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## Enhancing Safety and Security at Level Crossings of "FERROMOBILES"

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## Enhancing Safety and Security at Level Crossings of "FERROMOBILES"

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### Context

- Level crossing : safety critical component of railway system
- Production electric vehicle adapted to the road-rail technology
- Objective: ensure the safety of railway passengers as well as road users at LC's
- Innovative project called FERROMOBILE
- Able to run on the road and **autonomously** on the rails

### Objectives of the "Ferromobile" project



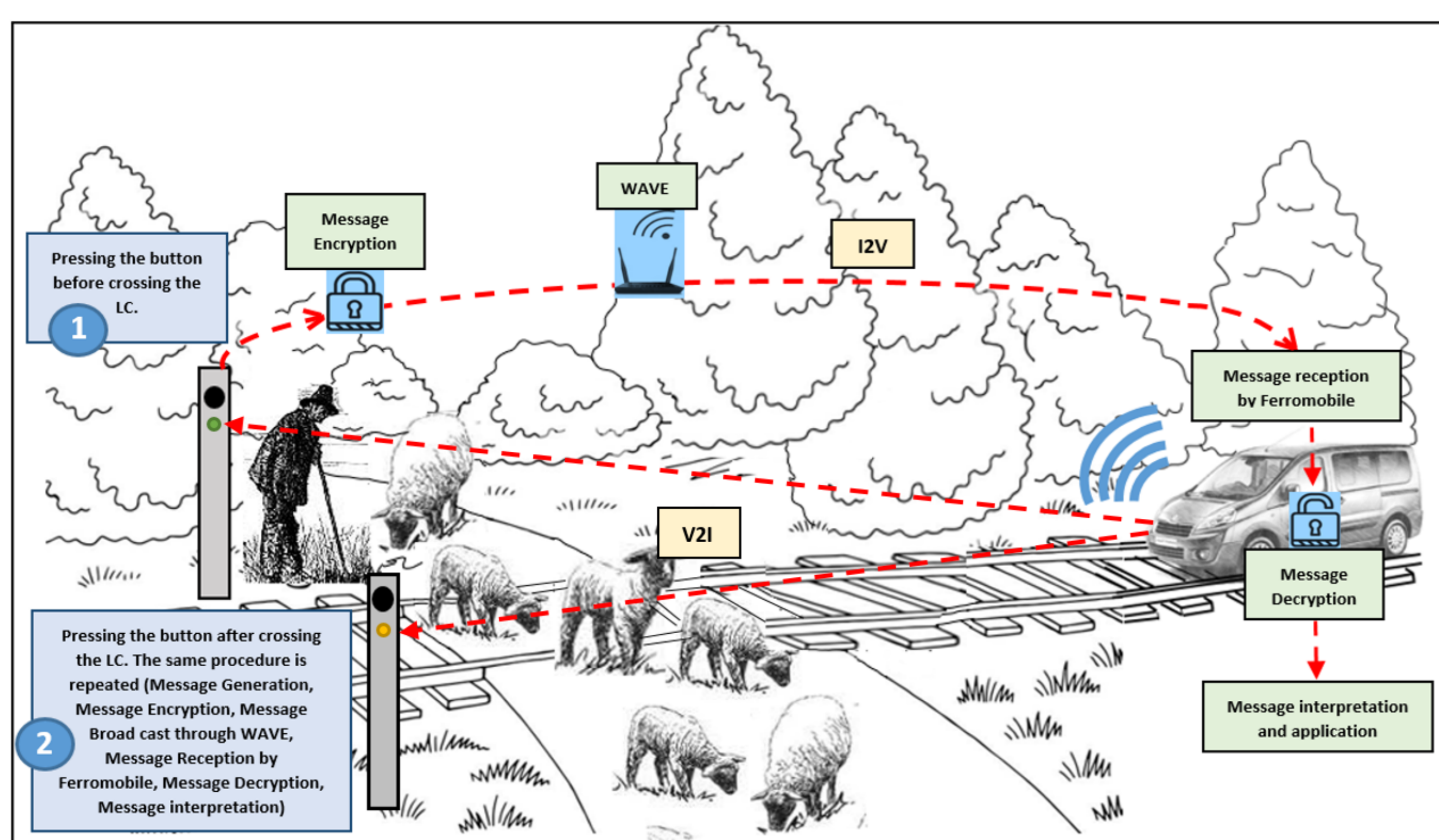
- Enabling residents to travel safely and flexibly without changing their mode of transportation.
- Will be available 24/7 in the territories.
- A Peugeot series vehicle, an 8-seater public transport, traveling at 70km/h.
- Its stopping distance is more than 10 times shorter than that of trains.

