

Entry

Two-Lane Highways: Indispensable Rural Mobility

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Definition: Two-lane highways refer to roadways consisting of two lanes in the cross section, one for each direction of travel. Occasionally, passing lanes may be added to one or two sides of the roadway extending the cross section to three or four lanes at those locations. In this entry, two-lane highways strictly refer to roads in rural areas meeting the previous definition and do not include urban and suburban streets.

Keywords: two-lane highways; rural; passing; platooning; access; mobility; low-volume roads

1. Introduction

Two-lane highways constitute the vast majority of roadways by length, particularly in rural areas. This is true here in the USA and in most other countries around the world. It is these highways that first brought motor vehicles to remote towns and villages over the past century and played a critical role in the growth and economies of rural communities. The dominance of two-lane highways in the current roadway networks in developed countries is driven by economics and the low level of vehicular traffic common in rural areas.

Two-lane highways serve various highway functions, from local roads serving very low volumes of local traffic to principal arteries connecting towns and small cities, and everything in between. Consequently, these highways vary in their standards, from unpaved highways in very remote areas to high-type pavement and wider cross sections for intercity routes and major arteries.

Two-lane highways, as we know them today, were mainly introduced with the introduction of the automobile. With the increase in motor vehicle traffic and the use of larger vehicles including buses and trucks, the majority of two-lane highways outside remote and frontier rural areas were paved to sustain traffic loads.

2. The Role of Two-Lane Highways in Today's Transportation System

Two-lane highways have played a critical role in the development of modern societies around the world, both in developed and developing countries. They provide essential access to rural areas with far-reaching social, economic, and lifestyle impacts.

Rural residents outside cities and urban areas need to be able to have access to nearby cities and major economic centers to satisfy their needs for food, goods, and other commodities. Further, rural residents also need access to hospitals, educational institutions, and other services that are not usually available in remote rural areas. Two-lane highways have always been used to provide this important access and the much-needed mobility to rural populations. Therefore, they take much of the credit for the continuous growth and development in rural communities and for making rural areas more livable places.

Two-lane highways also play an indispensable role in the growth of local economies in rural areas. Agriculture is an important sector of the economy in most countries and almost all agricultural activities take place in rural areas. Farmers, ranchers, and cattlemen, among others, need to be able to move their products from field to market, and much of that mobility takes place on two-lane highways. Similarly, farming-related industries, such



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as food processing and packaging plants, dairy products plants, etc., are all located outside cities and major urban communities, and both access and mobility are vital to the industry.

Further, two-lane highways provide critical access and mobility needed by the tourism industry. Touristic attractions and recreational activities usually exist outside cities and urban centers and many are located in remote rural areas, yet they receive a large number of visitors throughout the year or during peak seasons. Examples of those attractions are ski resorts, parks, fishing, and camping at rivers and lakes, etc. Here in the USA, national and state parks and forests receive millions of visitors every year who access these locations using two-lane highways. Additionally, two-lane highways are the only type of roads used to provide mobility within national parks and forests that extend over extensive geographic areas.

Aside from the critical roles described above, two-lane highways have also been used as major routes connecting small cities and towns. These routes usually serve as rural arteries providing essential mobility to motor vehicle traffic between small towns and urban centers.

Two-Lane Highways: Main Users

In practice, two-lane roads have primarily been designed for motor vehicle traffic, which includes passenger cars, buses, and trucks. The needs of non-motorized modes of traffic such as bicyclists and pedestrians are usually not addressed in the design of these roads. However, two-lane roads have increasingly been used by bicyclists (and occasionally by pedestrians) in touristic and recreational areas in many countries around the world. This has serious implications for roadway safety and operations. Bicyclists in rural areas tend to use shoulders, when present, and the edge of the travel lane in areas where no shoulder exists. This places bicyclists close to vehicular traffic and raises concerns about bicyclists' safety [1]. Rubie et al. [2] conducted a review of factors influencing the lateral passing distance when motor vehicles overtake bicycles. A recent study by Moll et al. [3] investigated the effect of sport cyclists on narrow two-lane rural roads in Spain and found that the presence of cyclists decreased the motorized vehicle average speed and increased followers and delays. Many other studies in the literature examined the behavior of bicyclists and drivers as they share the use of rural two-lane roads and the impacts on safety and operations [1,4–7].

