AN ABSTRACT OF THE THESIS OF

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In response to the growing environmental concern and higher operating cost of regular automobile, the concept of Low-Speed Vehicles (LSVs) is becoming popular as a sustainable mode of transportation. Primarily designed for protected environments and gated communities, the use of these vehicles is gradually increasing on public roadways as a short-range alternative to fossil-fueled autos. LSVs have a maximum speed limit of 25 miles per hour and these vehicles are not subject to the same federal requirements for occupant protection as regular passenger cars. This research investigated the safety standards and operating regulations pertaining to LSVs across the U.S. The finding of this study emphasizes the need for a LSV-friendly infrastructure in order to accommodate LSVs on the existing roadway system which is typically designed for larger and faster moving vehicles. However, development of a completely new LSV infrastructure and/or modification of the existing road network to accommodate LSVs would be very expensive, time consuming and in many cases, not feasible due to adjacent land use characteristics. Considering these issues, this research proposes a comprehensive planning methodology to develop a secondary low speed roadway network that can be applied to a small or medium-sized city with geographically compact activity spaces. The secondary roadway network would provide safe and efficient connectivity from residential neighborhoods to all major activity centers of the city by both human and non-human powered low speed

vehicles, while minimally affecting the road safety and traffic operations of regular automobiles, or exposing the LSV operators to undue risk.

Planning of a Secondary Road Network for Low Speed Vehicles in Small or Medium-Sized City

by
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Mafruhatul Jannat, Author

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1 Introduction

1.1 Motivation

Sustainable Transportation has become an important aspect of modern transportation system. Sustainable Transportation can be defined as “Satisfying current transport and mobility needs without compromising the ability of future generation to meet these needs” [1]. The concept of sustainable transportation cannot be attained through present auto-dependent urban transportation system. The auto-dependent city is significantly contributing to growing traffic congestion and air quality degradation due to increased mobile source emissions, increased energy consumption, and greater dependency on foreign fuel supplies [2, 3, 4, 5, 6, 7]. Statistics from 2001 National Household Travel Survey (NHTS) revealed that, in U.S. over 97% of rural households own at least one car vs. 92% of urban households in 2001, compared to 80% in the early 1970s [8,9]. Household motorized Vehicle Miles Travel (VMT) also increased 300% between 1977 and 2001, relative to a population increased of 30% during the same period [10, 11]. Consequently, congestion is becoming a critical problem that has drastically resulted in a cost of $115 billion in 2009 from $24 billion in 1982, measured in constant 2009 US dollars [12]. All these parameters indicate the dire necessity of major structural reform and technological innovation in the transportation sector. In this context, Low Speed Vehicles (LSVs) can play a significant role due to its vast array of social and environmental benefits that include zero tailpipe emission, energy efficient mobility, quieter transportation, reduction in petroleum imports and greenhouse gas emission, improvement of regional air quality, and lower operating cost, all these conventional automobile failed to offer. In addition, these vehicles do not require any development of new propulsion and energy systems; rather they are better suited to the limitations of today’s batteries than are full-sized electric vehicles (EVs) designed for highway travel [14] . Also, low speed local travel does not require much acceleration capability, so a vehicle powered for 20-30 miles per hour is sufficient for the purpose [15]. Therefore, in recent years the use of low-speed vehicles on public roadways is gradually increasing as a short-range alternative to fossil-fueled autos (OTREC RR-10-19)[16]. Specially, in multi-car households, people find it desirable and economical to substitute a conventional passenger car with a LSV for local commuting and personal errands due to their energy efficiency and lower operating cost. The U.S. Energy Information Administration estimates that the number of electric vehicles in use nationwide has increased from 6,964 in 1999 to 53,526 in 2006 – a seven-fold increase in seven years [17].

Low-speed electric vehicles (LSVs), also referred to as Neighborhood Electric Vehicles (NEVs), are limited to a maximum speed of 25 miles per hour [18]. In recent years, manufacturers have introduced Medium-Speed Electric Vehicles (MSEVs) that are essentially LSVs capable of faster speeds – usually 35 miles per hour. Both LSVs and MSEVs are expected to become more popular in the coming years for local travel and personal errands. Although, MSEVs are defined in Oregon regulations, but there are currently no MSEVs registered in Oregon and in many states they are prohibited. As of December 31, 2009, there were 265 LSVs and no MSEVs registered in Oregon. There are other types of electric vehicles registered (e.g. electric motorcycles), bringing the total number of Oregon registrations to approximately 400 electric vehicles [19]. The primary focus of this research is on LSVs that are limited to a maximum speed of 25 miles per hour. It is important to note that LSVs are not in the same vehicle classification as all-electric passenger cars. The new all-electric passenger cars and trucks have met or exceeded the Federal Motor Vehicle Safety Standards for occupant protection, and these vehicles are not speed restricted or limited to low-speed roadways (OTREC RR-10-19). In contrast, though Federal Motor Vehicle Safety Standards (FMVSS 500) require LSVs to be equipped with headlights, taillights, brake lights, turn signals, seat belts and other safety features, these vehicles do not have to meet all the federal motor Vehicle safety standards mandatory for conventional passenger car [18]. A study conducted in the University of California noted that such vehicles are typically shorter in length, width and wheelbase than the American Association of State Highway and Transportation Officials (AASHTO) designed passenger cars, and they also have slower acceleration [20]. Consequently, LSVs have inherent safety risks associated with their use on public roadways and where these roadways intersect with high-speed facilities. Thus, as LSVs continue to become more numerous on public roads, the need arises to investigate the impacts of their use to ensure the safety of the traveling public on the roadways (OTREC RR-10-19) [16].

A brief examination of other state laws shows a range of restrictions pertaining to LSVs. The basis of these state regulations, however, is often not clear. With such vehicles likely to come into more common use, there is a need to investigate a rational basis for regulations that would protect the public and also provide for the use of this energy-efficient, sustainable alternative to the conventional fossil-fueled passenger car for local, short-range travel (OTREC RR-10-19). At the same time, accommodations should be made to provide LSV-friendly infrastructure in the existing roadway system designed for larger vehicle and fast moving traffic. The LSV-friendly infrastructure would take into account LSVs' reduced length and width, lighter weight, lower speed and less crash protection characteristics. However, development of a completely new LSV infrastructure by modifying the existing road network in the city would be very expensive, time consuming and in many cases, not feasible due to adjacent land use characteristics. For example, provision of separate LSV path by increasing the total road width or narrowing the lane width on roads is not always feasible, especially when there is a bike lane beside the major through traffic lane on roads. Also acquisition of new land to expand the road width is very expensive and in many cases not possible for majority of the roads within the city. Therefore, instead of developing a completely new infrastructure for LSVs, a parallel or secondary low speed roadway network can be developed in addition to the primary road network within the city. The purpose of this low speed secondary road network would be to provide a safe connectivity from residential neighborhoods to all major activity centers of the city by human and non-human powered low speed vehicles It is important to note that this network would be developed based on the existing road system of the city, making any special infrastructural change of the roads, as least as possible.

1.2 Objective and Scope of the Study

The specific objectives of this research can be summarized as:

1. Conduct a comprehensive review of literature on the safety of LSVs and their regulation on public roadways in the North American, European, Asian and Australian continents.
2. Compile and analyze laws and regulations for LSV operations in all states, particularly as they relate to minimum and maximum operating speeds.
3. Collect information from state departments of transportation (DOTs) and the U.S. Department of Transportation (USDOT) on any crash data they have collected pertaining to LSVs.
4. Identify safety and regulatory issues on roadway infrastructures by analyzing the effects and impacts of LSV operations on public roadways, given their operational characteristics relative to other types of vehicles on the road.
5. Identify different factors influencing the route choice behavior of LSV users and conduct a survey on the LSV users of the city for that purpose.
6. Propose a comprehensive Planning Methodology to develop a secondary low speed network using the existing road system of the city that would take into account the LSV users' route preference characteristics.
7. Identify connectivity issues within roadway infrastructures where there are gaps between low-speed roadway connections within urban (growth) boundaries.
8. Propose recommendations to fill up the connectivity gaps within the low speed network in order to provide complete route connectivity by LSVs within the city.

It is expected that the following outcome can be made possible through the study:

1. Recommendation of a rational basis for regulations pertaining to the operations of LSVs in public roadways.
2. Development of a comprehensive planning methodology that would help to establish a secondary low speed network for a city. The planning methodology can be applied to a

small or medium-sized city with geographically compact activity spaces accessible by surface streets, for example City of Corvallis.

3. Development of the secondary low speed road network for the city would be accomplished through the following steps:

   i) Analyzing the existing roadway network of the city using Google Earth mapping tool. The road segment analysis with Google Earth software helps the planner not only to identify the travel infrastructure measures, but also provides detailed information of different road characteristics, for example number of STOP signs, type of traffic-signal used, location of the roadway, type of adjacent land use etc.

   ii) Coupling this road analysis with City's Transportation Plan and LSV users' route preference feedback to accomplish this network development process.

The developed low speed network would ensure a safe and efficient movement of low speed vehicles in the city not affecting the road safety and traffic operations of regular automobiles. The probability of vehicle to vehicle weight differentials and speed differential would also reduce at the route of this developed network that would protect the LSV occupants from exposure to undue risk.

2 Literature Review

2.1 Low Speed Vehicle Literature

In response to the growing environmental concern, the concept of LSVs has emerged as a new mode of urban transportation. These vehicles offer the benefits of zero tailpipe emission, reduced greenhouse gas emission, less energy consumption, low noise and low maintenance over conventional motor vehicle. The main component of petroleum-fuel motor vehicle exhaust is CO_2 that is the primary reason for global warming and disruptive change of world climate. The U.S. plays a leading role in generating CO_2 primarily due to the rapid VMT growth initially started around 1980s [14]. The 2011 U.S. Greenhouse Gas Inventory report reveals that the transportation sector of U.S. is responsible for about one third of its anthropogenic CO_2 emission [12]. In statistics, the U.S. transportation sector accounts for approximately 33 percent of total CO_2 emissions from fossil fuel combustion, nearly 60 percent of which resulted from gasoline consumption for personal vehicle use [12].

Therefore, there is an urgent need for major structural reform and technological innovation in the transportation sector. The concept of 'sustainable transportation" promoted the idea of multimodal transportation that will help to reduce dependency on regular petroleum-based motor vehicle and encourage the use of alternative fuel green vehicle. The Clean Air Act (CAA) of 1990, Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Energy Policy Act of 1992, and the National Climate Action Plan of 1993 are some of the steps to promote this sustainable transportation mode. In particular, the zero emission vehicle (ZEV) mandate issued by the California Air Resources Board (CARB) in 1990, promoted the marketing of electric vehicles (EV) and consequently reduced pollution rates. This mandate requires automobile manufacturers to produce and sale ZEVs equal to 2% of their California Sales in 1998. This percentage rose to 5% in 2001 and 10% in 2003 [14]. In return, automobile manufacturers receive credits for each electric vehicle sold [21]. This act has greatly influenced the manufacturers to produce and sale Low Speed Vehicles (LSVs) in large scale. Also, in response to the lobbying from Bombardier, a low speed vehicle manufacturing company, the U.S. issued regulations for LSVs in 1998, which excluded these vehicles from the passenger vehicle class and designated as a new vehicle class titled as “Low Speed Vehicle” [18].

In July 2001, the U.S. Department of Energy (DOE) published a report on the assessment of 348 LSVs and their introduction into 15 vehicle fleets in the United States, titles as “*Field Operation Program for Neighborhood Electric Vehicle Fleet Use*, 2001”. In this report, it was mentioned that 32 percent of the LSVs were used on public thoroughfares and that 12 percent had been used on both public and private thoroughfares. According to the report, these LSVs travelled a distance of 1.2 million miles per year or 3,409 miles per vehicle. These vehicles made significant contribution to energy efficiency and reduction of pollution. The report stated that LSVs prevented the consumption of 110,514 L (29,195 gal.) of gasoline, which equals 329 L (87 gal.) per LSV, and consequently the emission of 570 ton of GGE per year [21].

The Institute of Transportation Studies at the University of California, Davis published a report on a low-speed vehicle conference held on June, 1994, titled as “Proceedings of the Neighborhood Electric Vehicle Workshop: A Policy, Technology, and Research Conference”. The technology, land use and infrastructure, market opportunities and regulatory issues pertaining to the use of LSVs were discussed in this report [14]. According to this report, LSVs can play the key role in the transition to a efficient and environmentally benign transportation system, if the introduction of LSVs would be coupled with goal-oriented Intelligent Transportation System (ITS), demand management strategies, and infrastructural and transportation control measures that would provide a safe and convenient environment for the use of LSV. The urbanized region with geographically compact activity spaces accessible by surface streets can have the largest benefits of LSVs, the report stated. Another important aspect for LSV use that the paper indicated is the liability issue for LSV manufacturer. The importance of the mutual interrelation between vehicle suppliers, infrastructure providers, and regulatory agencies was also emphasized in the report [14].

In order to get a broader view of the LSVs and their use all over the world, literature pertaining to "Light Electric Vehicles" from Australia, New Zealand, Europe, and Canada was also reviewed. New Zealand and Australia currently do not permit these vehicles on public roads as a result of concerns for occupant safety [OTREC RR-10-09].

The Canada Government transportation authority, Transport Canada, has worked in partnership with the United States Department of Transportation to harmonize regulations so that LSV manufacturers can build LSVs for the North American marketplace (*NHTSA 1998*) [18]. In July 2000, in accordance with CMVSS No. 500, Canada adopted regulations introducing low-speed vehicles as a new vehicle class [21]. According to the Regulations amending the Motor Vehicle Safety Regulations (Low-speed Vehicles) published in the Canada Gazette Part II, "Low-Speed vehicle means a vehicle, other than an all-terrain vehicle, a truck or a vehicle imported temporarily for special purposes, that is powered by an electric motor, produces no emissions, is designed to travel on four wheels and has an attainable speed in 1 mile of more than 20 miles per hour but not more than 25 miles per hour, on a paved level surface." This definition of LSVs is similar to that of U.S., with the exception that in order to be authorized in Canada, the LSVs needs to be powered by an electric motor. According to the published report on the assessment of LSVs by Transport Canada, by authorizing this non-polluting LSVs, Canada can contribute to it's commitment to meet the Kyoto Protocol, to handle the problem of global warming and reduce polluting emissions. However, the provinces and territories in Canada also have the legal authority to prohibit the use of LSVs on public roadways or to require additional safety equipment be installed for their operation on roadways [16].

In Europe and other parts of the world, these vehicles are defined as electric or motorized quadricycles. The European definition, which has been adopted by many nations, was developed by the European Union and is eligible for European Community Whole Vehicle Type Approval (ECWVTA) (*UK Department of Transport, 1999*)[22]. An expansion of the definition for powered two- and three-wheel vehicles (including some quadricycles) includes vehicles that are capable of more than 6 km/h (3.75 miles per hour), and came into effect on 17 June 1999. "*Any newly designed, mass produced,* *model or type of vehicle within the scope of ECWVTA and first introduced and placed on the market of an EU Member State from that date must have ECWVTA, and a Certificate of Conformity issued by the manufacturer must be made available. To be valid in the UK, the Certificate of Conformity should indicate that the vehicle is suitable for use in left hand rule of the road traffic and has a speedometer calibrated in miles per hour. The ECWVTA definitions are as follows (UK Department of Transport, 1999).*

Category L6e -	***Light quadricycle** - Four wheels, with a maximum unladen mass of 350kg (not including the mass of the batteries in an electrically powered vehicle), a maximum speed of 45km/h, a maximum spark ignition internal combustion engine capacity of $50cm^3$, or maximum power of any other internal combustion engine of 4kW or maximum electric motor power of 4kW. The construction requirements are those for a three wheel moped unless otherwise specified in a particular Directive.*
Category L7e -	***Quadricycle** - Four wheels, with a maximum unladen mass of 400kg or 550kg for a goods carrying vehicle (not including the mass of the batteries in an electrically powered vehicle) and a maximum net power, whatever the type of engine or motor, of 15kW. The construction requirements are those for a motor tricycle unless otherwise specified in a particular Directive.*

Note - The Masses and Dimensions Directive, 93/93/EEC, applies controls on maximum dimensions and laden/unladen masses for vehicles" (UK Department of Transport, 1999) [22].

Construction standards for quadricycles are harmonized at the European level, the main instrument being European Parliament and Council Directive "2002/24/EC - the Framework Directive." This Directive requires compliance with a number of individual Directives that set out requirements for particular vehicle systems: brakes, lighting, wheels, and other components. These harmonized requirements are recognized by all 27 Member States of the European Community. Once the vehicle is approved to the standards of the Directive by any member state, the manufacturer has access to all 27 markets" (UK Department of Transport, 1999) [22].

The UK Department for Transport issued a news release on May 8, 2007, indicating that the Government was seeking a review of the European regulations for quadricycles after initial tests of their safety performance raised concern, and following their growth in popularity as a more environment friendly alternative to cars. Current safety standards, set at the European level, were established at a time when it was envisioned that this type of product would be used as a mainstream road vehicle. The UK Department for Transport began simulated impact tests once this growth in popularity had been determined. The vehicle that was tested passed all the European requirements applicable to quadricyles, but when it was subjected to the same impact test expected of normal cars, serious safety issues were revealed (*UK Department of Transport, 1999)*[22].

The UK Roads Minister Dr. Stephen Ladyman said: "*The safety regulations that govern this type of vehicle were designed at a time when it was thought they would cover four-wheeled motorcycles and some small, specialized commercial vehicles. Not city run-abouts that resemble small cars. But, given increasing environmental concerns, new vehicles that qualify as quadricycles have come to the market and are becoming more popular for urban use. Therefore it is right that we reconsider the regulations for this type of vehicle and whether safety regulations should be made more stringent. Now*[*that*] *we have the initial findings of our tests we will be taking this up with the European Commission and manufacturers, and will publish more information when the full programme of tests is complete. The Department for Transport is undertaking further tests on another make of quadricycle to help its discussions with the European Commission, and is now in urgent contact with the relevant manufacturers. Once the full analysis is complete further information will be made available*" (*BBC News 2007*) [23].

The occupant protection of a quadricycle is assessed by a frontal impact test where the vehicle is propelled into a deformable barrier (to simulate striking another vehicle) at a velocity of 56 km/h (~35 miles per hour). The impact takes place at a 40% overlap with the barrier and is concentrated on the driver's side of the vehicle. The UK Department tested two quadricycles. The first test, which involved a REVA G-Wiz electric vehicle, took place in 2007 (*BBC News 2007*)[23]. Currently for quadricycles and LSVs, as opposed to passenger cars, there are no requirements for occupant protection tests.

The objective of this study extends to propose a methodology to develop a secondary local roadway network for low speed vehicles in a small sized city. The urge for a safe and convenient road network for LSV has been mentioned in many of the literature related to LSVs [14, 20, and 21]. Stein et al. in [20] has discussed about developing new roadway infrastructure and modification of traffic control devices to safely accommodate LSV on roadways for large vehicles and fast-moving traffic. They proposed the geometric configurations for constructing new LSV lanes on existing roadways and also stated guidelines for the traffic signs that should be placed on roadways for the safe movement of LSVs. However, the roadway configuration and adjacent land use might not be suitable to provide separate LSV lane in every case. The cost of this new development is also an issue in this case. Again, the state and local regulatory policies should also be taken care of in this issue. Considering all these, this study attempts to develop a low speed road network based on the existing road infrastructure of the city. To attain this goal, the route choice factors and travel behavior of LSV users need to be assessed for the purpose. However, very few references are available to date that discuss the route preference and travel behavior pattern of LSV user. Though not exactly similar, LSV has some features analogous to bikes, such as zero tailpipe emission, lower crash protection than motor vehicle, less speed than regular traffic, alternative mode for cars to travel etc. Therefore, the literature related to the route choice, travel behavior and network development for bicyclist were also studied in this research.

In order to develop the low speed network, both link-level and route-level factors were considered that influence the LSV users decision to make route choice. Having similar kind of perceived risk that a bicycle experience on roadways, the literature pertaining to the link and route factors that affect the route choice decision of bicyclist, has been reviewed here. Howard and Burns [24], Moritz [25], Stinson et al [26], Landies et al [27] have discussed some of the link-level factors influencing the route choice of bicyclist, such as bicycle facility presence, motor vehicle traffic characteristics etc. Whereas, Landies et al [27] mentioned about the riding surface quality and Sener et al [28] talked about hilliness as some important link level factors influencing route preference decision of bicyclists.

The route-level studies of bicyclist used revealed preference (RP) surveys, stated preference (SP) surveys, or the Delphi technique to assess the route choice of bicyclists [26]. RP survey evaluates the users' route choice preference by presenting an actual choice environment. By assessing individual's actual experience of the trip, the RP survey might be able to yield more accurate result of potential route characteristics. However, this method is time consuming and limits the sample size and geographic scope of data collection. The route-level studies that used RP surveys include Howard and Burns [29], Aultman-Hall et al.[30] and Hyodo et al.[31].

A SP survey evaluates the users' preferences by presenting them a series of hypothetical scenarios. The major advantage of SP survey is the ability to obtain a large sample size and low cost of data collection [26]. Bovy and Bradley et al. [32] conducted SP survey to assess bicyclists' route choice factors and found that travel time is the most important factor in route preference. They also found that surface quality, traffic level, facility type and age are also some important factors for bicyclist. Abraham et al. [33] also used the SP survey in their study and found that commuter bicyclists' were willing to incur additional travel time to use routes with bicycle facilities. In the SP survey study conducted by Stinson et al [26], it was found that travel times, roadway functional classification, hilliness, roadway pavement condition, number of STOP signs are some of the important factors influencing bicyclists' route choice. The Delphi technique analyzes the expert opinions to identify the relative weight of the factors in route evaluation that might not be all time consistent with the observations found from RP and SP surveys. For example, Mescher and Souleyrette [34] in their bicyclists' route choice study conducted by Delphi technique found that mountainous topography and frequent high cross-street traffic are the most important factors for route choice, whereas travel time has ranked close to the bottom of their factor importance list.

2.2 Secondary Low Speed Network in the City of Corvallis

The City of Corvallis is the home of Oregon State University with a city population of 55,370 [35]. Corvallis is the seventh largest city in Oregon and also awarded as one of the best college town in U.S. by the American Institute for Economic Research's annual College (AIERC) Destinations Index. The city has diverse economy and well-planned public facilities. The grid pattern pleasant neighborhood made the city very livable to the community. Again, the trip generation characteristics inventoried throughout the city revealed that a significant component of the trips is home-based shopping or other. The trip generation characteristics also showed that as the city grows, there is a high potential for mixed-use development, allowing each area to have elements of housing, employment, schools, and shopping activities. This would potentially result in the shortening of length of daily trip made by city dwellers. All these characteristics provide a strong base to develop a secondary low speed network in the city using the existing low speed collector and neighborhood streets. The City also aims to provide energy efficient alternative sustainable transportation mode to its residents, as directed in the City Comprehensive Transportation Plan [36].

Therefore, a college-town like Corvallis, which is mostly, comprised of neighborhood areas, college communities and campuses, retirement communities and shopping areas, are best suited for driving the LSVs partly because the activity centers of the city are also closely spaced. In addition to that, the city authority provides an incentive to promote an energy efficient sustainable transportation system in the city. Therefore, a secondary low speed road network based on the current city roadway system would provide a safe and convenient connectivity to the activity centers for the low speed vehicle users of the city.

3 Low Speed Vehicle

Low-speed vehicle is a new vehicle classification that represents an energy efficient green sustainable transportation mode. As the name suggests, these vehicles are designed to make urban short trips at comparatively low speed. This chapter describes different vehicular, operational and regulatory aspects of low-speed vehicles. Part of this chapter is adopted from the project report on low speed vehicle compiled by the author in collaboration with her supervisor Dr. Kate Hunter-Zaworski and ODOT personal Lyn Cornell (OTREC RR-10-19) [16].

3.1 Background

In the early 1990, the use of golf carts with a maximum speed of 15 miles per hour was found to be growing within the retirement and planned communities. Several states from California to Florida authorized the operation of “golf carts” on public roadways with the constraint of not exceeding the speed of 15 miles per hour. Further, three states redefined their definition of golf carts to “a vehicle having maximum speed up to 25 miles per hour” or added a new category of vehicle titled as “neighborhood electric vehicle”, capable of having maximum speed of 25 miles per hour. These created a conflict between the state and federal laws in treating these vehicles. In addition to that, this conflict restricted the ability of vehicle manufacturers to produce and sell, and the ability of consumers to purchase those small vehicles. Because, according to the National Highway Traffic Safety Administration (NHTSA) regulation at that time, the golf carts and all other similar vehicle incapable of exceeding 20 miles per hour were only required to meet the state and local requirements regarding safety equipments. When the speed limit of these small vehicles would exceed 20 miles per hour, they would be treated as conventional motor vehicle and according to Federal law they must have to comply with the Federal Motor Vehicle Safety Standards for that vehicle type. Therefore, this created a conflict with the state and local laws because compliance with the full range of motor vehicle standards was not feasible for those small vehicles.

Again, the growing on-road use of these vehicles at different speed had led to several crashes. In the period of 1993 to 1997, these golf carts were involved in 16 fatal crashes and some severe injury crashes. Meanwhile, Bombardier Inc., a vehicle manufacturer company, requested that a new class of 4-wheeled vehicles be introduced for slow-moving, low-cost vehicles intended for short-distance travel. Considering all these, NHTSA mandated a new regulation defining a new class of vehicle titled as "Low Speed Vehicle (LSVs)". According to this new definition, LSVs include any 4-wheeled vehicle, not including trucks, with a maximum speed greater than 20 miles per hour, but not greater than 25 miles per hour. Also, this new category of low speed vehicles has to meet a new Federal Motor Vehicle Safety Standard No. 500 (49 CFR 571.500) established by NHTSA, as they were excluded from the vehicular category of regular passenger car. Conventional golf carts having a maximum speed of less than 20 miles per hour are not included in the classification of "Low Speed Vehicle" (49 CFR Part 571) [18].

3.2 Definitions

3.2.1 Federal Definitions

On June 17, 1998 the National Highway Traffic Safety Administration (NHTSA) officially included "Low-speed vehicles" as a motor vehicle category of the Federal Motor Vehicle Safety Standards and defined LSV in 49 CFR 571.3. According to the definition in this rulemaking, "Low-Speed Vehicle (LSV) is a four-wheeled motor vehicle whose attainable speed in 1 mile is more than 20 miles per hour and not more than 25 miles per hour on a paved level surface and has a gross vehicle weight rating (GVWR) of less than 3000 lbs." This group includes neighborhood electric vehicles, and speed-modified golf cars whose top speed is greater than 20 miles per hour, but not more than 25 miles per hour (*NHTSA 1998*) [18].

3.2.2 Oregon Definitions

Current Oregon Revised Statutes (ORS) are consistent with forty other states. ORS 801.331 defines "Low-speed vehicle" as a four-wheeled motor vehicle with a top speed of more than 20 miles per hour but not more than 25 miles per hour. This type of vehicle is permitted to operate on public roads posted at no more than 35 miles per hour (ORS 811.512). Addressing the case of three-wheeled LSVs, ORS 814.518 limits the speed of three-wheeled "motorized scooters" to 25 miles per hour. ORS 814.520 provides that these vehicles are in violation of the law if they are driven "at less than the normal speed of traffic using the roadway at that time and place" [37].

