



**HAL**  
open science

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

Rim Brahim, Simon Collart-Dutilleul, Philippe Bon, Pierre-Antoine  
Laharotte, Nour-Eddin El Faouzi

► **To cite this version:**

Rim Brahim, Simon Collart-Dutilleul, Philippe Bon, Pierre-Antoine Laharotte, Nour-Eddin El Faouzi.  
Enhancing Safety and Security at Level Crossings of "FERROMOBILES". RSSRail 2023 : 5th International Conference on Reliability, Safety and Security of Railway Systems, Oct 2023, Berlin, Germany.  
hal-04486216

**HAL Id: hal-04486216**

**<https://univ-eiffel.hal.science/hal-04486216v1>**

Submitted on 1 Mar 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

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

Rim Brahim, Simon Collart-Dutilleul, Philippe Bon  
 Univ Gustave Eiffel, COSYS-ESTAS, F-59650 Villeneuve d'Ascq, France  
 Pierre-Antoine Laharotte, Nour-eddin El Faouzi  
 Univ Lyon, Univ Gustave Eiffel, ENTPE, LICIT-Eco7, F-69675 Lyon, France

### 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 LCs
- 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)<br>Virtex7(Xc7vx330t-3) | 32             | 128            | 440                 |
| SIMON  | Spartan6 (Xc6s16)<br>Virtex7(Xc7vx330t-3) | 32             | 128            | 440                 |
| LED    | Spartan6 (Xc6s16)<br>Virtex7(Xc7vx330t-3) | 32             | 128            | 1920                |

### Communication-Assisted Stopping Distance

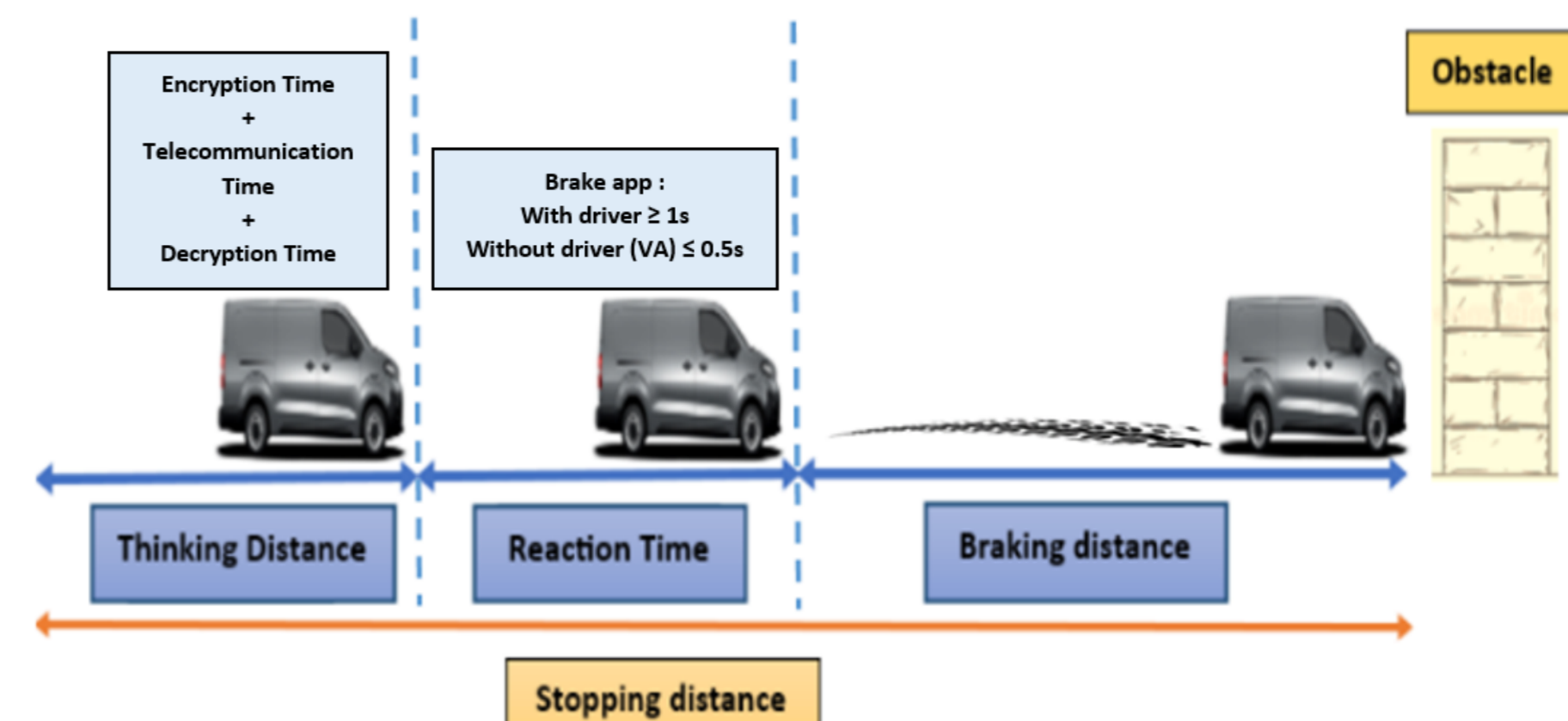
The stopping distance from the literature [2] is formulated in equation 1:

