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A Study On the Effectiveness of Rolling Barrier System at Straight Road and Curved Road: A Review

Ekarizan Shaffie[1,2*], Nursafa Maisara Mohd Zin[3], Fionna Shiong[1], Ahmad Kamil Arshad[1,2], Juraidah Ahmad[1]

[1]School of Civil Engineering, College of Engineering,
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, MALAYSIA

[2]Institute for Infrastructure Engineering and Sustainability Management,
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, MALAYSIA

[3]WCT Holdings Berhad,
B-30-01, The Ascent, Paradigm, No. 1, Jalan SS7/26A, Kelana Jaya, 47301 Petaling Jaya, Selangor, MALAYSIA

*Corresponding Author

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Abstract: The rolling barrier system is part of the road safety infrastructure that is used to improve and maintain road safety. It is also possible to overcome and reduce the number of crashes. A rolling barrier is a type of safety device that not only absorbs but also converts shock energy into rotational energy, thereby preventing fatal accidents for drivers and passengers. A rolling barrier should be installed in areas where vehicles are frequently collided. By absorbing shock energy, a rolling barrier will safely guide a vehicle back to the road or stopped the vehicle. This study was built on the findings of a previous study to determine the effectiveness of a rolling barrier system for use on both straight and curved roads. This research focuses on a new invention, the rolling barrier system, as opposed to the traditional barrier, in order to learn more about its mechanism and function. The study's scope was limited to focusing on the implementation of the rolling barrier system on straight and curved roads. According to the previous study, straight and curved roads have the highest incident rates compared to other types of roads. The Rolling Barrier System was strategically installed in three high-risk areas with a high incidence of fatal traffic incidents. The three high-risk road locations that require additional safety are straight roads, curving roads, and hilly roads, which are the most important locations to place Rolling Barrier Systems in order to decrease high-risk accidents and fatalities while also improving road safety. There are four types of roads that are appropriate for implementing a Rolling Barrier System. The Rolling Barrier types are straight roadside Rolling Barriers, curved roadside Rolling Barriers, steep roadside Rolling Barriers, and median Rolling Barriers.

Keywords: Rolling barrier system, road barrier, fatalities accidents, straight road, curved road, road alignment

1. Introduction

Road safety has become a major concern in today's society. According to the World Health Organization (WHO) in year 2020, road accidents is the world's third leading cause of death [1]. A road accident is generally defined as an unanticipated event caused by a lack of driving control until an object collides or causes a car collision, resulting in collateral harm, driver, passenger, and other road user injuries, or both [2]. An estimate since 2000 revealed that, the road accidents in Malaysia alone is responsible for the increase of the death rate by approximately 14% [3]. According

*Corresponding author: eka@uitm.edu.my

to the Malaysian Ministry of Transport [4] report, the total number of road accidents over the past decade have increased by approximately 41%, amounted to 369,319 and 521,466 mishaps in the year of 2007 and 2016, respectively. Consequently, the total number deaths were augmented from 6,282 to 7,152. Road accidents or collisions can occur due to a variety of factors such as road conditions, driver factors, or vehicle conditions. The number of accidents is increasing every day, and the majority of accidents or collisions occur on curving roads due to its particular road conditions [5].

A roadside accident happens when a vehicle leaves the lane of traffic, over an edge line or a center line, collides with branches, guardrails, power poles, and other natural or man-made objects on the roadside, or overturns or crashes into deep ditches or rivers [6]. As indicated in the construction sector transformation strategy, the government is always looking at the newest technologies that can assure the safety of road users. Korean manufacturer developed a novel longitudinal barrier design that included continuous pipes coated with urethane rings. They include both rigid and semi-rigid barrier stiffness characteristics. Rolling barrier systems differ from other types of conventional barriers. The rolling barriers are an obstruction that consumes energy from collisions and converts that energy into rotational energy, directing vehicles ahead rather than crashing through an immovable barrier [7]. The danger of traffic accidents and hazards is also decreased. Urethane has become the material of choice in so many of today's performance-driven technologies. Urethane has become the material of choice in so many of today's performance-driven technologies. This is due to urethane's superior physical and mechanical properties when compared to other materials This is due to urethane's superior physical and mechanical properties when compared to other materials [8].