ORS 801.341 defines a Medium Speed Electric Vehicle (MSEV), as "an electric motor vehicle with four wheels that is equipped with a roll cage or a crushproof body design, can attain a maximum speed of 35 miles per hour on a paved, level surface, is fully enclosed, and has at least one door for entry [37]. The presence of a roll cage or crushproof body does not guarantee that the vehicle is crash worthy, however.

Three-wheeled vehicles

In the state of Oregon, a three-wheeled vehicle that is not a human powered tricycle is defined as a motorcycle (ORS 801.365) [37]. This report does not address motor assisted scooters or three-wheeled electric vehicles; however many of the issues discussed in this report may pertain to motor assisted scooters. People who ride motorcycles have special licenses and many take special training in motorcycle safety. Traditional motorcycles do not experience the speed differentials that are discussed in Section 3.6, Safety Considerations, of this report.

> **Motorcycle**: A "Motorcycle" means any self-propelled vehicle other than a moped or farm tractor that:
> (1) Has a seat or saddle for use of the rider;
> (2) Is designed to be operated on the ground upon wheels; and
> (3) Is designed to travel with not more than three wheels in contact with the ground.

Figure 3.1 shown below is a flow chart to assist ODOT and law enforcement staff in identifying these special vehicles.

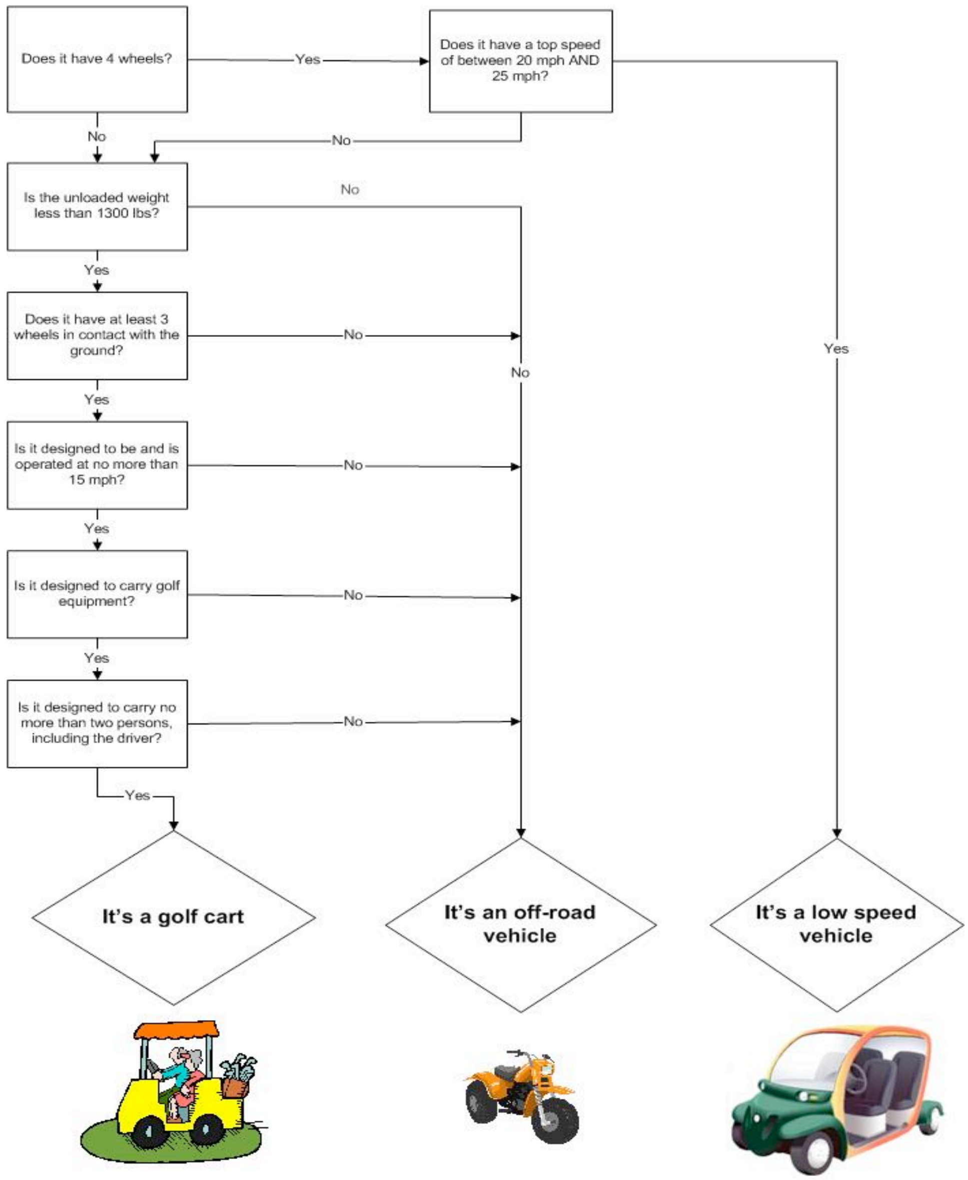


Figure 3.1: Flow Chart to assist with identification of LSVs (Courtesy of Michele O'Leary, ODOT-Safety Division)

3.3 Summary of Current Oregon Laws and Statutes for LSVs

Table 3.1 Summarizes current Oregon laws and statutes for LSVs.

Table 3.1: Current Oregon Laws and Statutes for LSVs

ORS Number	***Title***	***Brief Description***
801.331 http://www.leg.state.or.us/ors/ 801.331	Low-speed vehicle	Low-speed vehicle means a four wheeled motor vehicle with a top speed of more than 20 miles per hour but not more than 25 miles per hour
801.341 http://www.leg.state.or.us/ors/ 801-341	Medium-speed electric vehicle	Medium-speed electric vehicle means an electric motor vehicle with four wheels that is equipped with a roll cage or a crushproof body design, can attain a maximum speed of 35 miles per hour on a paved, level surface, is fully enclosed, and has at least one door for entry
803.300 http://www.leg.state.or.us/ors/ /803.300	Failure to register: Penalty	A person commits the offense of failure to register a vehicle if the person owns a vehicle in this state and the person does not register the vehicle in this state. This is a Class D traffic violation
803.420 http://www.leg.state.or.us/ors/803.420	Registration fee	The registration fee for a low-speed vehicle and medium speed vehicle is $43, for each year of the registration period
811.512 http://www.leg.state.or.us/ors/ /811.512	Unlawfully operating low-speed vehicle on highway; penalty	A person commits the offense of unlawfully operating a low-speed vehicle on a highway if the person operates a low-speed vehicle on a highway that has a speed limit or posted speed of more than 35 miles per hour; it is a Class B traffic violation. However, a city or county may adopt an ordinance allowing operation of low-speed vehicles on city streets or county roads that have posted speeds of more than 35 miles per hour
811.513 http://www.leg.state.or.us/ors/811.513	Unlawfully operating medium-speed electric vehicle on highway; penalty	A person commits the offense of unlawfully operating a medium-speed electric vehicle on a highway if the person operates a medium-speed electric vehicle on a highway with a posted speed limit that is greater than 45 miles per hour; it is a Class B traffic violation.

		However, a city or county may adopt an ordinance allowing operation of medium-speed electric vehicles on city streets or county roads that have speed limits or posted speeds of more than 45 miles per hour
820.220 http://www.leg.state.or.us/ors/820.html	Operation of low-speed vehicle in prohibited area; penalty	A person commits the offense of operation of a low-speed vehicle in a prohibited area if the person is a person with a disability and the person operates a golf cart or substantially similar motor vehicle on any highway with a speed designation greater than 25 miles per hour; it is a Class D traffic violation
807.010 http://www.leg.state.or.us/ors/807.html	Operating vehicle without driving privileges or in violation of license restrictions; penalty	A valid driver license is required
811.435 http://www.leg.state.or.us/ors/811.435	Operation of motor vehicle on bicycle trail	A person commits the offense of operation of a motor vehicle on a bicycle trail if the person operates a motor vehicle upon a bicycle lane or a bicycle path; it is a Class B traffic violation
811.130 http://www.leg.state.or.us/ors/811.130	Impeding traffic; penalty	The operator may be cited for impeding traffic

In order to analyze the impacts of LSVs in North America, the laws and regulations pertaining to LSVs in all U.S. states have also been analyzed below.

3.4 Summary of Laws Governing LSVs in Other U.S. States

The regulations of low-speed electric vehicles (LSVs) in almost all of the states have been reviewed. All the references for this section are included in Appendix A. To date, the states of Alabama, Arkansas and Connecticut do not have any laws permitting low speed electric vehicles on public roadways. Nebraska has passed LSV regulations, but the detailed information of the laws could not be further located. The states that do have regulations governing LSVs may be summarized into one of the following categories: the maximum roadway speed limit to legally operate an LSV, and the intersection speed limit that an LSV can cross.

3.4.1 Classification Based on Maximum Roadway Speed Limit

States that specify a speed limit greater than the speed of an LSV

Among the 51 states, approximately 35 states have specified the maximum roadway speed limit of 35 miles per hour for allowing an LSV, whereas the maximum operating speed of an LSV in those states is 25 miles per hour. This creates a potential speed differential of 10 miles per hour between LSVs and other motor vehicles. The states belonging to this group are as follows: Alaska, Arizona, California, Colorado, Delaware, Florida, Georgia, Hawaii, Idaho, Iowa, Kentucky, Louisiana, Maine, Michigan, Minnesota, Mississippi, Missouri, LSVsada, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, Wisconsin, and Wyoming.

There are some variations. Kansas has specified the maximum roadway speed limit as 40 miles per hour, creating a potential speed differential of 15 miles per hour. Texas has specified that an LSV may not be operated on a street or highway at a speed that exceeds the lesser of two measures: the posted speed limit or 35 miles per hour. The maximum potential speed differential is thus 10 miles per hour.

The states of Illinois, Maryland, and Massachusetts have specified the maximum roadway speed limit as 30 miles per hour, whereas the maximum operating speed of LSVs in those states is 25 miles per hour, resulting in a potential speed differential of 5 miles per hour.

States that specify a speed limit as the same as the speed of an LSV

The states of New Jersey, West Virginia, and Rhode Island have restricted LSVs to roadways with the maximum speed limit of 25 miles per hour, which is same as the maximum operating speed of an LSV. However, the New Jersey legislature has given the approval to state authority or local ordinance to increase the roadway speed limit to 35 miles per hour if required.

Indiana and New York have specified both the roadway speed limit on which LSVs may operate and the maximum operating speed of LSVs to be 35 miles per hour.

3.4.2 Classification Based on Intersection Speed Limit

States that Allow LSVs to Cross Roadways with Higher Speed Limits

Thirty states allow LSVs to cross at the intersection of roadways having higher speed limits. This group can be further divided into two categories: states that specify the type and control of the intersection, and states specifying no intersection controls.

The States that Specify the Type of Intersection

California specifies that an LSV may cross a roadway with a speed limit in excess of 35 miles per hour if the crossing begins and ends on a roadway with a speed limit of 35 miles per hour or less and occurs at an intersection of approximately 90 degrees. Also the operator of an LSV may not traverse an uncontrolled intersection with any state highway unless that intersection has been approved and authorized by the agency having primary traffic enforcement responsibilities for that crossing by a low-speed vehicle.

In Illinois LSVs may not cross a street with a speed limit in excess of 45 miles per hour unless the crossing is at an intersection controlled by a traffic light or 4-way stop sign. However, the Department of Transportation or a municipality, township, county, or other unit of local government has the authority to prohibit the operation of LSVs on streets if the public safety is jeopardized.

In Kentucky the legislation states that LSVs may cross an at-grade intersection with a roadway having a speed greater than 35 miles per hour if the intersection is equipped with traffic signals.

In Maryland a person may not drive an LSV across a highway for which the posted maximum speed limit exceeds 45 miles per hour, except at an intersection that is controlled by a traffic control signal or a stop sign at each approach to the intersection.

In Massachusetts an LSV may cross an intersection of a roadway with a posted speed limit of 45 miles per hour, if it is controlled by traffic signals or stop signs.

New Jersey legislation states that if the road is more than two lanes, divided, or has a speed limit over 35 miles per hour, an LSV crossing must do so only at a signalized intersection. Crossing at a non-signalized intersection can occur if approved by the state transportation agency.

In Vermont LSVs may cross a highway that has a speed limit of up to 50 miles per hour if the crossing begins and ends on a highway authorized for use by LSVs, and if the intersection is controlled by traffic signals.

In Wisconsin an LSV can cross those intersections where the highway under the jurisdiction of the municipality or county crosses a major state highway or a connecting highway only if the major state highway or connecting highway has a speed limit at the intersection of 35 miles per hour or less and is controlled by traffic control signals.

In Wyoming, an LSV can cross a state highway or a roadway with a speed limit over 35 miles per hour if the crossing begins and ends on a roadway with a speed limit of 35 miles per hour or less, occurs at an intersection of approximately ninety (90) degrees, and the local authorities have authorized the crossing.

States with No Description of Intersection

The following states mention that LSVs can cross the highway with a speed limit greater than 35 miles per hour, but they do not specify whether the intersection should be controlled or uncontrolled: Alaska, Arizona, Colorado, Delaware, Florida, Hawaii, Iowa, Louisiana, Kansas, Maine, Michigan, Minnesota, Missouri, LSVsada, New Hampshire, New York, New Mexico, North Carolina, North Dakota, Oklahoma, Rhode Island, South Carolina, Tennessee, Texas, Utah, Virginia, and West Virginia.

States that Specifically Prohibit Crossing Roadways With Higher Speed Limits

In Washington LSVs cannot cross a highway with a posted speed limit greater than 35 miles per hour unless the following criteria are met. “ LSVs cannot cross a roadway with a speed limit in excess of 35 miles per hour, unless the crossing begins and ends on a roadway with a speed limit of 35 miles per hour or less and occurs at an intersection of approximately ninety degrees, except that the operator of a neighborhood electric vehicle must not cross an uncontrolled intersection of streets and highways that are part of the state highway system subject to Title 47 RCW unless that intersection has been authorized by local authorities provided elsewhere in this section"(*Title 46 RCW*).

In Idaho LSVs are not authorized to cross any highway with a posted speed limit greater than 45 miles per hour.

No Mention of Crossings

There are four states with no regulations concerning the speed limit of an intersection where LSVs may cross. The states are as follows: District of Columbia, Indiana, Oregon, and South Dakota.

3.4.3 Other State Regulations

States that Include 3-wheeled Motor Vehicles in the State Definition of LSVs

The States of Colorado in C.R.S. 42-1-102(48.6) has defined an LSV as a self-propelled electric vehicle that has at least three wheels in contact with the ground.

Class B or Medium-Speed Electric Vehicles (MSEVs)

In 1998, a petition was made to NHTSA by Environmental Motors, Porteon Electric Vehicles, Inc., and Mirox Corporation for a rulemaking to create a new class of motor vehicles known as medium-speed vehicles, which would be limited to a maximum speed of 35 miles per hour. A number of reasons were cited in favor of this petition, but the most significant reason was related to potential environmental benefits, including facilitating the development of electric vehicles and fuel savings. The petitioners also mentioned that this new class of vehicle would meet a set of safety standards greater than those that apply to LSVs but substantially less than the full set of safety standards that apply to other light passenger cars (*NHTSA, 2008*) [18].

NHTSA, however, denied the petition, mainly due to safety concerns. According to NHTSA, with a 35 miles per hour speed limit, an MSEV would likely travel with high speed regular urban traffic. In such a traffic environment NHTSA requires the full set of Federal Motor Vehicle Safety Standards (FMVSS) to prevent fatalities and serious injuries in motor vehicle collisions, which an MSEV likely would not have met (given the petitioners' proposed MSEV criteria). The presence of a roll cage or crushproof body would not guarantee that the vehicle is crash worthy and would meet the FMVSS for passenger cars (*NHTSA, 2008*)[18].

In its denial of the petition NHTSA stated, "The concept of establishing such a class of motor vehicles with limited safety features that would be likely to intermingle with larger, higher speed vehicles in urban environments would result in significantly greater risk of deaths and serious injuries." NHTSA also said, "While we appreciate the importance of environmental issues, NHTSA does not believe that it is necessary or appropriate to significantly increase the risk of deaths and serious injuries to save fuel by introducing a new class of motor vehicles that does not provide adequate safety protection" (*NHTSA, 2008*)[18].

The NHTSA action does not preclude states from registering MSEVs and regulating their operation on public roadways (*IIHS 2010*) [42]. Accordingly, several states have specified maximum allowable speeds for MSEVs, as described below:

- Montana was the first state to enact MSEV regulations on April 23, 2007. It has defined an MSEV as a motor vehicle having a maximum speed of 45 miles per hour that can be operated on the roadway having posted a speed limit of no higher than 45 miles per hour.
- Colorado has defined an MSEV as a "Class B low-speed electric vehicle" that is speed limited at more than 25 miles per hour but less than 45 miles per hour and can be operated only on a roadway that has a maximum-posted speed limit of 45 miles per hour. However, it can directly cross a roadway that has a speed limit greater than 35 miles per hour at an at-grade crossing.
- In Georgia, Minnesota, Oklahoma, North Carolina, and South Carolina the allowable speed of MSEVs range from 30 to 35 miles per hour, and the maximum speed limit of the roadway on which these can be operated is 35 miles per hour.

- In Iowa the allowable speed of an MSEV ranges from 25 to 50 miles per hour, and the speed limit of roadways for operating an MSEV is 55 miles per hour.
- The Maryland legislature has redefined an MSEV as a Limited Speed Vehicle that has a maximum speed of more than 25 miles per hour but less than 55 miles per hour, and it cannot be operated on a highway if the maximum speed capability of the vehicle does not exceed the posted maximum speed limit for the highway by at least 5 miles per hour.
- In New Mexico the allowable speed of an MSEV is 30 to 40 miles per hour, but the roadway speed limit for this vehicle is 45 miles per hour.
- In Oklahoma and Oregon, the maximum speed of an MSEV is limited to 35 miles per hour, and the roadway speed limit for operating an MSEV is 45 miles per hour.
- Tennessee has specified the allowable speed of an MSEV at 30 to 35 miles per hour, and it can be operated on a roadway with a speed limit of 40 miles per hour.
- In Washington the allowable speed of an MSEV is 25 to 35 miles per hour, and the roadway speed limit on which they can be operated is 35 miles per hour. However, an MSEV can be also operated on a roadway having a speed limit of 45 miles per hour if the operator meets certain criteria mentioned the legislative bill.

States where Regulations of LSVs are in Process

As of the date of this report the states of Ohio and Pennsylvania were still in the process of developing regulations for LSV types of vehicles for the state legislature to consider. In the states of Alabama, Arkansas, and Connecticut there was no legislation found regarding LSVs.

3.4.4 Federal Motor Vehicle Safety Standards: FMVSS 500

The National Highway Traffic Safety Administration (NHTSA) has a legislative mandate – under Title 49 of the United States Code, Chapter 301, Motor Vehicle Safety – to issue Federal Motor Vehicle Safety Standards (FMVSS) and regulations, to which manufacturers of motor vehicles and equipment items must conform and certify compliance. FMVSS 209 was the first standard to become effective on March 1, 1967. A number of FMVSS became effective for vehicles manufactured on or after January 1, 1968. Subsequently, other FMVSS have been issued. New standards and amendments to existing standards are published in the Federal Register.

These Federal safety standards are regulations written in terms of minimum safety performance requirements for motor vehicles or items of motor vehicle equipment. These requirements are specified in such a manner “that the public is protected against unreasonable risk of crashes occurring as a result of the design, construction, or performance of motor vehicles and is also protected against unreasonable risk of death or injury in the event crashes do occur” (*NHTSA, 1998*)[18].

Federal Motor Vehicle Safety Standard No.500 (49 CFR 571.500), which became effective June 17, 1998, is a summary of the final rule of NHTSA which classified “Low-Speed Vehicle (LSV)” as a new group of motor vehicles. The rulemaking established the definition for LSVs and specified the minimum requirements those LSVs must have in terms of speed limit and vehicle equipment to ensure the safety of the vehicle occupant and other roadway users (*NHTSA, 1998)*. The rulemaking proceeding was initiated in response to a request by one of the LSV manufacturers, Bombardier, Inc. (*NHTSA, 1998*) [18].

3.4.4.1 Definition

The FMVSS No.500 has classified “Low-Speed Vehicle” as a small, 4-wheeled motor vehicle with a top speed of more than 20 miles per hour and not more than 25 miles per hour. Conventional golf-carts are not included in this classification, but a “neighborhood electric vehicle” (NEVs) is included in this classification.

3.4.4.2 Requirements

Speed

The maximum attainable speed of an LSV in 1 mile shall be not more than 25 miles per hour.

Equipment

Each vehicle shall be equipped with headlamps, stop lamps, turn signal lamps, tail lamps, reflex reflectors, one red on each side as far to the rear as practicable, and one red on the rear, an exterior mirror mounted on the driver's side of the vehicle and either an exterior mirror mounted on the passenger's side of the vehicle or an interior mirror, a parking brake, a windshield that conforms to the Federal motor vehicle safety standard on glazing materials (49 CFR 571.205), a VIN that conforms to the requirements of part 565 Vehicle Identification Number and a Type 1 or Type 2 seat belt assembly conforming to Sec. 571.209.

General Test Conditions and Procedures

Each vehicle must meet the performance limit for the above two requirements under the test condition and test procedure specified by the Standard No.500.

3.5 Dimensions of LSV

Low Speed Vehicles are small 4-wheeled vehicle designed for short trips within the community. These vehicles are generally shorter in length and width than regular passenger car. The AASHTO design passenger car has a length of 228 inch, width of 84 inch and wheelbase of 132 inch [20]. Whereas, the specifications of LSVs from different manufacturer companies indicate that the length, width and wheelbase of these vehicles are smaller than that of regular passenger car. In contrast, it has been found that the height of AASHTO design passenger car is almost 51 inch that is smaller than the height of LSVs available in the market. The following table shows the dimensions of LSVs of different manufacturer companies available in the market to date.

Table 3.2: Dimensions of LSVs from different manufacturer companies

Manufacturer	Model/Year	no of passenger	no of doors	Seatbelts positions	GVW (lb)	length (in)	Height (in)	Width (in)	Wheelbase (in)
Ford Th!nk	Ford Th!nk Neighbor/02	4	0	4	2300	114.1	67.7	56.4	77.9
Frazer-Nash	Fazer-Nash CityCar/01	4	4	4	2593	122.0	62.0	66.0	86.6
GEM	GEM e4/05	4	2	4	2100	131.1	69.1	57.7	102.1
Miles Electric Vehicles	Miles ZX40S-AD/08	4	4	4	2998	134.0	67.0	58.0	92.9
Columbia Parcar	Parcar 4-pasenger/02	4	0	4	2460	119.0	74.0	44.3	89.0
ZENN Motor company	ZENN 2 passenger/08	2	2	2	1807	120.8	55.9	58.0	81.8
Dynasty electric vehicles ltd	IT' Sport	4	4	4	2495	140.0	63.0	60.0	90.0

3.6 Safety Considerations

3.6.1 Crash Testing

The North American regulations for Low Speed Vehicles currently do not require that these vehicles meet any of the crash test requirements of conventional passenger cars, since these vehicles are designed to be used on low-speed and low-volume roadways such as in gated communities or on educational or industrial campuses. LSVs are becoming more prevalent, however, on higher speed and more highly congested public roadways in Europe, Canada, and the United States (*BBC, 2007*) [23]. Crash tests of LSVs have been conducted by; Transport Canada, the Insurance Institute for Highway Safety in the U.S., the Department for Transport in the UK, and in China (*IIHS, 2010*) [42]. Videos of these tests are available in the public domain. LSVs were not designed to meet the additional crash and energy attenuation requirements of passenger vehicles and therefore did not perform well in any of the crash tests [42]. The Canadian crash test video can be viewed at the Transport Canada link http://www.tc.gc.ca/eng/roadsafety/safevehicles-lowspeed-video-index-503.htm, and the Insurance Institute for Highway Safety video can be viewed at the following website: http://www.iihs.org/news/rss/pr052010.html

3.6.2 US and Canada Crash Tests

The NHTSA vehicle category of “Low-Speed Vehicle” has emerged as part of the sustainable green transportation system. NHTSA regulations restrict the top speed of these vehicles to 25 miles per hour in the intended operating environment of planned gated communities. NHTSA also states that this new classification of vehicle does not need to conform to the safety standards of a conventional passenger car and consequently does not require any crash testing, due to its restricted operating environment. According to the agency, “the safety requirements of LSVs are determined by the combination of three factors – vehicle design and performance, operator training and ability; and the operating environment” (*NHTSA, 1998*) [18]. The agency believes that the low speed and size of the vehicle, their limited operating environment and also the operator skill in combination with the Safety Standard No. 500 ensures the appropriate safety to the occupant of these vehicles, and also provides the vehicle with required crash avoidance and crash protection characteristics as well (*NHTSA 1998*). For these reasons, the low-speed vehicles do not need to meet any crash test program in the U.S., unlike other conventional passenger cars. However, given that their use has increased on public roadways among regular auto and truck traffic operating at higher speeds, these vehicles are becoming increasingly susceptible to risk even with the FMVSS 500 safety features and limited operating speed.

Transport Canada first conducted a series of crash tests on LSVs to determine the risks of mixing low-speed vehicles with high-speed and high-volume urban traffic. In one crash test an LSV was subjected to a frontal crash impact test with a rigid barrier at a speed of 40 km/hr (25 miles per hour). In another crash test a stationary LSV was subjected to a side crash test with a "Smart" microcar (Daimler AG), operating at a speed of 50 km/hr (31 miles per hour). The results of both of the crash tests revealed that the impact forces resulting from the collisions were directly transmitted to the occupants of the LSV, which would result in severe injuries or death to the passenger and driver of the LSV (*Transport Canada 2008*) [50]. The Canadian crash test video may be viewed at the Transport Canada internet site, at the following URL link: http://www.tc.gc.ca/eng/roadsafety/safevehicles-lowspeed-video-index-503.htm.

In the United States, the Insurance Institute for Highway Safety (IIHS) performed a crash test on low-speed vehicles to identify the impact of the operation of LSVs on public roadways. The IIHS was very concerned about the severe consequences of operating LSVs simultaneously with high volume regular traffic. The Institute's chief research officer, David Zuby said, "By allowing LSVs and mini-trucks on more and more kinds of roads, states are carving out exceptions to 40 years of auto safety regulations that save lives. It's a troubling trend that flies in the face of the work insurers, automakers, and the federal government has done to reduce crash risk" [42].

To perform the crash test, the IIHS used two electric LSVs, both GEM e2 models produced by Global Electric Motorcars of the Chrysler Group. According to the statement of the Chrysler Group – "GEM vehicles offer customers an inexpensive, clean solution for low speed environments and comply with the National Highway Traffic Safety Administration standards for low speed vehicles which limit the maximum speed of the vehicle to 25 miles per hour." [52]. In the test, the two GEM e2 LSVs were subjected to 31 miles per hour side crashes – one using a moving deformable barrier representing a pickup or SUV and the other using a "Smart Fortwo" (Daimler AG) as the striking vehicle. The "Smart" is currently the smallest passenger vehicle on U.S. roads that meets crashworthiness standards [42]. The Insurance Institute for Highway Safety video may be viewed at the IIHS internet site, at the following URL link: http://www.iihs.org/news/rss/pr052010.html.

