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Risk assessment in ramps for heavy vehicles—A French study

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ABSTRACT

This paper presents the results of a study dealing with the risk for heavy vehicles in ramps. Two approaches are used. On one hand, statistics are applied on several accidents databases to detect if ramps are more risky for heavy vehicles and to define a critical value for longitudinal slope. χ^2 test confirmed the risk in ramps and statistical analysis proved that a longitudinal slope superior to 3.2% represents a higher risk for heavy vehicles. On another hand, numerical simulations allow defining the speed profile in ramps for two types of heavy vehicles (tractor semi-trailer and 2-axles rigid body) and different loads. The simulations showed that heavy vehicles must drive more than 1000 m on ramps to reach their minimum speed. Moreover, when the slope is superior to 3.2%, tractor semi-trailer presents a strong decrease of their speed until 50 km/h. This situation represents a high risk of collision with other road users which drive at 80–90 km/h. Thus, both methods led to the determination of a risky configuration for heavy vehicles: ramps with a length superior to 1000 m and a slope superior to 3.2%. An application of this research work concerns design methods and guidelines. Indeed, this study provides threshold values than can be used by engineers to make mandatory specific planning like a lane for slow vehicles.

1. Introduction

The French fleet of heavy vehicles is composed of almost 550,000 units (data in 2012) cumulating a total of 19.5 billion kilometres of travelled distance per year. Heavy vehicles represent 3.4% of the vehicles involved in accidents with injuries and 9.9% of fatal accidents (ONISR, 2012). The evolution of heavy vehicles accidents in France has shown a continuous decrease (5719 accidents in 2002 and 3148 in 2012), especially for tractors semi-trailers. This trend can be explained by the complementary actions of French safety policy and the development of active safety systems like ABS (Anti-lock Braking System) or ESP (Electronic Stability Program). Despite researches conducted in the past decade on accidents related to heavy vehicles, knowledge is still needed to better assess accidents in ramps. Indeed, as analysis of accidents data showed that rollover and jack-knifing in curves represent around 2/3 of accidents in Europe (Desfontaines, 2003) (UNIFI, 2003) and similar trends were found in the rest of the world (Cate and Richards, 2000) (Häkkänen and Summala, 2001) (Moonesinghe et al., 2003) (Tsai and Su, 2004), most research have mainly focused on accidents occurring in curves. Thus, the case of ramps is less addressed.

An analysis of French accidents between 2005 and 2009 showed that 27% of accidents involving a heavy vehicle alone and 18% of accidents involving at least one heavy vehicle are observed on ramps (Cerezo et al., 2008).

Literature review showed that heavy vehicles accidents on American dual carriageways are more frequent in ramps (Agent and Pigman, 2002). Most accidents occur by front-rear collisions, considering both corporal and material accidents, and are due to a speed difference of 40–50 km/h between the involved vehicles (cars moving faster than the slow heavy vehicle in front). Ramps with a longitudinal slope higher than 4% prove to be more risky on Swedish primary roads (Othman and Thomson, 2007) whereas the threshold value is 2% in Italy (Caliendo and Lamberti, 2001) and in Washington State (Shankar et al., 1995). Moreover, Fu et al. (2011) found that not only the value of the longitudinal slope but also the length of the ramp have an impact on accident risk on primary roads in China.

This paper presents results of a research dealing with accident risk in ramps. It aims at improving knowledge about accidents in ramps and providing limit values for infrastructure characteristics to detect risky areas.

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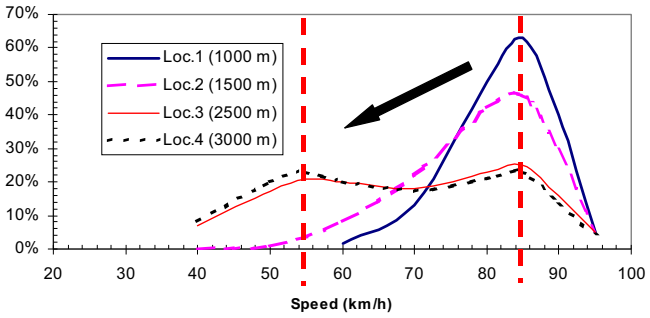

Fig. 1. Distribution of heavy vehicles' speed on different locations on the ramps (Cerezo et al., 2008).

2. Research conducted

2.1. Collision risk on ramps

Study conducted on a French motorway between 1995 and 2001 highlighted the fact that one third of materials and corporals' heavy vehicles accidents occurred on ramps of 5 km in length, which represent only 2% of the motorway length (Cerezo et al., 2008). Average values of the longitudinal slope range between 4 and 5%. Accidents were mainly located after 1500 m of ramp-up. Experiments were conducted to estimate the speed of heavy vehicles along a ramp and understand the causes of accidents. These experiments showed that after around 250 m of ramp-up, the speed of heavy vehicles was stabilized and the behavior of heavy vehicles can be split into two groups. In the first group, the vehicles were able to keep a constant speed on the ramp with an average value of 85 km/h. In the second group, vehicle's speeds decrease significantly and stabilize at around 55 km/h (Fig. 1). Based on these results, safety experts concluded that accidents on ramps can be explained by a gap of speeds between the vehicles involved in the accident. They also underlined the fact that a longitudinal slope higher than 4% and a length of the ramp higher than 1500 m highly contribute to the speed reduction and as a consequence increase the collision risk.

