourly volume for the roadway, the minimum left-turn volume, and the roadway speed. They also suggest alternative lane requirements based on the need to acquire right-of-way and the associated expense of the right-of-way (Mahmassani & Sheffi 1981).

Cross Street Lane Merge Characteristics:

Little is known about how cross-street lane geometry should be modified to accommodate left-turn volumes. The most common left-turn movement facilitates a simple merge with the cross-street traffic in a shared lane. For high-volume left-turn movements, an additional lane is often added to the cross street in an effort to facilitate unimpeded left-turn movements. A third scenario is a cross-street acceleration lane for vehicles to complete the left-turn movement unimpeded and then accelerate parallel to the cross street traffic prior to merging. For signalized intersections, the left-turn movement operates under the traffic control of the traffic signal; however, when the left-turn is physically separated from the adjacent approach traffic, alternative

traffic control measures are often implemented. For example, a yield sign is commonly positioned for a left-turn movement that coincides with a signalized intersection. The use of these supplemental signs is one of the treatment influences that will be discussed in further detail in this paper. The authors were unable to locate previous research evaluating the influence of these supplemental signs in combination with right-turn treatments(Cassidy *et al*. 1995).

Type Of Intersections:

There are some types of intersections that they use in geometric design.

- Grade separated with ramps (freeway interchange)
- Grade separated without ramps (over or underpass with no access)
- At-grade
- Conventional
- Roundabouts
- New concepts (e.g., "continuous flow")

Regarding to the location, the designer should use the special type for avoiding accident and delay in the intersection (Perkins & Harris 1967).

Islands:

Designer uses some strategies in geometric design such as using of canalization or traffic islands as a common design for delineation of left-turn movements. A Policy on Geometric Design of Highways and Streets identifies three primary functions of islands. These include canalization (to control and direct traffic movement, usually turning), division (to divide opposing or same direction traffic streams, usually through movements), and refuge for pedestrians. Urban Street Symposium Traffic islands can be painted or raised (curbed). Painted or flush islands are often used in lightly developed areas, at intersections where approach speeds are relatively high, at locations with very little pedestrian traffic, where fixed-source lighting is not available, and only where signals, signs or lighting standards are not needed on the island. Painted islands can also delineate turning lanes where room is not available for a raised island. Though painted islands are convenient for locations where snow removal may be required on a regular basis, the inclement weather decreases the effectiveness of the marked canalization (Wolfermann 2011).

Raised or curbed islands offer a more restrictive canalization of the right turn than flush islands. The raised island can be used as a refuge for pedestrians, a location for safe sign and traffic control device placement, a physical restriction for prohibiting undesirable traffic movements, and a technique for reducing excessive pavement areas that may permit and encourage uncontrolled vehicle movements. The used of curbed islands generally should be reserved for multilane highways or streets located in or near urban areas.

Common Right Turn Treatments:

For purposes of this effort, a right turn at a signalized intersection is considered a combination of entrance and exit treatments. "Entrance" will be used to describe the upstream, or entry point, geometric feature used by vehicles executing a right turn. This entrance treatment includes type of island (if used) and turn lane configuration. "Exit" will be described as the geometric condition and /or the traffic control device at the point at which the left-turning vehicle enters the conflicting stream of traffic. While it may seem unusual to combine geometric conditions and traffic control devices into the single category of "exit treatment," exit geometry and traffic control devices are dependent upon each other and must be evaluated as a combination of both influences.

Merging Parameters:

Speed is the important factor for the merging vehicles, so the designer should pay attention to this factor in the all approaches (major and minor approaches). Some important figures of merit for describing the lag acceptance phenomenon in freeway merging are the critical lag, percent of ramp vehicles delayed, mean duration of static delay accepting a length of queue, and total waiting time on the ramp. Critical value defined as the lag accepted by half the divers, it means the acceptable average minimum lag time. The principal use of a lag acceptance parameter is to simplify the computation of the delay duration by permitting the assumption that all intervals shorter than the critical value are rejected while all intervals longer are accepted (Kloeden 2001).