3. Two-Lane Highways: Operational Characteristics

The characteristic that separates two-lane highways from other highway types is that passing occurs in the opposing lane of traffic. Specifically, passing maneuvers are restricted on these highways and are typically performed using the opposing lane when sight distance and gaps in the opposing traffic stream permit [8]. This has serious implications for traffic operation and safety. From a traffic operation perspective, the limited passing opportunities results in a higher impact of slow-moving vehicles (mainly trucks, buses, and agricultural equipment) on mobility and performance. This impact generally increases with the increase in traffic level in the two directions of travel and the proportion of slow-moving vehicles in the traffic stream.

Two-lane highways are known for a higher level of interaction between vehicles moving in the same as well as in opposing directions. This is because traffic level in one direction is a major determinant of passing opportunities and, thus, operational performance for the opposing traffic stream. Lack of passing opportunities typically results in the formation of platoons with trailing vehicles subject to additional delay. Consequently, platooning or “bunching” is an important phenomenon that is specific to two-lane highways and has serious implications for operations and safety. In the United States, the operational performance on two-lane highways, which is directly related to the platooning phenomenon, is currently estimated using two surrogate measures; the percent-time-spent-following (PTSF) and average travel speed [9]. The PTSF is defined as “the average percent of total travel time that vehicles must travel in platoons behind slower vehicles due to inability

to pass on a two-lane highway” [9]. Platooning is also important on two-lane highways from a safety perspective. Drivers who are constrained by slow-moving vehicles and lack of passing opportunities may become frustrated and, therefore, tend to accept smaller gaps in the opposing traffic to perform risky passing maneuvers [10]. These risky passing maneuvers and driver distraction represent two main reasons for head-on collisions on two-lane highways. The use of passing lanes is known to alleviate this unique operational characteristic on two-lane highways with higher traffic levels. Passing lanes allow vehicles traveling at faster speeds to overtake slower-moving vehicles, thus breaking up platoons and reducing delays due to inadequate passing opportunities.

4. Two-Lane Highways: Unique Challenges

Despite the critical role two-lane highways play in providing access and mobility to rural areas, these highways pose unique challenges for highway agencies in charge of operating and maintaining the roadway network. These challenges are generally related to the following three aspects: safety, mobility, and infrastructure.

4.1. Safety Management on Two-Lane Highways

A large proportion of two-lane highways are characterized by low traffic exposure and are usually referred to as low-volume roads. These roads often provide access to remote rural areas, have lower functional class, and are built to lower standards (e.g., narrow lanes and shoulders, non-forgiving roadsides, etc.). Unlike two-lane highways along major routes, low-volume roads pose challenges for highway agencies in relation to safety management on the highway network.

In most developed countries, safety is managed on the highway system using ongoing highway safety improvement programs. These programs are funded by governments and aim to reduce the number and severity of crashes on the highway network using data-driven strategic approaches. Highway agencies have been increasingly facing tighter budgets, including funds dedicated to their ongoing safety improvement programs. One of the important steps in these programs is network screening, which is the process of analyzing the network to identify candidate safety improvement sites for further analysis and investigation. As it is not possible to conduct a detailed investigation across the entire network, network screening helps to pare down the list of sites [11]. Sites identified through network screening become candidates for safety improvement projects. Conventional screening methods using historical crash data (crash frequency, severity, and/or rates) at individual sites are the most widely used methods. While this conventional approach may work well for roads with high traffic exposure, it may not prove effective nor reasonable for low-volume two-lane highways. On one hand, low volume on these roads often results in a few sporadic crashes, and as such sites along these roads are unlikely to rank high on the list should crash frequency be used as the sole ranking criterion. On the other hand, low volumes are expected to result in higher crash rates even with only a few crashes taking place on these roads. Therefore, when using crash rates, those sites may rank high on the list, even though the few crashes occurring along these roads may be related to factors other than roadway characteristics (e.g., driver distraction, drinking and driving, etc.) [12].