To complete this previous study, statistical analysis was performed on accidents databases from two French regions (Rhône-Alpes and Auvergne). These two regions were chosen because they are representative of the traffic in France, with both transit (North–South) and local traffic, and geographical environments (plain, mountain, rural and urban). In a first step, accidents occurring between 2003 and 2008 were collected (Fig. 2) and studied.

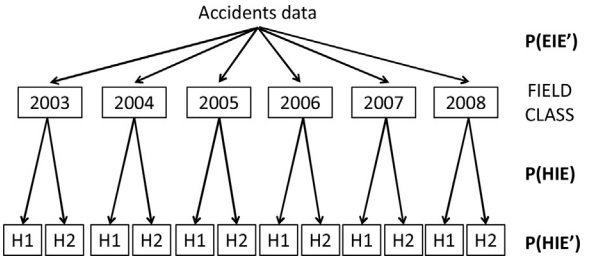

Fig. 3. Example of a map used to calculate probability of accidents with Bayes theorem.

In Auvergne, the annual number of accidents in ramps/descents (resp. outside ramps/descents) ranges between 13 and 32 (resp. 54 and 97) whereas in Rhône-Alpes this number ranges between 76 and 95 (resp. 288 and 400). Firstly, the data are analyzed with Bayes method to assess if the year has an impact of the probability of accidents occurring in ramps/descents (Fig. 3). The data are divided into six field classes (one per year). Two events are defined: H1 = {accidents occurring in ramps/descents} and H2 = {accidents occurring outside ramps/descents}. By using notations given in Fig. 3, Bayes theorem says that:

$$P\left(\mathrm{H}|E'\right) = \sum_{E=1}^{N} P\left(\mathrm{H}|E\right) \times P\left(\mathrm{H}|E'\right) \quad (1)$$

$$P\left(Hi\right) = \sum_{j=1}^{6} P\left(\mathrm{Hi}|Ej'\right) \quad (2)$$

with $i = 1$ for accidents occurring in ramps/descents
$i = 2$ for accidents occurring outside ramps/descents.
The results of the probability calculus are provided in Table 1.

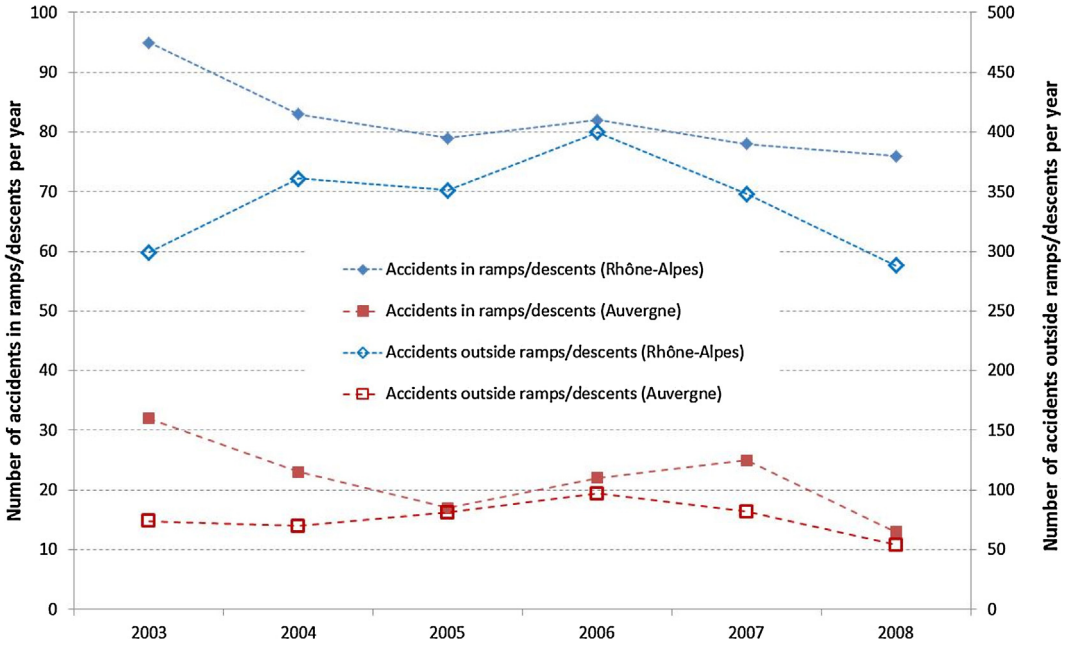

Fig. 2. Evolution of the annual number of accidents occurring in and outside ramps/descents.