Driving Characteristics At Intersections:

Driving a vehicle involves many skills such as visual search, perception, and judgment. In order to minimize the risk of an accident, the driver has to continually process new information, react to the environmental demands and make proper decisions. In this section, the focus is on the drivers' understanding of different left-turning signals, drivers' response to pedestrians, and information processing. Left-turning drivers can face three different signal alternatives at signalized intersections:

First, the permissive scheme, under which a driver has to let oncoming vehicles cross the intersection before undertaking the left-turning maneuver; second, the protected scheme under which a driver can turn without oncoming vehicles disturbing the maneuver; and, third, the permissive/protected scheme, under which a driver can turn without oncoming vehicles disturbing the maneuver during a segment of the green phase (e.g., flashing green or green arrow). The understanding by motorists of these different signal alternatives varies. These authors conducted a survey of drivers on the different signal alternatives for left-turning maneuvers in California. They found that the protected signals were best understood, followed by the permissive signals and the permissive/protected respectively(Adarns 1994).

The level of understanding can also be influenced by the consistency of traffic signals. Drivers operate with a set of expectancies (e.g., freeway exits are located on the right hand side) and if these expectancies are violated there is an increased risk of an accident. Therefore, traffic control devices, including traffic signals, should be located and designed according to driver's expectations. Traffic signals should be consistent in their type (e.g., horizontal or vertical heads), their location, and their interpretation (e.g., flashing green used as a protected left-turn). Unfortunately, many jurisdictions, particularly in rural areas, have traffic signals which are not consistent within the jurisdiction, l*et al*one with neighboring jurisdictions, such as in some Provinces in Canada for example. A number of researchers have examined driver behavior in the presence of pedestrians. Their studies usually involve the recording of vehicle speeds in the presence and absence of pedestrians for example, studied the situation in which drivers give way to crossing pedestrians in Israel. Some researches show that a reduction in vehicular speed was noticeable at the crosswalk when pedestrians were present. The authors also discovered that a greater reduction in speed occurred when the number of pedestrians was greater than one. In contrast, Thompson *et al*. studied driver behavior in Nottingham, England but found no differences in speed when pedestrians were present. At the same time, they studied the position of the vehicle on the road (i.e., the distance from the curb) and found that drivers did not change their paths (i.e., moving further away from the curb) when pedestrians were present. Experiments show that the interaction between drivers and child pedestrians also in Nottingham. He found that most drivers took avoiding actions within less than 20 meters from a child which was about to cross; this distance was less than the safe stopping distance in many instances(Shokri *et al*. 2010).

The complexity of the primary driving task can greatly influence the peripheral detection of pedestrians. For instance, a driver who is approaching an intersection has to concentrate on the traffic lights (primary task) as well as to detect potential threats at and around the intersection (peripheral detection). Peripheral detection as influenced by the complexity of the primary task. Subjects had to verbally track a central task while attempting to detect small peripheral lights for different task complexity. Researches show that the peripheral detection deteriorates when the complexity of the task is either too low or too high. In the former case, a monotonous task reduces the alertness of an individual.

Driving a car implies simultaneous accomplishment of a variety of driving subtasks which constitute the drivers' workload. Researchers examined drivers' cognitive load when they were performing three maneuvers at rural junctions in Sweden: straight, left-turn, and right-turn. They did the same kind of study in California. Both found that the mental load was greatest for left-turning maneuvers.

Visual search of drivers turning left at intersections is more frequent toward the right than the left. For example, researches show that the examined bicycle accidents and visual search at intersections in Finland. They found that drivers who are making left-turns made more head movements towards the right and closer to the intersection than right-turning drivers. Researchers found that visual search time increased with the increase in traffic(shokri *et al*. 2009b). They also observed that the last search before turning left on a highway was to the right (the fixations lasted for at least one second). Therefore, any changes to the left side of the driver would be unnoticed during this period (Kludt *et al*. 2006).