The results of both the side crash tests revealed that the impact of the collision on the low-speed vehicle would likely cause serious or fatal injury to the user of LSV. The test results also indicated that the safety features such as the airbag and the side body panel of the "Smart Fortwo" conventional passenger car protected its occupant from severe injury during the crash. From the crash test results, it was concluded that low-speed vehicles with safety features such as safety belts and thermoplastic body panels (sometimes accompanied by doors) provide substantially lower level of crash protection to their occupants during a collision than passenger cars in urban traffic [42]. According to the Institute's chief research officer, David Zuby, "GEMs and other LSVs weren't designed to protect people in a crash with a microcar like the Smart Fortwo, let alone larger cars, SUVs, and pickups in everyday traffic." [42].

It should be noted that crash tests conducted in Europe all used very small conventional passenger cars. No standard size or larger vehicles have been crash tested with LSVs.

3.7 Operating Environment

3.7.1 Speed

A study conducted in Quebec reported that drivers of LSVs feel more vulnerable. They reported that, while traveling on two-lane two-way roadways, other drivers expressed frustration due to a lack of sufficient road way for them to overtake the slow-moving vehicle. This should not be a problem on roadways posted at 25 miles per hour or less; however, LSV drivers have mentioned that other vehicle operators like to drive 5 to 10 miles per hour over the posted speed limit [21].

In the state of Oregon it is legal to operate LSVs with a maximum operating speed of 25 miles per hour on public roadways with posted speeds of 35 miles per hour, and in some locations even 45 miles per hour (ORS 801.331). These operating conditions increase the frustration of operators of other motor vehicles and the feeling of vulnerability by LSV users. In Oregon there has also been a lack of consistent information when LSVs are licensed from the ODOT Driver and Motor Vehicle (DMV) Division about the posting of the "Slow Moving Vehicle" emblem in the rear of an LSV under the provisions of ORS 815.110 [45].

3.7.2 Speed differential

The theory of minimizing speed differential on roadways is one of the basic tenets in the traditional transportation engineering discipline. A speed differential occurs when there is a vehicle moving faster or slower than the general traffic stream. One of the goals of traffic engineering is to have uniform traffic flow, as this increases the capacity of a roadway and improves overall safety but reduces speed fluctuations. This theory is applied to a number of situations such as the design of off- and on-ramps, and the design of driveways to improve safety and access management. There are a number of safety issues associated with slow speed operations. This is depicted in Solomon's Curve, shown in Figure 3.2. It shows that a 10-20 miles per hour speed differential increases the collision rate [48, 53].

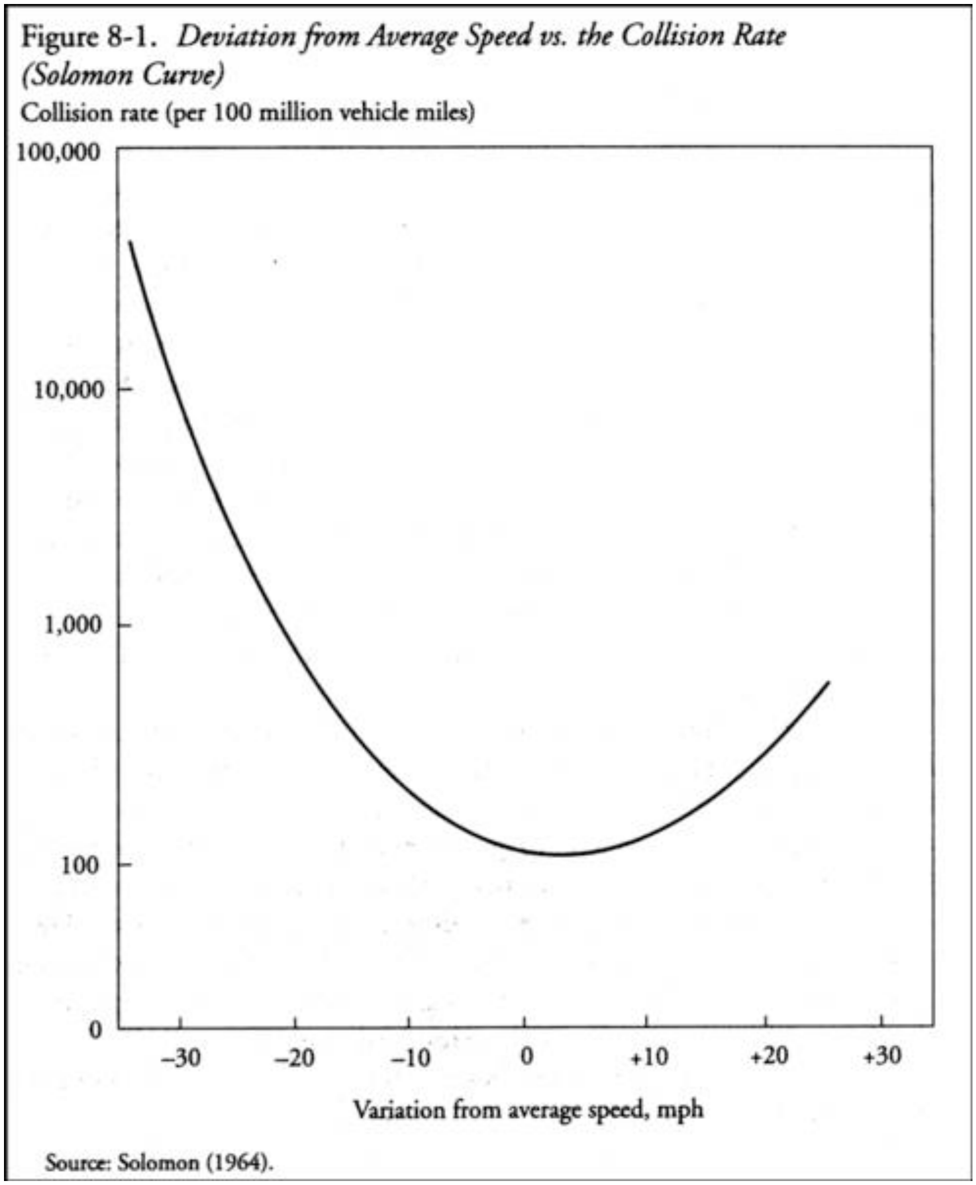


Figure 3.2: Solomon's Curve Deviation from Average Speed and Collision Rate

3.7.3 Vehicle Weight

In 1998, when NHTSA established Federal Motor Vehicle Safety Standard (FMVSS) No. 500, "low-speed vehicles," the definition of an LSV was established as, "a 4-wheeled motor vehicle, other than a truck, whose speed attainable in 1.6 km (1 mile) is more than 32 kilometers per hour (20 miles per hour) and not more than 40 kilometers per hour (25 miles per hour) on a paved level surface" (*NHTSA 1998*) [18]. But in 2005, NHTSA amended the definition of LSVs by dropping the restriction on trucks, and instead establishing a 2,500 pound maximum gross vehicle weight rating (GVWR). This amendment allowed small vehicles designed for work-related applications within the intended communities (such as landscaping or delivery) to be included within the definition of an LSV, without opening the category to unintended vehicles, such as street sweepers or speed-modified passenger cars. Also, the GVWR limit prevents attempts to circumvent the FMVSS for cars, trucks, and multi-purpose passenger vehicles by applying the LSV classification to vehicle types that are able to meet the standards. Defining an LSV as having a maximum GVWR of less than 2,500 pounds also provides an objective means for delineating between the vehicles for which the LSV requirements are appropriate and those vehicles that can be designed to meet the FMVSS for passenger cars and trucks. This approach also ensures that heavier, slow moving trucks (e.g., street sweepers) continue to be excluded from the LSV definition (*NHTSA, 1998*) [18].

In 2006, in response to petitions for reconsideration from Dynasty Electric Car Corporation and Global Electric Motorcars (GEM) – both manufacturers of electric LSVs – NHTSA increased the maximum GVWR for LSVs to 3,000 pounds. This was done, in part, to "level the playing field" between electric and gasoline-powered LSVs, by allowing for the additional weight in batteries required by electric vehicles. A 3,000-pound GVWR limit was selected because it was lighter than all FMVSS-compliant passenger cars and SUVs, with the exception of the Honda Insight. In addition, NHTSA limited the GVWR of an LSV to 3,000 pounds in combination with the maximum speed limit of 25 miles per hour for the purpose to restricting the use of these vehicles in mixed vehicle traffic for other than very short trips and to encourage their transportation within a planned, limited environment, such as retirement and gated communities (*NHTSA, 2008*) [18].

The GVWR was selected, by NHTSA as one of the criteria to define LSVs, rather than curb weight, because curb weight describes only the weight of the vehicle and not its capacity. But GVWR is a description of the maximum possible weight of the fully loaded vehicle. So GVWR is more pertinent to safety. Limitation of GVWR to "less than 3,000 pounds" in addition to the other limiting attributes of the definition of LSVs negate the need to specify a minimum rated cargo load (RCL) to prevent the operation of these vehicles in overloaded conditions for safety purposes *(NHTSA, 2008*) [18].

Transport Canada, in the spirit of regulatory harmonization, also made similar amendments to its regulation and defined a Low-speed vehicle as having a GVWR of less than 1361 kg. (*MVSA C.R.C.C 1038)*

3.7.4 Impact resistant cabs and other Safety equipment

In 1998, when NHTSA first defined the LSV class, the main purpose of these vehicles was to make short trips for shopping, social, and recreational purposes primarily within retirement or other planned, self-contained communities. Maintaining this goal, when NHTSA redefined the GVWR-based definition of LSVs in 2003, the agency limited the GVWR to 3,000 pounds. NHTSA's rationale for this decision was that this special class of vehicles, when provided with additional amenities and characteristics of a traditional passenger car, would be driven outside the planned communities and would be regularly mixed with high-volume traffic on roadways, even with 25 miles per hour speed limit. These special vehicles do not have any safety features such as air bags, energy attenuating bumpers, or crash resistant cabs. THE FVMSS 500 for LSVs does not require any crash safety amenities (*NHTSA,2008)*. None of the LSVs running on the road or available in the market to date, have any of these safety features. A study by Transport Canada revealed that a traditional passenger car needs to meet over forty safety standards, whereas LSVs are required to meet only four standards. (*Transport Canada 2009*) [51].

3.7.5 Vulnerability

Low Speed Vehicles are lighter than the FMVSS-compliant passenger cars. Also they do not meet all the safety standards of motor vehicles in the United States, Canada or the European Union. So they are less crash protective than any conventional car, even less than the smallest "Smart" passenger car. The forces and energy generated from the collision of an LSV with any rigid barrier or any other vehicle while operating in mainstream traffic is directly transmitted to the occupants of the LSV. Thus there is the potential for serious injuries, or death to the occupants of LSVs. With an increase in speed, the kinetic energy increases proportionally with the square of the speed. For example, with a 3,000 pounds GVWR, the kinetic energy generated from a collision at 35 miles per hour is almost twice the kinetic energy generated from a collision at 25 miles per hour. Therefore, operating an LSV on a roadway having a posted speed limit of 35 miles per hour with high-speed traffic makes the occupants of the LSV more vulnerable to the risk of serious injury or death. Table 3.3 shows the kinetic energy associated with increasing speeds of a 3,000 pound vehicle (including driver and cargo). The steep increase in the kinetic energy with increasing speeds provides an idea of the increase of risk in a collision of an LSV.

Table 3.3: Kinetic energy associated with increasing speeds

Vehicle Weight (lbs)	**Kinetic Energy (ft-lbs) at Different Speeds**		
3000	25 mph	35 mph	45 mph
	63021	123,520	204,187.5

The energy generated during the collision of a conventional passenger car, which meets all the safety standards of Motor Vehicles in either the U.S. or Canada, is dissipated to a great extent before it is transmitted to the occupants inside the car. This occurs due to the occupant-protected body and internal crash protecting design attributes of the passenger car. But LSVs lack all these crash protecting attributes. So the risk of fatal injury during a collision in an LSV increases dramatically with increasing speed (*Transport Canada 2008*) [50].

3.7.6 Street Infrastructure

Every mode of transportation has its own right-of-way, or it can share the path with other transportation modes. Passenger vehicles run on residential, collector, or arterial streets; bicycles are used on bicycle lanes or multi-use paths; and pedestrians walk on sidewalks and crosswalks. There are no dedicated rights-of-way for low-speed vehicles other than in communities that are specifically designed and built to accommodate these vehicles.

When LSVs use the same right-of-way with high-speed passenger vehicles and trucks, it imposes a great risk to the operator and passengers of LSVs due to the speed differential and the construction of the two different types of vehicles. Also, the use of the "slow moving vehicle" emblem for LSVs (like golf carts) is too limited to make faster moving vehicles aware of and accustomed to LSVs on roadways. All these factors make the operators of LSVs more vulnerable when they run simultaneously on high-speed roadways [20].

Sharing the Roadway

LSVs were designed to be used in protected environments such as gated communities and industrial and college campuses, but not on public roadways. An increased public awareness of climate change, the environment, and sustainable transportation has increased the popularity of these vehicles as a new mode of private transportation; consequently they are becoming part of the mix of vehicles on public roadways. Some of these vehicles look like passenger cars, and many consumers are not aware of the operating and safety limitations of these vehicles. In the next five years, there will be a number of all-electric passenger vehicles coming on the market that do meet the safety requirements and performance levels of passenger vehicles. It is very important in the interim that operating guidelines for LSVs are developed to protect all road users and also to recognize the environmental advantages of these vehicles.

Multi-use Paths

Multi-use paths are typically shared use paths of pedestrians, bicyclists, equestrians, and wheeled mobility aids that are operated by people with disabilities. These paths are typically not very wide and are not striped for two-way traffic. The rules of operation are that all users yield to pedestrians. LSVs are much wider, heavier, and faster than pedestrians and the other devices used by people of shared use paths. Thus there is the potential to put all the other multi-use path users at risk, unless the path is designed specifically to accommodate LSVs. It is not recommended that LSVs share multi-use paths unless the paths are specifically designed for that purpose.

Civic Interconnectivity

One of the challenges for operators of LSVs is navigating the urban roadways that meet all the speed restrictions. In many communities LSV operators are not able to complete a trip from origin to destination without violating either speed or crossing restrictions. One solution to this problem would be for communities to identify roadway networks that accommodate LSVs as well as other road users who operate mopeds and human powered vehicles, and who do not want to travel on high-speed, high-volume arterials.

3.8 Crash Data

The Oregon Department of Transportation Crash Code manual as well as the Federal Fatal Accident Reporting Systems (FARS) currently does not include any listing for low-speed vehicles. As a consequence, there is no crash data available for the State of Oregon.

3.9 Insurance

In almost every jurisdiction, to be qualified as a street legal vehicle, each vehicle on the roadway, including low-speed vehicles, must have insurance. The concept of electric low-speed vehicles is still relatively new to the auto insurance industry, and as a result not all of the insurance companies provide coverage for LSVs. GEICO, one of the leading insurance companies in U.S., only insures the LSVs in California, North

Carolina, and Rhode Island; in these states GEICO is bound by law to provide insurance coverage to LSVs. In other states, GEICO does not provide any insurance coverage for LSVs. Progressive, another well-known insurance company, does not insure LSVs at all, as it insures only those vehicles capable of maintaining a speed of 55 miles per hour. State Farm Insurance and the Allstate Insurance Company do offer insurance coverage for low-speed electric vehicles, but this does not include any collision coverage [43].

Among all the auto insurance companies identified by the published information on the Internet, only Foremost Insurance Group offers specialized insurance coverage for off-road and licensed on-road neighborhood electric vehicles. Their insurance policy includes important standard and optional coverage such as collision coverage, other than collision coverage, liability coverage, medical payments coverage, coverage for accessories and optional equipment (including towable trailers, solar panels, and aftermarket accessories), and coverage on transport trailers valued up to $7,500 [39].

Some other companies may offer insurance coverage for an electric low-speed vehicle that is purchased from that company; one such example is Gatormoto Utility Vehicles [40].

Some LSV owners in Oregon have indicated that their LSVs are insured under their homeowner's policy.

3.10 Proposed Recommendations

Following were several recommendations from OTREC funded research on LSVs (OTREC RR-10-19) [16].

3.10.1 State and Local LSV Regulations

State and local authorities need to understand the roadway safety implications for all road users, when LSVs are permitted to operate on roadways with posted speed limits that are higher than the maximum operating speed of the vehicles. In Oregon it is recommended that a revision be made to the current LSV legislation that was enacted in February 2010. Specifically, this would entail revising ORS 811.512 (Unlawfully operating low-speed vehicle on the highway) and/or ORS 811.513 (Unlawfully operating medium-speed electric vehicle on highway). In the spirit of regulatory harmonization, the recent Oregon legislation granting authority to local jurisdictions to set regulations for LSVs operating on roadways under their jurisdictions should also be amended to require local operating regulations to be consistent with state and federal regulations.

It is also recommended that medium-speed vehicles, which were denied a petition by NHTSA under FVMSS 500.571, should be required to meet the additional safety requirements of the federal motor vehicle safety standards for conventional vehicles or be limited to operation on roadways with a posted speed of 25 miles per hour or less.

3.10.2 State and Local Planning

It is recommended that State and local authorities work with their local LSV users and bicycle advocates to develop local networks of low-speed roadways that provide street connectivity of major residential neighborhoods and activity centers that provide employment, education, medical services, recreation, and retail shopping. These low-speed roadways would provide a secondary transportation network for multiple types of other road users who should not travel on higher speed corridors, such as human power vehicle users who prefer low-speed roadways. The low-speed roadways should also have separate pedestrian facilities. This recommendation does not have to involve construction of new facilities; it would entail the identification and signage of existing roadways that provide complementary connections between residential neighborhoods and activity centers.

3.10.3 Consumer Education

It is recommended that LSV operators be informed of the safety limitations of their vehicles, especially for models that look car-like. LSV consumers need to understand their personal safety risk exposure if they change the speed governors of their LSVs. LSV users should also be educated in the risk factors of driving a vehicle that does not provide crash protection on public roadways.

The above recommendations served as the motivation for the extended research on LSV and development of its route infrastructure described in the following chapters.

4 Network Study

4.1 Background

Low Speed Vehicles (LSVs) were designed to make short trips for shopping, social and recreational purposes primarily within retirement or other planned, self-contained communities [18]. LSVs are becoming more popular day by day to make short trip within the community, due to zero tailpipe emission, energy efficiency and lower maintenance cost. People use LSVs for those trips which are too long for walking, but do not require the use of full-size automobiles [20]. Therefore, in a small or medium-sized city with geographically compact activity centers accessible by surface streets, LSVs can be used to make regular trips to schools, workplaces, markets, shops, restaurants and hospitals other than social and for other recreational purposes [14]. To promote LSVs as a regular mode of sustainable transportation, a safe and accessible road network is necessary. It is important to note that the planning of a low speed vehicle network is different from the planning of regular motorized vehicle networks. For regular motorized traffic, trip distribution and assignment is relatively straight forward as it is influenced by impedance factors such as travel distance and vehicle-flow capacity constraint [27]. In the case of low speed vehicles, several other factors influence the route choice behavior of the user. Some of these factors include the speed of motor vehicles, the percentage of heavy vehicles in the traffic stream, the perceived hazard of sharing the roads with typical motorized traffic, and roadway geometrics. Therefore all these factors need also be considered in the planning of low speed networks.

There are many similar features between LSVs and bikes, especially from the safety point of view. Both LSVs and bikes are alternative modes of transportation, which had to make their own place in the car-dominated society. Though many of the LSVs have an appearance similar to that of a car, they do not possess any safety features except the seat belts and thereby, provide little occupant protection. A study conducted by the Vehicle Research and Test Centre (VRTC) revealed that many of these vehicles showed a great degree of instability and a tendency to roll, when loaded with two adult male passengers

[57]. So from the safety perspective, LSVs pose similar kinds of perceived risks as bikes on the public roadways shared by high speed vehicles. Therefore many other factors should be considered beyond roadway speed limit to develop a low speed roadway network. Many of these factors will be analogous to the factors considered in the planning of bicycle facility, described in the *"AASHTO Guide for the Development of Bicycle Facilities"* [56].

4.2 Factors Considered in Network Analysis

The maximum attainable speed of LSVs in one mile shall be not more than 25 miles per hour, according to NHTSA and most US states permit the operation of LSVs on public roads with posted at no more than 35 miles per hour. Therefore to develop the secondary street network for LSVs, the most important factors that need to be analyzed are the speed limit and traffic volume of the streets. Speed limit data represents the actual posted speed limit of the roadways, and the traffic volume data includes the average 24-hour period traffic data or average daily traffic (ADT), collected for that roadway [24]. However, many other factors, in addition to speed limit and traffic volume, need to be considered for developing the LSV network, which might influence the route choice behavior of the users. These factors can be categorized as link-level factors and route-level factors.

The link-level factors include roadway classification, geometric configuration of roads such as the number of lanes, percentage of heavy vehicles, barriers, elevation difference etc. The route-level factors include distance, number of stops, intersection type, accessibility, safety etc. Route level factors can be better valued when they are accumulated over the entire route [25]. Some other factors related to user characteristics, such as age and some factors related to authority, such as maintenance, funding, state and local laws etc would also be considered in this network development process. All these factors are described below.

Types of Roadways: Stein et al. stated that among the three functional categories of streets-local, collector and arterial, access to the arterial street is the most problematic for LSVs. Again a survey of 50 people conducted by the Centre for Electric Vehicle Experimentation in Quebec (CEVEQ), Canada revealed that 90 percent of the participants felt very safe to drive LSVs in the neighborhood streets, while only 34 percent participants felt safe to drive LSVs on roadways with actual speed ranged from 37 to 44 miles per hour.

However, the speed limits of arterial streets are in the range of 40 to 75 miles per hour [55]. But according to Federal definition (NHTSA), the maximum speed of LSVs is 25 miles per hour. Therefore, the minor collector streets and neighborhood streets where the maximum posted speed limit is comparatively lower with lower traffic densities, should be considered for developing low speed network. Arterial streets should always be avoided in developing the network.

Number of Lanes: There is a correlation between total number of lanes on a road and its traffic volume. Typically, streets having two travel lanes, one in each direction, have lower traffic volumes and lower speed limits. Therefore, the streets having no more than two lanes should be chosen for the low speed network.

Percentage of heavy vehicles: When LSVs are driven with heavy vehicles on the same streets, it creates speed-differential as well as weight-differential for LSVs. Due to lower occupant protection feature of LSVs, the probability of risks for LSV users is significantly high during the period of collision with heavy vehicles. Therefore, the streets those allow heavy vehicles like trucks, school buses, city buses etc. should be avoided in the low speed network development.

Distance: Distance is an important factor for LSVs user. LSVs were designed primarily for short trips within the neighborhood [NHTSA, 1998]. However, a study showed that the people making commuter trips live within the LSVs traveling range, in fact half of them live within about 3 miles of work [25]. Therefore if a low speed network is developed within the city range, it would create an incentive for using the LSVs as an alternative transport mode for these commuters, especially in the school and retirement communities. Again, in the cities where the activity centers are compact and can easily be accessible with street network, LSVs can be a superior transportation mode to multi-car households. This can be reasoned to the fact that it would allow them to maintain a high level of accessibility at a lower cost [14].

Personal Characteristics: The age and health conditions are important factors of LSV users. The bicycle mode requires a relatively high level of agility and physical fitness, which is an issue for older adults. Therefore, walking or biking may not be a suitable mode for their short trips within the community. In this case, LSVs can serve as the best suitable mode to reach their destination within the community with lower operating cost. Therefore, a secondary low speed network is very necessary for senior adults, especially in the college and retirement communities.

Accessibility: The success of LSVs as a transport mode would depend on a safe and efficient LSVs network accessible to the activity centers and neighborhood areas. Therefore the low speed network should be developed in a way such that it would provide an easy and frequent access to the users to their destinations.

Continuity: Continuity of that network is another aspect of the network that plays a very important role to the users. If a network is discontinuous at various points of its routes, users do not feel the incentive to use that network for regular purpose. Therefore the low speed network should provide a continuous and convenient riding path for LSVs between major residential neighborhoods and all activity centers.

Hilliness (elevation difference): It is expected that LSVs user will prefer a flat terrain than a mountainous terrain. LSVs will consume more battery charge to climb a mountainous ground from a flat level. Again, it was found that the speed of some LSV models drop by half on uphill grades and present a safety risk [21]. Therefore, alternative route for the mountainous path should be provided in the network.

Types of Intersection: A high probability of crashes always exists at the intersection. Especially the intersection of high speed roadways poses a great risk to the LSV occupants. Therefore, the low speed network should be developed avoiding the higher speed roadway crossings, if possible. However, where LSVs need to cross the intersections of higher speed roadways, those must be four-way STOP or traffic signal controlled intersections.

Number of Stops: Frequent acceleration and deceleration due to STOP signs and traffic signals will cause faster battery discharge of the vehicles. Therefore, the low speed network should contain the minimum number stops for the most efficient uses of these vehicles.

Barriers (railroad, river, bridges): In some places, the topographical features like rivers, railroads, brides provide physical barriers to LSVs. River bridges can be presented with narrower lanes and high speed traffic [56]. LSVs riding on these bridges might not feel safe when higher speed vehicles would overtake them. Therefore, routes that include these types of barriers should be avoided, if possible, during developing the network.

Regulatory Issues: The State and local laws should promote the safe and increased use of LSVs. Also the characteristics of the developed network must encourage the LSV users to operate in a manner that is consistent with the local laws. Therefore, the success of LSVs as a sustainable transportation mode can be better achieved by the cooperation between infrastructure providers, LSV users and the regulatory agencies [14].

All these above factors are summarized in the table below (Table 4.1).

Table 4.1: Factors influencing the network development

Factor Types	Factors
Link-Level	Roadway type, Number of lanes of road, Percentage of heavy vehicles, Barriers, Intersection type, Elevation difference.
Route-Level	Number of stops, Distance, Accessibility, Continuity,
User Characteristic	Age, Health condition
Regulatory	State and Local Laws, coordination between infrastructure providers and regulatory agencies.

4.3 Users' Route Choice Study Using Revealed Preference Survey

4.3.1 Survey Approaches

There are several different approaches to study the users' preference of the route level characteristics of the network. The route level studies include revealed preference (RP) survey, stated preference (SP) surveys and Delphi technique [26]. A SP survey evaluates the users' preferences by presenting them a series of hypothetical scenarios. It helps to identify general attitudes towards ideal road conditions [29]. A large sample size can be used in this survey method. On the other hand, a RP survey measures the users' route choice preference by presenting an actual choice environment. It reveals the travel behavior characteristics of an individual user by providing the direct report of their actual trips. Though, this method is time consuming and limits the sample size and geographic scope of data collection, the presentation of the individual's actual experience of LSV trip may yield more accurate result of potential route characteristics. The Delphi technique analyze the expert opinions to identify the relative weight of the factors in route evaluation, which might not be consistent with the observations found from RP and SP surveys [26].

4.3.2 Survey Goal

This survey followed the revealed preference approach to obtain information on the route choice behavior of the LSV users, associated with the spatial analysis of the actual route of low speed network. The information obtained from this survey helped to identify the influence of different factors on users' route choice behavior that can be applied to the planning of the low speed network.

4.3.3 Survey Limitations

This research study followed Revealed Preference (RP) survey technique, which limited the sample size and the geographic scope of the data collection. The survey conducted here was to get an idea of the route choice factors of LSV users in the City of Corvallis, which would assist to develop the low speed network for the city. For that purpose, a selection of a random sample of LSV users was desired. But this was beyond the scope of what could be accomplished. The owner of all low speed vehicles across the community could not be located due to lack of proper sources and adequate time.