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2. Working Mechanism of the Rolling Barrier

The rigidity of both flexible and semi-rigid barrier characteristics is combined in the Rolling Barrier. In terms of routes, the Rolling Barrier varies from other forms of conventional barriers. It also reduces the possibility of injuries and risks on the lane. Urethane has been the product of choice in far too many performance-driven applications because it offers exceptional physical and mechanical characteristics that other components just do not have. The flow chart of the Rolling Barrier's operating mechanism is shown in Fig. 1 below. The rolling barrier has the following characteristics; (a) made of copolymer of ethylene and vinyl acetate (EVA); (b) easily installed and maintained on curving roads; (c) has a reduced frequency of repair when compared to typical barriers; (d) three times more corrosion resistant property; (e) separated barrels are supplied; (f) led guide lamp (solar energy) is provided; (g) reduces vehicle speed (during collision); (h) powder coating in a variety of colors is available upon request; (i) minimal vehicle damage with rollers and dual guardrails; (j) highly elastic resin roller is hardly damaged on impact; (k) consists of a steel tube with plastic cylinders that spin on impact; (l) drivers will notice the color and self-luminescence since it is prominent.

The Ethylene-Vinyl Acetate (EVA) spinning barrel with excellent shock absorption capability, as well as buffering frames and thick props to support the frames, are included in the Traffic Innovation (ETI) product. Rotating barrels have a political aided (mirror-like) sheeting for improved sight. EVA is more flexible and elastic than other polyethylene resins, and it has a lot of rubber-like characteristics [9]. When a car collides with a guardrail, the barrels quickly transform the shock energy into rotational energy. Upper and lower frames alter the tires of bigger and smaller cars, respectively, to prevent the steering system from becoming inoperable. The front rails absorb the second and third shocks, while the metal pipe inserted into the post reinforces it [9].

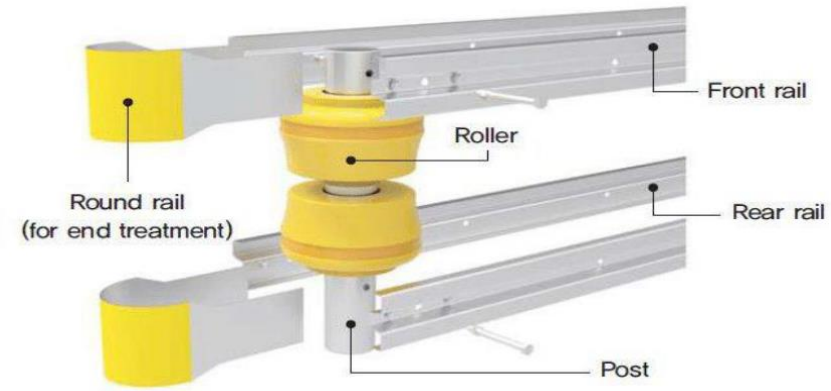

Fig. 1 - Rolling barrier parts arrangement [10]

The rolling barriers absorb the impact energy, but they also perform other functions. Instead of possibly breaking through an unbreakable barrier, they transform impact energy into rotational momentum to push the automobile ahead. The ETI product has a spinning EVA barrel with exceptional shock absorption, 3D buffering frames, and robust props to support the frames. Reflective sheeting is used to improve visibility on revolving barrels. EVA is more flexible and pliable than other polyethylene resins, and its properties are most comparable to those of rubber. It is more malleable than urethane and lighter than rubber. In shorts, it's tough to destroy. When a car collides with a guardrail, the impact energy is converted into rotational energy by the rotating barrel. Upper and lower frames modify the tires of big and small cars to protect the steering system from failure. Railway rails and liquid props absorb impact energy from collisions, but autos and frames with a smooth surface adjust tires and turn vehicles in the driving direction to avoid more rear-end collisions. The second shock is distributed and absorbed by the 3D structure of the D – shaped frame and buffering bracket [11].