### Encryption process

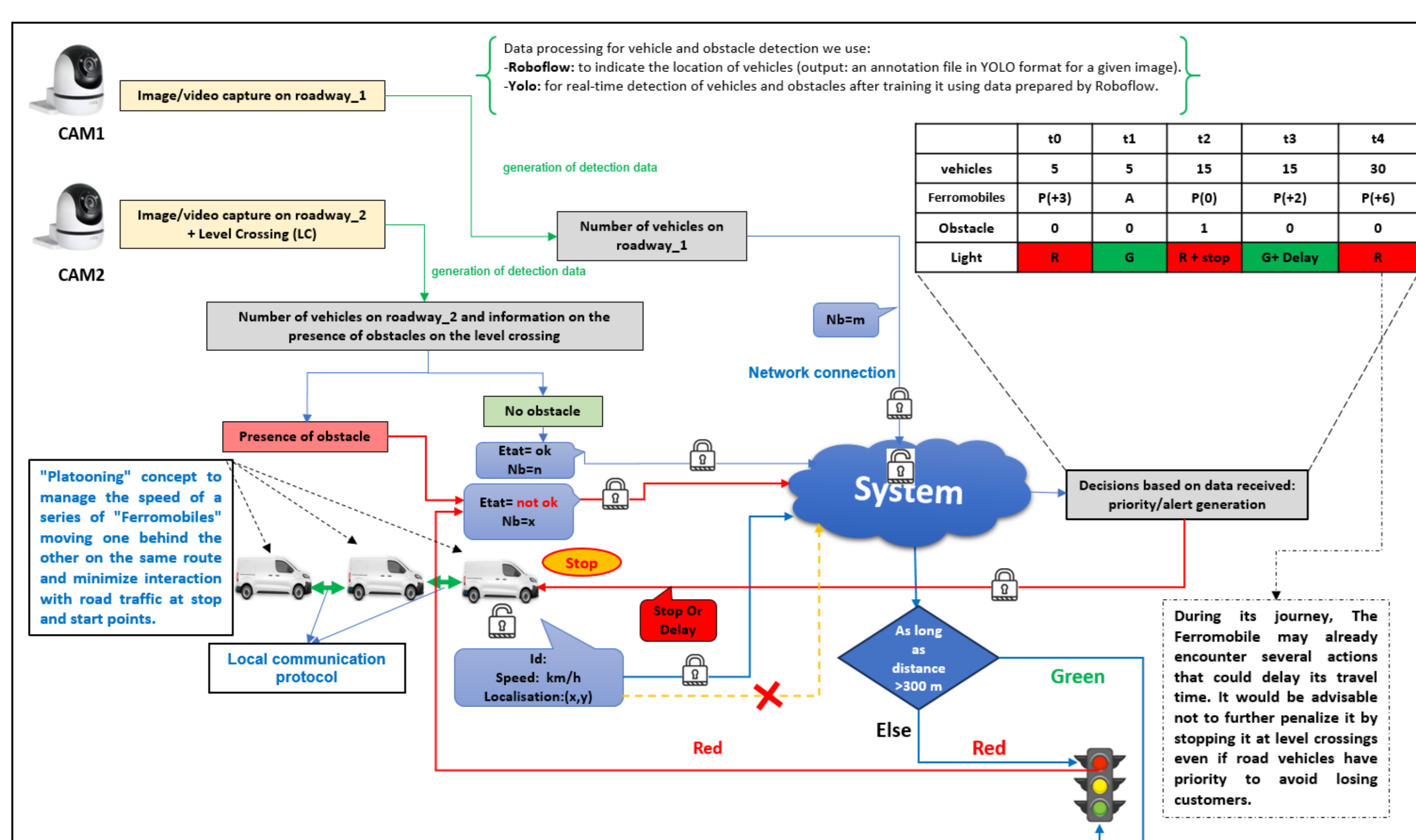
	FPGA	Data path(bit)	Key size (bit)	Execution time (ns)
SIMECK	Spartan6 (Xc6s16) Virtex7(Xc7vx330t-3)	32	128	440
SIMON	Spartan6 (Xc6s16) Virtex7(Xc7vx330t-3)	32	128	440
LED	Spartan6 (Xc6s16) Virtex7(Xc7vx330t-3)	32	128	1920

