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The influence of moving vehicle wakes on the effectiveness of roadside barriers in residential canyons utilising moving reference frames

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SUMMARY:
Traditional vehicular urban canyon models often overlook the kinetic energy contribution of moving vehicles, which can misrepresent flow conditions at pedestrian level. This research aims to investigate vehicle-induced airflows in residential canyons while maintaining computational complexity to a minimum using CFD simulations with a moving reference frame. Results show that traffic movement is the dominant driver of street-level air currents even at speeds as low as 30 km/h, inducing a lateral flow pattern rather than a standard urban canyon circulating vortex. The performance in attenuating such airflows of 0.5 m and 1 m high roadside barriers is then evaluated and results demonstrate that these barriers effectively shield pedestrian zones by disrupting the lateral flow. Under these symmetric, lateral conditions, roadside barriers exhibit higher reliability compared to their performance in standard urban canyon flows with negligible vehicle effects. These findings suggest that traffic movement must be integrated with aerodynamic assessments to accurately optimize urban microclimate interventions in areas of high traffic throughput.

Keywords: CFD, pedestrian urban canyon flows, vehicle induced flow, pedestrian comfort

1. INTRODUCTION AND LITERATURE SUMMARY

Flows in urban canyons have been analysed and established for decades (Hunter et al., 1990; Oke, 1987). These bodies of research have been important contributions towards the general understanding of pollutant transport(Abhijith and Gokhale, 2015), pedestrian comfort and safety (Blocken et al., 2012), building erosion (Tang et al., 2004), etc. However such studies often simplify the kinetic energy contribution from vehicle movements to cut down on computational complexity by assuming either very sparse or very congested traffic (Qin et al., 2025; Sacco et al., 2025). This research aims to investigate the airflow characteristics of residential traffic by simulating a simplified, translationally symmetric canyon. The computational complexity is greatly reduced by using a moving reference frame leveraging the translational symmetry of the geometry (Bhautmage and Gokhale, 2016). Such CFD infrastructure will then be the cornerstone in studying the aerodynamics of the microclimate in the pedestrian zones to answer critical questions and carry out further research regarding pedestrian comfort. Namely, the aim is to analyse the change in the pedestrian microclimate as a result of roadside barriers.

2. METHODOLOGY AND TEST CASES

The setup for this investigation involves a CFD simulation in OpenFOAM (OpenFOAM, 2026; Weller et al., 1998) running in steady-state with a RNG $k-\varepsilon$ turbulence model. The mesh geometries were defined to be translationally symmetric street-wise aided by cyclic boundary conditions at the cross-sections. The canyon dimensions are a square of sides 10 m and a roof width of 15 m as shown in Figure 1 (a). The moving reference frame is then implemented by a mesh translation paired with a moving wall composed of the ground and adjacent buildings both having velocity V_{vehicles}, while the vehicles were modelled as a generic Ahmed body (Ahmed et al., 1984). The traffic speed was varied and a 2 m/s freestream wind velocity at 33 m height was introduced over the buildings.

The application investigates 2 pairs of roadside barriers (one with square cross-sections of sides 0.5 m while the other is a 1 m high barrier of the same width) separating the street from the pedestrian zone. Like the walls and ground, these were defined to have a moving wall boundary condition of the same velocity. All the cases are summarised in Table 1. The simulations with the geometries as seen in Figure 1 will then be compared using a velocity profile within the pedestrian zone to assess and compare the effect of the inclusion of the barrier.

Table 1. A table detailing all the cases tested. The cases from 0 to 3 are according to the mesh displayed in Figure 1(a) and case 4 and 5 are according to the mesh displayed in Figure 1(b).

Case Number	V_{vehicles} (km/h)	Barrier height (m)	Barrier width (m)
0	30	0	0
1	40	0	0
2	50	0	0
3	60	0	0
4	40	0.5	0.5
5	40	1.0	0.5