Again, due to the survey distribution technique, all the respondents were LSV users with good access to computers. This computerized distribution did not include users of low speed vehicle, both human or non-human powered, who do not use computers. A good example of such group might be older and/or retired persons' group of the community. Also, the respondents who participated in the survey were not selected randomly from the Electric Vehicle (EV) group. The respondents volunteered their participation in the survey. Therefore self-selection bias exists in the data for this research. Also, the total number of questionnaires received during the study phase was only 10. This number was lower than the expected response. Therefore, it can be concluded that the respondents' perceptions are not necessarily reflect the perceptions of whole LSV user group at large.

4.3.4 Survey Distributions

Survey was distributed through the internet. Most of the survey was distributed through email. As all the LSV users could not be identified, emails were sent to all those users who were known to use LSVs by personal contact. The survey questionnaire was attached in doc. (document) format with the email, so that users can fill out the questionnaire without printing it. The survey was also distributed online using the web based survey tool "kwiksurveys.com", to the Electric Vehicle group of the community named as "Corvallisevclub".

4.3.5 Survey Design

The first portion of the survey contained questions on low speed vehicle users' regular mode of transport, about their travel time and travel distance. It also contained questions on the use of low speed vehicles in terms of distance traveled and travel time. The study asked two questions on the factors that influence the use of LSVs and also not using the LSVs as a transport mode. Participants were given multiple options to choose among the factors. Some questions asked the participants to provide information on the route attributes like type of roadways, pavement type and hilliness.

To assess the safety on roads while driving the LSVs, the study asked three questions on crashes. To avoid reporting minor crashes, a reporting threshold of $100 was set for personal injury or property damage.

One of the figures (Appendix B) of the survey questionnaire represents an intersection of a major collector and major arterial (HWY 99) running through Corvallis, Oregon. From the spatial perspective, this intersection resembles one of the most risky intersections in the city for the LSVs to cross. Participants were asked about their preferences regarding the crossing of this higher speed roadway intersection.

In another figure (Appendix B), the study presented participants with two route choices between two activity centers of the city. Route 1, marked by the orange line, indicates the route of residential streets with less traffic signal and more STOP signs, but longer travel path; whereas, Route 2, marked by purple line, indicates route of arterials with more traffic signals, but shorter travel path. The questions of the study asked the participants about their route preference. Based on the path chosen by the LSV user, the relative weight between safety and shorter travel distance will be evaluated as user's route preference characteristics.

In the last stage of the survey, participants were asked about their occupation, age and gender. This would help to assess the characteristics of the population in the community who use LSVs. Finally, the study provided options to the participants to make comments on their own perceptions about LSVs and low speed road network.

A copy of the complete survey questionnaire has been added in Appendix B.

4.3.6 Survey Analysis

Different analysis methods were applied for the dataset. The highest, lowest and average values were calculated for the questions with numeric answers, for examples the number of years for LSV use, estimates of one-way commute distance by LSVs in miles etc. For questions in which one option was requested to choose from a set of options, the fraction of every option was calculated and expressed as the percentage of total responses. In the case of questions, where multiple options could be selected, all the affirmative responses were summed and expressed as a percentage of total responses.

4.3.6.1 The Commuting Characteristics of LSV Users

Number of years of LSV use:

The total number of responses received was 10. Among the 10 respondents (N=10), 40% of the LSV users were reported to be using LSVs for about 1 year and another 40% users were using the LSVs for 2 years. Although 10% of the respondents were found to be using LSVs for 3 years, the average period of time reported to use LSV was 1.65 years. The minimum time period of using LSV was reported to be 1 year.

Usual mode of transportation:

During the period of using LSV (current): It has been found that at present 40% of the respondents use LSVs for their regular trip purpose, among whom 25% use LSVs only for the work purpose owned by his/her employer. Another 40% of the users use car, 10% use bicycle, and rest 10% user uses walking mode for their regular trip purpose.

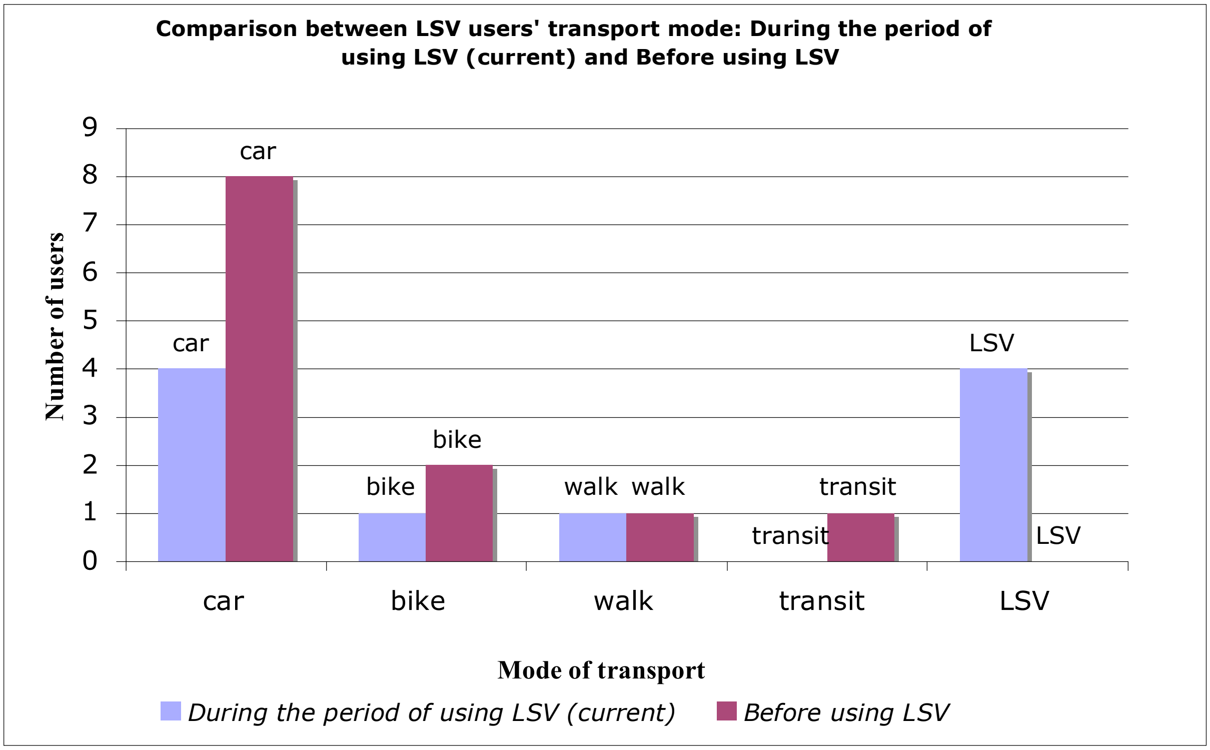


Figure 4.1: LSV users' mode of transportation

Before using LSV:

It has been found that, 40% of the respondents who uses LSVs for their current trip purpose, 75% of them used to commute by regular car before using LSV. The remaining 25% of users among them used to commute by car, transit and bike before using LSV. The rest of the participants' were found to use the same mode of transportation for their regular trip purpose during both time periods.

The above Figure 4.1 describes the percentage of different travel modes used by the participants during current period and before they used LSVs.

One-way commute distance by LSV:

The maximum distance traveled by LSV users was 5 miles, as reported in the survey. This value represents the one-way commute distance from home to work or other activity centers within the city. This finding is consistent of what was expected regarding the trip length of the LSV users in this research. The average of the distances traveled by LSV users was found to be 3.5 miles within the city.

4.3.6.2 Participants Profile

Age and Sex

Among the participants of this survey, 50 percent users were male and rest 50 percent was female.

The age group of the participants was also collected in the survey. It was found that the majority of the LSV users were in the age range of 51 to 75. Among them 40% of the users were male and 30% LSV users were female. 20% of the total participants were below the age of 25 and all of them are female. 10% of the participants represented the age group of 26 to 50 and reported to be male.

Table 4.2 categorizes the LSV users by different age and sex.

Table 4.2: Percentage of LSV drivers by age and sex

	<=25	**26-50**	**51-75**	**>75**	**Total**
Men	0%	10%	40%	0%	50%
Women	20%	0%	30%	0%	50%
Total	**20%**	**10%**	**70%**	**0%**	**100%**

Occupation

The respondents were asked to mention their occupation. It was found that 40% of the participants were retired person and 30% users were students. Another 10% of the LSV users were found to be professional, 10% users was small business owner and rest 10% had occupation related to sales. The following Figure 4.2 displays the occupation of the LSV users.

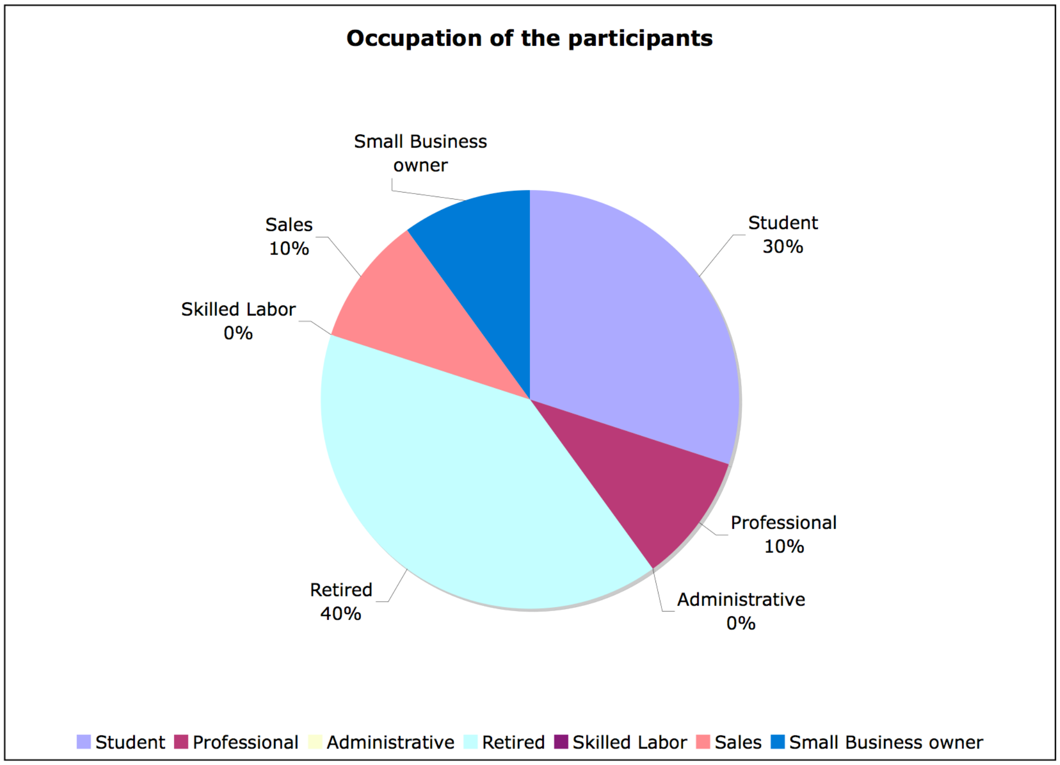


Figure 4.2: Participants' Occupation

4.3.6.3 General Aspects of LSV

Reasons for purchasing LSV:

Participants were presented with different factors that might influence their decision to purchase LSV (Figure 4.3). From the figure, it is found that gas price, environmental concern and distance were the major factors for 70% of the participants' decision to purchase LSV. This was followed by the availability of car parking that was chosen by 60% of the users. Health was also an important factor for 10% of the users. Other factors, such as pleasure, savings of energy etc were also found to be significant in users' decision making process.

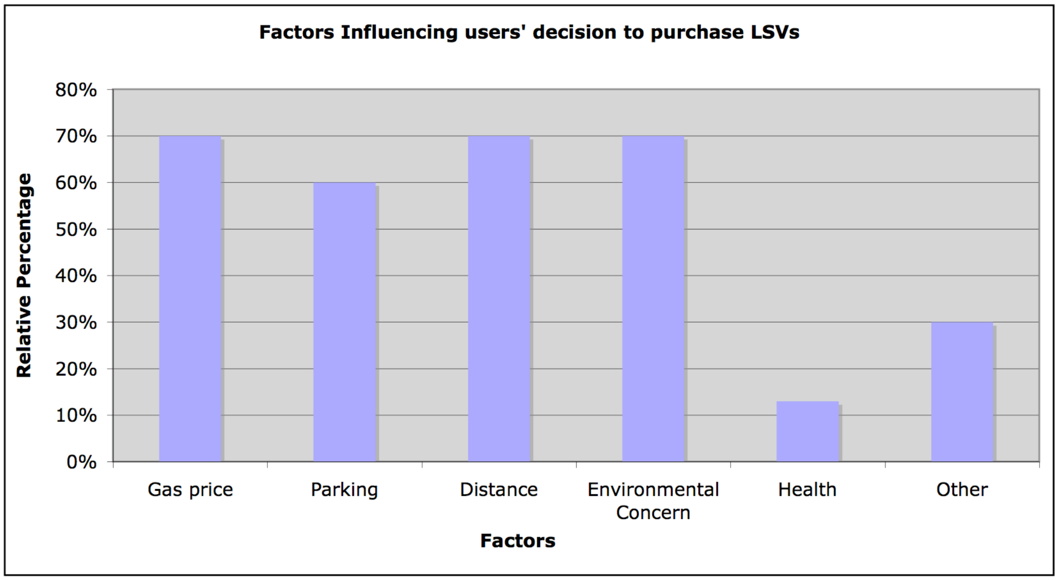


Figure 4.3: Factors influencing users' decision for LSV purchase

Reasons that discourage the use of LSVs:

This study also attempted to investigate the factors that discourage users for using LSVs as a regular mode of daily trip (Figure 4.4). It was found that weather was the leading factor that negatively influences 31% users' preference of LSV as a mode. Again, longer distance to destination was also important reason for not using LSVs for 25% of the users. These were followed by risks on roadway and family reasons, such as pick up or drop off of children. Network discontinuity was also found to be important for 6.25% of the users. Users also reported that other factors, for example too much load to carry, also prevent them from using LSVs as a regular mode of travel.

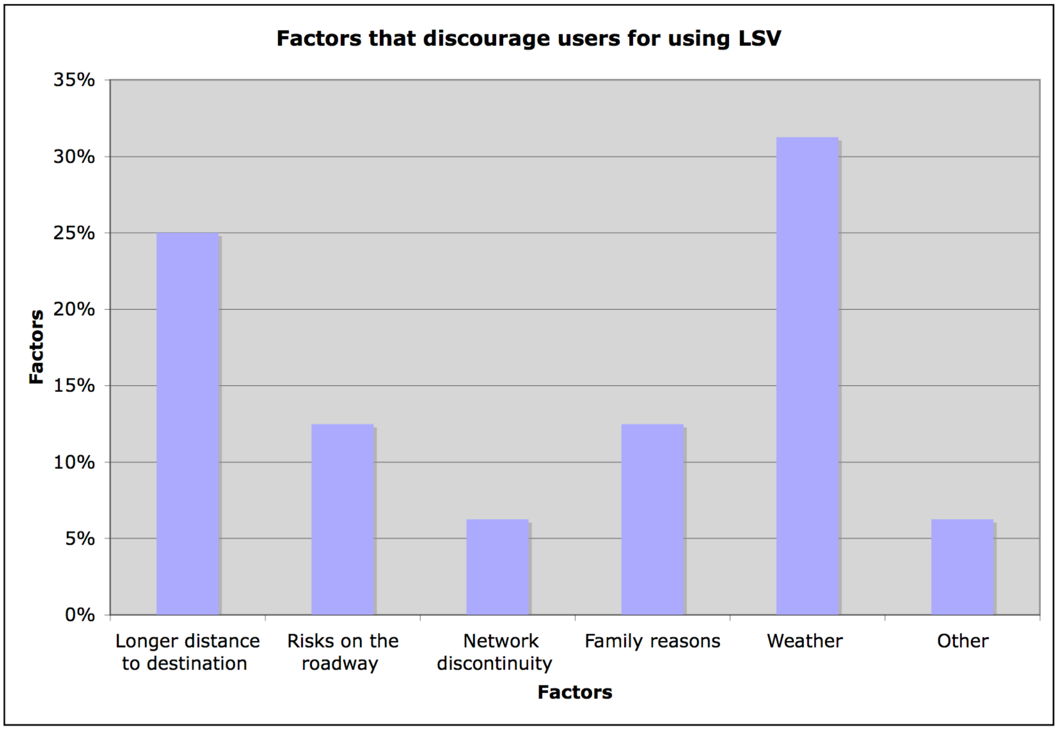


Figure 4.4: Factors discouraging people for using LSVs

Factors influencing route choice behavior of LSV users:

Several factors that might influence the route choice behavior of the LSV users were presented to the participants. Traffic volume was found to be the most significant factor followed by vertical elevation of the route and pavement condition. Presence of heavy vehicles was also found to be an important contributing factor. Again, when there were more than two lanes, one in each direction- that also affected the comfort of driving LSV on that road. The number of traffic signals or STOP signs in a particular roadway corridor kept impact for 50% of the LSV drivers. Multiuse path affected 30% of the users' route choice decision, whereas the presence of a bike lane was significant for only 10% of the LSV users.

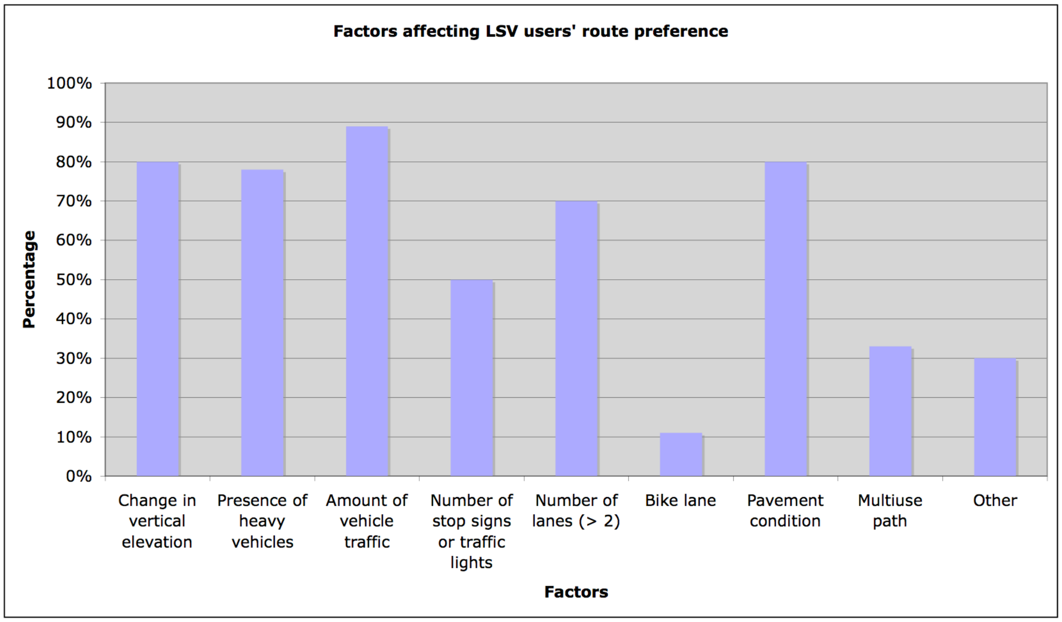


Figure 4.5: Factors influencing LSV users' route choice decision

Some other factors, such as ambience of the route, presence of police officer in the route also impacts LSV users' route choice decision. The influence of different factors is described in the above Figure 4.5.

Network Continuity:

To evaluate the importance of network continuity on the LSV users' decision-making process, participants were presented with a road network. It was found that 40% of the users believed that network continuity is very important for their travel by LSV; whereas 50% of the LSV users found this factor to be moderately important. This percentage is described in the following Figure 4.6.

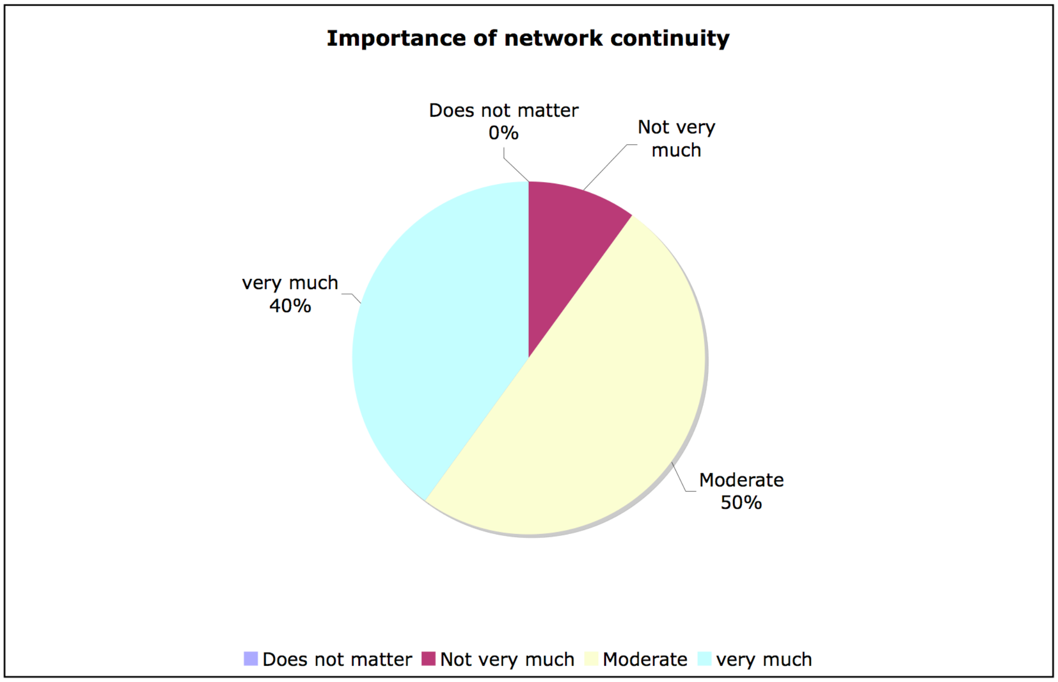


Figure 4.6: Importance of network continuity

4.3.6.4 Safety Aspects of LSV

Degree of comfort on different class of roadways:

Participants were asked about their degree of comfort in terms of safety while driving LSV on different classes of roadways. It was found that every participant, i.e. 100% of the users felt it very uncomfortable to drive LSV on major arterials with a speed limit higher than 45 miles per hour. In contrast, 100% of the users had good or excellent experience while driving LSVs on neighborhood streets with maximum speed limit of 25 miles per hour. In the case of major collectors with speed limits between 35 miles per hour to 45 miles per hour, 70% users thought it uncomfortable to drive LSV; whereas for collector streets with speed limit between 25 miles per hour to 35 miles per hour, 50% of the users had a good experience and 30% users had a moderate experience driving LSVs. The following Table 4.3 describes users' perception of safety of driving LSVs on different classes of roadways.

Table 4.3: Degree of comfort in terms of safety, while driving LSV in the different class of roadways

	Excellent	**Good**	**Neutral**	**Fair**	**Poor**
Major Arterials: Speed Limit > 45 mph	0%	0%	0%	20%	80%
Major collectors: 35 mph<Speed<45 mph	0%	0%	30%	30%	40%
Collectors: 25 mph<Speed<35 mph	0%	50%	30%	20%	0%
Neighborhood Street: Speed limit<=25 mph	60%	40%	0%	0%	0%

Perception of safety of the user while crossing high-speed roadway intersection by LSV:

To assess the perception of safety while crossing high-speed roadway intersections by LSV, participants were presented with an intersection of high speed arterials and collector streets of the city. It was reported that 50% of the users felt it unsafe to cross high-speed intersection by LSV. In contrast, 30% users felt it somewhat safe to cross the high-speed intersection by LSV and 20% of the users thought it was neither safe nor unsafe to cross such high-speed intersection by LSV (Figure 4.7).

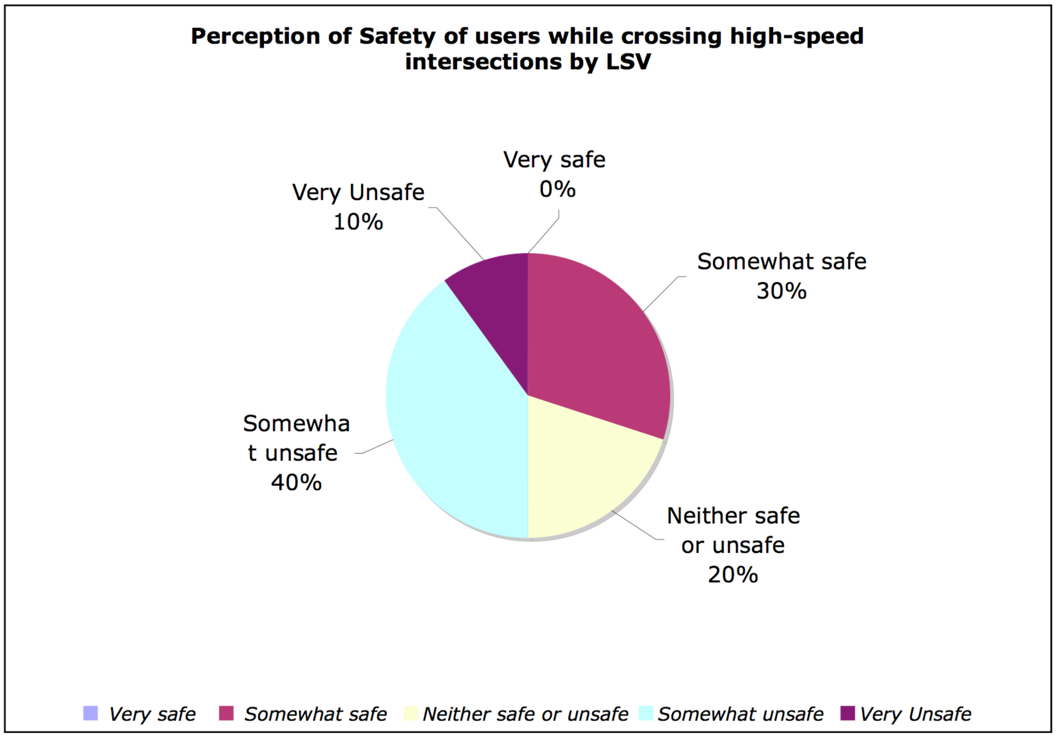


Figure 4.7: Perception of safety while crossing high-speed intersection

Consequently, it was also found that 50% of the user would cross this high-speed roadway intersection to reach their destination, whereas the other 50% of users showed reluctance to cross this high-speed roadway intersection by LSVs.

Influence of route characteristics on LSV users' route preference:

To assess the influence of different route characteristics on the LSV users' route choice decision, they were presented with two different routes between two destination points. One route represented a neighborhood street with lower traffic volume and low speed limit, whereas the other route represented an arterial street with high speed limit. The neighborhood street had a longer travel path than the arterial street. It was found that 90% of the users chose the routes comprised of neighborhood streets to reach the destination point by LSV. It was reported that they would feel it safe to drive LSV on that route as the route passed through the residential area having lower traffic volume and fewer traffic signals. In contrast, one participant chose to drive LSV on the route of arterial streets, because the user did not feel comfortable to drive through unknown neighborhoods and also did not want to travel longer distances to a destination that could be reached by an alternative neighborhood route.

The chart (Figure 4.8) below depicts the factors that influenced the LSV users' decision to prefer neighborhood street routes over the arterial street route.

