

Operational Assessment of Speed Priority for High-Occupancy Vehicle Lanes over General-Purpose Lanes

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Abstract: Current guidelines arguably do not properly address how much priority high-occupancy vehicle (HOV) lanes should be over general-purpose (GP) lanes. In response to this issue, this study developed a scheme to measure HOV speed priority via mathematical derivation. The concept of vehicle occupancy was incorporated to reflect the HOV core value — carrying more persons in fewer vehicles. As traffic increases, the scheme leads to HOV lanes' speed increasingly greater than GP lanes'. Contrasts were made between the proposed scheme and the conventional travel time saving principle. Two case studies were implemented; the local one indicates that Taiwan's first HOV lane was under-prioritized while the foreign one shows that the HOV lane of SR-60 in California was well-prioritized. The results can be used to further assess the necessity of HOV policy adjustment.

Keywords: High-Occupancy Vehicle Lane, Average Vehicle Occupancy, Travel Time Saving, Freeway Operations

1. INTRODUCTION

High-occupancy vehicle (HOV) priority can benefit transit and ridesharing users, and encourages shifts from single-occupancy vehicles to HOV travel modes to improve traffic performance (VTPI, 2014). HOV facilities are popular in the United States, and yet they can be found in Asian countries including Taiwan, South Korea, and Indonesia. Performance evaluations based on specific volume or speed criteria are essential to HOV operations. Such evaluations analyze how well HOV facilities achieve different goals, e.g., efficiency, safety, etc. Performance criteria for HOV facilities have long been documented under various guidelines. For example, identical to the guideline provided in the Washington State's policy (WS DOT, 1991), the Transportation Research Board (TRB, 1998) suggests that the HOV lane should carry more people in fewer vehicles than adjacent general-purpose (GP) lanes. The TRB (1998) also proposed a minimum threshold of 400 to 800 vehicles per peak hour per lane (vphpl), and 1,200 to 1,500 vphpl for the degrading thresholds on concurrent HOV facilities. In contrast, the American Association of State Highway and Transportation Officials (AASHTO, 2004) set the high end of the maximum volume ranges for most HOV facilities at 1,600 vphpl. The California Department of Transportation (Caltrans, 2003) gauges HOV facilities with desired volume utilization between 800 and 1,650 vphpl, for a minimum of 1,800 persons per peak hour per lane (pphpl). In addition, speed and time saved are commonly used performance measures. The "Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users" (SAFETEA-LU, 2005) considers that HOV facilities' effectiveness is degraded if the average vehicle speed is less than 45 mph in one or both of the peak hours, for more than 18 out of 180 days, which is similar to the WS DOT guideline (1991). The TRB (1998) and Caltrans (2003) suggest that HOV facilities save at least 1 min per mile and a total of 5-10 min compared to GP lanes.

The above criteria, however, are insufficient for evaluating freeway operations. First, the “1 min saved per mile” principle is not applicable for extensive traffic conditions. For instance, to comply with this principle, a speed of 40 mph in a GP lane will require an impossibly high HOV lane speed of 120 mph. This principle should be only for GP lane speeds of less than 35 mph, with corresponding HOV speeds less than the legitimate maximum speed of 80 mph. Second, consider two speed pairs for HOV and GP lanes reported on a highway: (65, 64) and (65, 55) mph. The (65, 64) mph pair presents good traffic conditions, but the HOV lane barely offers any time saving incentive compared to the (65, 55) mph pair. The HOV lane users would think that the (65, 55) mph pair is an adequate condition, whereas the GP lane users would expect that the (65, 64) mph pair is more reasonable. The existing guidelines do not provide an explanation for this discrepancy. In addition, as Taiwan launched its first and the only freeway HOV lane in 2013, there has been a concern about how much the authority should prioritize HOV lanes over GP lanes.

The objective of this study is thus to address the above issues. HOV priority is presented based on speed because, for operational aspects, it measures mobility and time saved, and for monitoring aspects, speed is accessible to motorists and most traffic management centers. A new scheme was developed via mathematical derivation to complement the existing guidelines; it can determine (1) under-prioritized HOV, which indicates that the HOV speed is too slow, (2) well-prioritized HOV, which indicates that the HOV and GP lanes are at “speed balance,” and (3) over-prioritized HOV, which indicates that the GP lane speed is too slow.