After searching for potential threats, a driver must be able to perceive and identify these threats in order to take proper action to avoid a collision. At intersections, the detection of other road-users that are in motion can be very difficult. Indeed, the observer's self-motion in a stable environment produces an apparent visual motion or optic flow of the physical objects in that environment. Researchers studied the perception of moving vehicles at intersections in France; they found that drivers traveling towards an intersection had difficulties detecting possible future collisions with vehicles whose path intersected their own. Another study attempted to explain child pedestrian accidents in England in terms of driver perceptual error. He discussed the effect of visual motion (optic flow) on the detection of pedestrians. This author demonstrated that drivers have difficulty estimating the possible path of a pedestrian in motion, which in turn may lead to a collision (Schroeder & Rouphail 2011)

Researches supported this finding with statistics from accidents between pedestrian's and vehicles. Elderly drivers are more likely to be involved in intersection accidents than younger drivers. Researches compiled accident data from various cities located in Virginia. They found that the involvement ratios of older drivers to younger ones for right and left-turn maneuvers are significantly higher than for straight-through movements; the

left-turning maneuvers being the highest. Researchers found that the elderly drivers in British Columbia and about 24 percent of the respondents recognized that the turning maneuvers gave them difficulties.

The higher involvement ratio for older drivers can be explained by various changes with age, including narrowing of their visual field, poorer contrast sensitivity, and increased time required to change focus, slower eye movement, problems with depth perception, ands lower decision making. Similarly, older drivers appear to have more difficulties in judging time-to-collision and acceptable gaps, especially when turning left at intersections.

Pedestrian Characteristics:

During a journey, the pedestrian needs to perform maneuvers, detect obstacles, and make decisions. An error in these skills or physical limitations of the pedestrian may lead to serious injuries or death as the pedestrian interacts with vehicles. This section presents an overview of pedestrian characteristics including crossing time and visual search at intersections.

At signalized intersections, the green phase has to be long enough to permit pedestrians to cross safely. The current engineering standards establish the walking speed of pedestrians at 1.22 m/sec (4 ft/sec) for design purposes (Dewar 1992). However, many researchers consider this speed to be too fast for design purposes. For example (Fruin, J.J. 1971), researchers examined the speed distribution of pedestrians in free-flow conditions in Port Authority and Penn Station, New York. This author showed that nearly half of pedestrians walk below 1.22 m/sec (Dewar 1992). Researchers examined pedestrian walking speeds at urban intersections located along arterial roads in the United States. They found that the average walking speeds were 1.35 m/sec for adults below 60 years of age and 1.03 m/sec for people above 60 years old (Bowman, B.L. and R.L 1994). Researches also did field studies of walking speeds at 16 crosswalks in the United States and found that the 15th-percentile walking speed of younger pedestrians (ages of 14 to 64) and older pedestrians (ages of 65 and above) were 1.25 m/sec and 0.97 m/sec respectively (Knoblauch, R.L. 1996). In addition, they found that the walking speed is influenced by many factors such as weather conditions, type of street crossed, signal cycle lengths, medians, and crosswalk markings. None of these were, however, important enough to change the standard. Researches (Virkler, M.R., and D.L. Guell 1984) studied pedestrian crossing-time requirements at intersections in the United States. They found that the walking speed of pedestrians decreased as the number in the group got larger (especially for the people at the back of the group) and they proposed a new method to evaluate the minimum crossing time. These authors suggested a regression equation which takes into account the number of pedestrians in the platoon.

Signalized intersections can be provided with separate pedestrian signals (e.g. WALK and DON'T WALK). The use of pedestrian signals at an intersection is based on several criteria such as pedestrian and vehicle volumes, school crossings, and obstructed vision. The main purpose of pedestrian signalization is to improve safety by providing the pedestrian signalization fails to improve safety, as discussed by researchers Part of the ineffectiveness of pedestrian signalization can be attributed to the high violation rate and part to the low comprehension rate. Indeed, it is estimated that only 39 percent of the population understand the meaning of the flashing hand (ITE Technical Committee 4A-15 1985). Pedestrians also need to understand traffic signals for vehicles to know which phases are exclusive to vehicles and to know when to cross when no pedestrian signals are present. There may be an increased risk of collision if a pedestrian starts crossing during a protected left-turn phase because drivers may not expect a pedestrian then. Unfortunately, none of the studies reviewed examined this topic (Gettman & Head 2003).

