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Sensitivity Analysis of Lagrangian-Based Variable Speed Limit Strategies apropos of Market Penetration and Spatial Distribution of Connected Vehicules

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Introduction

Context

Traffic control strategies need to be refined and adapted to **mixed traffic situation** *i.e* traffic composed of Human-driven and Connected Vehicles (HDVs and CVs).

Variable Speed Limit (VSL) systems consists in i) dynamically detecting a shockwave on a motorway by using current traffic conditions such as speed and flow and ii) computing an applying a speed restrictions upstream to **artificially reduce downstream throughput** and dampen congestion waves to **improve traffic conditions**.

Positioning

CVs are often study in the literature to explore the impact of their new skills, of platoon size or of the ratio of CVs *i.e* Market Penetration Rate (MPR). To the best of our knowledge there is no study to explore **the impact of CVs spatial distribution** at various MPR levels.

Objectives

With the deployment of CVs, 2 new VSL strategies entirely based on lagrangian data resulting from CVs and I2V communication have been implemented previously by the authors [1] [2] The objective of this paper is to explore their sensitivity to Cvs distribution in the flow at various MPR.

Methodology

Implementation of both VSL systems

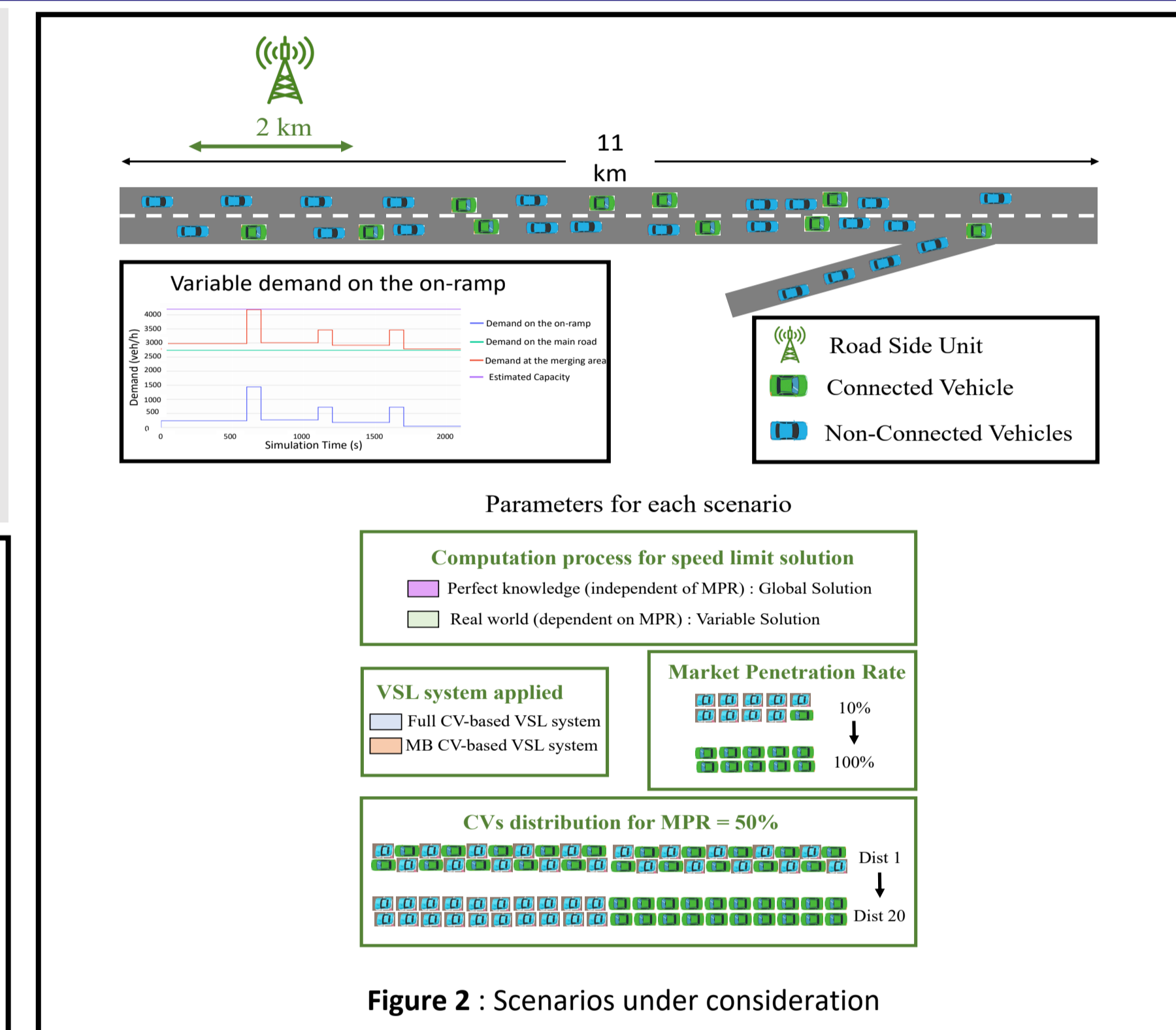
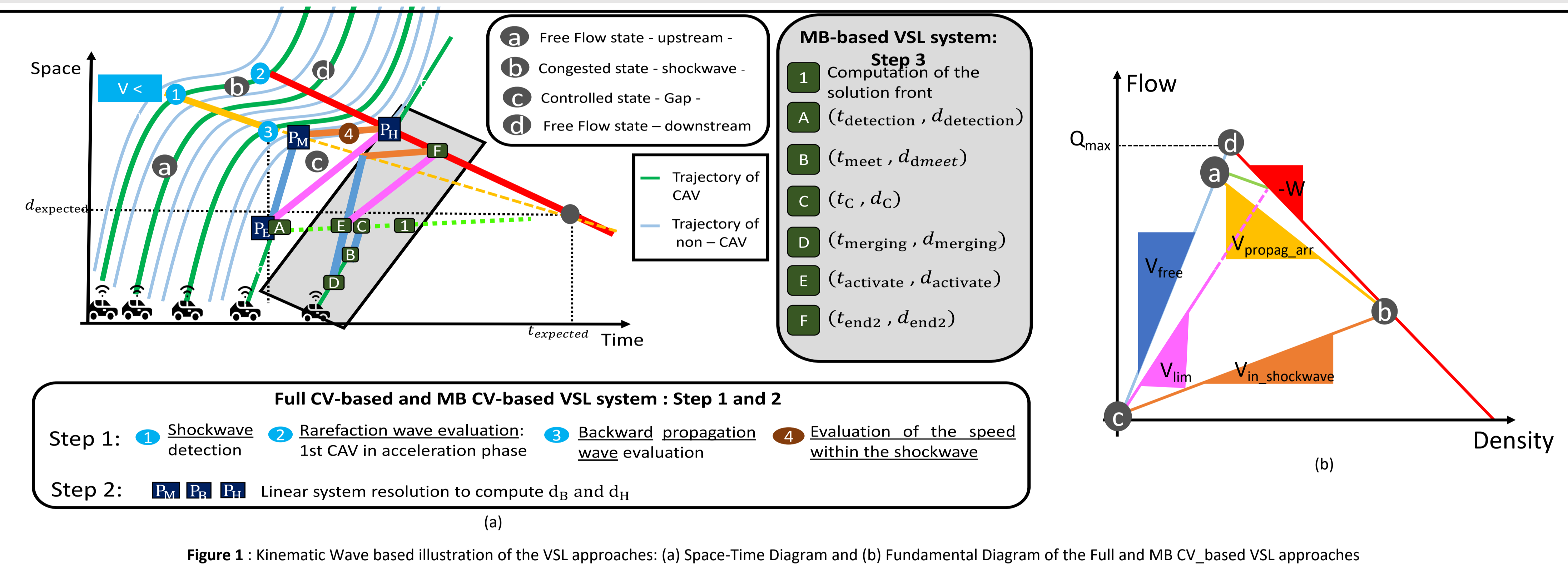
Both VSL systems use the strong relationship between the **Fundamental Diagram** and the **Space Time Diagram**.

