Evaluating and Mapping the Hazard and Risk of Vehicle Instability Within a Flood Prone Area

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INTRODUCTION

Floods negatively affect the territory generating social and economic losses. Among the elements that can be affected by floods are vehicles, which in turn can intensify the effects of floods when they are washed away by the flow (Teo et al., 2012). In cities, the highest number of deaths during floods occurs inside vehicles (Fitzgerald et al., 2010). Additionally, the rescue of people from vehicles in flooded areas can be quite expensive (Smith et al. 2017).

Despite the serious impacts that the drag of vehicle can have during floods, very few studies has been done to date to establish the hazard and risk to which vehicles are subject during these events. This research identified the risk of vehicles instability due to overflowing of the Rambla del Poyo, which is located in the East coast of Spain.

CASE STUDY

The case study was the estimation of the hazard and risk of vehicles due to overflows of the Rambla del Poyo in the municipalities of Massanassa and Alfafar , which are located in Valencia - Spain (Figure 1).

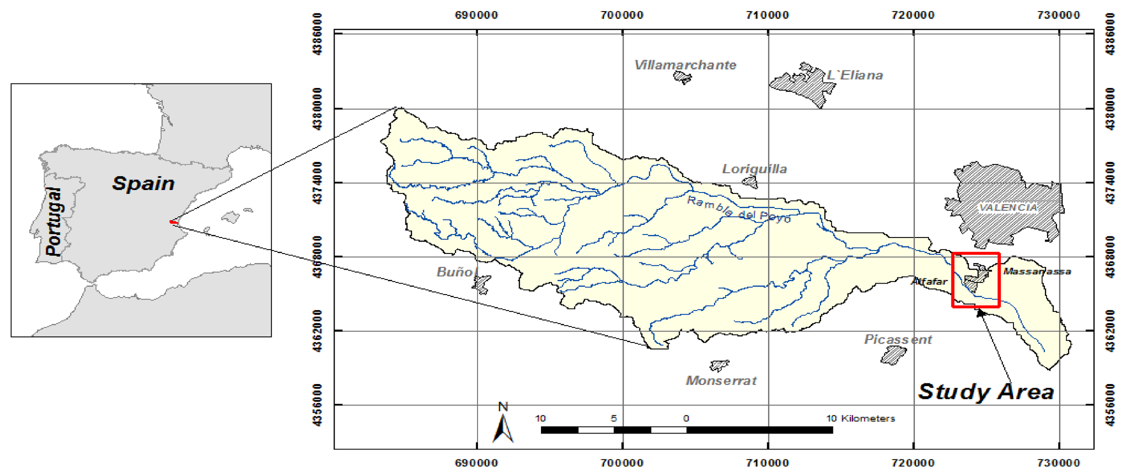

Figure. 1. Location of Rambla del Poyo catchment and the analyzed study area

Rambla del Poyo is an intermittent and strongly anthropized stream that has a catchment of 430 km² and a mean annual precipitation less than 500 mm.

The main dimensions and the proportion of the analyzed cars in the vehicle fleet are shown in the Table 1.

Table 1. Characteristics of studied vehicles

Characteristic	Utility Seat Ibiza	Compact Seat León	Small SUV Peugeot 2008	Medium SUV Volkswagen Tiguan
Length (m)	3.68	4.18	4.16	4.43
Width (m)	1.61	1.74	1.74	1.81
Height (m)	1.42	1.44	1.56	1.67
Ground Clearance (m)	0.12	0.12	0.17	0.18
Density (Kg/m³)	108.00	125.86	104.41	115.26
Proportion	0.26	0.32	0.15	0.27

METHODOLOGY

To establish the hazard and the risk, different types of vehicles and maximum velocity and depth inundation maps for the return periods of 50, 100 and 500 years were used.

Using the stability model proposed by Arrighi et al. (2016), it was possible to map the hazard for each type of vehicle individually and the risk for all vehicles that circulate or are parked in the case study. According with Arrighi et al. (2016), stability of a car is establish by means of hazard index (θ_{vcr}/θ_v).

$$\frac{\theta_{Vcr}}{\theta_V} \begin{cases} > 1 & \text{Vehicle in motion by sliding} \\ = 1 & \text{Start of sliding of the vehicle} \\ < 1 \text{ y} \geq 0 & \text{Vehicle at rest} \\ < 0 & \text{Vehicle in motion by flotation} \end{cases}$$

The mobility θ_v and critical mobility θv_{cr} parameters are calculated using the following equations, which are defined based on Figure 2.