Headway and Acceleration Characteristics:

One of the methods for determination of the intersection characteristics is determination of the vehicle headway. Headway is the interval time from the bumper of the car to the bumper of the following car. For finding the acceleration the vehicles at the signalized intersection we have to do some activities such as:

- The required time for vehicle to start moving.
- The distance which the car pass in the given time after starting.
- The space between vehicles

There are two type of reaction time has been studied:

- Reaction time of the first vehicle related to the signal change.
- The reaction time between two successive vehicles.

When the light change from red to green the vehicles start to move and the first vehicle spend a little time for starting to move, regarding to the researches it s between 0.6 and 2.9 seconds. Also another delay that happen in the intersection is related to the successive vehicles which start to move and it's different between 1.0 to 1.8 second (Dewar 1992). There are some factors that interfere to the vehicle performance in queue are

position of stop, reaction time and time distance performance. The exact position of stop depends on pavement markings. The time distance performance of each individual vehicle is not as easily analyzed. However, the distances reached in given times are of great significance to the traffic engineer because they form the basis for timing signals and for determining street capabilities.

Most investigators have found that headway between successive vehicles decrease at a lessening rate as one progress until through the queue. As speed increase, the times pacing between vehicles decreases until the fifth in line vehicle has entered the intersection. After 50 vehicles, headway tends to level out at approximately 2.0 seconds (Wildermuth, B.R. 1962). Results of study conducted by indicate that the length of the green phase does have a substantial effect on average headway, with a 10 seconds green phase. The average headway was 2.35 seconds and with a 35 to 45 seconds green phase 2 second headways were obtained. Large vehicles and turning traffic both tend to reduce the capacity of signalized intersections because they have greater headway. This confirms the effect of the initial starting characteristics of the queue is decreased and the vehicles far back in the queue have a greater effect on the average headway. Therefore for long phases average headway will be less than for shorter phases(Xin 2008).

Acceptable Right Turn Gaps:

Often the right-turn movement must occupy a lane shared with vehicles that are left-turn or through movement vehicles. Clearly, the likelihood for a right-turn vehicle to proceed through the intersection unimpeded after the driver stops and perceives an acceptable gap is directly dependent upon where the driver's vehicle occurs in the traffic queue and what vehicles (straight or left-turning) are positioned between the driver and the intersection. Often an exclusive right-turn lane may be warranted to minimize the delays incurred due to vehicles on the same intersection approach.

The taper and lane-length design are also based on deceleration, storage, or both. Lin concurs with these warrants and also suggests that the ability of an auxiliary right-turn lane to reduce vehicle delays also depends on the RTOR policy, type of signal control and signal timing settings, and the pedestrian flows. Their guidelines suggest appropriate thresholds for right-turn lanes based on the design hourly volume for the roadway, the minimum right-turn volume, and the roadway speed. They also suggest alternative lane requirements based on the need to acquire right-of-way and the associated expense of the right-of-way. Because of the limited use of the 'right turn on red' law apparently no research has been accomplished concerning the gap acceptance of vehicles turning right on red. Considerable research has been conducted concerning gap acceptance at shop sign intersections. Research found that the median acceptance time for right turns was 7.30 seconds. In his field investigation, obtained median lag and gap acceptance times of 5.25 seconds. Defines the average minimum acceptable gap as that value minimum acceptable gap as that value minimum accepted gap time for right turning movements was found to be about 6 seconds. The difference in the values may have been caused by differing driver characteristics in different parts of the country (Cassidy 1995).

Acceptable Left Turn Gaps:

The subject of delay of left turning vehicles and left turn canalization has been studied at length. However, base on the literature there are only a few studies that have concentration on left turn gap acceptability. The critical gap of the drivers plays an important role in the delays experienced by the left turning vehicles and therefore will determine whether the shared lane will be blocked or not. The critical gap of the drivers plays an important role in the delays experienced by the left turning vehicles and therefore will determine whether the shared lane will be blocked or not. This dictates the need for the separate left turning lane. It was necessary to measure the critical gap of the vehicles in the field to examine left turn behavior.