They are based on the same three steps : 1) **Shockwave detection**, 2) **Solution computation** and 3) **Speed Limit application**.

Only Step 3 has different process between both VSL systems.

For the Full-CV based VSL system the speed limit is applied by all the CVs which are between $d_{detection}$ and d_h from $t_{detection}$ until t_h with $P_h(t_h, d_h)$ on Figure 1.

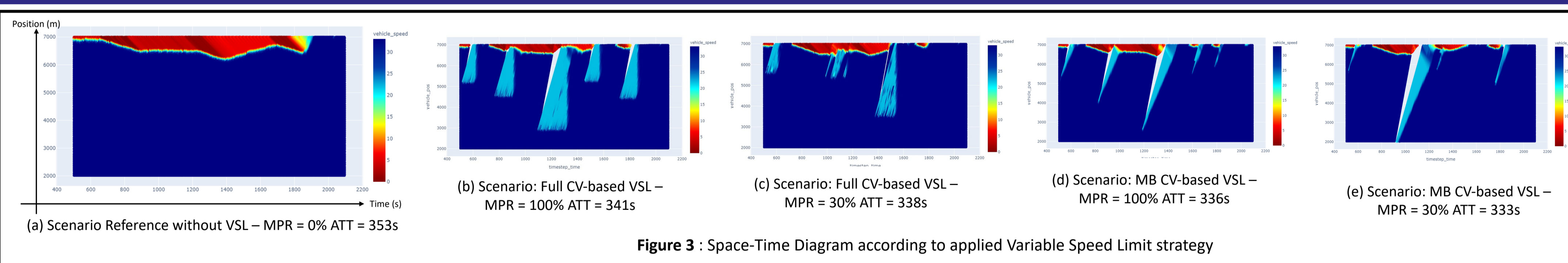
For the MB CV-based VSL system it is only applied between $d_{activate}$ and d_{end2} (Point E et F on Figure 1) by 2 CVs side-by-side forming a moving bottleneck. This requires a refinement of the previous algorithm to select and match the 2 CVs.