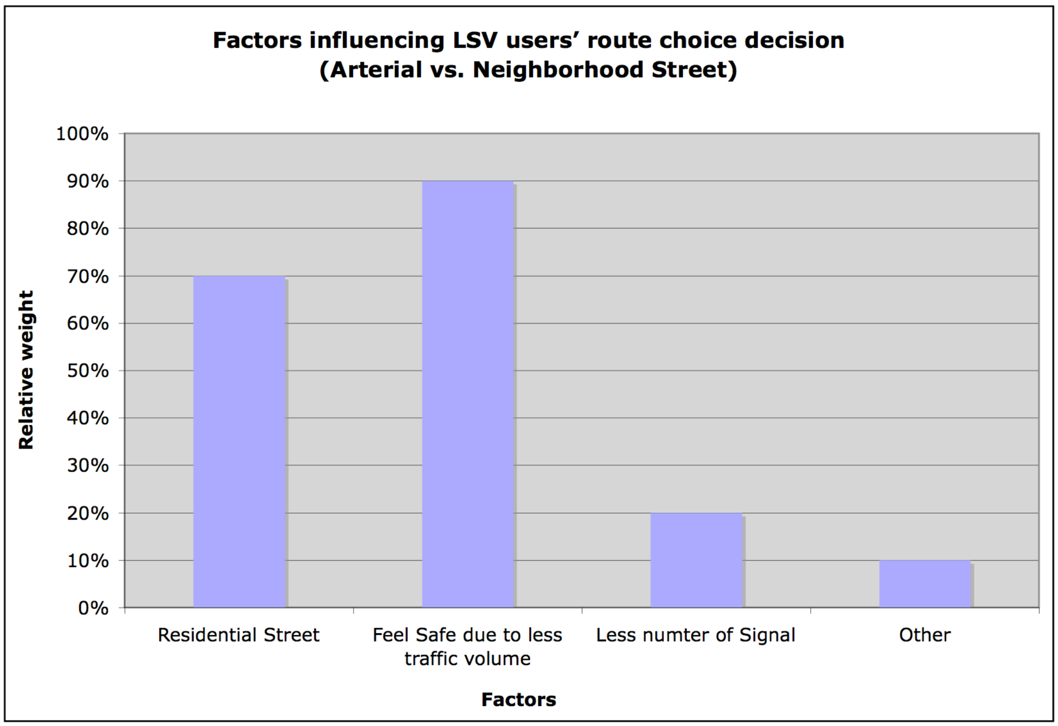


Figure 4.8: Influence of route characteristics on LSV users' route preference

LSV related crashes:

The percentage of the users to have LSV related crash on public roads was small. Only 10% participant was reported to have a property damage crash associated with LSV at multiuse path.

4.3.7 Results/Findings

It is to be mentioned that the results of this study should not be considered as the representative of all the LSV users of the country. The results represent only a particular group who participated in the survey. However, it is believed that the analyzed result obtained from this survey provides important insight to the trend of route preference characteristics as well as user characteristics of LSVs.

From the study, it was found that a large portion of the LSV users belongs to the age group of 51 to 75. Most of them were reported to be retired person. This finding supports the argument for which LSV was originally designed, i.e. LSV serves as a superior mode of travel within the retirement community (NHTSA, 1998). Again, the maximum trip length of the LSV users was found to be 5 miles. This is also consistent with the finding described in other literature, where the maximum trip length driven by LSVs was predicted to be 5 miles within the city [14]. According to NHTSA, LSVs were originally designed to make short trips within the community.

One of the important findings of this study was that, people who at present use LSVs for their regular trips, previously used passenger car as their regular trip mode. The important factors that lead to their migration from car to LSVs are mostly found to be - high gas price, concern for the environment and distance. In addition to these, another important finding is that, some percentage of the users actually migrated due to health and age reason.

However, some factors were reported to have negative impact on the comfort of LSV driving. Heavy volume of traffic and presence of heavy vehicles are two major factors that were found to have negative influence on LSV driving. Participants also reported that the change of vertical elevation of the roads or uphill grade poses problem in their driving of LSVs. The findings of this survey on the route choice characteristics of LSV users' are consistent with that found in other literature related to LSVs [21]. Number of lanes on a road was also an important factor for LSV drivers. The LSV users are not comfortable driving LSVs when high-speed regular vehicles overtake their lightweight small vehicles. Pavement condition and continuity were also found to have significant impact on the LSV users' route choice decision. Participants also reported that they would consider the weather as a factor before purchasing a LSV, though they did not mention what kind of weather was the most problematic for driving the LSV. Weather definitely poses negative impact for the doorless LSVs. Longer distance to destination was also an important consideration for not choosing LSVs. Participants also reported that they do not prefer to drive LSV when they have to errand within the city with too many loads.

This study also reveals LSV users' perception of safety while driving LSVs on different classes of roadway. Users reported that they would prefer to drive their LSVs on neighborhood roadways with posted speed limit of 25 miles per hour or less. When the posted speed limit of roads exceeds beyond 35 miles per hour, users found that it was unsafe to drive LSVs on those roads and did not prefer to drive on 45 miles per hour posted arterial streets. This finding is consistent with the State law of Oregon related to the driving restriction for LSV on public roadway, which states that LSVs can be driven on public roadways with speed limit of no more 35 miles per hour (OR 811.512). In case of crossing high-speed roadway intersections, half of the participants felt it unsafe to cross that intersection by LSVs. This result is consistent with the recommendation of this research mentioned in previous chapter. However, the oter half of the participants reported they would cross this high-speed intersection to reach their destination, which was not expected in this study. Another important finding of this survey was, users would prefer a smooth and safe driving route for the sake of longer driving miles to destination. It was also reflected from the survey analysis that LSV drivers do not feel uncomfortable with the presence of bike lanes on the roads. However, multiuse paths pose problem for LSV users, as reported in the survey. Participants were reported to have LSV related crash on multiuse path of the city.

This survey results revealed some valuable aspects that impact the route choice behavior of LSV users. The public opinion collected through this survey helped to identify different factors of the low speed routes. If these factors are considered in developing the low speed network- that would ensure a safe and convenient LSV riding path as well as would enhance the overall acceptability of the network to its users. Therefore, all the factors revealed from this survey analysis will be considered in the network development phase described in the following chapter.

5 Planning the Low Speed Network

The use of LSV on public roadways is increasing as a short-range alternative to fossil fueled autos. However, as stated earlier, when these vehicles share the same roadways with high-speed automobiles and heavy vehicles, it posses risk to the vehicle occupants due to its lower crash protection features. Therefore, it is very urgent to develop a secondary low speed roadway network in the city in addition to the primary road network to ensure the safe operation of this alternative mode of transport. To date, this research found almost no study that examines the route planning of low speed vehicle on public roadways. LSVs and bicycles have similar types of perceived risks on roadway, and therefore a number of studies on the Bicycle Facility Planning were reviewed for the purpose of low speed network planning. These include the AASHTO Guide for the Development of Bicycle Facilities, Wisconsin Rural Bicycle Planning Guide, the Comprehensive Plan of the City of Corvallis, Bicycle Planning Guide by Virginia Department of Transportation etc [36, 56, 62, 63].

This research aims to develop a Planning Methodology for the Low Speed Route Network in the city of Corvallis based on the city's existing road network system. The methodology does not propose any design modification for the roads that would be used as the potential link of low speed network. Also, when the proposed network cannot provide any connectivity to certain part of the city through its low speed route, this research recommends some mitigation criteria to resolve the connectivity gap, for example, changing the posted speed limit for certain segment of the roads or modifying the operational classification of roadways etc to accommodate LSVs on those roads.

In this planning process, linear transportation segments or corridors have been used as the basic unit of analysis. This is different from conventional transportation planning which uses large aggregated areal units like cities or traffic analysis zones (TAZs) as the unit of analysis [58]. In this research, linear transportation segments are used because individual LSV users make their trips within this aggregated unit, therefore micro-environment analysis is important for LSV trips, not the aggregated traffic zone analysis.

The purpose of the secondary low speed network planning is to provide a continuous and accessible secondary roadway network that would ensure the safe use of low speed vehicle, both human and non-human powered and would reduce the reliance on regular automobiles. The planning methodology includes the following steps:

i) Development of a vision and objective for the low speed network
ii) Identification of stakeholders and impact groups for the low speed network
iii) Inventory and analysis the local policies and existing roadway conditions; and identification of the connectivity gaps
iv) Involvement of local community and municipal authority, and other community stakeholders
v) Development of the low speed network with minimum modifications of the existing system
vi) Recommendation the mitigation criteria to resolve the connectivity gaps

The focus of this planning methodology is a small or medium-sized city with geographically compact "activity spaces". The City of Corvallis, Oregon was selected as an example of small city, to illustrate the planning methodology of secondary low speed network. The step-by-step planning methodology is summarized in the following schematic diagram.

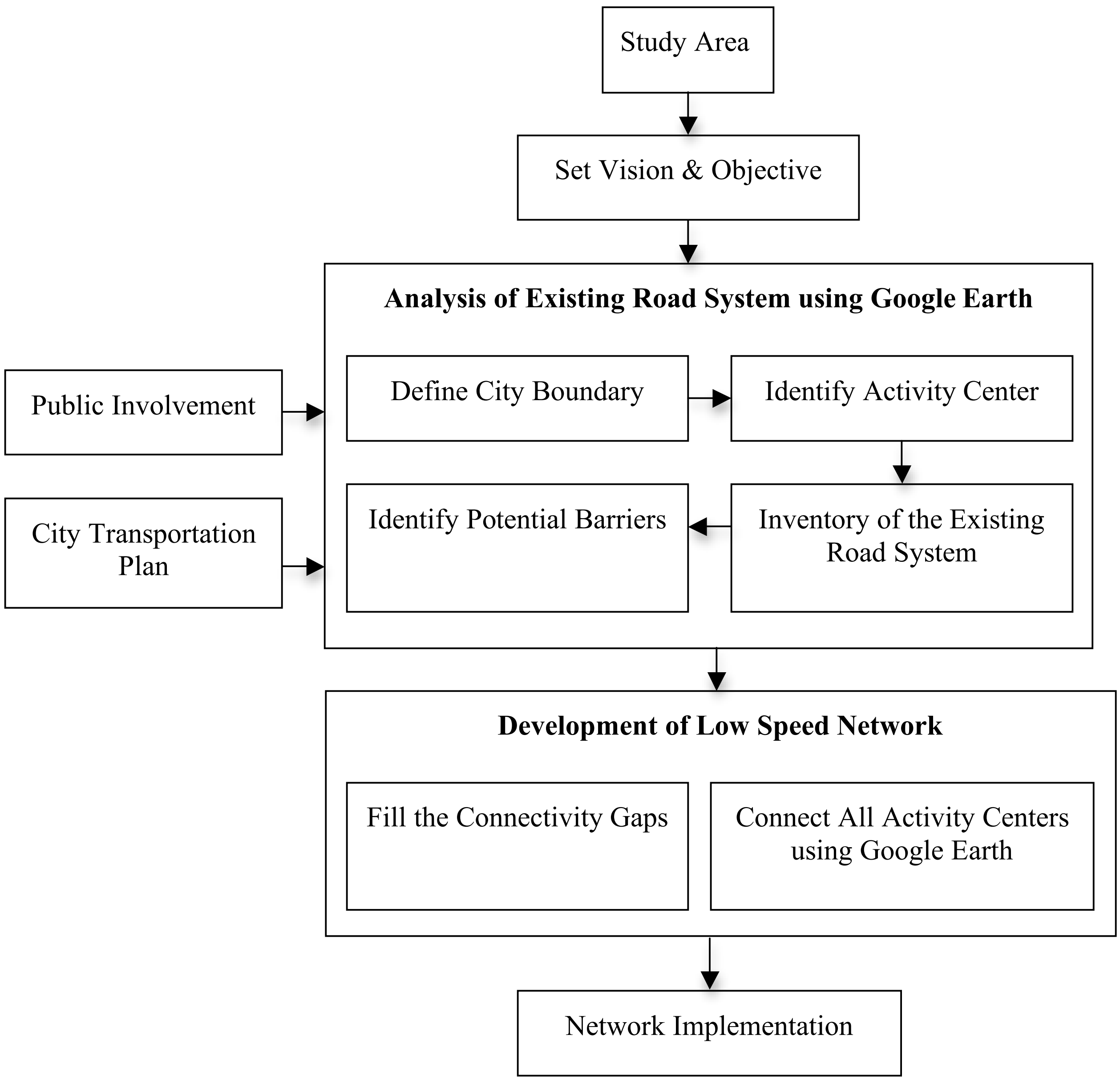


Figure 5.1: Schematic Diagram of the proposed Planning Process for Low Speed Road Network

5.1 The Planning Methodology

The step-by-step planning methodology will be described in this section to develop the secondary low speed network in the city.

5.1.1 Study Area

The first step of this planning methodology is to define a study area where the methodology will be applied. The study area represents a small or medium sized city with closely spaced activity centers and neighborhoods, that are in need of developing a secondary road network to accommodate the safe movement of LSVs. As stated earlier, the City of Corvallis, Oregon was chosen as the study area where the planning methodology will be applied. The City of Corvallis is located at the heart of Oregon's Willamette Valley. It is the seventh largest city in Oregon and located within 90 miles of the Oregon coast and Portland Metropolitan area [36]. Corvallis has a residential population of 55,370 and is the home to Oregon State University(OSU) [35]. Currently, there are approximately 17 miles of arterial, 28 miles of collector streets and 113 miles of local streets running within the city. The City also maintains 49 miles of bike lanes and an additional 9.8 miles of separated bike paths. Transit is another regular mode of transport within the city. The public transit system is fully accessible for passengers with disabilities and runs regularly to provide continuous service to the residents. There are sidewalks and trails within the city for safe pedestrian movement. Bikeways provide access to almost every major activity center within the city [36].

The concept of urban sprawl is not applicable for the city of Corvallis. The grid pattern neighborhood areas and the activity centers of the city are closely located. Again, the existing trip generation characteristics of the city revealed that a significant portion of the trips is home-based shopping or other. The city downtown and OSU are the most significant trip origin and destination point in the city, which is also within a very easy reached distance from the neighborhood areas. All these characteristics provide an effective base to develop a secondary low speed road network within the city that would ensure a safe and direct access to home and other desired destinations for the low speed vehicles.

The "Transportation System Planning Policies" of the City of Corvallis states that the Policy number §§10.1.3. emphasis to develop and promote a safe, economic and convenient alternative transportation system for the residence, whereas Policy number §§10.1.5 focuses on providing energy efficient transportation alternatives. These transportation policies provide an incentive to promote LSVs as energy-efficient, sustainable alternative transportation mode for the city [36].

5.1.2 Vision and Objective

The second step of the planning process is to set up vision and objectives. A vision is a goal or an ideal future condition to which a community hopes to attain. The objectives give specific intermediate steps to attain a goal. Objectives represent some measurable actions in support of the overall goal [62].

The vision of this secondary low speed network planning is to provide a safe, efficient and continuous operating path for low speed vehicles throughout the city. This low speed network would be developed using mostly the neighborhood streets and collector streets of the city that would provide LSVs a safe and direct access to homes and activity centers of the city. This is how the low speed network would help to promote LSVs as an alternative transportation mode especially in multi-car households and would also reduce automobile dependency of the city dwellers. The ultimate vision of this planning methodology is to achieve the sustainable transportation goal of the city.

The main purposes of this planning process are:

i) To provide a safe and efficient network for low speed vehicles within the city and to integrate that with the existing land use pattern.
ii) To promote low speed vehicles as a sustainable component of the City's transportation system
iii) To reduce the demand on the automobile system

iv) To increase the livability of the community by improving mobility and reducing air pollution, noise and high speed travel

v) To continue to implement the City's Comprehensive Transportation Plan

5.1.3 Public Involvement in Developing the Plan

One of the most important components of the planning methodology is public involvement. To make the planning process truly fruitful, the involvement of the representatives from the relevant stakeholder groups is very necessary. The opinion of the local community groups, LSV advocates, and other interested citizens should be included from the beginning of the planning process. Public opinion helps to assess user's route preference for driving LSV as well as assist the planner to set goal and objectives in the planning effort. Moreover, incorporating public opinion during the development of low speed network plan also helps to develop a basis for supporting the alternative transportation within the city [30]. Public involvement can be made in various ways and various stage of the planning process. However, at least one public meeting should be held early in the plan preparation process to increase understanding and support for the plan and seek public input [62].

In this planning methodology, the survey approach was used to reach to the LSV user community of the city. The survey was designed and disseminated to owners and operators of LSVs who are members of the local electric vehicle user group, and employees of the university who regularly operator low speed vehicles. All the survey participants belong to the low speed vehicle user community of the city. Participants were provided with a proposed low speed network in the survey. Some of the connectivity gaps within the network were identified from their response. Their feedback also provided insightful information about the route choice as well as user characteristics of low speed vehicles. All these information worked as one of the major decision making criteria while developing the network.

5.1.4 Review of the Transportation Development Plan of City

The city transportation plan should be reviewed that would provide a detailed information on the land use pattern and traffic characteristics of the city. Again, different aspects of the existing road system of the city can be revealed from the city transportation planning document, which is an important criteria for this planning methodology. The City of Corvallis maintains a comprehensive transportation planning framework, documented as "Corvallis Transportation Plan" that contains a detailed description of the city transportation system and its different component. After a major update in 1983, the draft of the planning document was finalized in that year and is referred as "Corvallis Transportation Plan" [36]. Transportation elements of the Capital Improvement Program are updated each year in that plan. The vision of this planning document is to ensure a safe and convenient access to all areas and locations by all members of the city. The vision would be attained by coordinating the resources and providing efficient facilities and transportation alternatives throughout the community. Describing the functional classification of the roadway, the plan also presents a detailed description of the existing roadways system running inside the city and address different issues associated with the current road system. To enhance the livability and safety of the neighborhood, the plan promotes alternative transportation facilities, e.g. transit, cycling and walking, reducing the reliance on the automobile. The Plan aims to provide a balance between environmental protection and mobility within the City, economic development, and livability. The purpose of the plan is to allow the City to take actions that effectively respond to existing and future conditions in a timely and responsible manner. Anticipating the growth rate identified in 1989 planning document, this transportation plan developed a long range planning for 30-50 years. The challenge identified in the long range planning is to ensure the adequate fulfillment of the community needs as it grows maintaining good level of service, while not degrading the natural environment or compromising the quality of life of the city dwellers. The planning document also evaluates different funding sources to ensure adequate fund to meet the anticipated transportation needs as the city grows. It ensures consistency with local land use laws and state and federal direction. Overall, the city transportation plan serves as a policy tool for the decision makers and municipal authority to evaluate the existing transportation system of the city, analyze the effects that any development, specific transportation and land use decisions, and other social phenomena will likely have on it, and finally initiate proper steps to resolve any issue related to this system. The transportation plan also serves as a analytical tool for the user, by which he can get to know the characteristics of city's transportation facilities, can anticipate the types of improvements going to take place within the community; and be informed about the future development decisions planned for city's transportation system.

5.1.5 Overview of the Tool

The popular mapping tool, Google Earth is used in this planning methodology. Initially launched in 2005 and released to the public in 2006, Google Earth is a virtual globe program that uses satellite imagery of earth surface, aerial photography on GIS maps, and on top of all these uses Google Search to make geographical information available to the user. Google Earth has been very useful for a lot of purposes that include visual exploration of places, map directions etc. A free version of Google Earth is available for users and, it runs on web and it therefore easily accessible from everywhere, it runs on smart phones as well as it runs on almost every platform (Windows 2000 and above, Mac OS X 10.3.9 and above, Linux kernel: 2.6 or later and FreeBSD) on desktops [64].

Google Earth allows users to view any point of interest (POI) within a city, like airports, schools, hospitals, banks, restaurants, recreational areas etc. It also allows users to measure distance and estimate areas. The user can put own 'Placemark' at any location significant to him, designate it and then save it as "My Places" folder. Advanced users such as planners can use it for planning and spatial analysis. Such users can draw free-form paths and polygon in the 3D viewer and provide all the features of placemark data, including name, description, style view, and location to the paths, and finally save it for later uses. Users can also open GIS image files in Google Earth and have the files correctly projected over the proper map coordinates in the 3D viewer [64].

This study used Google Earth to develop the secondary roadway network for low speed vehicle, with a set of particular goals:

(i) The "Google Street View" option provides a panoramic view of the roads that enables the planner to virtually walk on the street and analyze different road characteristics. The navigation control of Street View allows the user to rotate 360 degrees, which helps him to view the street from different perspectives [64]. Users also can explore the physical characteristics of roadway, for example- number of lanes in each direction, presence of curb, shoulder or medians, types of traffic control system present as well as can get to know the type of adjacent land use. This gives the planner an idea about the functional classification of streets- whether it is a collector or neighborhood street. The Planner can also detect the number of STOP signs or traffic signals present at that street. The 'Street View' navigation also helps the planner to identify some of the on-road facilities, for example the presence of on-street parking, availability of bus stops, presence of traffic calming device such as rumble strips, speed humps or traffic circle and also if there is any barrier present at the right of way, such as bridges, rivers etc. All these characteristics significantly affect the route choice behavior of the low speed vehicle user. Therefore, planner can evaluate different roadway characteristics and assess the factors influencing LSV users' route preference behavior from this Google Earth roadway analysis.

(ii) It is freely available software; planners can easily access software from their personal computer anywhere in the world, provided having an Internet connection. It work even without internet connection, but the features are limited and the maps are in low resolution. Therefore, low speed network users have easy access to the network path (designed in this project) free of cost. It is also easy to understand the network path without any prior knowledge.

5.1.6 Analysis of the Existing System

This step of the planning process will be accomplished through the coupling of City's Transportation Development Plan with the road data analysis by Google Earth mapping tool.

In this planning process, the network is developed based on activity-based travel model instead of following the conventional four-step planning model. The four step model considers zonal-based trip making in aggregate and divides the region into smaller travel-analysis zones, where the estimated trips are associated with those zones on average [55]. Therefore, this conventional model does not reflect the individual LSV user's activity pattern within the micro-environment. In contrast, the activity-based model represents an individual's demand for activity and travel as an activity pattern and set of tours, where tour can be defined as a sequence of trip segments originated from home and ends at home [59]. The activity-based model is suitable for this study because this model deals at the individual or disaggregates level rather than following zone-based analysis at aggregate level. The output of this activity-based model is an origin-destination matrix. In this research, home is considered as the origin of the trip, while all other activity centers where the trip ends are considered as the destination of the trip. A trip can also be defined as tour, analogous to the tour concept of the activity-based model [59]. Again, home and all other activity centers, i.e. all origin-destination points are also considered as the nodes of the network, while all the connecting streets of these nodes are considered as the links of the network. All the trips made through the network in this study are categorized in the following groups:

Table 5.1: Trip Generation Characteristics

Trip Purpose	Origin- Destination
Work Trip	Home- Private, City, State and Federal Government Offices, Employment Centers
School Trip	Home- Education, K-20 (Kindergarten-Community College, Higher Education)
Shopping Trip	Home-Major retail facilities
Social or Recreational trip	Home- Recreation Centers, Worship Centers, Parks, Senior Homes
Special Trips for Senior Person	Home (Assisted Living Facilities), Senior Center, Medical Center

5.1.6.1 Identification the Activity Centers

To develop the low speed network, the major activity centers within the city need to be identified that will serve as the node of the network. As mentioned earlier, home is considered as the origin of the trip, whereas the activity center, where the trip ends, is considered as the destination of the network. Trips are made through the link from one node to another.

Google Earth makes this step of identifying activity centers in the city very easy for planners. The map with legends in Google Earth depicts different activity centers within the city in a 3D view. The '*Layer*' panel of Google Earth holds an extensive list of activity centers or "Point of Interest (POI)" in a city [64]. By checking in the different 'point of interest' check box, a planner can get to know different activity centers within the city. The list of activity centers include:

Residential areas: All the neighborhood areas within the city belong to this category. It is assumed in this planning methodology that every trip will begin from this category.

Education: This category includes elementary, middle and high schools, community colleges and universities. This category is a major trip generator of low speed vehicles within the city.

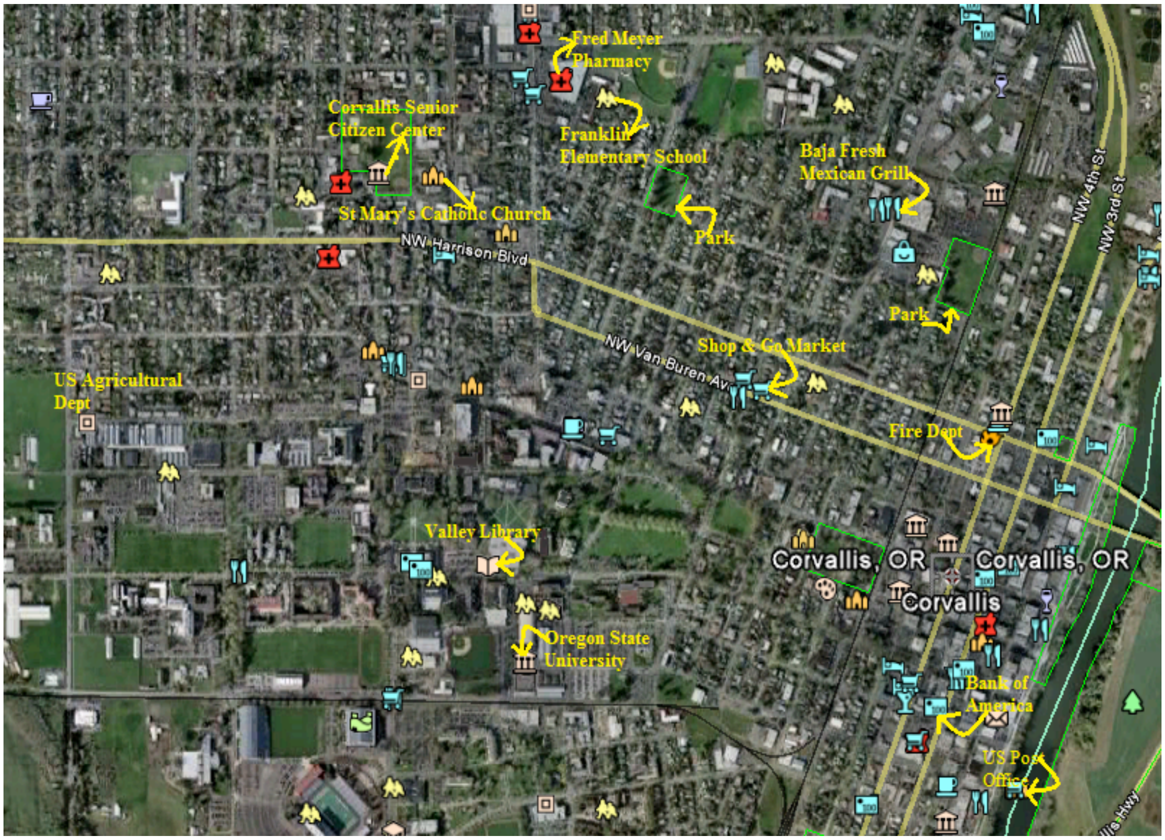
Employment Centers: City, State and Federal Government Offices, banks, private agency offices and other employment centers are included in this category. A major portion of these employment centers is located within 5 miles of the neighborhood places in many small or medium-sized cities [28]. In those cases, a low speed vehicle can be a potential mode of regular travel to the employment centers. Again, these employment centers are one of the major sources of single occupancy automobile trips in the city. Therefore, it is expected that a safe and accessible low speed network running through the employment centers will encourage the increasing use of energy-efficient low speed vehicles and reduce dependency on automobile traffic.