3. Type of Rolling Barrier

Guardrails and longitudinal barriers are other names for rolling obstacles. When automobiles collide with dangerous barriers and highways such as rocks, traffic signposts, bridge supports, trees, and construction walls, the Rolling Barrier keeps them on track. Rolling Barriers are categorized into two types based on their function and the degree to which they may deflect a vehicle when it collides with them [7]. The role of the traffic barrier is to reduce the severity of run-off-road collisions by smoothly redirecting the run-of-vehicles at a low exit angle and lowering the danger of colliding with other vehicles. A traffic barrier also protects automobiles from permanent hazards on either side of the carriageway boundary, differentiates vulnerable road users (pedestrians, bicyclists, and motorcyclists) from other motorists, divides competing traffic on split roads, and prohibits entry. The traffic barrier has been shown to be an effective technique in lowering the occurrence of accidents [12].

On the other hand, the location of the traffic barrier must be thoroughly investigated. It is not required to be placed if the severity of the collision is expected to be greater than falling down an embankment, crossing into an adjacent lane, or colliding with a fixed object. The position of the road barrier, including the roadside and median barriers, can be utilized to identify the traffic barrier [12]. The w-beam barrier, concrete barrier, and wire rope barrier are all popular barrier methods in Malaysia and will be discussed further in this article. When compared to other sites, each traffic barrier system will have features that distinguish and make a chosen barrier system more desirable in such location. According to the previous statistics, road alignment has a substantial impact on the build-up of various forms of traffic barriers. In the case of a road accident, the appropriate type of traffic barrier can decrease the chance of harm. According to the 2013 WSDOT study, one of the most essential things to consider when choosing on the type of barrier to employ is road alignment [12]. Rolling Obstacles, often known as guardrails, are a type of structural obstacle. The Rolling Barrier keeps cars from hitting with dangerous items and roadways while they are protected, such as concrete, road signposts, bridge supports, trees, and building walls. Based on the functions they serve and the degree to which they can deflect a vehicle when it comes into contact with the Rolling Barrier, there are two types of rolling barriers [7]. Table 1 depicts the types of barriers based on their function. There are various types of rolling barriers, including roadside Rolling Barriers on straight roads (Fig. 2), curved road Rolling Barriers (Fig. 3), steep road Rolling Barriers (Fig. 4), and median Rolling Barriers (Fig. 5).

Table 1 - Type of rolling barriers [8]

No.	Types of Barrier	Function
1.	Roadside Rolling Barrier (Fig. 2 and Fig. 3)	Its primary role is to safeguard transportation from potential risks and dangers. A steep slope, a heavy stiff body, and an accumulation of water are all potential hazards.
2.	Median Rolling Barrier (Fig. 5)	Its goal is to keep vehicles from crossing the median and creating an accident.
3.	Rolling Barrier on Curves (Fig. 4)	Furthermore, it is bigger in size than roadside barriers. The bridge barrier prevents automobiles from crumbling and crashing into the river on the bridge's side.

Fig. 2 - Roadside rolling barriers at straight road [13]

Fig. 3 - Roadside rolling barrier at curved road [14]

Fig. 4 - Roadside rolling barrier at hilly road [15]

Fig. 5 - Median rolling barrier [11]

4. Difference Between Other Barrier and Rolling Barrier

In this subsection the understanding of other barrier includes concrete, steel, and cable towards rolling barrier was explored in terms of their differences and comparison.

4.1 Difference Between Concrete Barrier and Rolling Barrier

Concrete road barriers, as seen in Fig. 6, are used to separate opposing lanes on all sorts of roadways. To keep cars out of the opposite lane, concrete barriers are necessary. When a vehicle crosses into the opposite lane, serious traffic accidents can occur; as a result, concrete barriers are necessary to prohibit automobiles from crossing into the opposing lane, protect drivers from injury or death, and prevent vehicle damage. Concrete barriers are also used to keep cars away from potentially hazardous areas such as roadside ditches, narrow medians, and bridge barriers [16].

Concrete barriers offer a few advantages, but they also have a few drawbacks. The most important is the cost difference between a concrete barrier and a rolling barrier. Solid barriers are much more expensive than rolling barriers. When vehicles collide with a concrete barrier, damage occurs that must be repaired as quickly as possible, and in certain cases, the entire block must be replaced. The cost of repair is much higher than the cost of a rolling barrier. Simply replace the broken roller material in the rolling barrier, which is made of a solid rubbery substance [8].