Sensitivity analysis

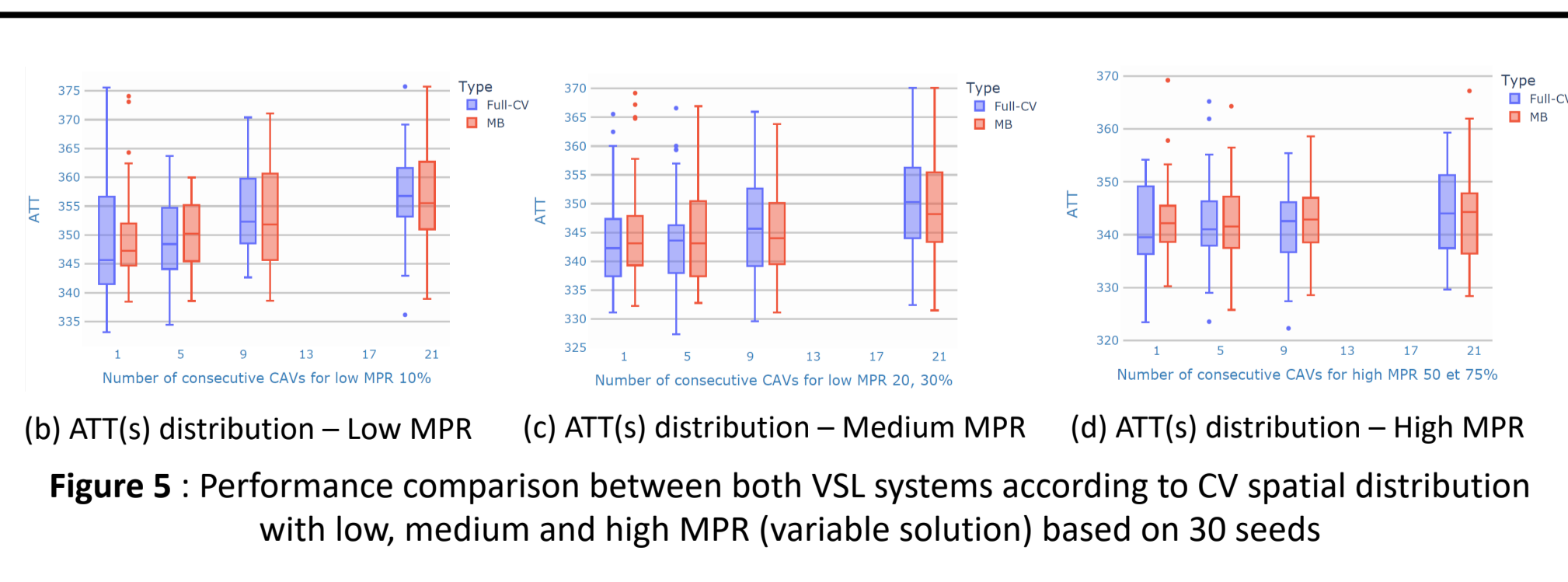
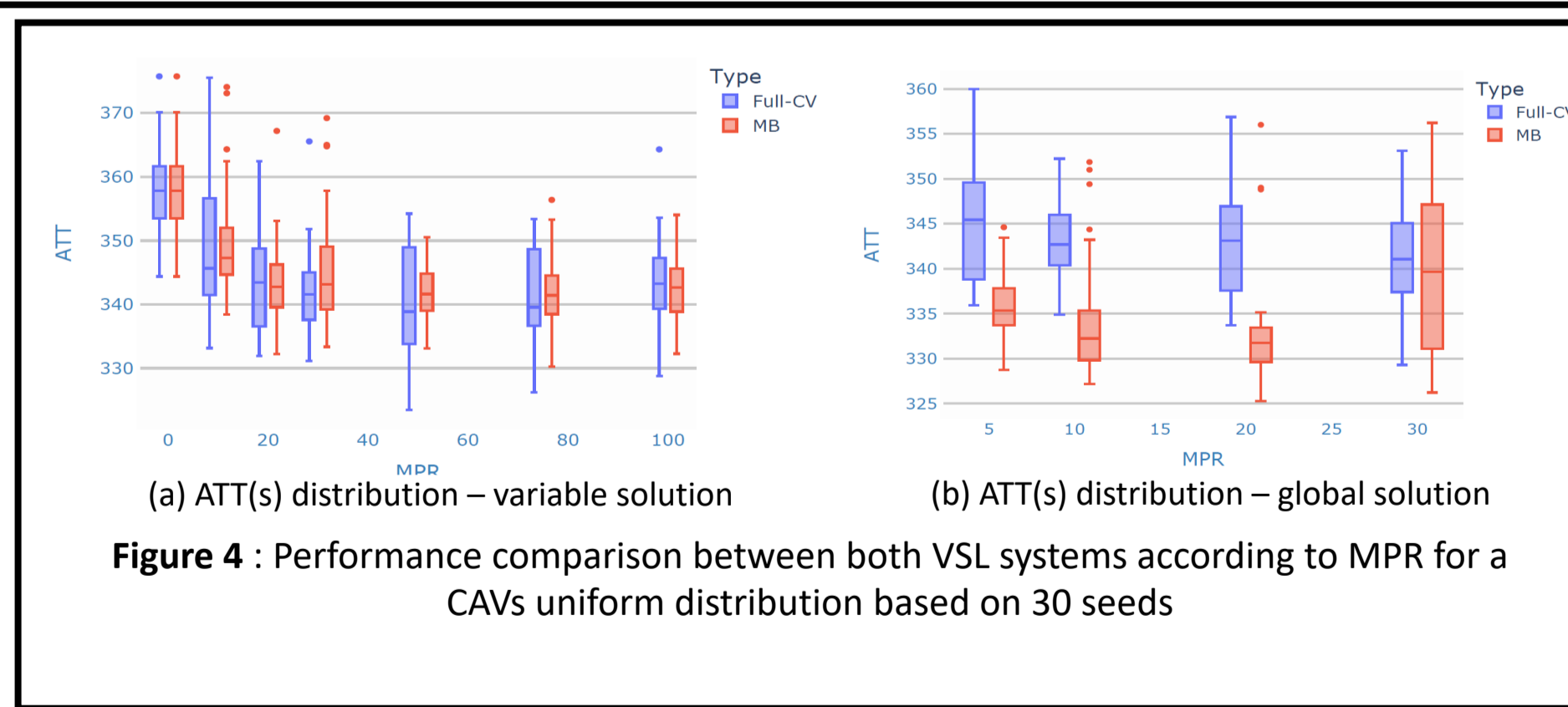
The analysis is performed thanks to the traffic micro-simulation framework called **SUMO** and its Traffic Control Interface (TraCI). The distinction between CVs and HDV only results in the CVs communication ability. For each scenario, simulations are conducted with **30 seeds** and performances are evaluated in **terms of the Average Travel Times (ATT)**.