$$\theta_v = \frac{2L}{(H_v - h_c)} * \frac{l}{l * Cos\beta + L * sin\beta} * \left(\frac{\rho_c * (H_v - h_c)}{\rho * (H - h_c)} - 1\right)$$

$$\theta_{Vcr} = 8{,}2 * Fr^2 - 14{,}1 * Fr + 5{,}4$$

where: ρ_c = car density, ρ = water density and Fr =Froude number

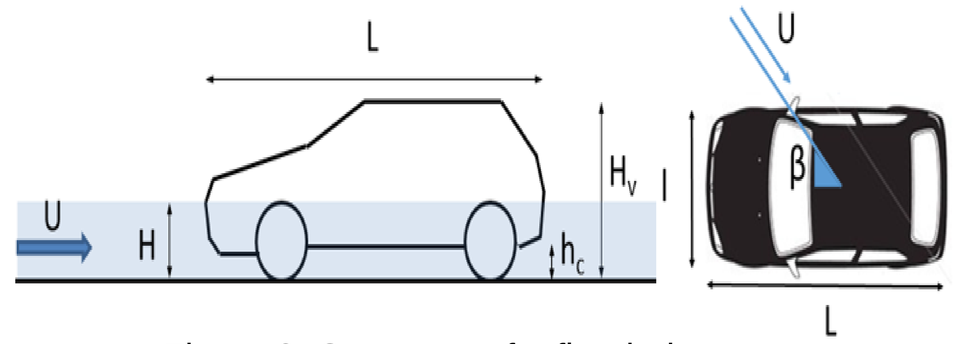

Figure 2. Geometry of a flooded car.
Source: Arrighi et al. (2016)

The risk of flooding for vehicles was calculated as follows for one pixel in mean number of vehicles washed away per year per unit area:

$$Risk = \sum_i^K \sum_j^N d * f[i] * D[j] * \Delta P_j$$

where:
K= Number of types of vehicles through which the vehicle fleet is represented
f [i] = Proportion of type car i
d = Density of vehicles in the pixel
N = Number of flood hazard maps, each of them for a given return period T_j
D [j] = Stability of the vehicle given by equation
ΔP_j = Occurrence probability between two considered events j and j-1

RESULTS

Maps of Hazard Index for the Volkswagen Tiguan in the case study with return periods of 50, 100 and 500 years

a. Tr = 50 years

b. Tr = 100 years

c. Tr = 500 years

Stability Conditions	Hazard Index	
Loss of stability by flotation	< 0	
Safety zone	0 – 0.5	
	0.5 – 1.0	
Loss of Stability by sliding	1.0 – 1.5	
	>1.5	

Map of flood risk of vehicles that are circulating or parked in the case study

Risk (cars/ha/year)						
0.0 - 0.2	0.2 – 0.4	0.4 – 0.6	0.6 – 0.8	0.8 – 1.0	1.0 – 1.2	1,2 – 1.4

CONCLUSIONS

Overflows of Rambla del Poyo corresponding to return periods higher than 50 years constitute a high hazard to cars that circulate or are parked in large areas of the urban centers of the municipalities of Massanassa and Alfafar. In general, flotation and sliding are the two possible mechanisms of vehicle destabilization. However, the combination of depths and velocities in this case study results in a high percentage of vehicles loses their stability due to the phenomenon of flotation.

As expected, the medium SUV vehicles shown to be the most stable vehicles among the types of analyzed cars.

Flood risk of vehicles in the analyzed municipalities is relatively high (in the order of 1.4 cars/ha/year) in a sector whose size is slightly larger than a third of the flooded areas. When relative frequency of each type of car is introduced, the vehicles with greatest risk correspond to the compact ones and the vehicles with the lowest risk are represented by the small SUVs.

Determining hazard and risk levels of vehicle stability during floods would help the implementation of actions in urban planning and civil protection that can decrease the negative effects of this type of events.

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REFERENCES

Arrighi C., Huybrechts N., Ouahsine A., Chaseé P., Oumeraci H., Castelli F. (2016). Vehicles instability criteria for flood risk assessment of a street network. Proc. IAHS, 373, 143-146.

Fitzgerald, G., Du, W., Jamal, A., Clark, M., Hou, X. (2010). Flood fatalities in contemporary Australia (1997–2008), Em. Med. Australasia, 22, 180–186.

Smith G. P., Modra B. D., Tucker T. A., Cox R. J. (2017). Vehicle stability testing for flood flows. Technical Report. University of New South Wales. Sydney, Australia.

Teo Y., Xia J., Falconer R., Lin B. (2012). Experimental studies on the interaction between vehicles and floodplain flows. Intl. J. River Basin Management, 10 (2), 149–160.

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