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

$D_R$  : 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:

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

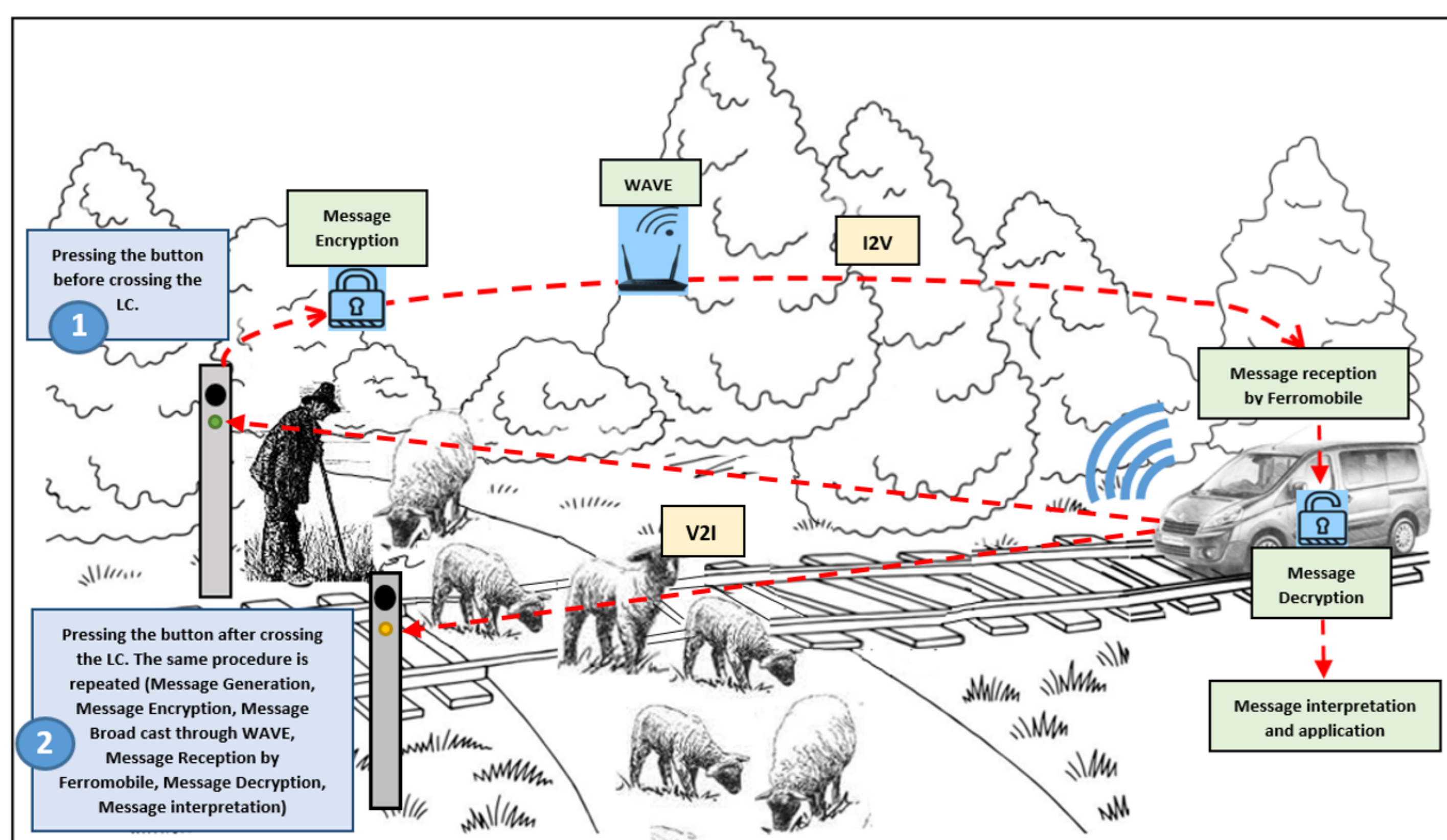