The damaged roller section can be repaired, but not the damaged concrete part. Engineers must take into account environmental issues. The Earth has gotten more heated as a result of carbon-dioxide emissions. The present carbon-dioxide scale is much higher. As a result, it needs to be reduced. Concrete produces carbon dioxide, which has an environmental impact. In contrast, the material used in rolling barriers is ecologically benign and does not affect the environment. The rolling barrier can also be used to replace an existing concrete barrier.

Fig. 6 - Concrete barrier [10]

4.2 Difference Between Steel Barrier and Rolling Barrier

Steel barriers of various types are commonly erected along roadside to prevent cars from leaving the road, ensure the safety of vehicle occupants, and protect things adjacent to the barrier. Manufacturers of road management and safety equipment work hard to achieve a balance between efficacy, quality, and cost in barrier placement and

maintenance concerns [17]. Steel barriers, particularly designable steel barriers, are available in a range of forms and sizes, although they are not utilized on roadways. For aesthetic considerations, the bulk of designable barriers are located in residential neighbourhoods. The most common form of steel barrier is the normal steel barrier. These barriers are more durable than concrete barriers, but their height is insufficient for heavy trucks or large vehicles (buses), and the main problem is that they cause substantial vehicle damage, which is not cost efficient. Rolling barriers are made of strong rubber that has been tested with stainless steel and has the same strength as steel barriers [8].

The main advantage of rolling barriers over steel barriers is that they may cause less automobile damage and give higher life protection. Fig. 7 illustrates both the damage to a steel barrier and the damage to a rolling barrier [18].

Fig. 7 - Steel barrier [18]

4.3 Difference Between Cable Barriers and Rolling Barrier

There are several types of barriers, but the most common are concrete and steel barriers. Cable barriers, as illustrated in Fig. 8, are extensively utilized in many nations due to their low installation cost, fast maintenance time, and ease of construction. Furthermore, cable barriers have been shown to minimize the number of cross-median collisions, which are typically high-severity events [19].

Another type of barrier that we have explored earlier is a cable barrier. However, the cable barrier is not long-lasting. A cable barrier's primary function is to absorb the impact of passing cars. Other impediments, such as a safer barrier, can be utilized to buffer the impact. A safer barrier, on the other hand, must be more expensive than a rolling barrier; while a cable barrier is less expensive, the rolling barrier's lifetime is considerably superior to that of a cable barrier. Damage to the vehicle is also considerably less than that produced by a wire barrier.

Fig. 8 - Cable barrier [12]

5. Advantages of Rolling Barrier

A barrier is a sort of impediment that attempts to keep cars inside their respective lanes and avoid collisions with objects or other vehicles. On steep horizontal bends, there is a greater risk of an accident. On the sides of the horizontal curve, barriers are placed. These barriers can minimize the incidence of accidents, but when a car collides with one, it causes significant damage to the vehicle, injury to the human body, or even death. Because the car is no longer in

control after the accident, it may be overthrown or suddenly halt, inflicting significant damage. The “Rolling Barrier System” was created by the South Korean business ETI (Evolution in Traffic Innovation). It transforms shock energy into rotational energy.

Rolling barriers are those that have rollers put on them. When a vehicle collides with a rolling barrier, the rolling friction is activated. When a car hits the roller on the barriers, it begins to roll, preventing the vehicle from being quickly halted or overthrown, and so reducing the severity of the collision. Its application may be shown to be more successful on horizontal curves, where the majority of accidents occur.

Each new technology must be more powerful than the one that came before it. Any innovation has certain advantages. Without incentives, neither people nor the government would adopt the technology. The first advantage of the rolling barrier is that it protects both vehicles and people [8]. There are numerous advantages to installing a rolling barrier on a curved road in order to increase road safety. The advantages and disadvantages of the rolling barrier are shown in Table 2.