### Overview of the global architecture

#### Level Crossings in the countryside



#### Level Crossings in towns



### Communication-Assisted Stopping Distance

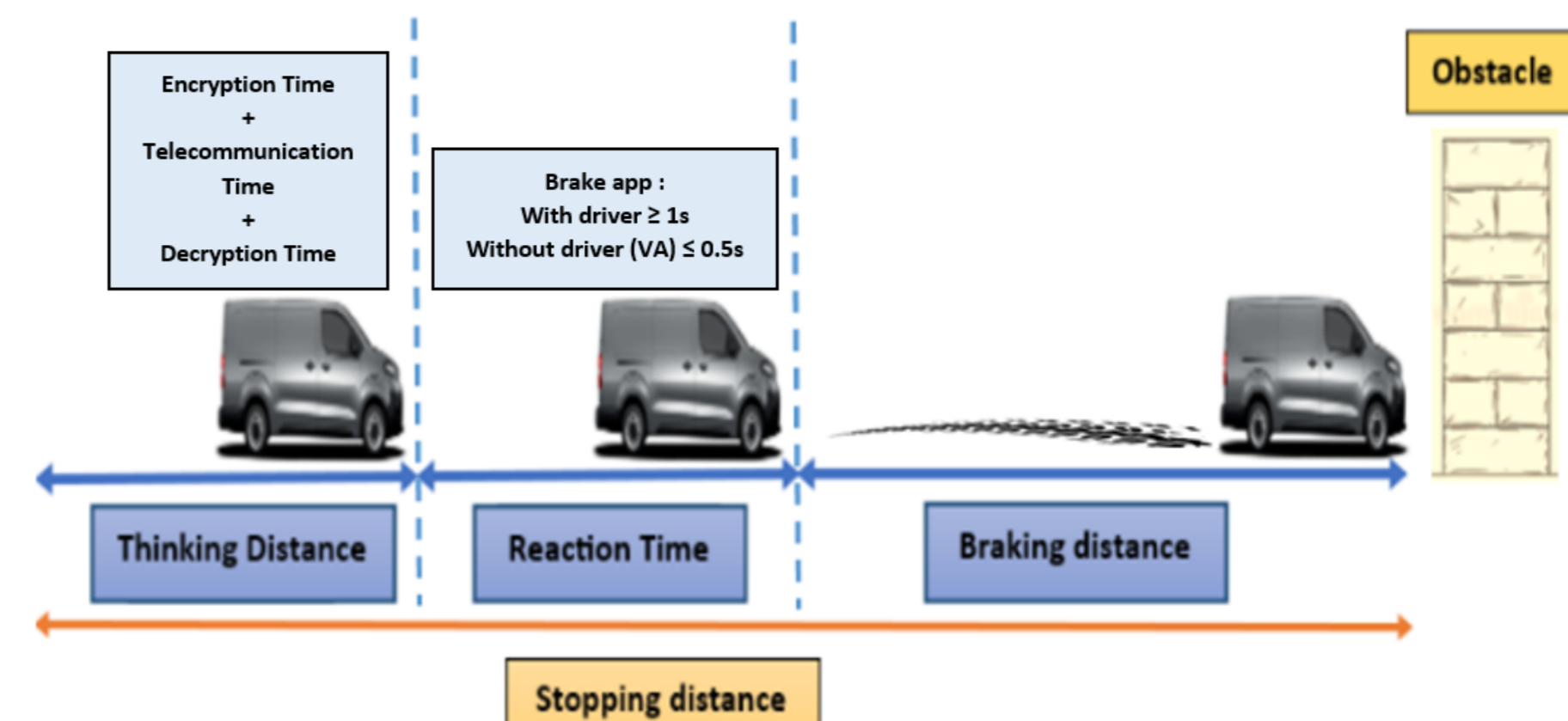
The stopping distance from the literature [2] is formulated in equation 1:

$$D_S(m) = D_R + D_B : \text{ with } D_R(m) = V * T_R \quad \text{and} \quad D_B(m) = \frac{V^2}{2g\mu} \quad (1)$$

$D_R$  : The thinking distance /  $V$ : Velocity /  $T_R$  : reaction time (less than or equal to 0.5s [3]) /  $D_B$  : The braking distance /  $g$ : Gravity ( $9.81 \text{ m/s}^2$ ) /  $\mu$ : coefficient of friction (usually around 0.8).