Results



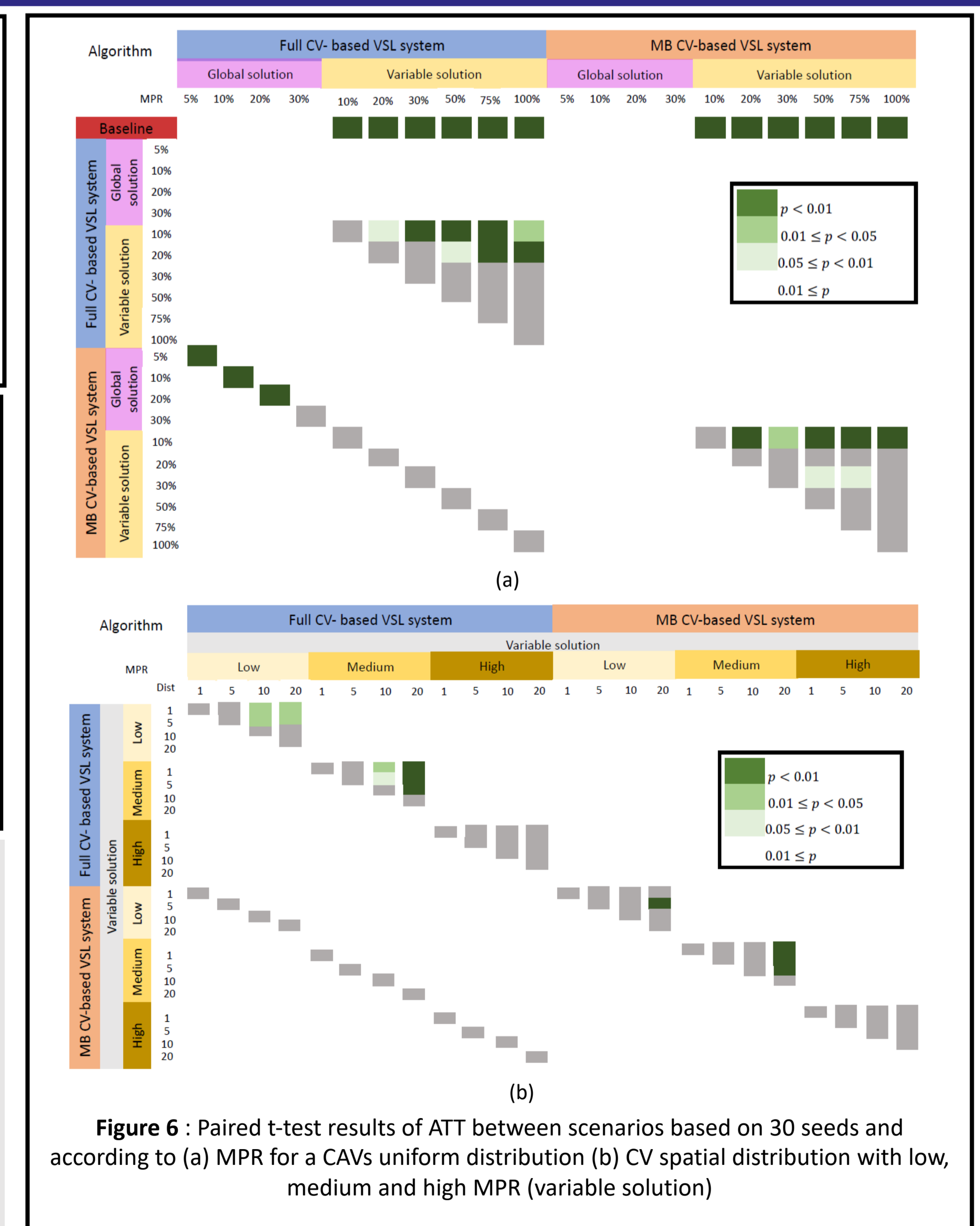
MPR impact under a uniform spatial distribution of CVs