$T_E$ : Encryption time /  $T_T$ : Telecommunication time /  $T_D$ : Decryption time.

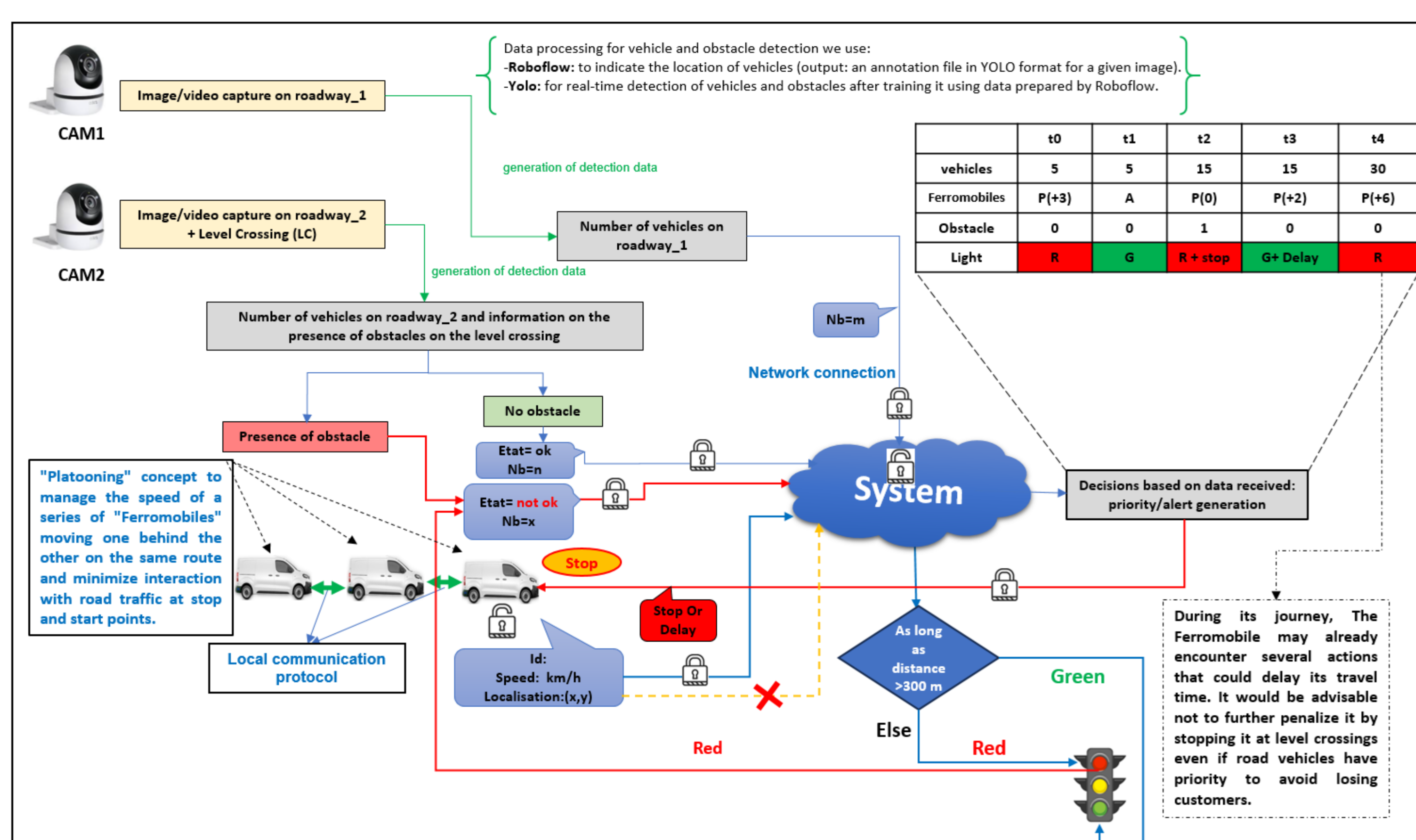
The stopping distance for a car travelling at 70 km/h is approximately "43.25 meters".