Commercial Places: Shopping centers, malls, restaurants, grocery stores, downtown areas, and other major retails belong to this category. LSV can be of particular use to make regular trips to grocery stores or other retails located a few blocks within home, where the use of a regular automobile is waste of non-renewable energy.

Social and recreational areas: Recreation Centers, worship places, parks, Senior centers, historical, natural or scenic places inside the city are one of the major attractors of low speed vehicle trip. The survey, conducted in this study, revealed that a large portion of the retirement community of the city use LSV for their regular trip purpose. Therefore, a safe and efficient low speed network within the city will be very beneficial for the senior members in the community.

Special Trips for Senior Person: The link of the low speed network should also connect Assisted Living Facilities, Senior Citizen Center, medical centers and pharmacies in the city to facilitate the regular travel of senior persons in the community.

All these activity centers are identified through Google Earth for the city of Corvallis. The following figure (Figure 5.2) shows the map of Corvallis city with different activity centers displayed on it. After identifying the activity centers within the city, a detailed planning should be conducted to link all these activity centers as many as possible to facilitate an easy and continuous travel of low speed vehicle within the city.



Legends:

University · Coffee shop or baker · Daycare · Dining

Fire Station · Mosque · Dentist · Doctor

Hospital · Pharmacy · Post office

Bank · Tourist Destination · Residential Complex

Lodging · Shopping · Supermarket

Temple or place of worship · Airport

Civic building · Museum

Stadium · School

Park · Library

Figure 5.2: Location of different acitivity centers in the City of Corvallis

Source: Google Earth

5.1.6.2 Inventory of Existing Road System

The inventory section of this planning methodology deals with the analysis of the existing roadway condition. A comprehensive analysis of the system includes identification of speed limit of different roads, their functional classification, the roadway geometrics as well as potential barriers that may obstructs the regular movement of LSV. All these important factors are then combined together to select potential routes for low speed network. Nevertheless to mention here that this low speed network will be completely based on the existing roadway network of the city; construction of a completely new road or any structural modification of the existing road is not considered anywhere in this planning methodology. This section includes the following two important steps:

i) Analysis of the current roadway system

ii) Identification of the potential Barriers

Analysis of the Current Roadway System

The existing roadway system of the city is used as the base of low speed network in this planning methodology. The potential links between different activity centers are chosen from the existing roadway network based on the speed limit, traffic characteristics and roadway geometric features to establish the low speed network.

Data on roadway speed limit and roadway functional classification is collected from the City's Engineering Department or Local Planning Guide. Comprehensive Transportation Plan maintained by the City of Corvallis includes a detailed description of current roadway system of the city, including the speed limit and roadway classification. In addition to that, a comprehensive analysis of the physical characteristics of the roadway is conducted by Google Earth to develop the low speed network. However, the analysis of actual routes in a Google Earth helps the planners to evaluate the routes that the users will choose to travel. This evaluation is based on users' travel behavior and route characteristics rather than only distance or time to reach the destination.

(a) Roadway Classification: The functional classification of roadways is a very important factor in the development of low speed network. Freeways and arterial roads provide a highest level of mobility, but limited access to the moving traffic. Therefore, the speed limit and volume of the traffic in freeways and arterials are generally very high [36]. The primary purpose of collector and local streets is to provide vehicle access to different activity centers inside the city. For this reason, the speed limit of collectors and local streets are generally low [36]. Therefore, the aim of this study is to avoid the freeways and arterial streets, and use collector and local streets of the city as much as possible, to develop the low speed network.

Based on the level of mobility and access provided by the roadways, the City of Corvallis proposed a modified Functional Classification System for the city road system in the "Corvallis Transportation Planning" document. No freeways or expressways run through the Corvallis city. Therefore, the roadway classification for the city was based on arterials, collectors and local street network system.

According to the modified roadway classification, arterial street system that provides the highest degree of mobility to through traffic is composed of two types of roadways- State highways and Arterial Streets. State Highways are the primary gateways into the city. There are four state highways serving the city- US 20, OR 34, OR 99W (3rd & 4th St.) and US 20/0R 34. The arterial streets connect the state highways and link major commercial, residential, industrial, and institutional areas. Some of the north-south arterial streets are 9th St., 53rd St. and east-west arterial street running through the city are Walnut Blvd., Airport Road.

The collector street system consists of collectors (roughly equivalent to existing collectors defined by AASHTO) and neighborhood collectors. These collector streets, which are equivalent to standard collector defined by AASHTO, provide access and circulation within residential neighborhoods and commercial/industrial areas, for example, Country Club Drive, West Hills Road, Monroe Avenue etc. The neighborhood collectors are designed to reduce auto traffic impacts from collector roadways serving predominately residential neighborhoods. The basic difference between collector and neighborhood collector is that in case of a neighborhood collector, land use along its route is generally low to medium density residential in nature. And to control traffic speeds on neighborhood collectors, traffic calming techniques such as traffic circles, bulbed intersections, or speed humps are generally used [36].

Local Streets provide access to immediately adjacent land. This system includes local connectors and locals. Local connectors are relatively continuous local streets that provide access between low use locals and other local connectors or collectors, whereas, locals represent those streets which have a very low desirability for use as a through street. Examples of locals are Cul-de-sacs less than 600 feet in length and serving no more than 18 dwelling units or a series of parallel low-use streets in which no specific street has significantly greater probability of through use [36].

General parameters for speed and volume on these various classifications of roadways have been provided below in the table. It is to be mentioned here that these volumes are not intended to be absolute maximums or minimums. Also, some streets may have dual classifications, since their function changes, for example Circle Boulevard and Highland Drive [36].

Table 5.2: Functional Classification - General Traffic Volume and Speed Guide

Roadway Type	***Daily Vehicles***	***Managed Speed (miles per hour)***
Arterial Highway	> 10,000	45-55
Arterial Street	>5000	25-45
Collector	>2000	25-35
Neighborhood Collector	>2000	25
Local Connector	<2000	25
Local	<2000	15-20

Source: Corvallis Comprehensive Transportation Plan

(b) Roadway Speed Data: Corvallis Comprehensive Transportation Plan also presents the speed data of different roadways in the city, developed by the State Traffic Engineer. The speed represents 85th percentile speed of the vehicles. From the Speed Zone Inventory data, it has been found that most roadways in the city have a posted speed limit between 25 miles per hour to 35 miles per hour, except the State Highways and Arterials that have speed limit of 55 miles per hour and 45 miles per hour respectively. Therefore, existing roadway system of the city provides a good base upon which the low speed roadway network can be developed.

According to NHTSA, low speed vehicles have maximum attainable speed of 25 miles per hour. After analyzing the safety issues related to these vehicles, this study has recommended that the operation of this LSV should be limited to public roadways with a posted speed limit of 25 miles per hour (OTREC RR-10-19). As discussed earlier in this study, when low speed vehicles are operated with regular traffic operating in higher speed, it creates a speed differential that can pose potential risk to the occupants of low speed vehicles. Therefore, the speed data of the roadways is an important factor to develop the low speed network. The speed data of different roadways in city usually can be collected from city's engineering database. For this study, the roadway speed data for the Corvallis city was derived from the City's Comprehensive Plan.

(c) On-Road Facilities: There are some other factors that need to be considered while developing the low speed network. These factors include the physical and topographical characteristics of roadways. From the user's response obtained from the survey, it was revealed that number of lanes, vertical elevation or hilliness of the roads, functional types of roadways, percentage of heavy vehicles etc. significantly influence the user's route choice to drive the low speed vehicles. Therefore, all these characteristics of roadways are analyzed using Google Earth in order to evaluate the suitability of that road as a potential route for the low speed network.

Analysis of the route using Google Earth

Google Earth presents a comprehensive map of the city with legends depicting different activity centers in the city. This property has been used earlier in this study to identify the activity centers that will generate the low speed vehicle trip within the city. This mapping tool has also been used to mark some potential low speed route in the city. These marked low speed routes has been used in the survey to get user feedback on these low speed network.

In developing the local low speed network, Google Earth is used to analyze the physical and topographical characteristics of roadways. This information is then used to assess the suitability of the roads to be included in the low speed network. Usually the analysis of routes assumes the concept that travelers use some form of minimum-cost or minimum-distance path from their origin to destination [30]. However, the route analysis with Google Earth helps the planner to identify the actual roadway condition. The planner then can use this information to assess users' route preference decision. Therefore the use of Google Earth assists the planner to develop the low speed network not only based on travel time or distance between origin and destination, but also considering other roadway factors important for making route choice decision.

The Satellite View of the Google Earth provides aerial imagery of the streets and also provides street names and other features on the map. The Street view option of this software allows user to view and navigate down to the streets of different places in a 3D environment [64]. The planner can experience different roadway features by navigating on the streets with the "Street View" option. Therefore, the 'Street View' application is used to analyze different on-road characteristics in this planning methodology. The analysis of different roadway characteristics with Google Earth has been described below.

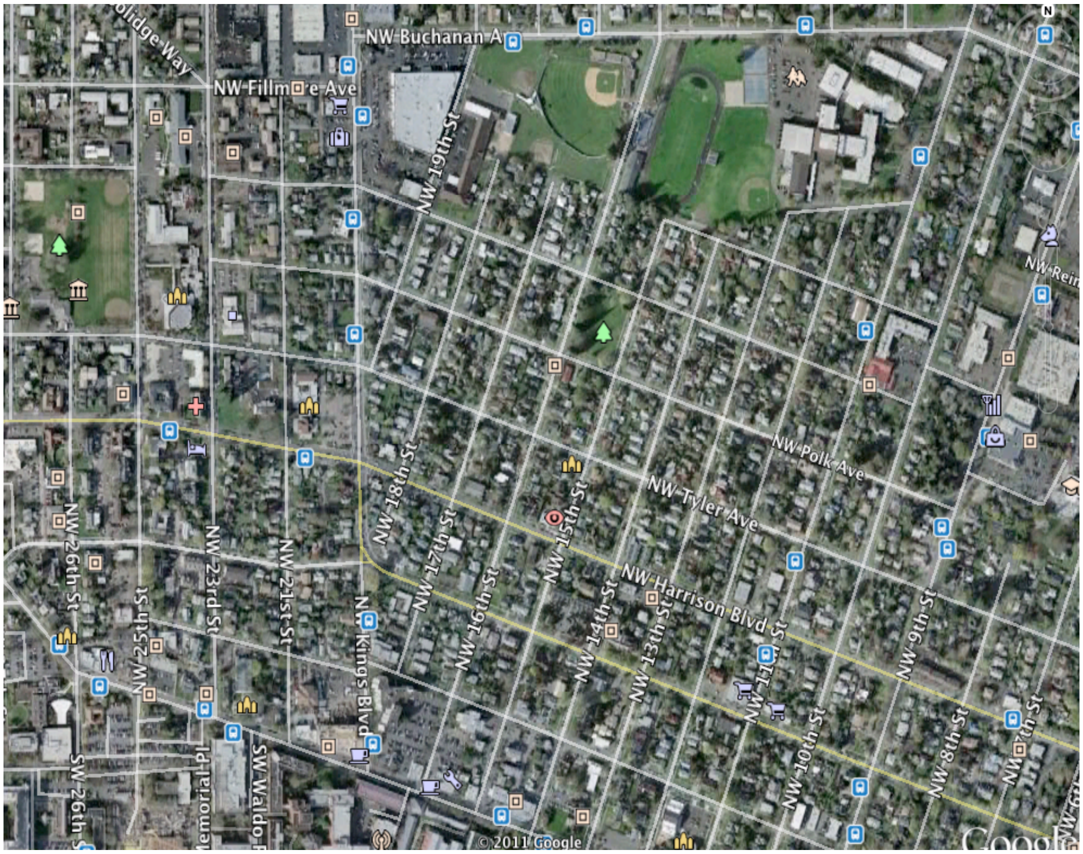
i) *Types of roadway*: Google Earth can display the road map information of cities located in U.S., Canada and many other international countries. This information includes names and position of interstates as well as major highways, county roads, and city streets [64]. While displaying the map of a particular city displayed in Google Earth, the solid yellow line on the map represents the state highways running inside the city. Some of the arterial streets are also depicted by solid yellow line in the City map. Therefore, this aspect of Google Earth makes it easy for the planner to identify these roadways and discard them as a potential link in the first step of network development process. However, not all the arterials are highlighted in the city map displayed by Google Earth. In this case, the coordination with the speed data collected from city's Transportation

Plan is a mandatory to screen out these arterial streets in the network development process.

ii) *Traffic volume*: The volume of motor vehicle traffic in the roadway considerably impacts LSV users' trip experience. Higher motor vehicle traffic substantially creates weight differential as well as speed differential for low speed vehicles. This increases the probability of potential conflicts between LSV and motor vehicles. The Street view imagery of Google Earth helps the planner to assess the traffic volume of the road. In addition o that, a planner must consult the city's Transportation Plan to obtain traffic volume data of the city roadways.

iii) *Number of Lanes*: Number of lanes is an important consideration for developing the low speed network. It has been observed from the survey that the low speed vehicle users prefer roadways with no more than two lanes in both ways. When the number of lanes in both ways of roads increases more than two, their perceived risk of operating LSV on those routes also increases. This is due to the reason that, with increasing number of lanes, traffic volume and roadway speed limit also usually increase. Also, LSV users do not feel comfortable when any vehicle-heavier and faster than LSVs overtake them. Therefore, the roadways that have more than two lanes, one in each direction, should be avoided in the development of LSV network.

The 'Satellite View' of Google Earth allows the user to identify the number of lanes in every direction of the roadway. This view also helps to figure out the existence of bike lanes on the road. Planners can also count the number of lanes and identify whether it is a through lane; or left or right turning lane by virtually walking on the street with the 'Street View' option of Google Earth.



Legend Bus Stop

Figure 5.3: Routes With () and without heavy vehicles (bus) in Corvallis City, OR
Source: Google Earth

iv) *Heavy Vehicles:* Presence of bus and truck in the roadway keeps a negative impact on the route choice behavior of LSV users. Heavy vehicles in the traffic stream creates significant weight differential, which poses potential risk to the LSV users, stated earlier. The “Transportation’” option in the ‘Layer’ panel of Google Earth indicates the streets in the city carrying heavy vehicles by showing the icon of ‘Bus Stops’(Figure 5.3). This is an important information for this study because it is assumed that the most percentage of heavy vehicles that run on the city streets at regular basis is City Buses, which might significantly create weight differential for LSVs. Therefore, using this information planners can easily identify the routes with city buses and can avoid those routes as a link of the low speed network.

v) *Hilliness*: The route preference of the LSV users indicates that users prefer flat terrain to drive the LSV than hilly terrain. Despite the fact that hilly terrain often offers visual and scenic view, users tries to avoid routes with hilly terrain. As stated in the previous chapter, one probable reason for this might be higher battery power consumption while riding the LSV from flat to hilly terrain. Also for some of the LSV models, the speed drops by half on the uphill grades [21]. Again, most of the LSVs are lighter than regular passenger vehicle. Therefore, downhill might pose a perception of risk to the LSV drivers by a possibility of rolling down from the hill. For these reasons, hilly routes are tried to avoid in developing the low speed network. The 'elevation' options in the status bar at the lower part of the Google Earth window displays the elevation of any point on earth. Integrating the use of 'elevation' option in Google Earth and route preference options obtained from feedback of local people, the routes of higher elevation or hilly routes are identified and consequently avoided as a link of the low speed network.

vi) *Types of intersection*: This is an important factor in the planning of low speed network. One of the recommendations suggested in the previous report (OTREC RR-10-19) on LSV is that these vehicles should be restricted to crossing higher-speed roadways at four-way stops or traffic-controlled intersections due to safety issues. Therefore, the low speed network will be planned in a way that the incident of crossing the high-speed intersections of arterials or major collector roads will be the minimum. Google Earth allows the planner to view the physical and functional characteristics of the intersections. These characteristics of the intersections also can be thoroughly reviewed by the City Comprehensive Transportation Plan. If the intersection generates a high traffic volume and the speed limit of the intersecting roads are very high for driving LSV, then that intersection is tried be avoided in the low speed network.

Figure 5.4 Signalized intersection connecting the arterials and major collectors of Corvallis, OR
Source: Google Earth

Figure 5.5 4-way STOP controlled intersection connecting neighborhood streets in Corvallis, OR
Source: Google Earth

vii) *Continuity*: Continuity is a route level factor, which is most meaningful when accumulated over the entire route [26]. From the user's feedback of the low speed network, it has been confirmed that they have a strong preference for continuous low speed routes to different activity centers of the city. Therefore, the connectivity gaps in the low speed road network should be carefully identified and measures should be taken to provide a solution, or at least recommended an alternative option for those connectivity gaps. The 'Satellite" view of Google Earth allows the planner to follow the complete street network of the city and identify if there is any connectivity gap in the network.

viii) *Accessibility*: One of the major characteristics of a good road network is to ensure accessibility to the activity centers of the city. According to Handy, "Accessibility can be defined as a way of describing the opportunities for participating in activities, such as, work, shopping, recreation, available to residents of a given place" [60]. It is determined by the connectivity between activity centers as provided by the transportation systems. Therefore, the low speed network should be planned in a way that it provides accessibility between the residential neighborhood and all other activity centers within the city. Major connectivity gaps should be identified and proper measures should be proposed to mitigate those gaps in order to ensure accessibility throughout the major destination points of the city.

Identification of Potential Barriers

In the early stage of the planning process, potential obstacles that may hinder the regular movement of low speed vehicles, need to be identified. These may include physical barriers or local regulatory aspects, such as high-speed intersection, that might potentially obstruct the safe passage of low speed vehicles.

a) Physical Barriers: Physical barriers can be natural or man-made. Sometimes these barriers can be eliminated, for example removing bollards from multiuse path. But if the barriers cannot be removed, then alternative routes should be proposed to make the route accessible and continuous. Physical barrier includes:

i) *Mountainous terrain*: Routes in steep hills hinder the movement of low speed vehicles. It has been found that mountainous terrain is in general undesirable as a preferable route inside the city. In addition, the acceleration and braking capabilities of low speed vehicles potentially differs than regular passenger cars [8]. In the survey study of this research, people showed a negative attitude to drive LSV in steep hills due to the perception of safety and strenuous acceleration of vehicles to climb the uphill. Therefore, routes with steep hill need to be identified and avoided in the network development, if possible.

ii) *At-Grade Rail Crossing*: Rough and unsmooth railroad crossing might be problematic for the movement of low speed vehicles. If the pavement adjacent to rails are left open crack, the smooth driving of low speed vehicles can be hampered. Through Google Earth or from consultation with local people, these uneven crossings should be identified. Proper measures need to be taken to make the rail crossings as smooth as possible. Sometimes filter materials can be used to reduce the gap next to the rail [61].

iii) *Manholes and Utility Covers:* Manholes those are lower or higher than existing pavement surface can create obstacles to the movement of low speed vehicles. This problem occurs during roadway resurfacing when a manhole is not raised to the new pavement surface level [61]. Such spots should be identified and measures should be taken to raise the manholes to maintain a same pavement level through the entire cross section of the road.

iv) *Presence of traffic calming device:* Sometimes the presence of traffic calming device can also place barriers for the movement of low speed vehicles. For example, in some places bollards are placed at neighborhood or local streets to restrict the movement of high-speed vehicles. It might be possible to allow low speed vehicles on those local roadways still preventing the regular

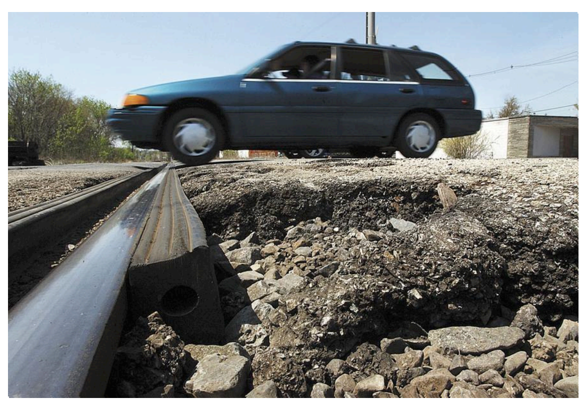


Figure 5.6: Large holes developed at at-grade crossings
Source: Google

traffic. Also, high speed bumps in the neighborhood areas are sometimes problematic for the smooth passage of LSVs that needs special attention while designing the network.

v) *High crash locations:* Motor vehicle high crash locations in the city can also pose safety issues for the low speed vehicles [62]. Because, LSVs are more vulnerable to risks than conventional motor vehicles. Therefore, these high crash locations need to be identified possibly from the Traffic Engineering Report of the city. The low speed network should be designed in a way such that LSVs do not have to cross these high crash locations.

vi) *Multiuse path*: Multiuse paths are physically separated from the motor vehicle traffic and are dedicated for pedestrian and bicycle traffic. The way motor vehicles pose risk for LSVs, similar way LSV running at 25 miles per hour, might pose risk to the pedestrian and bicyclist. Therefore, multiuse path are not recommended for LSVs and these paths should not be included in the low speed network.

Poor pavement conditions also hinder the smooth passage of low speed vehicles. In addition to the physical barriers local or regulatory laws can also place obstacles to the movement of low speed vehicles.

b) Infrastructural Barriers: In many cases, high-speed roadways surround neighborhoods or activity centers. These high-speed roads create a barrier to the access of low speed vehicles to those activity centers.

Once these potential barriers in the existing roadway system are identified, appropriate measures need to be taken to eliminate or overcome or bypass those barriers, if possible. Examples of eliminating the barrier could be structural improvement of the road surface, removal of temporary bollards etc. Sometimes, the speed limit of certain corridor of the roads also might need to be reduced to provide safe connectivity of low speed vehicles. When the elimination of barriers is not possible, a convenient alternative route should be proposed for the movement of low speed vehicles.

Findings from above on city's road system, roadway speed data inventory, different on road facilities etc. is considered in developing the low speed network described in the following sections.

5.2 Development of Low Speed Network:

Once the inventory of the existing roadway system is done and all the potential origin and destination point of the city are identified, a low speed network is developed by integrating the output from public involvement, city's transportation plan and road data analysis by Google Earth mapping software. This developed low speed network will allow the low speed vehicle users to safely drive LSV inside the city, and will also promote the low speed vehicle as a potential green travel mode for regular trips in city dwellers' daily life. This low speed network will also help the city planner to reach their multimodal transportation system plan.

This next section describes following two processes:

a) Connecting the origin and destination points

b) Propose recommendation to fill up the connectivity gaps in order to ensure a continuous network

5.2.1 Connecting the Origin and Destination Points:

The major origin and destination points have been marked on the city maps through Google Earth in the previous section. These points of interests, e.g. activity centers need to be connected by links to develop a network. The "Add Path" option of the Tool Bar in Google Earth allows the planner to depict a path by drawing lines on the city map. These lines would represent potential travel routes for low speed vehicles. The different color-coding property of these lines would help the user to distinguish the routes of different characteristics on the low speed network map. Below is a step-by-step procedure to develop the low speed network through Google Earth:

Step 1: Identify the City Boundary - First step is to define the city boundary on the city

Figure 5.7: City boundaries of the Corvallis City, OR including the activity centers
Source: Google Earth

map displayed by Google Earth. This step can be accomplished using the "City Boundaries" option in the Layer panel. The yellow line in the figure indicates the boundary surrounding the city (Figure 5.7).

Step 2: Roadway Class - All the State Highways and major arterials running through the city will be identified by their solid bold yellow lines on Google Earth city map and will be avoided as a link of the network. For example, in the map of Corvallis city, Oregon, displayed by Google Earth, the State highways- US 20, OR 34, OR 99W (3rd & 4th St.) and US 20/0R 34 are depicted by solid yellow line (Figure 5.8). As a part of State highways, these roadways have higher speed limit of 55 miles per hour. Therefore, these roadways are avoided as a potential route while developing the low speed network. Again, the arterial streets, also depicted by solid yellow line in the City map are avoided in the development of low speed network. For example, Van Buren Blvd., Harrison

Blvd., 53rd St., have not been included as routes of the low speed network. For the arterials that are not highlighted by yellow lines, the Corvallis Comprehensive Plan is consulted to identify those arterials. Consequently these arterials have not been included in the low speed network. For example, 9th St and Kings Boulevard running through the north-south part of the city are avoided as a route of the low speed network.

Figure 5.8: State Highways and major arterials running through Corvallis City (marked by Yellow lines)
Source: Google Earth

The type of adjacent land use can also be viewed the Google Earth. The planner can assess the functional types of roadway from the type of adjacent land use. For example, the following figures represent two different types of roadways in the city. The following first figure (Figure 5.9) represents the street imagery of 16th St, in Corvallis city. From

Figure 5.9: 16^{th} St., Corvallis, OR- Example of Neighborhood Street
Source: Google Earth

this figure it can be easily assessed that this is a neighborhood street with very low volume of traffic, which can be a potential route to drive low speed vehicle. In contrast, the following second figure (Figure 5.10) represents an arterial street, named the Kings Blvd., which links other two major arterial streets running through the city. It also can be assessed from the figure that this roadway carries a high volume of traffic. Therefore, this roadway has been avoided to use as a low speed network link, as stated earlier.

Figure 5.10: Kings Blvd, Corvallis, OR- Example of Arterial Street
Source: Google Earth

Step 3: Roadway Traffic Volume - Traffic volume of the road is associated with the functional class of roadways. For example, from the above figure, it can be assessed that neighborhood streets have a low traffic volume, whereas the traffic volume in major collectors of the city is comparatively high. To illustrate, it has been revealed from the Corvallis Comprehensive Plan that the 29th St at Circle Blvd., in Corvallis city carries almost 9000 vehicles per day, whereas any neighborhood street such as 27th St carries less than 2000 vehicles per day [36]. Therefore, a major collector such as 29th St has been avoided in developing the low speed network.

Step 4: Roadway Speed Limit - As the arterials and major collectors of high speed limit are avoided as much as possible in developing the low speed network, therefore, the aim of this section is to develop the network based on the city's minor collector and neighborhood streets with speed limit no more than 25 miles per hour. Typically, majority of the neighborhood streets have a posted speed limit of 25 miles per hour. So, the base of this low speed network is the neighborhood streets that pass through the grid-pattern neighborhood areas in Corvallis City.

However, to provide connectivity to some major activity centers of the city, some roadways with speed limit more than 25 miles per hour, but no more than 35 miles per hour need to be included as a potential route of the low speed network. For Example, Circle Boulevard is one of the major streets of the city connecting the east part to the west part of the city. At the west of 29th St., it serves as a two-lane collector street with posted speed limit of 25 miles per hour, whereas at the east of 29th St., it serves as an arterial street of four and five lanes and with posted speed limit of 35 miles per hour. In this case, to provide connectivity from the west part to the east part of the city, Circle Boulevard has been included as a potential route of the low speed network. This street also provides access to many major activity centers of the city. For example, Corvallis Department of Motor vehicle (DMV), the branch office of Hewlett-Packard, the UPS store, some major retails and shopping centers such as Kmart, Market of Choice, and worship centers, schools and also to some pharmacies of the city. Therefore, this is an important east-west link in the city. The traffic volume at Circle Boulevard is comparatively lower (13,200 ADT in 1991) than the other major east-west link, Walnut Boulevard (15,700 ADT in 1991) [36]. Also, from the route preference of the local LSV user obtained from the study survey, it has been found that Circle Boulevard is one of their major driving routes for their daily trip by LSV. Users also reported that the route of Circle Boulevard is much safer than Walnut Boulevard due to lower speed limit at the west of 29th St. and also due to the reason that a portion of this street runs through the neighborhood areas. Therefore, in spite of having higher speed limit than 25 miles per hour at the east of 29th St., Circle Boulevard has been included as a potential route of the low speed network. However, it has been recommended in this study, that city planner should take initiative to change the speed limit of Circle Boulevard at the east of 29th St. to 25 miles per hour in order to provide a uniform speed limit throughout the entire corridor of Circle Boulevard. This initiative would also help to ensure the safety of low speed vehicle, both human and non-human powered, at the cost of little delay to regular vehicular traffic due to reduced speed limit.