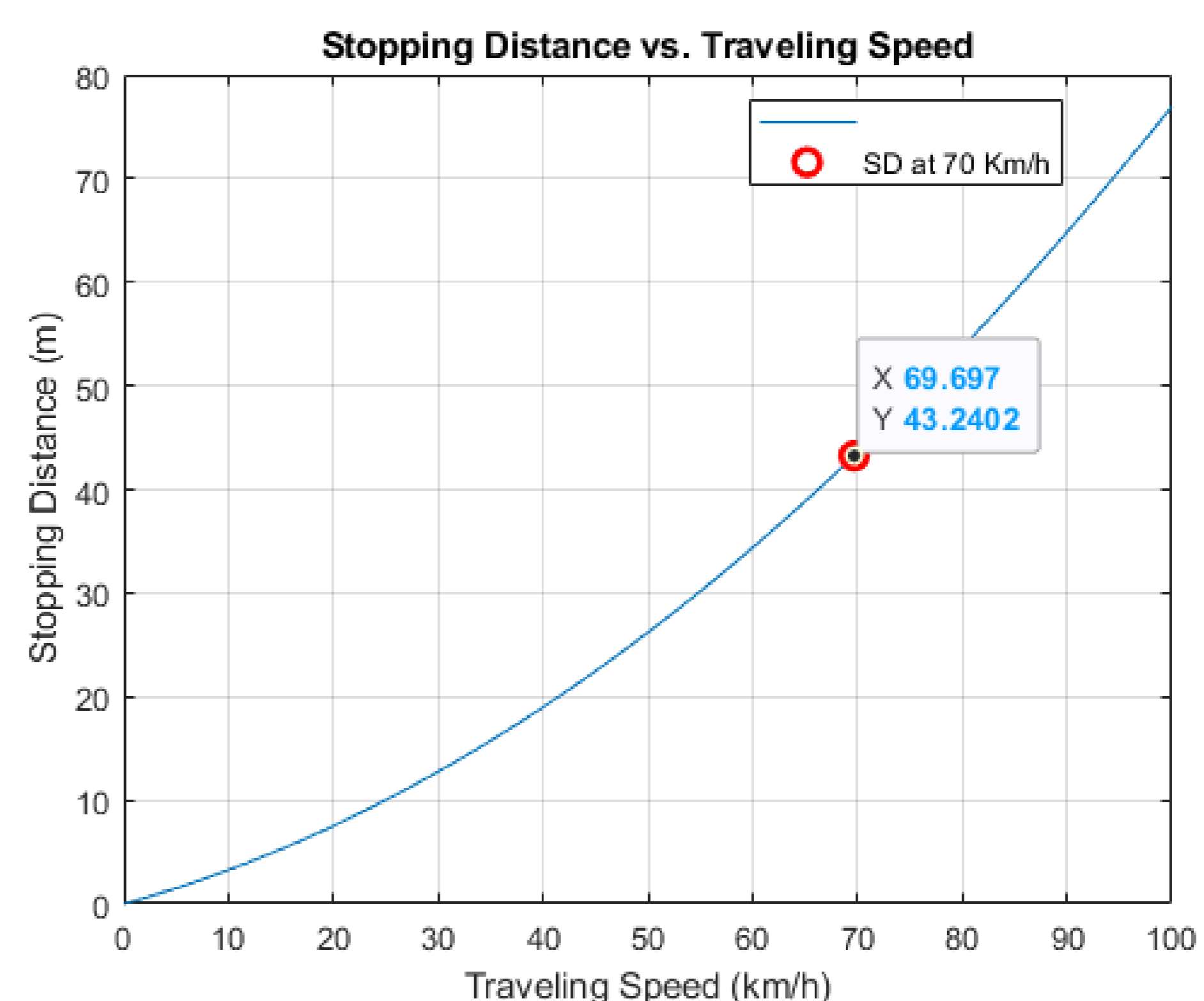
In our case, the thinking distance is:

$$D_R(m) = V * (T_R + T_E + T_T + T_D) \quad (2)$$



$T_E$ : Encryption time /  $T_T$ : Telecommunication time /  $T_D$ : Decryption time.

The stopping distance for a car travelling at 70 km/h is approximately "43.25 meters".



- The thinking time and reaction time of 1 second is used.
- Since the WAVE protocol allows for signal transmission at a distance of 1 km [1]: FERROMOBILE has enough time to come to a complete stop before a collision occurs at the LC.

### Conclusion

- Two systems to be developed are proposed : countryside and urban areas
- Stopping distance : compatible compared to the shorter-distance radio communication
- The existing margin allows to use encryption technologies protecting these systems against attacks

### References

[1] Kashif Dar, Mohamed Bakhouya, Jaafar Gaber, Maxime Wack, and Pascal Lorenz. Wireless communication technologies for its applications [topics in automotive networking]. *IEEE Communications Magazine*, 48(5):156–162, 2010.

[2] Steven Knowles Flanagan, Zuoyin Tang, Jianhua He, and Irfan Yusoff. Investigating and modeling of cooperative vehicle-to-vehicle safety stopping distance. *Future Internet*, 13(3):68, 2021.

[3] Rahul Patel, Michael W Levin, and Stephen D Boyles. Effects of autonomous vehicle behavior on arterial and freeway networks. *Transportation Research Record*, 2561(1):9–17, 2016.