Moreover, two-lane low-volume roads often have geometric and roadside features that are built to lower standards which constitute an added risk to road users, yet above-normal crash frequencies may not be observed at those locations due to low traffic volumes and the random nature of the crash occurrence. It is also important to remember that many crashes on remote low-volume roads, particularly those with lower severities, may go unreported. All these factors on low-volume roads make it very difficult to rely solely on crash history in determining sites that are good candidates for safety improvement projects. Unlike freeways, expressways, other major thoroughfares, and urban streets, two-lane highways are usually owned and operated by different levels of governments (e.g., state and local governments such as counties, townships, etc.), which adds to the complexity of safety management on these roads.

Given the challenges described above for managing safety on two-lane highways in general, and low-volume roads in particular, the following strategies are recommended to address these challenges [13]:

- Adopting a systemic approach to safety: A systemic approach to safety involves improvements that are widely implemented based on high-risk roadway features correlated with particular severe crash types [14]. This approach considers multiple locations with similar risk characteristics, selecting the preferred countermeasure(s) appropriate and affordable for widespread implementation; it is best suited for low-cost safety countermeasures. While applying the systemic approach has merits regardless of traffic exposure, it is particularly important for low-volume rural two-lane highways where crash history alone may not be adequate to identify sites for safety improvements. It is important to note that the systemic approach does not replace the conventional hot-spot analysis approach. It is a complementary technique intended to supplement site analysis and provide a more comprehensive and proactive approach to safety management efforts [14].
- Applying network screening methods sensitive to risk factors: Low traffic exposure often makes it difficult to isolate high-crash locations for safety improvements. Therefore, any network screening method that relies solely on crash history may fail to perform satisfactorily on low-volume roads. As such, it becomes imperative for network screening on low-volume roads to incorporate risk factors in identifying candidate sites for safety improvements, i.e., factors that contribute to an increased level of risk or hazard throughout the network. This approach is rational given the fact that most low-volume rural roads are built to lower standards compared with other major roads (e.g., narrow lanes, no/narrow shoulders, fixed objects at roadsides, etc.). These methods mostly utilize risk factors in conjunction with crash and traffic data.

4.2. Maintaining Acceptable Operational Performance

The unique operational characteristic of two-lane highways is that passing maneuvers occur in the opposing lane of traffic. These maneuvers can only be performed if there is adequate sight distance (thus, passing is legally allowed) and large enough gaps in the opposing traffic stream. If sight distance is restricted due to terrain or geometric alignment or if the traffic level in the opposing direction is high, then passing opportunities would become limited. This explains the high level of interaction between traffic streams in the two directions of travel, which is unique to two-lane highways. If passing opportunities are limited due to the aforementioned reasons, platoons form when faster vehicles catch up with slow-moving vehicles resulting in lower travel speeds and inferior quality of service (in practice six levels of service from A to F are used to describe the quality of service in operational analyses).

To maintain acceptable operations (i.e., an acceptable level of service) on two-lane highways, highway agencies apply certain treatments to improve passing opportunities on two-lane highways such as adding turnouts, passing lanes, or shoulder use sections at regular intervals [15]. The most popular treatment among these is the use of passing lanes where a lane is added to one or both directions of travel at regular intervals to improve traffic operations and level of service by breaking up platoons and allowing faster vehicles to overtake slower-moving vehicles. A passing lane layout in one direction of travel is shown in Figure 1.

Turnouts are also used to increase passing opportunities at locations where adding a passing lane may not be a viable option. Examples of these situations are two-lane highways in difficult terrain or in situations where adding passing lanes may not be a cost-effective solution. The use of shoulder sections is not as common in practice as the previous two treatments, because wide shoulders do not exist on many two-lane highways. When used, the shoulder-use section functions as an extended turnout. This approach enables a highway agency to promote shoulder use only where the shoulder is adequate to

handle anticipated traffic loads and the need for more frequent passing opportunities has been established by the large amount of vehicle platooning [15].