Table 2 - Advantages of the rolling barrier [8]

No.	Advantage of Rolling Barrier	Descriptions
1	Shock Absorbs System	The firm rubber material (the roller) can absorb the effects of the automobiles. The car's speed was reduced as it reached the barrier. If the car is travelling at a speed of 40 km/h, the number of accidents is reduced by 80%. If a driver is able to regulate his traffic, which will fail if the automobile meets the barrier at that moment, the speed will decrease, and the vehicle will be under control.
2	Convert Shock Energy to Rotary Rotational Energy	Fig. 2.5 depicts one of the rolling barrier's major advantages: it absorbs stress and seeks to redirect shock energy into spinning rotational energy. That's why the flipped automobile is struggling to regain control. Do not abandon the course. If there is a steep area and it struggles to stay on the road, it can go off the track and cause deaths.
3	LED Light	The solar-powered LED light, which might be beneficial for drivers, is one of the major characteristics. He can see the barrier well at night, and the collision will be muffled.
4	Stainless Steel	Fig. 2.6 depicts one of the most important rolling barrier components. The roller is ready to use because it is made of stainless steel. The barrier is strange without it.
5	Color of Barrier	The color of a roller is yellow. The golden color may be seen from a great distance. The driver will notice the barrier from a great distance and will continue to warn from that distance. That's why a concrete and steel barrier was painted yellow.
6	Reflective Tape	Reflective tape is a type of tape that shines brightly when the vehicle's headlights shine on it. A reflective tape is used in any roller to alert the motorist. Fig. 2.7 demonstrates how it helps at night when the light from the automobile enters the tape and alerts the driver that there is an impediment.
7	Easy to Install	Another major advantage is that the construction process is considerably simpler than any other challenge. It is also quite simple for the worker to replace the roller. Only raise the stainless-steel bars that are horizontally positioned, remove the broken roller, and install the replacement roller and the pin of the steel bar that is horizontally positioned.
8	Recyclable Materials	Chemical composite rubber-based hard products are environmentally benign and recyclable. As a result, it lowers the cost of maintenance.

6. The Application of Rolling Barrier

The rolling barrier is a protective system that not only absorbs but also converts rotational energy into shock energy, therefore protecting drivers and riders from catastrophic damage or death [7]. The rolling barrier is a safety device that not only absorbs but also transforms shock energy into rotational energy, therefore protecting drivers and riders from serious injury or death. The Rolling Barrier preserves existence while also prohibiting the greatest degree of vehicle damage and has proved that the rolling barrier systems are a promising transport engineering technology [7]. The present installation of Rolling Barrier Systems in Malaysia demonstrates the efficacy of the Rolling Barrier System. On December 14, 2016, Malaysia erected a Rolling Barrier System at Jalan Lapangan Terbang Subang, which leads onto the Federal Highway. Gerard Lye of the Star contributed to this report (2017), According to the Work Ministry, the installation of the rolling barriers safety system along selected highways in Malaysia has helped minimize

accidents by 94%. The Deputy Minister, Datuk Rosnah Abdul Rashid Shirlin, stated that the ministry has been monitoring the system since its installation, and that the findings demonstrate that the Rolling Barrier Systems are one of the most effective ways to minimize road deaths caused by accidents [8]. The rolling barrier performance test was performed to compare the standard barrier to the rolling barrier in order to evaluate the extent of damage to the barrier caused by the vehicle's shock effect. In test 1, depicted in Fig. 9, two tests were carried out to analyse the normal and rolling barriers to determine the degree of damage produced by the car's collision. The results of the test indicated that conventional barriers were more injured than rolling barriers. In a related crash test, test 2 illustrated in Fig. 10 compares the impact of a passenger car and a large vehicle on a rolling barrier ant, demonstrating that the impact of a passenger car did not do any harm to the rolling barrier, but minimal damage is detected in the case of a big vehicle [7]. Performance tests were conducted to evaluate the extent of damage done on the barrier as a result of a vehicle hit and to compare the normal and rolling barriers. Fig. 9 depicts crash simulation representations (Test 1). It was discovered that, when compared to the Rolling Barrier, the traditional barriers sustained more damage. In a comparable crash test (Test 2), a contrast is established between the effect of a passenger vehicle and a large truck on the Rolling Barrier, as shown in Fig. 10. The impact of the passenger car did not cause any damage to the Rolling Barrier, however some damage was recorded in the case of a large vehicle.