Another example of such exception is Western Boulevard. This is a two-lane east-west arterial to the north of and parallel to U.S. 20/0RE 34. Western Boulevard runs through the south side of OSU and provides access to OSU's Parker Stadium and Gill Coliseum and many other residential areas. At the east of 35th St., the speed limit of Western Boulevard is 30 miles per hour whereas it has a speed limit of 35 miles per hour at the west of 35th St. Although Western Boulevard has higher speed limit, it has been included as a route of the low speed network, because it is an important link to the OSU. For to the same reason 35th St. is included in the low speed network, which has a speed limit of 35 miles per hour from NW Jackson Avenue to US 20 highway.

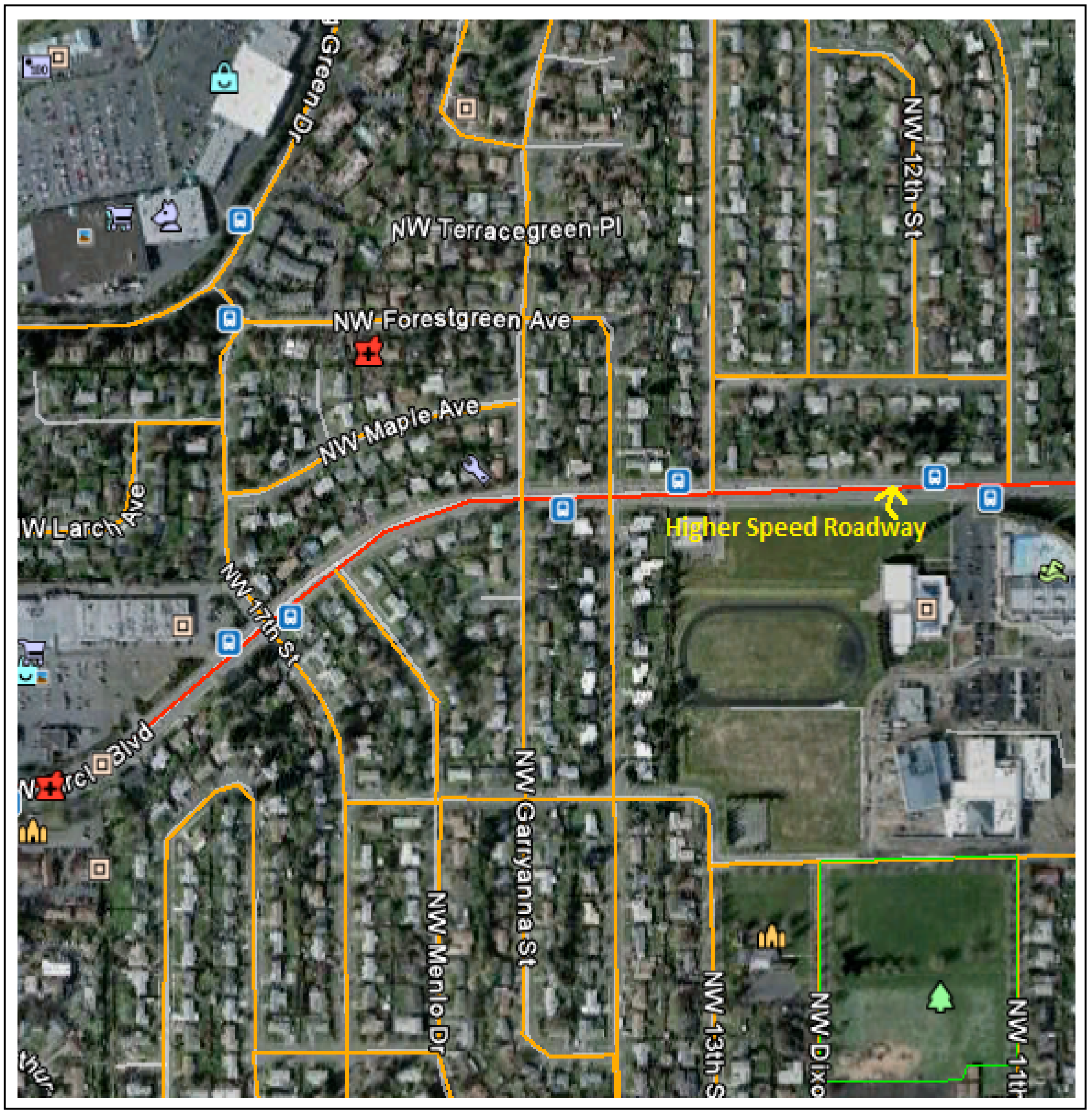


Figure 5.11: Higher Speed roadway marked by red line and regular roads with 25 mph speed limit are marked by orange line
Source: Google Earth

To distinguish the higher speed routes on the network, those are marked using red lines, whereas orange lines on the network mark the regular routes with 25 miles per hour speed limit (Figure 5.11). It should be noted that the speed limit of high-speed roadways never exceed 35 miles per hour posted speed limit.

Step 5: Number of Lanes - Typically it can be generalized that more number of lanes is associated with higher traffic volumes of the roadway. The number of lanes also reflects the functional classifications of the roadway in most cases. For example, most neighborhood streets in the city possess no more than two lanes, one in each direction; whereas the arterials and major collectors have more than two lanes in both directions to accommodate higher traffic volume. Therefore, effort has been made to include the neighborhood streets as the potential links of the low speed network that have in general two lanes in both directions. For example, the following Figure 5.12 displays the Satellite view and Figure 5.13 displays Street view of 9th St., which is a major arterial street of the city. From both the figures, planner can count that on 9th St., there are 5 lanes in both directions with an exclusive left turn and right turn bay and two bike lanes.

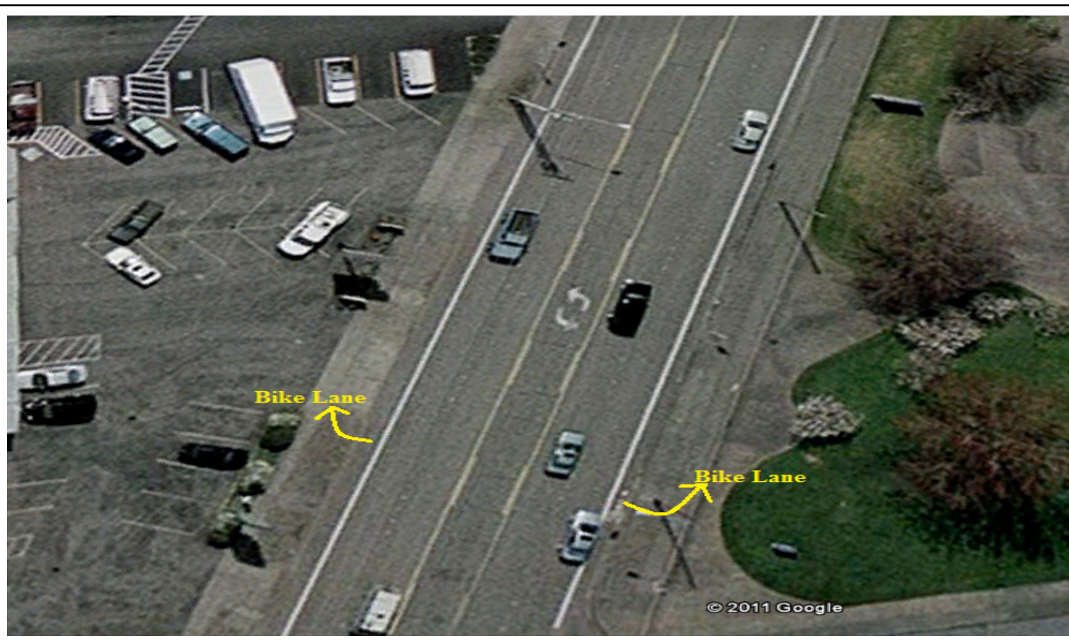


Figure 5.12: Google ‘Satellite View’ of 9th St of Corvallis City, OR
Source: Google Earth

Figure 5.13: Google ‘Street View’ of 9th St of Corvallis City, OR
Source: Google Earth

However, some arterials and collector streets with more than two lanes in both ways could not be avoided in developing the low speed network, since those roadways are the major links between the two parts of city. In addition to that, those roadways are also important to provide access to the major activity centers of the city as described in this chapter. For example, Walnut Boulevard is an arterial running the northern and western part of Corvallis city with comparatively higher volume of traffic, but it is still necessary to incorporate the part of this arterial from NW Highland Dr to NW 9th St. in the network to provide connectivity to some major activity centers, for example U.S. Bank, City’s Prosthetics & Orthotics Center etc. It is important to note that the speed limit of that segment of Walnut Blvd. is 25 miles per hour (Attached Map in the Appendix).

Step 6: Heavy Vehicles - Heavy vehicles in the regular traffic stream pose risk to the occupants of LSV due to weight differential factor. Hence, routes that include heavy

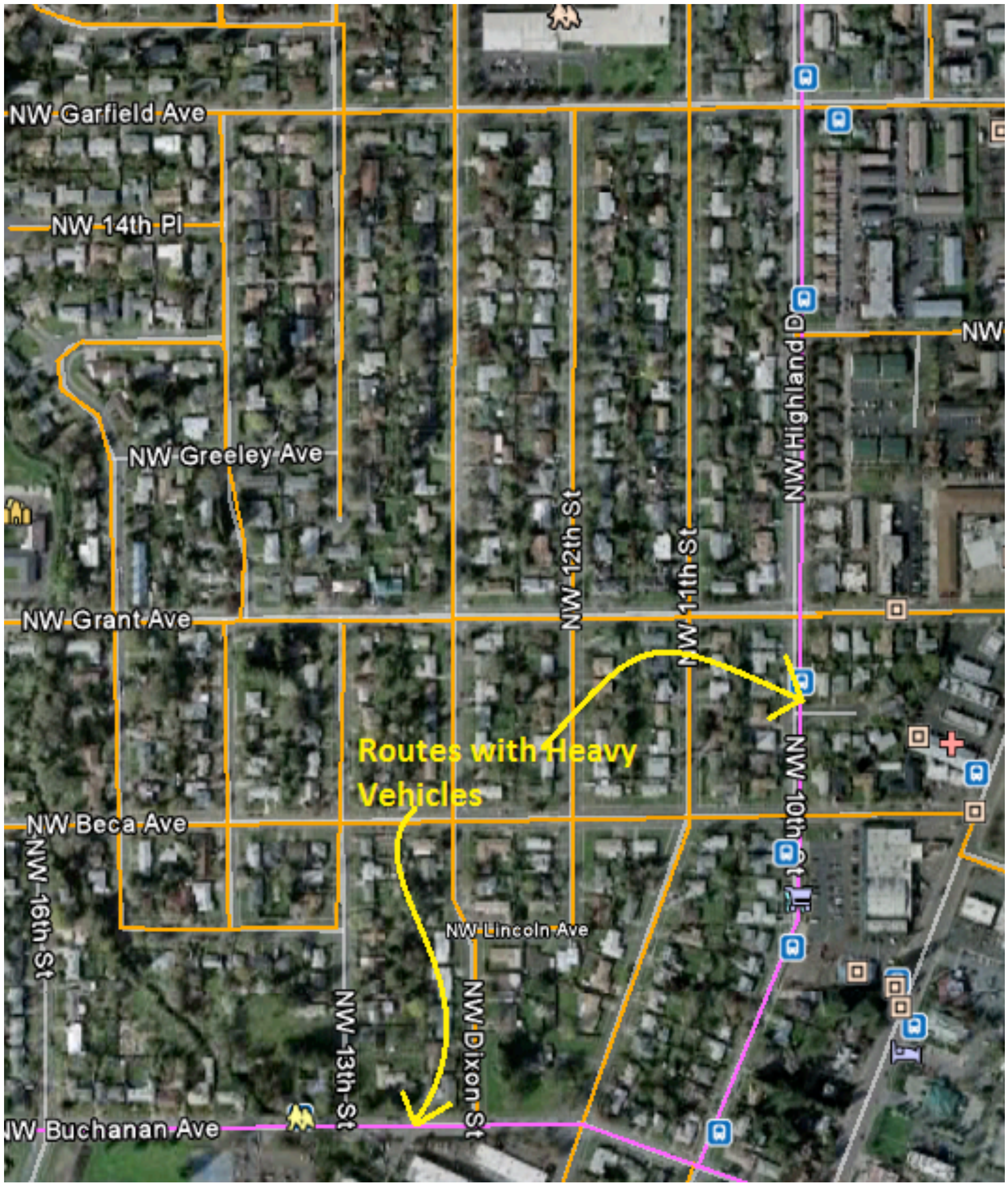


Figure 5.14: Routes with Heavy Vehicles (bus)
Source: Google Earth

vehicles are avoided as possible in developing the network. Typically, large trucks are not driven in the neighborhood streets. The routes that are used by city buses can be identified with Google Earth, as mentioned earlier. Therefore, one of the screening parts of this study is to identify the neighborhood streets that are included in city bus routes, and avoid them as much as possible. For example, some major bus routes of the city are 29th St., 4th St. etc. and these streets are not included in the low speed network.

However, it is often not possible to avoid all the roadways that carry city buses running inside the city. Especially for a college town like Corvallis, buses run almost every major route link of the city to provide access to neighborhood areas. Therefore, some bus routes are included in the low speed network. However, planners should try to select such bus routes to include in the network; those have lower bus volume as well as lower volume of motor vehicle traffic. While developing the low speed network for the city of Corvallis, some bus carrying roads that give access to the OSU, for example Monroe Ave., 14th St., SW Jefferson Way etc. are necessary to be included. Again some other major city bus routes that give access to many residential areas and some important activity centers are also included as potential link of the low speed network. Examples of such routes are: Highland Dr. /10th St, Circle Boulevard, Buchanan Ave., Western Boulevard etc. The bus routes that are included in the low speed network are marked by purple color, so that users can easily identify the low speed routes with heavy vehicles (Figure 5.14).

Step 7: Hilliness/Change in vertical elevation: It was observed from the survey that low speed vehicle users generally do not prefer hilly routes or routes with higher vertical elevation. Therefore, alternative routes for the hilly routes in the city need to be provided as the driving route of low speed vehicles. However, in case of City of Corvallis, almost every roadway in the northwest end of the city boundary has higher elevation than other part of the city. These roadways provide access to numerous homes, some schools, city's athletic club and city parks. For example, NW Witham Hill Dr. and the north most part of 29th St. lead to many apartment complex and private houses of the city. Again, Satinwood Dr. and Samaritan Dr. at the northwest part of the city are collector roads that provide access to the healthcare facility of the city and also have higher elevation. Therefore these destination routes with higher vertical elevation cannot be avoided in order to provide complete accessibility of low speed vehicles to all parts of the city. However, while developing the low speed road network, these hilly routes are marked with blue color in order to distinguish them easily from other routes of the network. This color-coding of hilly routes would allow the LSV users to identify them in the network map and help them to make their route choice decision to drive LSV (figure 5.15).

Figure 5.15: Hilly Routes
Source: Google Earth

Step 8: Accessibility - Accessibility reflects the ease with which potential destination points in a place can be reached [60]. Therefore, the aim of the low speed network is to provide direct line access from residential areas to employment centers, stores, shopping malls, schools, parks, recreation centers and other community places. For a small city like Corvallis, where the residential areas and other major activity centers are closely spaced, the low speed network need to be developed in a way that the potential routes of network run through every residential street. It will allow the LSV access to every household and people will get more incentive to use this energy efficient low speed vehicle for their daily regular trip.

However, when it is not possible to include every neighborhood street in the low speed network, attempt need to be made to include every alternate neighborhood street in the network. For example, while developing the low speed network of the City of Corvallis, 29th St. cannot be included as it carries city bus traffic and comparatively high motor vehicle traffic. Therefore to provide accessibility to the adjacent neighborhood, 30th St., 28th St. and 27th St. are included as potential routes of the low speed network. All three of these streets are included due to the reason that adjacent 28th St. is discontinued after few blocks in the regular road network of the city. Again, some of the hilly routes, 35 miles per hour roadways and also the bus routes, which are less desirable to the LSV users for driving their low speed vehicles, are still included in the low speed network in order to provide accessibility to different destination points of the city.

Step 9: Identify connectivity gaps - The presence of potential barriers in the regular roadway network that might pose obstacle to the regular movement of low speed vehicles and therefore need to be identified. As mentioned earlier, these barriers include both physical and regulatory barriers.

For the city of Corvallis, the major obstacles to provide complete accessibility to all parts of the city by LSVs are some hilly routes and high-speed roadways with higher traffic volume. Due to very high vertical elevation, some of the routes at the most northwest end of the city are not included in the network. Examples of such routes are NW Boxwood

Dr., NW Glenridge Dr. etc. Therefore, there is a connectivity gap of low speed route to some of the neighborhoods located at the northwest end of the city. However, all the routes that have comparatively higher elevation could not be avoided since those roadways connect to some major residential areas and health centers of the city. Therefore, those hilly routes included in the low speed network, are marked by different color in the low speed network map.

Another example of lack of connectivity with low speed routes in the city is 9th Street, which is a major north-south 5-lane arterial with a center two-way left turn lane and, carries a high volume of traffic that including trucks. Lack of access control, multiple driveways and heavy traffic volume pose safety concerns for LSV on this street. Also, the posted speed limit of this arterial is 35 miles per hour. Therefore, 9th St. is not a safe driving path for LSVs and is not included in the low speed network, although this street provides connectivity to many activity centers of the city. However, to minimize the connectivity gaps to 9th St., all the across collector streets and parallel 10th St., that have lower speed limit and comparatively lower traffic volume, have been included in the low speed network.

Again, the land use and transportation infrastructure pattern of the south part of the city made it quite difficult for the LSV users to access that part of the city. The south part of the city is connected to north part of the city, i.e. OSU and the many other activity centers of the city through SW 3rd St. that is part of State highways, OR 99W and OR 34. These high-speed state highways are the only connection to all the neighborhoods and activity centers in the south part of the city. A local road running through a city park named "Avery Park" provides connectivity between some neighborhood areas of the southeast part of the city from northwest part and OSU. However, the southwest neighborhood areas and some activity centers in the south part of the city are completely isolated from the major part of the city to be accessed by low speed vehicle without driving on the high speed state highways. The city airport is located at the south part of the city. A LSV user cannot go to the airport driving his LSV, unless he chooses this high-speed state highway, which not only is very risky but also unauthorized.

The same condition exists for northeast part of the city. Some major shopping stores, schools and city regional office of Hewlett-Packard are located in the northeast part of the city. This city part cannot be accessed without crossing the high-speed intersection of state highway, OR 99W. Crossing such high-speed roadways intersection might not be very safe for LSVs and therefore; these intersections serve as a barrier for LSVs. Multiuse paths sometimes create barrier in the movement of low speed vehicle. For example, the Campus way running inside the college campus of the Oregon State University, has become a multiuse path starting from 35th St. up to 53rd St. Immediately crossing after the 53rd St Campus Way gives access to Benton County Fairgrounds-center for numerous city activities, such as fairs, community gathering, religious gathering etc. Campus Way is the only connectivity to Fairgrounds from the main part of the city, other than city major arterial 53rd St. that is not permitted for driving LSVs. However, from the 35th St. up to 53rd St corridor of Campus way leading to the Fairgrounds, cannot be used by LSVs either as it is a multiuse path. Also bollards that are placed on Campus way at the intersection of 53rd St. prevent the regular motor vehicle from using this corridor of roadway. Therefore, low speed road network cannot provide any connectivity to this activity center located at northwest part of the city due to presence of multiuse path.

5.2.2 Recommendations for Connectivity Gaps

It is not always possible to eliminate the natural barrier, such as hilly terrain. Alternative routes need to be proposed in such cases, if possible. For the case of man-made barriers, various mitigating steps can be adopted to eliminate or avoid both physical and regulatory barriers, and therefore fill up the connectivity gaps. Some of proposed mitigating strategies are described below.

i) *Modification of local regulatory laws*: The local authority can amend the on-road regulations for a specific roadway of the city in order to provide access to low speed vehicles to certain part of the city. For example, in case of Corvallis city, to mitigate the connectivity gaps with the south part of the city, the speed limit of the southwest corridor of the 3rd St. starting from the SE Crystal Lake Dr. up to the city boundary, can be modified, in addition to provision of adequate traffic control signs. This step might compromise with the efficiency for the sake of increased safety and accessibility of that road. It would entail the identification and signage of existing roadways that provide complementary connections between residential neighborhoods and activity centers.

ii) *Treatment for multiuse path*: When a multiuse path presents a barrier to the movement of low speed vehicle, alternative route of that multiuse path need to be proposed to provide access. However, when alternative route is not available, the operational classification of that multiuse path can be modified to accommodate LSVs, provided the safety aspect of that roadway is not hampered. For instance, in Corvallis city, the corridor of Campus way from 35th St. to 53rd St. is a multiuse path. However, this part of Campus way is basically a farm road and can be used by low speed vehicle. Allowing only low speed vehicles, while not permitting the movement of regular vehicular traffic might not hamper the safety issue of the road. In order to accommodate LSV, the operational classification of this road needs to be changed from 'multiuse path' and the existing bollards need to be removed. Again, to prohibit the movement of regular passenger car on this roads, some regulatory signs could be placed that would state the authorization of LSVs but prohibition of automobile on this road.

iii) *Corridor Management Plan*: A corridor management plan could be undertaken to provide access to the activity centers by low speed vehicles. For example, in order to provide potential solution for the accessibility to 9th St. in Corvallis city by LSVs, a corridor study could be conducted by the corresponding authority. Following that, a set of strategies could be implemented to mitigate the connectivity issues to 9th St. by the low speed network.

To resolve the connectivity issues of low speed road network in the city, the city transportation agencies, municipal authority, stakeholders and the community people need to work together to develop and implement the mitigation strategies.

5.3 Characteristics of the Low Speed Road Network

The low speed road network developed through Google Earth mapping tool has the following characteristics:

a. The network has been developed completely on the basis of existing roadway system of the city. No new construction of the roadway infrastructure has been proposed in this network development.

b. The network has been developed mostly using the local neighborhood and collector roads that has maximum-posted speed limit of 25 miles per hour.

c. The roadways containing heavy traffic volume that also includes heavy vehicles have been avoided in the low speed network.

d. The city range is displayed by city boundary line, while different attraction points and activity centers of the city are marked using different symbols on developed network map.

e. The high speed routes included in the low speed network that have speed limit more than 25 miles per hour but no more than 35 miles per hour, are marked by red lines in the road network map for the ease to identify them.

f. The routes with higher vertical elevation are marked in blue lines so that users might avoid those routes if necessary.

g. Routes that carry heavy vehicles, i.e. city buses in this specific case of Corvallis City are marked in purple line in the map so that users of low speed routes can identify them.

h. The network development process does not interact with the bike lanes present on its route. Therefore, bicyclist can ride on the bike lanes present on the low speed routes the same way they used to ride on these roads before.

i. The low speed network provides connectivity to almost every part of the city and also to numerous activity centers displayed on the map.

j. The low speed network map is a complete guide of the city to the low speed vehicle users and this intends to provide a safe and convenient LSV driving experience.

5.4 Incorporating the "Three E" Program

The introduction of the "Three Es (education, encouragement and enforcement) Program" can greatly support and promote the comprehensive low speed network plan. This program would help to develop public concern about the safety of low speed vehicles and also to promote the benefits of using these vehicles. Successful incorporation of the 3E programs would also encourage the proper maximum but safe use of low speed network of the city. This program would help to identify the connectivity gaps of the low speed network as well as get proper community feedback about their mitigation strategies. The local government agencies, such as City Police Department, Park and Recreation Department, and private agencies, such as city regional offices, local hospitals as well as state transportation department can sponsor this program.

5.4.1 Education

LSV education program would help people to identify the different benefits of using LSVs. This would make the users aware of the safety limitation of a LSV and the risk associated with driving LSVs at high-speed roadways. By using the low speed network high-speed severe crashes can be avoided - this lesson can be conveyed to the user by the LSV education program. As the low speed network will be a new concept to the community, therefore, community members should be made well informed about the advantages of using the network and also become familiar with different routes of the network. This program will also help to develop other motorists' attitude toward low speed vehicles. Again, sometimes some car-like-LSVs have the outfit of regular passenger car, but really do not possess all the safety features of passenger cars. An education program can make user aware of all the safety features of a LSV. Public education program can potentially educate both the LSV users and the motorist about the effective driving principles in low speed roadways; therefore ensures the safety of LSV users and the adjacent neighborhood dwellers. Some examples of LSV education program can be “Go Green”, “Community LSV safety Initiative”, “Public service announcement”, “LSV & Sustainability” etc. Billboards can be erected in the public places to make people informed about the presence of LSVs in the city.

5.4.2 Encouragement

Low speed vehicle is comparatively new mode of alternative transportation than other conventional mode of travel. Therefore, encouragement program is very important to promote this vehicle as an energy efficient green travel mode to the community. Some of the ways to encourage the people for using low speed networks are:

- The purpose of low speed network is to provide a safe and convenient LSV driving experience to the users. Therefore, if the community members are provided with the map of low speed network, that may encourage them to drive their low speed vehicle, either human or non human powered, on the low speed routes. As the low speed network also contains the symbols of different attraction points and their connectivity with low speed route, therefore if a legend sheet needs to be provided with the map, it will encourage people more to use the low speed network.
- Another way to encourage people for using the low speed network is by maintaining a web site that will contain the complete information of low speed route, local LSV program, multiple benefits of using LSV etc.
- Local and regional LSV groups can be formed to encourage the use of LSVs. Usually such groups are very active in the community. This group can also serve as the key advocacy group to maintain an efficient low speed network in the city.

5.4.3 Enforcement

Enforcement of speed regulatory laws and traffic control signs are very important to ensure the safety of LSVs on public roadways. Municipal authority should strictly maintain the speed limit of the low speed roads and adequate enforcement should be applied to ensure that the speed limits are followed. Rules and regulation pertaining to driving of LSVs should be easily accessible [27]. The enforcement of uniform laws and regulation throughout the low speed network would encourage people to use low speed routes. Enforcement can be established in the following ways:

- *Police on LSVs*: The City Police Department can acquire LSVs for monitoring and patrolling purpose in various city places, such as parks, downtowns, college campus etc. This would help promote the LSVs as a transport mode to the community people as well as would assist the law enforcement department to perform their duties. Again, due to the nature of the vehicles, LSVs make it easier for police officers to carry out monitoring activities, respond quickly and safely, and be more visible [19].
- *Charge tickets for violating the laws*: Law enforcement should be strictly maintained so that LSV users as well as automobile users follow the speed limit and other rules of the low speed route. This law enforcement should be more stringent at the early stage of establishing the network, possibly by charging fine for violating the rules at the low speed routes.
- *LSVs crash reporting*: All kind of LSV crashes, even not severe, should be reported. As this vehicle is comparatively new on the road, analysis of the LSV related crashes would help to assess the factors leading to crashes and would also help to identify the LSV high crash locations in the city. In turn, this information would assist the authority to take appropriate mitigating steps and improve the level of low speed travel.