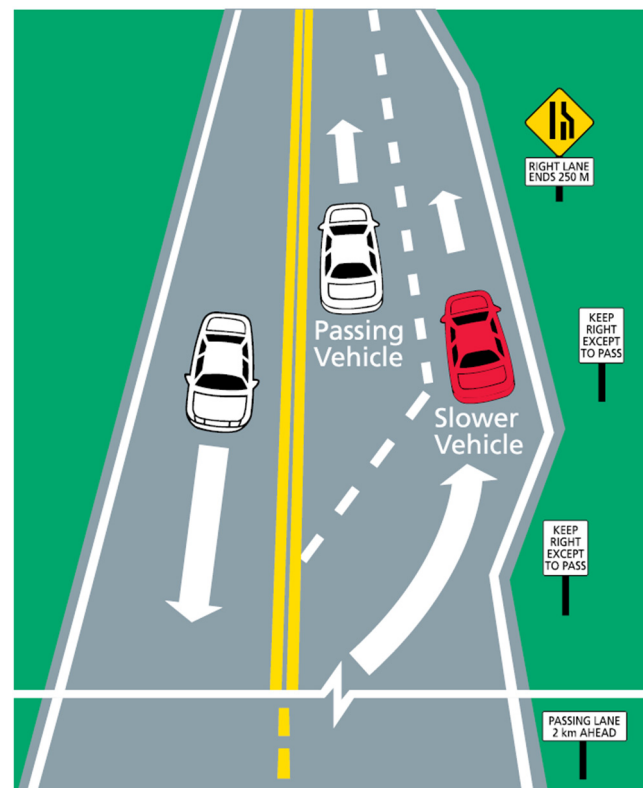


Figure 1. A drawing showing a passing lane layout [16].

4.3. Infrastructure Preservation and Maintenance

Though critical to rural access and mobility, a large proportion of rural two-lane highways only carries a small amount of traffic. The low traffic level causes these roads to receive little attention and funding for maintaining a good state of repair. While the discussion in this section applies to two-lane highways, in general, it is particularly concerned with low-volume two-lane highways in rural areas.

A recent report titled “Investment Prioritization Methods for Low-Volume Roads” by the U.S. National Academy of Sciences states that “low-volume roads are at a disadvantage relative to other roads within traditional investment prioritization processes that focus on volume-based metrics of benefit and impact” [17]. In general, the fewer the road users, the less funding is available for road maintenance and restoration, much less engineering. Consequently, low-volume two-lane highways around the world typically need reconstruction and improvement. The highest-volume highest-rate-of-return proposals receive priority for limited research funding [18]. This is consistent with other studies that confirm how difficult it is to advocate for investments in roads with very low volume on a traditional economic basis, because of the relatively small user or impact group for any given low-volume road [19]. Nevertheless, agencies see value in maintaining existing low-volume two-lane roads because of their role in providing access to rural or isolated areas and supporting economic activity (e.g., farming, logging, mining, or other industry), as well as for their network coverage role within the broader transportation system. These roads also play a role in providing access to other remotely located facilities or destinations, such as international border crossings, military facilities, and national and state parks. Further, they provide public access to essential health, education, civic, and outdoor recreational facilities. The link these roads provide between raw materials and markets is critical to economies locally and nationally in all countries around the world.

The World Bank argued that the evaluation of low-volume two-lane highway improvements must be different from that of other roadway projects because their goal is to both reduce travel costs and to support economic development and social objectives [20]. Asset management and investment prioritization processes should go beyond the traditional process, which aims to minimize lifecycle agency and user costs and consider additional factors such as the vital accessibility to remote areas and the social and economic role these highways play in addition to the mobility function. This and other related discussions in the literature all point to a common agreement that low-volume two-lane roads can be important in ways that go beyond the level of traffic they carry, and that their significance merits special consideration within the planning and resource allocation process.

5. Concluding Remarks

Two-lane highways claim the largest proportion of the highway network by length in most countries and help to extend the transportation system coverage over extensive geographic areas. These highways have unique operational characteristics as there is only a single lane for the traffic stream in each direction of travel. Passing on these highways occurs in the opposing traffic lane and is only possible when traffic conditions and sight distance permit. Therefore, platooning is a common phenomenon on two-lane highways and is a major determinant of operational performance.

Two-lane highways play a critical role in providing accessibility and mobility to rural areas and are considered indispensable for rural populations and industries given the social and economic role these highways play in all countries around the world. This role is at the core of the United Nations sustainable development goals with strategies that improve health and education, reduce inequality, and spur economic growth [21]. As such, there is a common agreement that two-lane roads can be important in ways that go beyond the level of traffic they carry. Nonetheless, two-lane highways are also unique in the challenges they pose to highway agencies owning and operating them. Three challenges were discussed, namely, safety management, maintaining acceptable operational performance, and infrastructure preservation and maintenance. An overview of these challenges and the strategies used in practice to address them were briefly presented in this entry.

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