Analyzing the Effects of Mobility-On-Demand Pick-up and Drop-off Processes on Link Capacity

Master‘s Thesis of Sebastian Reyes Arroyo

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Introduction

The rise of Pick-up and Drop-off (PUDO) processes related to Mobility-On-Demand (MoD) services, specifically ride-hailing, has already begun to disrupt traffic dynamics. With the potential inclusion of autonomous vehicle fleets in the future, PUDO frequency may increase even further, prompting the research question: “How do Mobility-On-Demand pick-up and drop-off processes impact the capacity of a link according to geometric attributes, street configuration, PUDO attributes, and demand level?”

Methodology

This study proposed eleven independent variables for analysis, classified into four categories as shown in Figure 1.

Geometric attributes	
Variable	**Values**
Lane width [m]	2.5, 3.5
Lane length [m]	150, 200, 250

Street configuration	
Variable	**Values**
Number of directions [-]	1, 2
Number of lanes [-]	1, 2
Speed limit [km/h]	30, 50

PUDO attributes	
Variable	**Values**
Dwelling time [s]	30, 45, 60
PUDO frequency [veh/h]	12, 24, 36, 48, 60
Stop position [-]	beginning, middle, end
Curbside availability [-]	True, False

Demand levels	
Variable	**Values**
Eastbound flow [%]	40, 60, 80, 100
Westbound flow [%]	0, 20, 40, 60

Figure 1 Proposed values for independent variables

Combining all proposed values of the independent variables yields 17,280 scenarios. These scenarios were simulated using the open-source software Simulation of Urban MObility (SUMO).

Figure 2 illustrates an example of a simplified fictitious network used for the analysis. In this network, ride-hailing vehicles travel from west to east and perform a PUDO process somewhere along the central link. Private vehicles either go straight or turn right; left turns were excluded for isolation and simplification purposes.

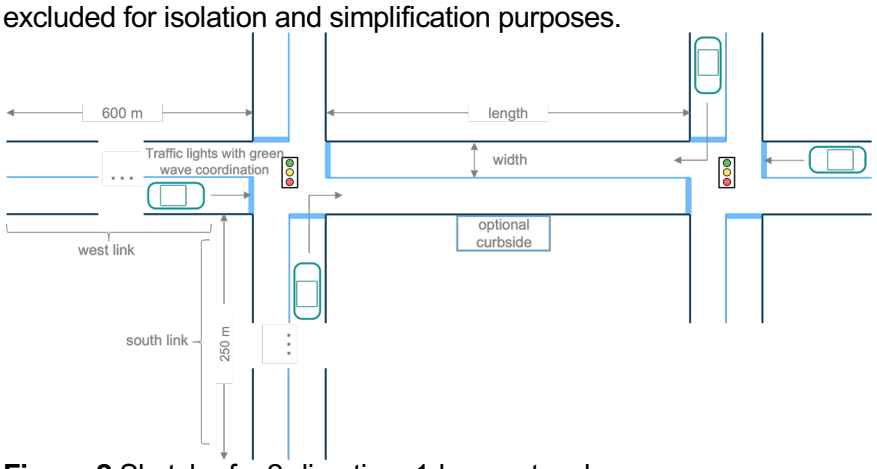

Figure 2 Sketch of a 2-direction, 1-lane network

The impact of the independent variables was assessed using three dependent variables related to traffic dynamics: speed, delay, and maximum waiting queue. Speed and delay were analyzed separately for private vehicles and ride-hailing vehicles. The maximum waiting queue was evaluated separately for the west and south upstream links, as shown in Figure 2.

Results

The results were grouped by the following types of street configurations: 1-direction with 1-lane, 1-direction with 2-lanes, and 2-directions with 1-lane. A random forest model was fitted to each configuration. According to the feature importance analysis, eastbound flow level and PUDO frequency were the two most influential variables across all three configurations. Figure 3 illustrates the relative importance of the independent variables for the 1-direction with 2-lanes configuration.