As mentioned earlier, for both signalized and unsignalised intersections, the arrival time at the stop line of each left-turning vehicle on the subject link was recorded. The arrival time at the stop line of each opposing vehicle was also recorded. The difference in these times would be the gap that is available for the left-turning vehicle (Wu 2012). The left-turning vehicle would accept or reject this available gap; therefore, all these gaps were measured and classified as "R" for rejections and "A" for acceptances. A curve showing the rejections and acceptances was plotted for that particular site. The intersection of the curve for A and R gave the gap above which drivers would accept and below which drivers would reject, which is the critical gap at that particular site. This was done for both signalized and unsignalized intersections. The procedure described here can be found in (Raff, M.1956).

Lag Acceptance In The Freeway Merging Process:

When one car try to change the direction it should merge to the flow which comes from another direction and after finding the appropriate gap it will merge to the flow. The analysis on merging generally aims to furnish detailed information on the following effect that geometric variable on the merging of ramp traffic, the development of usable distribution of traffic variables for simulation programs, and the development of an optimum ramp metering and merging control system. The theoretical development of models and useful

parameters for describing the merging process include the derivation of the forms of the mean and variance of the delay to a ramp vehicle on position to merge. In addition this involves the treatment variability of critical lags and lag acceptance among drivers through the identification of the representative forms for both critical lag distributions and lag acceptance functions. Regarding to the latest researches, there is relation between the percent lag acceptance and lag size are established (Schroeder & Rouphail 2011). The probity analyses are generalized to establish a relationship between the acceptance percentage, the lag size and vehicular speed. In this approach, the characteristics of lags and gaps and single and multiple entry merges are compared, as well as the fast to slow moving merging vehicles. Some researches has been attempted to find the mathematical treatment of the merging maneuver but they faced somewhat limited success because of the complexity of the vehicles interactions. Computer technologists have contributed several digital computer simulation programs but lack of detailed criteria on lag acceptance and merging logic has hampered progress(Cassidy *et al*. 1995). In the summer of 1965 The U.S Bureau of Public Roads undertook research to furnish detailed criteria on the merging of ramp vehicles into the freeway system. The general aim of this research is the development of a relationship between the many variables associated with the interaction of vehicles traversing a ramp and merging into a freeway so as to determine the effects of the following on merging operation and level of service. The variables include:

- Traffic characteristics such as lag availability, lag acceptance Speed and volume.
- Ramp geometric such as length, curvature/Angle of convergence and grades and acceleration lane geometric such as length, Shape, delineation and location of lateral obstructions.
- System considerations such as interchange type, ramp configurations, frontage roads and upstream or downstream bottlenecks. Environmental elements such as metropolitan area size, location within the city and fighting.
- Control devices such as freeway lane controls, yield or merge ahead signs, traffic signal feeding the entrance ramp and ramp metering stations.

The underlying purpose of this research is the application of this information:

- The furnishing of more detailed information on the effect that geometric variables and traffic characteristics have on merging traffic.
- The development of usable distributions of traffic variables for simulation programs. To fulfill the broad project objectives, 32 ramp freeway connections located in8 metropolitan areas in 6 states from coast to coast and from border to border were chosen.

There are three purposes for conducting field studies of traffic characteristics in ramp freeway merging areas. The first is for the eventual testing and refinement of models. The second purpose for collecting data is that at the present time only limited data of this type are available. Lag acceptances data are prime examples of this. Much of the merging lag acceptance data available is very old, based on small sample size or for a peculiar situation such as left hand ramp or stop sign control. These conditions severely limit the usefulness of these data. No data have been collected on the effect of ramp and acceleration lane geometries on the lag acceptance characteristics of vehicles on the ramp(Shokri *et al*. 2012a).