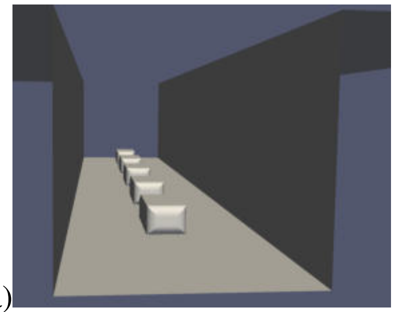
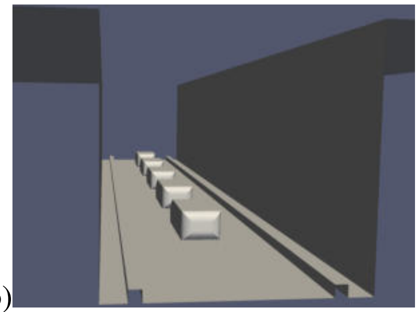
(a)  (b) 

Figure 1. The geometry of the canyon being simulated where **(a)** shows the urban canyon and the vehicles and **(b)** shows the same canyon but with the inclusion of the roadside barriers of case 4.‘

3. RESULTS

Unlike simulations where vehicular effects can be considered negligible, the case when there is frequent and moving traffic describe a different picture of the flow conditions in a street canyon. Primarily, the kinetic energy contribution of the vehicles becomes the dominant driver of the air currents. As can be seen in Figure 2, the higher the vehicle velocity V_{vehicle} relative to the flow velocity in the canyon stationary reference frame $U_{\text{stationary}}$, the greater the effect on the flow and the larger it is compared to the atmospheric wind from the freestream.

With regards to the roadside barriers, the dominant vehicular effects simplify their design process by turning it into a symmetric problem instead of needing to account for different flow conditions between leeward and windward sides (Sacco et al., 2025). The flow being almost exclusively horizontal also provides the ideal conditions since it’s easier to work with than vertical flow as seen in Figure 3. Both in the case of wind comfort and pollutant control, roadside barriers will become inherently more effective when the traffic can move freely. However a more thorough analysis would need to be carried out to support such an extended conclusion.

This impact of the roadside barrier on the pedestrian microclimate is most clearly demonstrated by comparing the velocity profiles of Case 1 (no barrier), Case 4 (0.5 m solid barrier) and Case

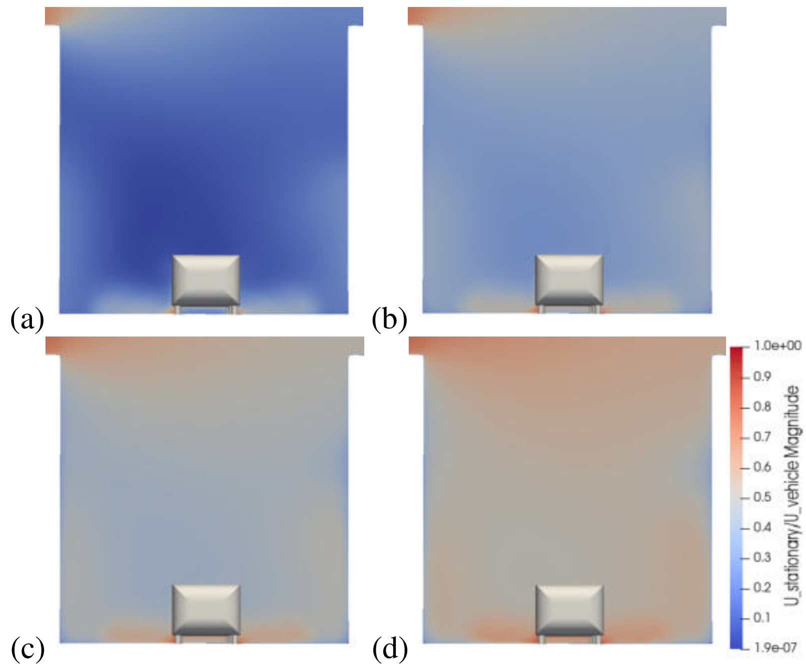


Figure 2. The contour plot of the ratio $U_{\text{stationary}}/V_{\text{vehicle}}$, where $U_{\text{stationary}}$ is the magnitude of the stationary air velocity and V_{vehicle} the magnitude of the traffic velocity. Where V_{vehicle} is **(a)** 30 km/h, **(b)** 40 km/h, **(c)** 50 km/h, **(d)** 60 km/h.