5.5 Implementation of the Developed Low Speed Network

Once the low speed road network is developed, the local authorities should work with the State authority, local LSV operators as well as users of other transportation mode in the city to implement this network. Different short term and long term project can be adopted to implement this network. At the same time, adequate funding sources need to be identified for the proper implementation and maintenance of the network. The funding could be attained through different transportation funding programs at Federal level through SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) act as well as by State level funding programs. Different city departments, such as Park and Recreation departments, city municipality can also sponsor funds to implement as well as maintain this low speed network.

6 Conclusion

In the recent era when energy crisis and greenhouse gas (GHG) emission are the most severe issues the world is experiencing, LSVs can potentially contribute to reduce the scale of severity of these issues. LSVs alone clearly is not the solution of all transportation problems, but this vehicle can play a key role to reduce the automobile dependency and increase livability in the community, especially for the cities with geographically compact activity spaces. However, LSVs have inherent safety risks associated with their use on public roadways due to their less crash protection features. The North American safety standards do not require any features for occupant crash protection other than seat belts for LSVs, because these standards were developed with the underlying premise that these vehicles would be operated on low-speed roadways in protected environments. Again, the outcome of the investigation conducted in LSV project (OTREC RR-10-19) has revealed that the states, provinces and local governments in North America have the legal authority to set regulations pertaining to motor vehicles operating on the roadways under their jurisdictions. In many circumstances, these regulations significantly increase the risk exposure to LSV users. For the protection of all road users, there is a need to make the federal vehicle safety standards and the state and local roadway vehicle regulations consistent. It is recommended that if LSVs are limited to roadways with the maximum posted speed limit set to equal the maximum speed of the LSV – and in most regions this is 25 miles per hour – then the current safety regulations are appropriate, provided the roadway does not have heavy traffic volumes or heavy vehicles. Again, the Medium-speed vehicles (MSEV), which were denied a petition by NHTSA under FVMSS 500.571, but still are being operated on public roadways, should be drawn to meet the additional safety requirements of the federal motor vehicle safety standards for conventional vehicles, including passing crash tests. Otherwise they should be limited to operation on roadways with a posted speed of 25 miles per hour or less (OTREC RR-10-19).

Though LSVs were developed for use in protected environments. Still many people realized the environmental benefit of these vehicles and are operating them on public roadways. The unrestricted use of LSVs on all public roadways does not ensure a safe and convenient operation of LSVs. Considering these issues, this research proposes a comprehensive framework to develop a secondary road network primarily intended for the operation of low speed vehicles, both human and non-human powered, in a small or medium sized city. The Google Earth based analysis of the existing road system integrated with City Transportation Plan helped to analyze city's transportation infrastructure; whereas the public involvement in the process provided valuable insight on users' route preference as well as helped to identify the connectivity gap through low speed network. Therefore the low speed network developed here is completely based on city's existing road infrastructure, and would serve as a complete guide for the LSV users' providing a safe and efficient connectivity to all major activity centers and neighborhood areas of the city, as much as plausible. Also, the low speed routes planned for this network do not interfere with the existing bike lane on the roads. Therefore, this network would also assist the city planner to reach their multimodal transportation system goal for the city. However, to establish the low speed network in the city and resolve the connectivity gaps of this network, municipal authority should work together with the related stakeholders, local LSV operators and users of other transportation modes in the city. The next section proposes summarized recommendations as an outcome of this research.

6.1 Recommendation

LSV is a sustainable mode of transportation that has the benefit of reduced air pollution and lower operating cost over conventional automobile. However, in an automobile-dominated community, the accessibility of these green vehicles must be balanced with safety of all road users. Therefore, some of the recommendations from this research are:

6.1.1 State and Local Authority

- The State and Local government should limit the on-road operation of LSVs to the roadways having maximum-posted limit equal or less than the maximum operating speed of the LSVs and in most cases that is 25 miles per hour.

- The municipal authority should allocate reserve parking spaces for these small-sized vehicles, possibly in all public places. It would encourage the community people to use this non-polluting mode of transportation and thereby, would help to enhance the livability of the community.

- The municipal authority should also establish the battery-recharging facilities in the important locations of city accessible by the low speed network, such as Oregon State University, shopping malls, near downtown area etc.

- The municipal authority should promote various incentives to purchase LSVs in the community. For example, LSV users could be provided access to high-speed automobile for long range travel by car-pool system or relatively inexpensive availability of car rental system in the city.

6.1.2 Low Speed Vehicle and the Route Network

- As LSVs are comparatively new transportation mode to the community compared to other conventional modes, the users should be made aware of the safety features of this vehicle and also be educated about the associated risk of their operation in the mixed traffic stream. Especially for the LSVs with car-like appearance, owners are usually not aware of safety risks of these vehicles. Therefore, proper consumer education program should be held in the community to ensure the safe operation of these vehicles.

- Before implementing the low speed road network in the city, inputs should be collected from all parts of the community as well as from other road users. Motorists', pedestrians', bicyclists', law enforcement officers' and other stakeholders' opinion should be considered on these small, low-speed vehicles sharing the roadway and also on the developed low speed network. Proper modification should be made thereafter to the proposed low speed network to accommodate the expectation and requirements of LSV users as well as other road users as much as possible, without affecting the safety aspects of the network.

- During the establishment of the low speed road network within the city, adequate publicity should be made to make people informed of this network and also about this green transportation mode. Local TV channels, newspapers, public meetings and billboards erected at important locations of the city, can play significant role in this publicity.

- The routes of the low speed network might sometimes increase the travel length of the LSV users, but the low speed route attempts to reduce the inherent risk of LSV occupant in high speed traffic stream containing heavy vehicles. While it is completely users' discretion to choose the route to his destination within this developed network, but it is recommended to drive LSVs in this low speed network as possible for the sake of all road users' safety including LSV driver.

- Low Speed Vehicle, as well as the low speed route network is comparatively new concepts to the community. Therefore a before-after study should be conducted after implementing the low speed network to evaluate the overall impact of LSV and its route network on the community.

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Appendices

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Missouri: (Missouri Revised Statutes 304.029)
http://www.moga.mo.gov/statutes/c300-399/3040000029.htm

Montana: (Montana Code Annotated 2009)
http://data.opi.mt.gov/bills/mca/61/1/61-1-101.htm

NEBRASKA: (Nebraska Revised Statute 60-119.01)
http://nebraskalegislature.gov/laws/statutes.php?statute=60-119.01

LSVsada: (LSVsada Revised Statutes NRS 484B.637, Substituted in revision for NRS 484.527)
http://www.leg.state.nv.us/Division/Legal/LawLibrary/NRS/NRS-484B.html#NRS484BSec637

New Hampshire: (New Hampshire Revised Statutes 259:66-b; 265:158; and 266:114)
http://www.gencourt.state.nh.us/rsa/html/XXI/259/259-66-b.htm
http://www.gencourt.state.nh.us/rsa/html/XXI/265/265-158.htm
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New Jersey: (New Jersey Statutes 39:4-31)
http://lis.njleg.state.nj.us/cgi-bin/om_isapi.dll?clientID=231787&Depth=4&TD=WRAP&headingswithhits=on&infobase=statutes.nfo&rank=&softpage=Doc_Frame_Pg42&wordsaroundhits=2&x=25&y=19&zz=

New Mexico: (New Mexico Statutes 66-1-4.12 and 66-3-1103)
http://www.conwaygreene.com/nmsu/lpext.dll?f=templates&fn=main-h.htm&2.0
http://www.conwaygreene.com/nmsu/lpext.dll?f=templates&fn=main-h.htm&2.0
http://www.zenncarsabq.com/pdf/HB0294%20as%20introduced.pdf

New York: (New York Vehicle and Traffic Law 121-f)
http://law.justia.com/newyork/codes/vehicle-traffic/vat0121-f_121-f.html

North Carolina: (North Carolina General Statutes § 20-125)
http://www.ncga.state.nc.us/sessions/2001/bills/house/pdf/h1052v5.pdf
http://law.onecle.com/north-carolina/20-motor-vehicles/20-121.1.html
http://www.ncga.state.nc.us/Sessions/2009/Bills/House/HTML/H1257v0.html

North Dakota: (North Dakota Century Code 39-29.1 and 57-40.3-01)
http://www.legis.nd.gov/cencode/t39c291.pdf
http://www.legis.nd.gov/cencode/t57c403.pdf

Oklahoma: (Oklahoma Statutes 47-1-134.1, 47-11-805.1, 47-1102, SENATE BILL 1384, JANUARY 9, 2008, HOUSE BILL 2695, JANUARY 17, 2008)
http://law.justia.com/oklahoma/codes/os47.html
http://webserver1.lsb.state.ok.us/2007-08bills/SB/SB1384_ENR.RTF
http://webserver1.lsb.state.ok.us/2007-08bills/HB/HB2695_ENR.RTF

Oregon: (Oregon Revised Statutes 801.331, 801.341, 811.512, 811.513)
https://www.oregonlaws.org/ors/801.331
http://www.lawserver.com/law/state/oregon/or-statutes/oregon_statutes_801-341
https://www.oregonlaws.org/ors/811.512
https://www.oregonlaws.org/ors/811.513

Rhode Island: (Rhode Island Code 31-19.4-1)
http://www.rilin.state.ri.us/statutes/title31/31-19.4/31-19.4-1.HTM

South Carolina: (South Carolina Code of Laws 56-1-10, 56-2-100 to 56-2-130, and 56-5-820)
http://www.scstatehouse.gov/code/t56c001.htm
http://www.scstatehouse.gov/code/t56c002.htm
http://www.scstatehouse.gov/code/t56c005.htm
www.scstatehouse.gov/sess118_2009-2010/bills/419.docx

South Dakota: (South Dakota Legislature 32-3-71, 32-5-152, 32-25-27, 32-6B-12.1, 32-35-125, 32-12-4.8, 32-3-1)

http://legis.state.sd.us/statutes/DisplayStatute.aspx?Statute=32-3-1&Type=Statute
http://legis.state.sd.us/statutes/DisplayStatute.aspx?Statute=32-3-71&Type=Statute
http://legis.state.sd.us/statutes/DisplayStatute.aspx?Statute=32-5-152&Type=Statute
http://legis.state.sd.us/statutes/DisplayStatute.aspx?Statute=32-25-27&Type=Statute
http://legis.state.sd.us/statutes/DisplayStatute.aspx?Statute=32-6B-12.1&Type=Statute
http://legis.state.sd.us/statutes/DisplayStatute.aspx?Statute=32-35-125&Type=Statute
http://legis.state.sd.us/statutes/DisplayStatute.aspx?Statute=32-12-4.8&Type=Statute

Tennessee: (Tennessee Code 55-8-101 and 55-8-191)
http://state.tn.us/sos/acts/105/pub/pc0959.pdf
http://www.tn.gov/revenue/notices/titlereg/08-20.pdf
http://www.tn.gov/revenue/forms/titlereg/f1314301Fill-in.pdf

Texas: (Texas Statutes, Transportation Code 551.301-551.303)
http://www.statutes.legis.state.tx.us/Docs/TN/htm/TN.551.htm#551.301

Utah: (Utah legislature 41-6a-1508)
http://le.utah.gov/~2010/bills/hbillamd/hb0238.htm

Vermont: (Vermont Statutes Title 23, Chapter 1, Section 4, and Chapter 13, Sections 1007a and 1043)
http://www.leg.state.vt.us/statutes/fullsection.cfm?Title=23&Chapter=001&Section=00004
http://www.leg.state.vt.us/statutes/fullsection.cfm?Title=23&Chapter=013&Section=01007a
http://www.leg.state.vt.us/statutes/fullsection.cfm?Title=23&Chapter=013&Section=01043

Virginia: (Virginia Code 46.2-100, 46.2-908.2, and 46.2-908.3)
http://www.vsp.state.va.us/downloads/Golf_Carts_and_Utility_Vehicles_2008.pdf
http://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+46.2-908.2
http://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+46.2-908.3

Washington: (Revised Code of Washington 46.04.295, 46.04.357 and 46.61.723-46.61.725)
http://apps.leg.wa.gov/RCW/default.aspx?cite=46.04.357
http://apps.leg.wa.gov/documents/billdocs/2009-10/Pdf/Bill%20Reports/Senate/6207%20SBR%20TRAN%2010.pdf
http://apps.leg.wa.gov/rcw/default.aspx?cite=46.04.295
http://apps.leg.wa.gov/rcw/default.aspx?cite=46.61.723
http://apps.leg.wa.gov/rcw/default.aspx?cite=46.61.725

West Virginia: (Reference West Virginia Code 17A-3-1, 17A-3-2)
http://www.legis.state.wv.us/WVCODE/17a/code/WVC%2017%20A-%20%201%20%20-%20%20%201%20%20.htm
http://www.legis.state.wv.us/WVCODE/17a/code/WVC%2017%20A-%20%203%20%20-%20%20%202%20%20.htm

Wisconsin: (Wisconsin Statutes 349.26)
http://www.legis.state.wi.us/2009/data/SB321-ASA1.pdf

Wyoming: (Wyoming Statutes 31-5-1701, 31-1-101)
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B Survey Questionnaire

SURVEY FOR LOW SPEED VEHICLE USER
April, 2011

The aim of the survey is to collect data on the route preferences for driving low speed vehicle (LSV). It is recommended that your answers be based on your personal experience of driving LSV on public roadways. The survey results will help to identify the factors related to driving LSV and will assist in developing a secondary roadway network for LSV.
A Legend Sheet has been included to describe the different roadway types in the attached roadway network. This will help to distinguish among different roadway types.
Please write your answer in the space provided with the question. For multiple options question, please select the number corresponding to your particular choice.
Your participation in this survey is completely voluntary. Your responses will be strictly confidential and data from this survey will be reported only in the aggregate. Your information will be coded and will remain confidential.
Thank you for your participation.

Questionnaire:
A Two-way trip indicates round trip (i.e. home-work-home), unless otherwise stated.

1. How many years have you been regularly using LSV on public roadways?
   ____

2. During the past year, what was your USUAL (> 50%) commute mode?
   ____
   1. Transit
   2. Van/carpool
   3. Car
   4. Motorbike
   5. Bike
   6. Walk
   7. LSV
   8. Other, Please specify:
      ____

3. What is your ONE- WAY commute distance and time for your USUAL mode?
   a. Miles _______ b. Minutes _______

4. What is your ONE- WAY commute distance and time for your LSV mode?
   a. Miles _______ b. Minutes _______

5. Which mode did you use before you started using your LSV?

____

1. Transit
2. Van/carpool
3. Car
4. Motorbike
5. Bike
6. Walk
7. LSV
8. Other, Please specify: ______________________________________

6. If 100% of your commute trips are NOT by LSV, what is the primary reason for not using LSV on these occasions? (you can choose more than one option) ____________________
   1. Longer distance to destination
   2. Risks on the roadway
   3. Personal safety
   4. Network discontinuity
   5. Family reasons (i.e. drop off/ pick up children)
   6. Weather
   7. Other, Please specify: ______________________________________

7. What percentage of your LSV trip is made on:
   a. Major Arterials/Highway with posted speed limit higher than 45 mph? _______
   b. Major Collectors/Arterials with posted speed limit between 35 and 45 mph? _______
   c. Collector with posted speed limit between 25 and 35 mph? _______
   d. Local Street/Neighborhood Collector with posted speed limit equal or less than 25 mph? _______

8. On a scale of 1 to 6, please rate your degree of comfort in terms of safety, while driving LSV in the following class of roadways, where lower score (1) represents more comfort and (6) very uncomfortable conditions, and (3.5) neutral opinion.
   a. Major Arterials/Highway with posted speed limit higher than 45 mph? _______
   b. Major Collectors/Arterials with posted speed limit between 35 and 45 mph? _______
   c. Collector with posted speed limit between 25 and 35 mph? _______
   d. Local Street/Neighborhood Collector with posted speed limit equal or less than 25 mph? _______

9. Do any of the following factors play a part in your decision to operate the LSV? (No=0, Yes=1)
   a. Gas price/tax _______
   b. Parking _______
   c. Distance _______
   d. Weather _______
   e. Environmental Concern _______

f. Health

____

g. Other , Please specify: ____

10. Would any of the following factors impact your route choice for LSV? (No=0, Yes=1)
    a. Change in vertical elevation/ hilliness

    ____

    b. Presence of buses or trucks in the route

    ____

    c. Amount of vehicle traffic

    ____

    d. Number of stop signs or traffic lights

    ____

    e. Number of lanes (> 2)

    ____

    f. Bike lane

    ____

    g. Multiuse path

    ____

    h. Other, Please specify: ____

11. Please rank the pavement condition in descending order (in terms of 1, 2, and 3) that you would like to prefer for driving LSV?
    a. Rough pavement, but shorter route

    ____

    b. Smooth pavement, but longer route

    ____

    c. Coarse gravel surface, but shorter route

    ____

12. How many injury or property damage accidents (in excess of $100) did you have in the last 12 months while driving LSV, if no accidents skip to question 15?

    ____

13. How many of those accidents involved:
    a. A motor vehicle

    ____

    b. Bicycle

    ____

    c. Pedestrian

    ____

    d. Animals

    ____

    e. Another LSV

    ____

    f. Run off the road

    ____

    g. Other, Please specify:

    ____

14. How many of those accidents occurred on a:

a. Highway

____

b. Major Collectors/Arterials

____

c. Collectors

____

d. Local Street/Neighborhood Collector

____

e. Bike lane

____

f. Multiuse path

____

g. Another facility type, Please specify:

____

Based on the attached image of the intersection (Figure 1):

15. From your experience of driving LSV, how do you feel crossing the 45 mph roadway (red marked line), when you are driving in the direction green arrow? ________
    1. Very safe
    2. Somewhat safe
    3. Neither safe or unsafe
    4. Somewhat unsafe
    5. Very unsafe

16. Would crossing an intersection of 45 mph or higher speed roadway prevent you from going to the shopping complex by your LSV due to the higher speed roadway intersection? ________
    1. No
    2. Yes

Based on the attached image of alternative route between Timberhill Shopping Center to Kmart (Figure 2):

(Please see the attached figure 2, to learn about the attributes of two different routes)

17. Which route would you like to prefer to drive to go from the Timberhill Shopping Centre to Kmart (Place Marked)? ________
    1. Route 1: marked by blue line (go to question 18)
    2. Route 2: marked by orange line (go to question 19)

18. If the previous answer is ‘1’ (choosing Route 1), then what is the primary reason for not choosing Route 2 to drive the LSV? (you can choose one or more options) ________
    1. Longer miles to drive
    2. Unknown neighborhood
    3. Risks on roadway
    4. Other, Please specify: ______________________________________

19. If the previous answer is ‘2’ (choosing Route 2), then what is the primary reason for choosing this route to drive the LSV? (you can choose one or more options) ________
    1. Residential Street
    2. Feel safer due to lower traffic volume
    3. Less number of signals
    4. Other, Please specify: ______________________________________

Based on the attached image of complete Low speed road network (Figure 3):

20. What do you think about the attached low speed networks? ________

1. Not convenient
2. Neither convenient or inconvenient
3. Convenient but discontinuous (Please specify the location of discontinuity)
   ____
4. Convenient and continuous

21. How much 'Continuity" of the network influences your route choice? ________
    1. Does not matter at all
    2. Not very much
    3. Moderate
    4. Very much
22. Your occupation? ________
    1. Student
    2. Clerical
    3. Professional
    4. Administrative
    5. Academic/teacher
    6. Retired
    7. General/ skilled labor
    8. Sales
    9. Other, Please specify: ____________________________________

23. Age range? ________
    1. Under 25
    2. 26-50
    3. 51-75
    4. Over 76

24. Gender? ________

    1. Male   2. Female

Comments: ____
____
____

Thank you!!
Please Complete and return the survey to:

Mafruhatul Jannat
Department of Civil Engineering
220 Owen Hall, Oregon State University
Corvallis, OR 97331-3212
E-mail: jannatm@onid.orst.edu

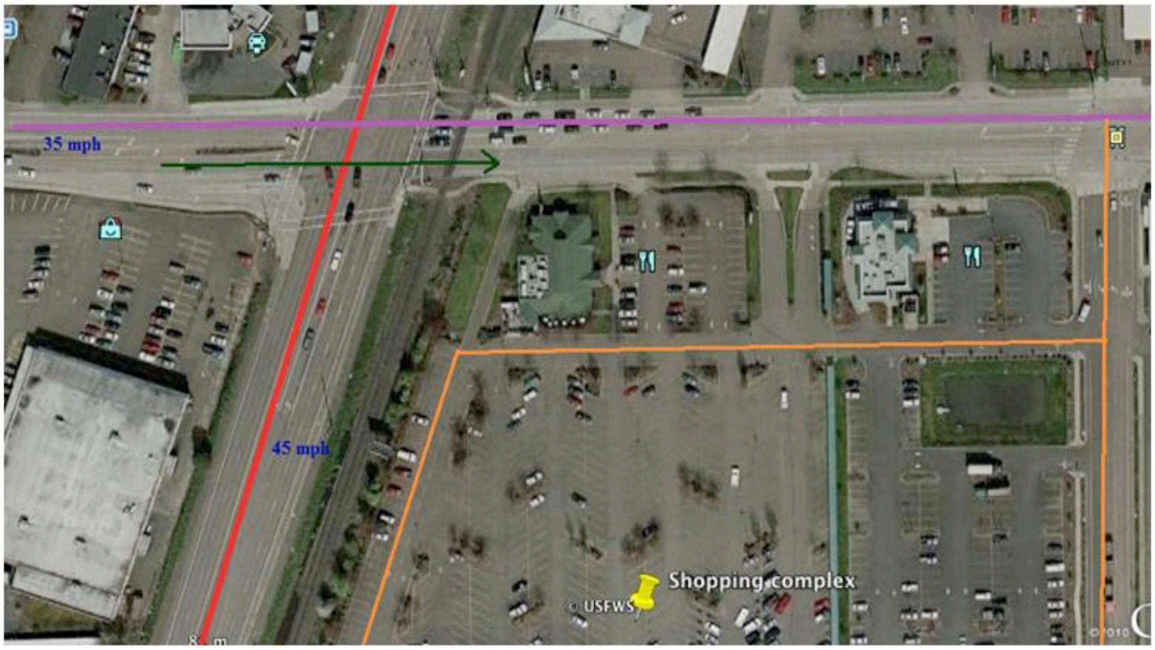

Figure 1: Intersection of 35 mph and 45 mph roadways

The above image shows an intersection in the City of Corvallis, OR. The intersecting roadways are 35 mph major collector and 45 mph major arterials (HWY 99) running through the city.
The following colored lines represent different types of roadways.

Legends:

The red line	( )	Major Arterials/Highway with speed limit 45 mph
The purple line	( )	Major Collectors/Arterials with speed limit 35 mph
The orange line	( )	Neighborhood Collector with speed limit 25 mph
The green arrow	( )	Direction of LSV travel

Figure 2: Figure of alternate routes between Timberhill Shopping Center and Kmart

Different attributes of Route 1 and Route 2:

Route 1 (marked by blue and red links)
- Arterial Street
- 4 lanes
- Speed Limit 35 mph
- Higher number of traffic signal
- Less miles to drive

Route 2 (marked by orange and red links)
- Neighborhood Street
- 2 lanes
- Speed Limit 25 mph
- Less number of traffic signal, more STOP signs
- More miles to drive

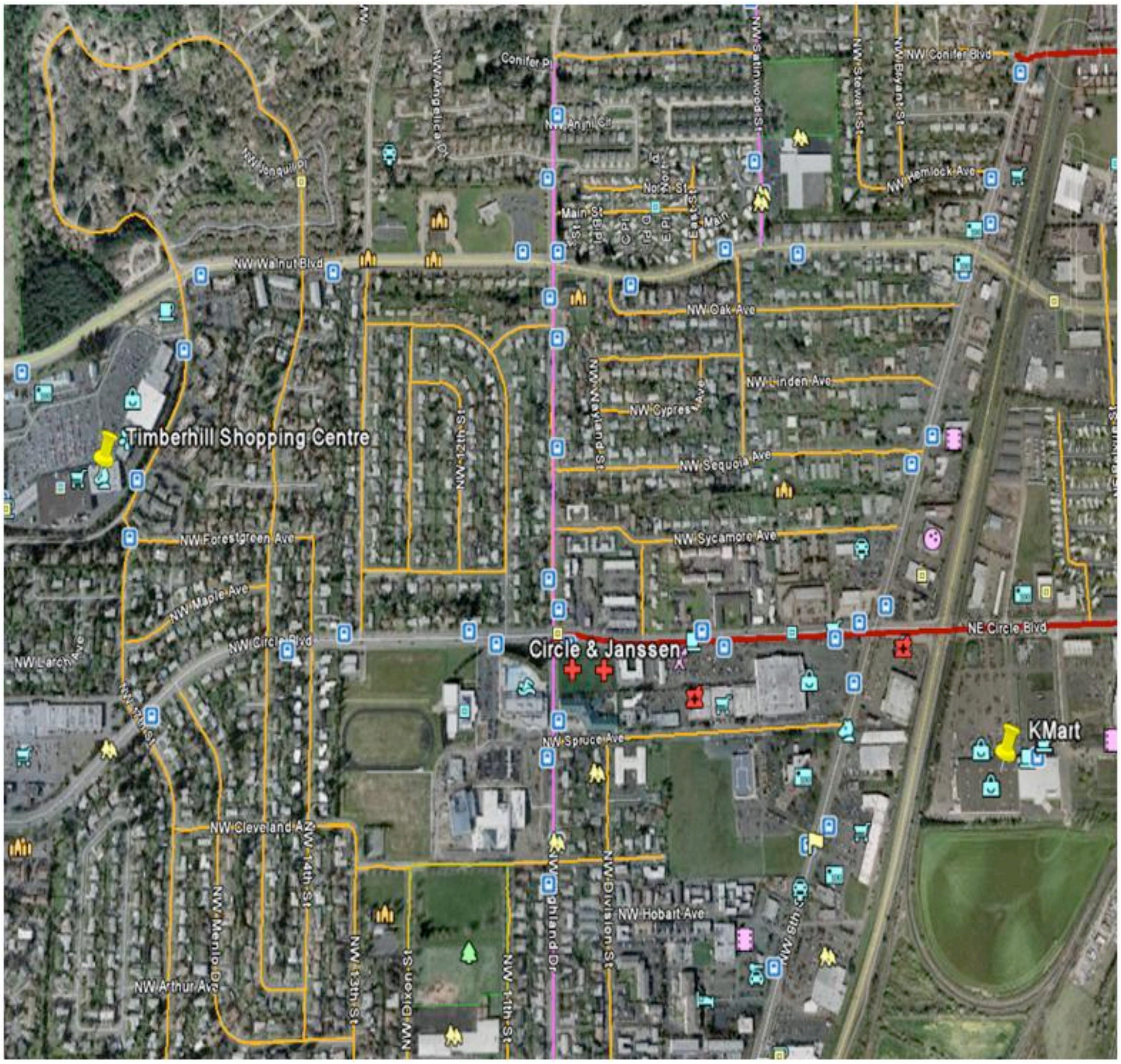

Figure 3: The Proposed LSV network

In the figure, the low speed vehicle network is marked by orange, purple and red lines. The orange line indicates neighborhood streets where speed limit is 25 mph. The purple line also represents neighborhood streets of 25 mph, but shared by buses. The red line represents arterials of 35 mph speed limit and crossing an intersection with major highway of 45 mph speed limit.