Fig. 9 - Crash test 1: comparison of traditional barriers and rolling barriers [20]

Fig. 10 - Crash test 2: car and truck accident at rolling barrier [20]

7. The Strategic Location for Rolling Barrier

Variables such as the road, the driver, and the vehicle all have an impact on traffic accidents. Depending on the kind of accident, the influence of each component on traffic accidents varies. The effects of roadway factors on traffic accidents will be determined, leading to better road design [21]. There is a lot of loss in steep places. If the automobile is really fast, regulation is difficult, and there is a chance of sliding off the cliff. The mechanism of the rolling barrier is distinct from that of other types of conventional barriers. It also reduces the possibility and danger of success injuries nowadays. A curved collision absorbs shock energy, which is then transformed into rotational energy [22]. Accidents on curved roads are usually more dangerous than accidents on straight roads. The majority of prior study has

concentrated on the connections between curved portions and roadway geometric characteristics [23]. One of the important components of highway protection is horizontal and vertical alignment. It is usual to expect that more road accidents occur on curves or slopes than on generally straight tangent portions owing to reduced visual distance and other variables. According to [12], crash rates for horizontal curves are greater than for tangent portions, with rates ranging from 1.5 to 4 times higher than for straight sections [12]. They also said that just 34.6 percent of incidents occurred on a level lane, whereas 65.4 percent occurred on a gradient or at the point where grades change. The scenario in Malaysia, on the other hand, shows a distinct pattern, with a large frequency of incidents on a straight and flat segment [12]. This observed tendency is related with straight and curve alignment crash results in Malaysia during a five-year period (2008-2012), as shown in Table 3.

Furthermore, it focuses on the 439 traffic accidents reviewed by MIROS from 2007 to 2010 that resulted in three or more deaths in instances involving all types of vehicles and at least one motor vehicle fatality. MIROS has therefore revealed that a poor crash barrier is one of the causes of injuries in curve and straight section accidents (3.5 percent on curve section and 1.9 percent on the straight section). It is also crucial to recall that damage in slope and flat road accidents has the same proportion for the collision barrier's substandard component, i.e. 2.5 percent. Surprisingly, while the overall number of instances evaluated on the straight and flat portion is more than on the curve and slope part, the inadequate crash barrier component causes more damage to the curve and slope section [12]. Sharp horizontal curves increase the danger of an accident. The number of accidents is lowered when rolling barriers are erected on both sides of a horizontal curve [24].

Table 3 - Road accident by straight and curve alignment [12]

Year	Type of Road Accident	Road Alignment	
		Straight	**Curve**
2008	Fatal	4,014	1,065
	Serious	4,150	1,014
	Minor	7,762	1,532
2009	Fatal	4,450	936
	Serious	4,424	919
	Minor	7,430	1,222
2010	Fatal	3,767	1,050
	Serious	3,362	813
	Minor	5,900	1,072
2011	Fatal	4,216	1,119
	Serious	2,852	758
	Minor	5,811	943
2012	Fatal	4,374	1,058
	Serious	2,818	649
	Minor	6,020	961
Total Accident		**71,350**	**15,111**

Rolling barriers absorb high impact energy from cars and transform the energy impact to rational energy. The rotating energy prevents high-impact vehicles from bursting through the barrier [9]. The rolling barrier has a different function or objective than other barriers because it transfers shock energy to rolling and blocks or prevents impact energy from breaking through the barrier and colliding with hazardous roadside objects such as trees, culverts, embankments, cliffs, electricity substations, retaining wall poles, and many more [8, 9]. It would be a wise investment for the government if the rolling barriers were put in areas where accidents are likely to occur and on curving roads. Some lives may be risked on a curving road; the trailer's driver may be unable to handle the vehicle correctly and lose control, driving straight into the other lane and colliding with other drivers [8]. Rolling barriers can be installed in the center of the road and utilized as separators for two-way traffic. Rolling barriers can be used to prevent collisions on twisting roadways [7].

8. Conclusion

This review discusses the effectiveness of rolling barrier system at straight road and curved road. From this, it can be concluded that:

- Previous researchers confirmed that the rolling barrier system is better than the other barrier system in terms of new technology. It serves two purposes: (i) it acts as a road barrier while also minimizing the impact of automobile crashes on the barrier, and (ii) the barrier's roller system was brilliantly designed, and the roller bottle was constructed of high-quality materials.
- The Rolling Barrier System was strategically installed in three high-risk areas with a high incidence of fatal traffic incidents. The three high-risk road locations that require additional safety are straight roads, curving roads, and hilly roads, which are the most important locations to place Rolling Barrier Systems in order to decrease high-risk accidents and fatalities while also improving road safety.

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