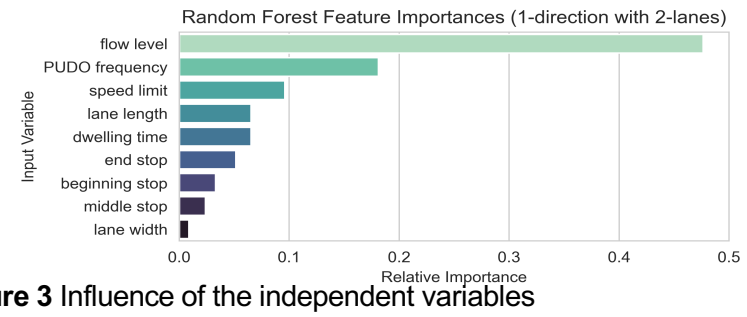

Figure 3 Influence of the independent variables

Figure 4 shows that for three PUDO frequency values, at least one scenario reached the hypothetical 600 m queue length, indicating a gridlock effect, which extends beyond the link level. Additionally, the mean maximum queue length is significantly higher than in the benchmark scenario without PUDOs (see bars for the 48 and 60 veh/h PUDO frequencies).

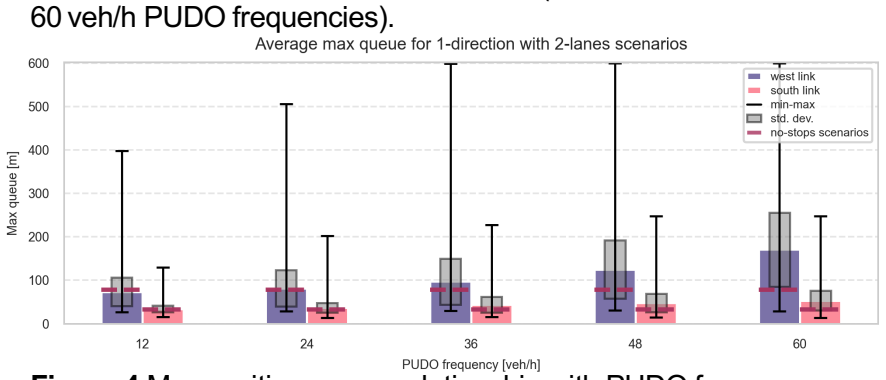

Figure 4 Max. waiting queue relationship with PUDO frequency

Table 1 shows the percentage differences between the stop and no-stop scenarios for the two most critical independent variables at their highest analyzed values. The waiting queue is the most affected by PUDOs, while speed is the least affected.

	Flow level results (900 veh/h)			PUDO freq. results (60 veh/h)		
Scenario	speed priv. veh. [%]	delay priv. veh. [%]	max. queue west [%]	speed priv. veh. [%]	delay priv. veh. [%]	max. queue west [%]
1-dir. 1-lane	-33	130	194	-41	250	339
1-dir. 2-lanes	-22	65	55	-19	95	120
2-dir. 1-lane	-29	102	162	-33	183	260

Table 1 Comparison between stops and no-stops scenarios

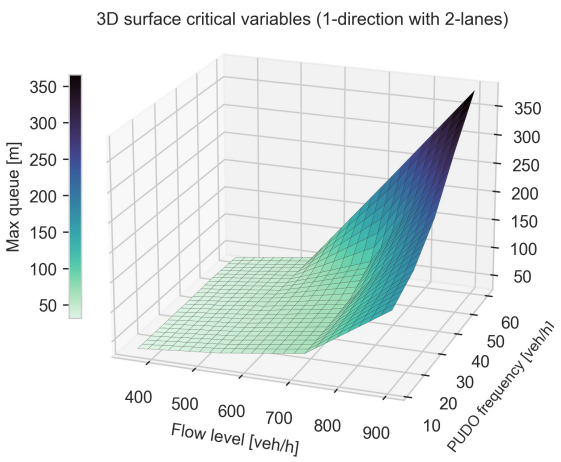

Figure 5 shows how the eastbound flow level and PUDO frequency interact with the maximum waiting queue on the west link. A non-linear relationship is observed, with a visible region of relatively low queue lengths, demonstrating that the right combination of values is critical.

Figure 5 Relationship between critical variables

Conclusions

Street configuration had a significant impact, as the possibility of overtaking considerably reduced the effects of PUDOs. Flow conditions determined how severe the impact of PUDO processes could be. The right combination of values may help mitigate their effect on traffic dynamics; however, under certain conditions, the impacts extend to a macroscopic level. The lane width variable did not show any significant influence in any street configuration.