



## Some Design Considerations for Moped-dominating Suburban Bridge – The Safe Systems Approach for Mixed Car-Moped Flow

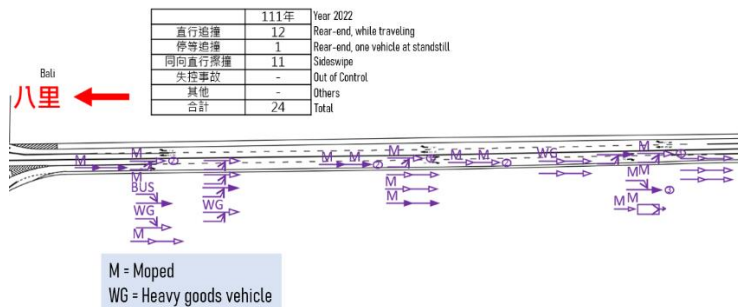
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Designing the cross-sections for roads with mixed car and moped traffic flow has been challenging in many Asian cities. Founded on the assumption of serving cars on Guandu Bridge in Suburban Taipei, the lane-based design has been deployed for the past 41 years. However, the bridge's 14-metre-wide four-lane carriageway with a speed limit of 30km/h is plagued by intermodal collisions of mopeds and cars, possibly resulting from the original design for *all-car* traffic that has never matched the actual flow composition.



This study aims to increase the safety of roads with mixed flow by redesigning the cross-section serving high volumes of moped and car traffic. Applying *Safe System Approach* and *Self-Explaining Roads*, crucial questions and their corresponding results/discussions are listed below.

(Q1) Should mopeds be treated as vulnerable road users (VRUs)? If mopeds are viewed as VRUs, then a 30km/h limit should be enforced for road sections with mixed flow, whereas 50 km/h and above is possible only when two modes are physically separated.

Safe System Approach (ITF, 2016) -	Road Design Policy
<ul style="list-style-type: none"> <li>• Principle 2- limited physical ability of human body.</li> <li>• Principle 3- A shared responsibility.</li> </ul> Aspirational operating speeds (ECMT, 2006): <ul style="list-style-type: none"> <li>• 30 km/h - Where there is the possibility of a collision between a vulnerable road user and a passenger vehicle.</li> </ul>	<ul style="list-style-type: none"> <li>• 30 km/h if VRU and motor vehicles are mixed.</li> <li>• 50 km/h if VRU can be separated from motor vehicles.</li> </ul>

The injury records suggest that mopeds should be treated as VRUs, although they are themselves motorised. The moped's injury rate is 0.750 [injuries/crash], which is significantly higher than that of other modes. Two policies are possible, but this study only focuses on the



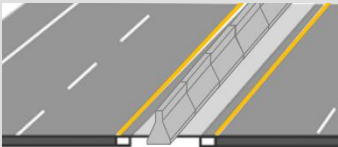
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30km/h design with mixed flow. Another treatment, physical separation of the mopeds by exclusive paths, is not within the scope.

Mode	Number of Crashes (2022)	Number of Injuries (2022)	Injury rate [injuries/crash]
Moped	120	90	0.750
Car	89	14	0.157
HGV	28	5	0.179

(Q2) What separation type shall be offered for a two-way 30km/h bridge with a mixed flow of mopeds and cars?

The first step is determining centre directional separation. High-profile concrete barriers and flexible barriers should not be considered since they are not self-explaining for 30 km/h roads. They impress the road users that the driving environment would be 70km/h and above and may cause the users to inappropriately adopt a higher-than-expected speed.

Self-Explaining Roads	Road Design Policy High-profile concrete barriers & flexible barriers should only NOT be placed on low-speed roads to offer a self-explaining environment.
Aspirational operating speeds (ECMT, 2006): • 70 km/h - Where there is the possibility of a head-on collision between passenger vehicles.	Road Design Policy High-profile barriers aim to prevent head-on collisions of 70 km/h and above. 

Then, consider the features of mixed mopeds and 4(& above)-wheelers. The major feature of mixed-flow traffic is the number of sideswipe collisions. Since many mopeds travel in between vehicles, inattention of either the car or the moped user would cause a sideswipe collision, and this is a sharp contrast to homogeneous traffic, whose sideswipe collisions happen only after lane departure. Notably, when a road user is aware of a potential sideswipe, the lateral evasive behaviour can revert the crash course. Such evasive actions may illegally infringe the opposite direction's right-of-way, but they may produce a safe outcome. As such, the barriers, albeit preventing head-on collisions, also undesirably produce nonrecovery for near-sideswipe events lacking an evasive course. Notably, such a feature is specific for the moped-car mixed flow traffic, but not reported in car-dominating environments.

Directional Separation	Appropriateness & Discussion
High-profile concrete barrier & Flexible barrier	<b>Should NOT be used</b> <ul style="list-style-type: none"> <li>▪ <b>Not Self-Explaining for 30km/h Road.</b> Inviting unsafe road usage: road users may perceive high-profile concrete barriers as speeding-welcoming invitations.</li> </ul>
[C]Low-profile concrete barrier	<b>Appropriate, with some risks on same-direction sideswipe.</b> <ul style="list-style-type: none"> <li>▪ <b>Pro-</b> Eliminate users' lane departure errors causing intermodal head-on.</li> <li>▪ <b>Risk-</b> Cannot revert a near-sideswipe since no evasive path of infringing the centre line possibly to avoid a sideswipe.</li> </ul>
[D]Delineator Posts	<b>Less appropriate, with risks on same-direction sideswipe and head-on.</b> <ul style="list-style-type: none"> <li>▪ <b>Pro-</b> Eliminate the intermodal head-on caused by intentional violation of the centre line, but not eliminate the head-on caused by errors.</li> <li>▪ <b>Risk-</b> Intermodal head-on with unintentional cross of centreline.</li> <li>▪ <b>Risk-</b> Cannot revert a near-sideswipe since no evasive path of infringing the centre line possibly to avoid a sideswipe.</li> </ul>
[E]Sole markings	<b>Appropriate, with risks on lane departure head-on.</b> <ul style="list-style-type: none"> <li>▪ <b>Pro</b>—Inter-modal sideswipes may be avoided if there is some infringement in the opposite direction to revert the near-sideswipes.</li> <li>▪ <b>Risk-</b> Potential of inter-modal head-on collisions.</li> </ul>



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(Q3) How can self-explanatory cross-sections for mixed-flow traffic be offered? The experience of the standard or narrow lanes may cause severe outcomes when a moped collides with others in between another vehicle (or even an HGV) and the kerbside barrier. On the other hand, a lane that is too wide welcomes inappropriate use and is, therefore, non-self-explaining. Dashed lane markings softly separate the modes, which may create more self-explanatory usage of where mopeds and cars shall be and concurrently not offer too wide a lane for cars. The final suggestion for the cross-section is shown (figures below) - The ideal cross-sections are Type D-1 and Type E-1, offering self-explaining spaces along the kerbside and or even in between lanes for mopeds. A compromise form E-2 can be used should the responsible agency hesitate to place “between-lane” spaces. It seems unreasonably wide (3.25m) for 30(km/h)-imposed car-dominated traffic, but considering the filtering behaviour of the mopeds, it creates some safety margins for the mopeds, at the expense of car users’ perception - misinterpreting as a higher-speed-limit road.

The proposed design is at its conceptual stage. The follow-up study can be designed with the following tasks: (1) acquiring potential users’ responses via questionnaire and (2) testing the potential users’ behaviour via driving simulators.