A third very important application of the data on the merging characteristics is for simulation inputs. Specific objectives of this phase of the U.S Bureau of Public Roads project research are:

- Development of models and useful parameters for describing lag and gap acceptance and delay in the merging maneuver.
- Determination of any differences in lag acceptance characteristics for different points of entry along the acceleration lane.
- Delineation of the roles of absolute and relative speeds in the merging process and their effect on lag acceptance.
- Identification of lag acceptance characteristics of more than single ramp vehicles so as to determine the efficiency of platoon merging.
- Investigation of the effect of outside freeway lane volumes on gap acceptance.

Application Of Lag Studies:

In a study of lag acceptance at urban intersections, wrote "it is safe to say that the main street volume does not have an appreciable effect in the critical lag." Similarly for ramps whole attributed a slightly smaller percent acceptance at higher freeway volumes to sampling rather than a difference in driver behavior (Raff, M.1956).

The results of the U.S Bureau of Public Roads tend to support the conclusions of Raff and whole. However, since lag acceptance is a function of speed and speed is a function of volume, a relationship between lag acceptance and volume does exist. Because of the form of the speed volume relationship, it is evident that the volume lag acceptance relationship is very complex. It would suffice to say that lag acceptance is independent of volume for a given level of service and that changes in lag acceptance between different levels of service may be predicted from differences in speed rather than the service volumes. Whole highlighted that from a practical point of view, since a much larger lag is needed for a freeway volume of 1800 vph under a forced flow condition (20 mph) than under a stable flow condition (40mph). Positive means should be implemented to prevent the freeway from becoming congested (HCM). An important application of the results of the U.S Bureau of Public Roads research lies in the field of simulation. Computer technologists have been quite active with several digital computer programs developed for simulating freeway and interchange operation. As a design and operational tool, present programs are not sufficiently validated to warrant confidence in their ability to predict behavior or needs at freeway interchanges.

While developments of simulation hardware and programs have proven feasible, lack of detailed criteria on traffic stream interactions has hampered progress. While some simplifications are necessary in models, simplification necessitated because of lack of knowledge of the pertinent variables reduces the model's realism. Over simplification of the merging logic is a case in point. For example, distributions for merging lag acceptance under different geometric, traffic and environmental conditions have been lacking. The results of the probity analysis serve to present the pertinent lag acceptance variables in the form of distributions and equations, making them extremely usable as inputs to digital simulation models. The project by the U.S Bureau of Public Roads involved undertaking:

- More detailed information on the effect that geometric variables have on the merging of ramp traffic.
- Develop usable distributions of traffic variables for simulation program.
- Develop an optimum ramp metering and merging control system.

The importance of preventing freeway congestion was mentioned with reference to the volume lag acceptance relationship. The concept of ramp control as a means of deferring congestion is now a reality. It only remains for these ramp control systems to be generalized to include merging control. The design of such a merging control system will depend on the proper interpretation of merging lag acceptance characteristics.

Safety Of Intersection Design Elements:

For safety in the intersection the designers use some strategies for decreasing the conflict and accidents in the intersections such as:

- No control: vehicles adjust speed.
- Stop control: where traffic on minor roadway must stop prior to entering major roadway.
- Yield control: vehicles on minor roadway must yield to major roadway traffic
- Signal control: where vehicles on all approaches are required to stop by either a stop sign or traffic signal All way stop.
- Stopped major roadway left-turn vehicles – must yield to oncoming traffic.

The aim of this study is related to the safety effects of a wide variety of geometric design, traffic, and control elements of at-grade intersections. Focuses on the safety effectiveness of intersection left- and right-turn lanes, the initial scope of the research was not limited to this topic and could potentially have included the safety evaluation of any type of intersection design improvement. Therefore, this study is organized to emphasize studies related to the safety effectiveness of turn lanes, but it also includes a review of all geometric, traffic, and control elements that affect the safety of at-grade intersections (Archer 2004).