### Overview of the global architecture

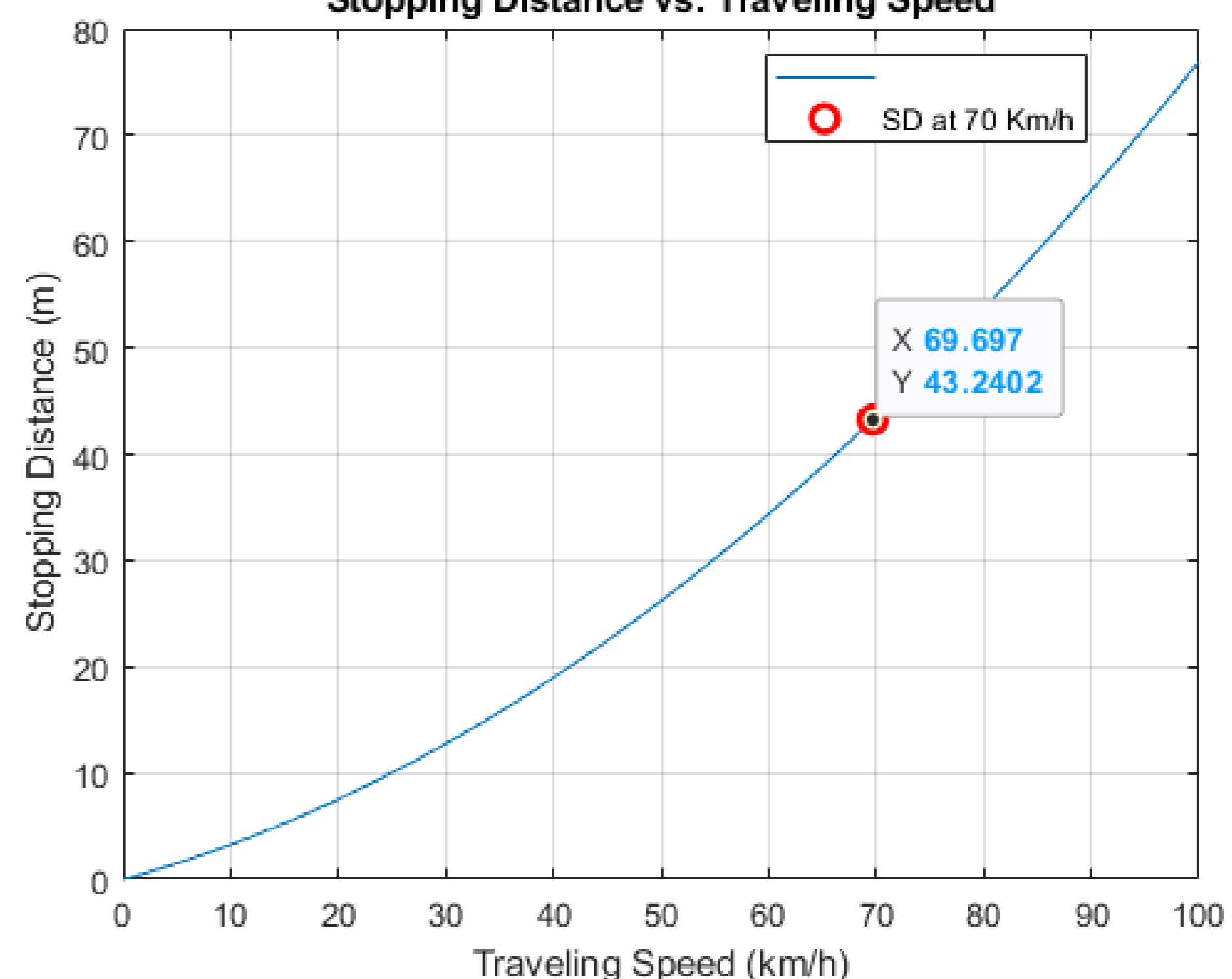
#### Level Crossings in the countryside



#### Level Crossings in towns



#### Stopping Distance vs. Traveling Speed



- 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.