- **Variable solution** : -Both VSL system are outperforming the baseline with benefits growing until reach a plateau at 30% for the full CV-based VSL system and 20% for MB CV-based VSL system
- No statistical difference between both VSL systems for each same scenario
- **Global solution** : MB CV-based VSL outperforms significantly performances of the Full CV-based VSL for very low MPR (under or equal to 20%)



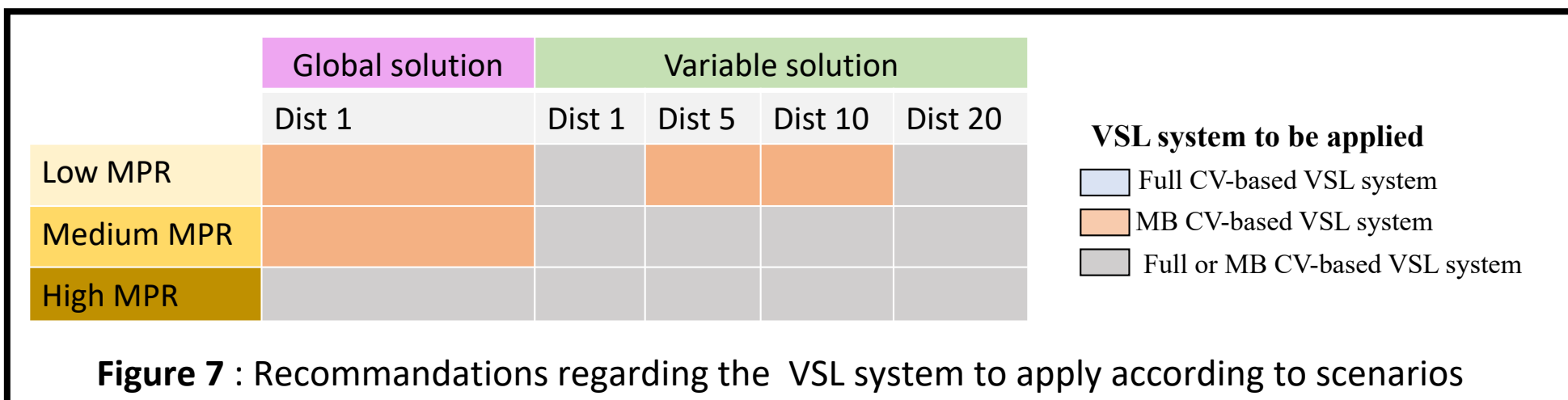
CVs distribution impact under different values of MPR

Performances for the Full CV-based VSL decrease significantly when the number of consecutive CVs (*dist*) increases for low and medium MPR => uniformly distributed CVs bring better performances. For the MB-VSL system the distribution has no impact on performances until *dist* = 10 even at medium and low MPR.



Conclusion

Both VSL system are statistically outperform the baseline with some sensitivity to the MPR and spatial distribution. Some recommendations are given regarding the VSL system to apply according to the different scenarios.



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