Sometimes the short lane is not enough wide and because of that some problems will occur Because so many drivers use the free-left-turn lane, long queues often This created a hazard for through motorists, who had to stop unexpectedly or swerve because of slow/stopped vehicles ahead In conjunction with a real estate development. Comparing the data from before and after study the researchers found that the installation of a separate left-turn phase was associated with a reduction of left-turn accidents by 85% and an increase in rear-end accidents by 33%. Total intersection accidents were reduced by 15 %(Agent, k.R & Deen, R. C. 1977). The accident analysis was similarly meager the main results being from four intersections converted to protected/permissive phasing. While total accidents decreased from 70 to 58, left-turn accidents increased from 16 to 24. Perhaps the most interesting finding of the survey was that 70% of those responding were in favor of the protected/permissive signal phasing and 77% thought that it reduced delay (Perfater, M. A. 1983).

For preventing the crashes there are some signs which they use to inform the conditions of the roads to the driver also they limit them to drive under the limitation of the traffic rules also the guidelines that are developed depend on volume, left-turn accidents, traffic conflicts, left-turn delay, site conditions (sight distance, number of

opposing lanes, geometries, access management), the trade-off between delay and safety, and engineering judgment. Safety considerations are based on the 'rate quality control' method by which a critical value (of accidents, accident rate or conflict rate) is computed representing a mean few standard deviations. This number then serves as a caution that 'accident experience' is unusually high. Developed guidelines for left turn phasing based on field studies. A three-level decision process was suggested to reflect the trade-off between operational efficiency and safety. The first decision is whether the left-turn phasing should be 'Permitted' or some whether some protection is required. If protection is required, the next choice is between some mix of 'Protected' and 'Permitted' phasing and the 'Protected' only phasing. The third decision is between leading, lagging or leading/lagging (Maze, T. H., Henderson J.L &sanker, R.1994).

Shebeeb examines safety and efficiency of left turn phasing at 54 intersections (179 approaches) in Texas and Louisiana. Efficiency was measured by stopped delay/vehicle for the left-turning maneuver in the peak period. In addition to the usual phasing options the author considered the "Dallas" phasing described as giving "additional 'Permissive' green for left-turn vehicles during the opposing left-turning vehicle's protected time"8(Shebeeb, O.1995).

Present some results of the work of Committee 4A-30 formed by the Institute of Transportation Engineers to undertake a thorough research on Protected/Permissive Left-Turn Phasing to propose nationwide guidelines for consideration by the ITE Technical Council. On the basis of their review of the literature and responses to a questionnaire, recommendations for new installations were formulated. The general tenor of these is that 'Protected/Permissive' phasing results less delay than protected phasing but is not as safe and should not be used at sites with high accident potential. The recommendations consist of three parts:

- Conditions,
- Minimum Requirements
- Suggested Guidelines reproduced below. If all conditions are met and any of the minimum requirements are also met, 'Protected/Permissive' left-turn phasing should be considered and guidelines followed (Koupai 1999).

Conclusion:

In this review, many studies are described and discussed for designing and building the intersections but the most important are to reduce the severity of potential conflicts between motor vehicles, pedestrians, and facilities while facilitating the convenience, ease, and comfort of people traversing the intersection and Provide ease/control of access consistent with the function of intersecting roadways Main function is to provide for change of direction also its source of congestion in urban areas. Intersections are of greatest importance in highway design because of their effect on the movement and safety of vehicular traffic flow. At one intersection a vehicle transfer from the route on which it is traveling to another route, crossing any other traffic streams which flow between it and its destination. To perform this maneuver a vehicle may diverge from, merge with, or cross the paths of other vehicles. Priority control of traffic at junctions is one of the most widely used ways of resolving the conflict between merging and crossing vehicles. The universal adoption of the 'Give Way to traffic on the right' rule at roundabouts together with the use of 'Give way' and 'Stop' control at junctions has considerably increased the number of occasions at which a driver has to merge or cross a major road traffic stream making use of gaps or lags in one or more conflicting streams. Both urban and rural motorways make use of priority control at grade separated interchanges and junctions where merging vehicles have to enter a major traffic stream. While certain locations require the use of traffic signal control for junctions, other locations due to relatively low volumes of flow specifically during non-peak hours and the need to maintain priority the flow along the major arm has caused priority junctions being preferred in many cases.

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