5 (1 m solid barrier) all at a vehicle speed of 40 km/h, whose flow field is displayed in Figure 3 as well as the probe lines. As shown in Figure 4(b) and Figure 4(c), the y-component of the velocity in the pedestrian zone is significantly mitigated by the presence of the barrier. While the no-barrier case exhibits a continuous increase in velocity magnitude with height, the solid barrier maintains near-zero velocity up to approximately 1 m, effectively shielding the lower pedestrian zone from the direct incoming vertical flow generated by traffic. The x-component profiles in Figure 4(a) further highlight this flow disruption; the barriers induce a positive, outward velocity peak at lower heights (< 0.75 m) before letting the flow of the wake in, compared to the no-barrier case. These profiles support the hypothesis that the barrier provides a consistent protective "shadow" at typical pedestrian heights, supporting the conclusion that such passive measures are highly effective under the symmetric, vehicle-dominant flow conditions identified.

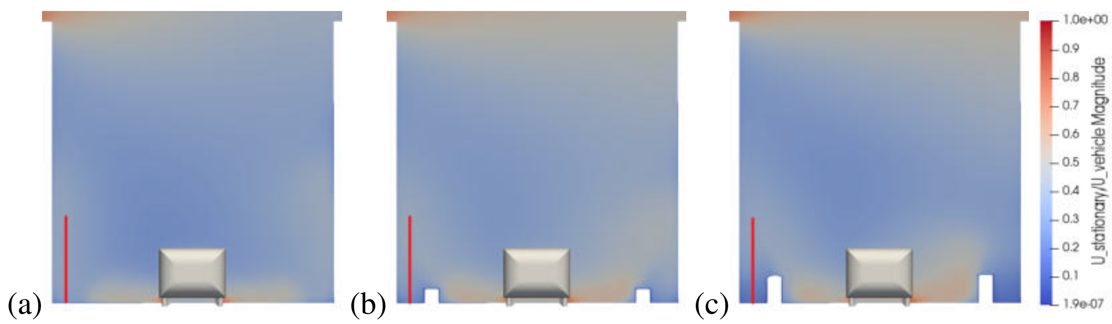


Figure 3. The contour plot of the ratio $U_{\text{stationary}}/V_{\text{vehicle}}$, where $U_{\text{stationary}}$ is the magnitude of the stationary air velocity and $V_{\text{vehicle}} = 40$ km/h the magnitude of the traffic velocity. (a) shows the flow without a barrier, (b) shows the flow with a0.5m barrier, and (c) shows the flow with a 1 m barrier. The red line indicates the location of the probe line.

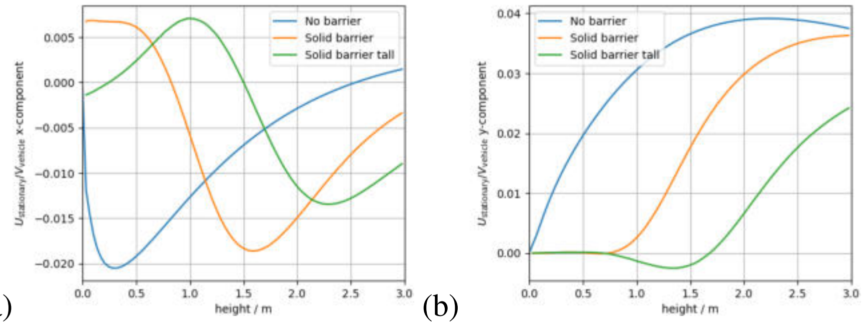


Figure 4. The components of the velocity profiles comparing a no-barrier case in blue with the case with a solid 0.5 m by 0.5 m barrier in orange along the height 0.5 m away from the wall within the pedestrian zone. Green is a similar barrier but 1 m high. This is the case of the leeward side and the windward side was omitted due to symmetry. Both cases have vehicle speeds of 40 km/h. **(a)** shows the *x*-component and **(b)** shows the *y*-component.

4. DISCUSSION AND CONCLUSION

The following main conclusions can be drawn from this study:

- Compared to the slow-moving traffic approximation, including vehicle induced flows has a drastic effect on the flow environment experienced at street level with even slow speeds making vehicles the dominant source
- Rather than the typical canyon circulating vortex, flows in high traffic streets exhibit a lateral flow pattern outward from the middle of the street.
- Roadside barriers show more invariant and reliable performance when such symmetric vehicular effects are included, compared to the circulating flow of the slow-moving traffic approximation.
- As a consequence of the higher reliability, it can be inferred that roadside barriers are more impactful in streets that exhibit such conditions.

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