Case Study
Reducing Risks Associated with Grade Crossing Accidents

This case study shows how cost-effectiveness can be used in conjunction with probabilistic risk assessment to determine the best ways to reduce one category of risks of associated with transportation systems.

Hundreds of people are killed each year in grade crossing accidents. A grade crossing (also known as a level crossing in some countries) is where a road crosses a railroad at grade, so that it is possible for a train and a highway vehicle to collide. Accidents may by caused by people who are too sleepy or too drunk to notice that they are approaching a crossing or by people whose car is stuck in traffic while trying to get across the tracks or whose car breaks down on the crossing. A few accidents are caused by malfunctioning of the signals, and a great many are caused by people who ignore the warnings and try to beat the train across the intersection.

The probability of such an accident occurring varies primarily with the density of rail traffic and with the type of protection that is available. At a crossing equipped with flashing lights, the probability of an accident is on the order of 2 per million trains. If there are 20 trains per day, then the expected number of accidents per year would be (20 trains/day x 365 days per year/1 million trains) x (2 accidents per million trains) = 0.0146 accidents per year for such a crossing. For a rail route with 100 such crossings, the expected number of accidents per year would be 0.0146 (100) = 1.46. Although the probability of an accident at any crossing is very low, the likelihood of an accident somewhere along this route is quite high. In fact, such accidents are not uncommon. In the United State, there are more than a quarter million grade crossings and thousands of grade crossing accidents per year.

The second step in estimating risk is to determine the expected consequences if an accident occurs. Even a small passenger train weighs hundreds of tons, so that the consequences of a collision between a train and an automobile are very predictable. The car will be destroyed, any people who fail to get out of the car are likely to be killed or severely injured, and the locomotive may sustain some minor damage. In addition, the engineer and anyone else in the cab of the train will be suffering an emotional shock after a) knowing that the accident was about to happen and b) being completely unable to stop a train in time to avoid hitting someone trying to sneak across before the train arrives. If the train is a passenger train, the major consequence for most passengers will be a delay to the train; passengers might not even notice the impact and will simply wonder why the train stopped.

Accident rates at grade crossings can be reduced by installing flashing lights, putting in crossing gates (arms that automatically come down and block the travel lane when a train approaches), by installing 4-quadrant gates (4 arms block the entire road, so that motorists cannot run around the gate), or by building a bridge. It is even possible to have the entire road blocked, while uniformed personnel ensure that pedestrians do not try to skip across in front of a train, but this expensive solution can only be justified in very unusual circumstances.

Table 1 shows the cost of installing (or upgrading) to each level of protection along with typical accident rates achieved with this type of protection. Note that the accident rate is driven (in this simplified model, but also in reality) by train traffic, not by highway traffic.

Table 1 Grade Crossing Accident Rates

Protection	Cost/crossing	Accident Rate (per million trains)
Signs only	$500	10
Flashing lights	$20,000	2
Gates	$100,000	1
4-quadrant gates	$200,000	0.2
Bridge	$2,000,000	0

Assume that you are the safety officer in a state Department of Transportation, and you have a budget for improving highway safety. You would like to use some of this budget to reduce crossing accidents. You have categorized crossings into the categories shown in Table 1. With this information, you can calculate the cost effectiveness for each strategy in reducing accidents and identify the most cost effective strategies to pursue.

Table 2 Possible Upgrades

Highway Traffic per year	Trains per Year	Base Acc. /year	Current Protection	Possible Upgrade
20 million	100,000	0.1	Gates	Bridge
20 million	100,000	0.1	Gates	4-quadrant
2 million	50,000	0.05	Gates	4-quadrant
200,000	50,000	0.1	Flashing lights	Gates
20 million	5,000	0.01	Flashing lights	Gates
20,000	2,000	0.02	Signs	Flashing lights
20,000	200	0.002	Signs	Flashing lights

The first step is to estimate the effect of the upgrade on accident rates and the number of accidents per year for each category of crossing. The new accident rate per million trains comes directly from Table 1. The expected accidents per year is the product of the new accident rate per million trains multiplied by the number of trains per year. For example, if 4-quadrant gates are installed for crossings with 20 million highway vehicles and 100,000 trains per year, then we can expect the accident rate to drop to 0.2 per million trains, while the expected number of accidents per year will be 0.2 accidents per million trains multiplied by 0.1 million trains/year or 0.02 accidents per year.

The next step is to compute the cost-effectiveness, which is the cost per annual reduction in accidents. This can readily be calculated as the cost of the upgrade divided by the number of accidents avoided. The accidents avoided per year is calculated as the difference between the base and the new number of accidents per year. The cost of the upgrade is shown above in Table 2. The result is the cost per accident avoided. The most cost-effective measures turn out to be:

1) Install flashing lights at crossings with 2,000 trains per year that are currently only protected by signs ($1.25 million per accident avoided per year)
2) Install gates at crossings with 50,000 trains per year that are currently only protected by flashing lights ($2 million per accident avoided per year)
3) Install 4-quadrant gates at the very busy crossings with 100,000 trains per year ($2.5 million per accident avoided per year.

As the safety officer for the state department of transportation, you would still have to determine whether there are more cost-effective strategies to pursue in terms of reducing risks within your state. To do this, you would have to have an estimate of the consequences of grade crossing accidents, so that you could calculate cost-effectiveness in terms of risk reduction rather than in terms of accident reduction. You could then compare strategies for reducing risks at grade crossings to strategies such as adding more policemen to enforce speed limits, requiring seat belts, or upgrading dangerous highway intersections.

Resource: Project Evaluation: Essays and Case Studies
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