2. VEHICLE OCCUPANCY SCHEME

The person throughput of HOV facilities is a major concern for transportation authorities (Chang *et al.*, 2008). Ideally, HOV speed priority is secured because of higher person movement capacity via greater average vehicle occupancy, or *AVO*, relative to GP lanes. In this scenario, speed priority is defined to increase with *AVO*, or more specifically, to be proportional to *AVO*, as shown in Eq (1).

$$P_{ln}^s = AVO_{ln} f(X) \propto AVO_{ln} \quad (1)$$

where P_{ln}^s is the speed priority and ln denotes HOV and GP lanes respectively. P_{ln}^s is a function of the lane-related variable, AVO_{ln} , and the lane-independent variable set, X , such as speed limits, geographic elements, etc. Eq. (1) recognizes speed priority granted in the following order: bus lanes, HOV3+ lanes, HOV2+ lanes, and GP lanes.

The maximum priority occurs when the lane operates at about the free flow speed ffs , whereas the minimum priority occurs at the jam speed S_j . The greater the difference between the average speed S_{ln} and the free flow speed, the lower the speed priority, as expressed below:

$$P_{ln}^s = \frac{1}{ffs - S_{ln}} g(X), \text{ for } S_j \leq S_{ln} < ffs \quad (2)$$

Eq. (2) indicates that speed priority of a lane is about 0 when ffs is much greater than S_{ln} , and is close to infinity if traffic operates around ffs . The priority relationship between HOV and GP lanes is thus as follows:

$$\frac{P_{hov}^S}{P_{gp}^S} = \frac{ffs - S_{gp}}{ffs - S_{hov}} = \frac{AVO_{hov}}{AVO_{gp}} = R \quad (3)$$

Eq. (3) highlights that greater AVO_{hov} would provide the HOV lanes with more priority in terms of greater speed, or moderate the GP lanes with less priority in terms of lower speed, and vice versa. The AVO ratio R can be obtained via regular HOV surveys. In California, for example, bus volumes are relatively low, and motorcycles and hybrid vehicles are allowed to use HOV lanes without the occupancy constraint; R was generally found to be approximately 2 and 3 for HOV2+ or HOV3+ lanes, respectively (Caltrans District 4, 2009; Caltrans District 7, 2011). In Taiwan, on the other hand, the first and the only HOV3+ lane at the National Freeway No.1 has more buses than the freeways in California, making a potentially greater R for the HOV3+ lane. With the AVO ratio, we can turn Eq. (3) as follows:

$$S_{hov} = \frac{S_{gp} + ffs(R-1)}{R} \quad (4)$$

HOV and GP lanes are regarded as well-prioritized if both speeds comply with Eq. (4); the corresponding values are called balanced speeds. Otherwise, either HOV or GP lanes are over-prioritized because of the mismatched speeds; this affects their contributions to person movement. The scheme derived from the concept of vehicle occupancy can be associated with the Greenshield's speed-density (S - K) relationship: $S_{ln} = \alpha K_{ln} + ffs$. If we substitute Eq. (3) with the S - K equation, we can find that:

$$\begin{aligned} \frac{ffs - S_{gp}}{ffs - S_{hov}} &= \frac{-\alpha K_{gp}}{-\alpha K_{hov}} = R \\ K_{gp} &= K_{hov}R \end{aligned} \quad (5)$$

Eq. (5) actually echoes the core value of HOV lanes, i.e., carrying the same amount of persons by fewer vehicles than GP lanes. This scheme prioritizes the lanes based on person transport instead of vehicle traffic. In the balanced status, the speed difference between the two lanes increases with the AVO ratio and free flow speed, but decreases when either speed goes up, i.e.,

$$\begin{aligned} \Delta S &= S_{hov} - S_{gp} \\ &= (R - 1)(ffs - S_{hov}) \\ &= \left(1 - \frac{1}{R}\right)(ffs - S_{gp}) \geq 0 \text{ for } R \geq 1 \end{aligned} \quad (6)$$

Based on Eq. (4), Figure 1 further identifies the relationship between the HOV speed, GP lane speed, and AVO ratio, given the general freeway traffic settings in Taiwan: S_{hov} and S_{gp} from 0 to 110 km/h, R from 1 to 5, and ffs of 110 km/h. The lines and curves represent the status that the HOV lane is well prioritized. Such a scheme has the following characteristics:

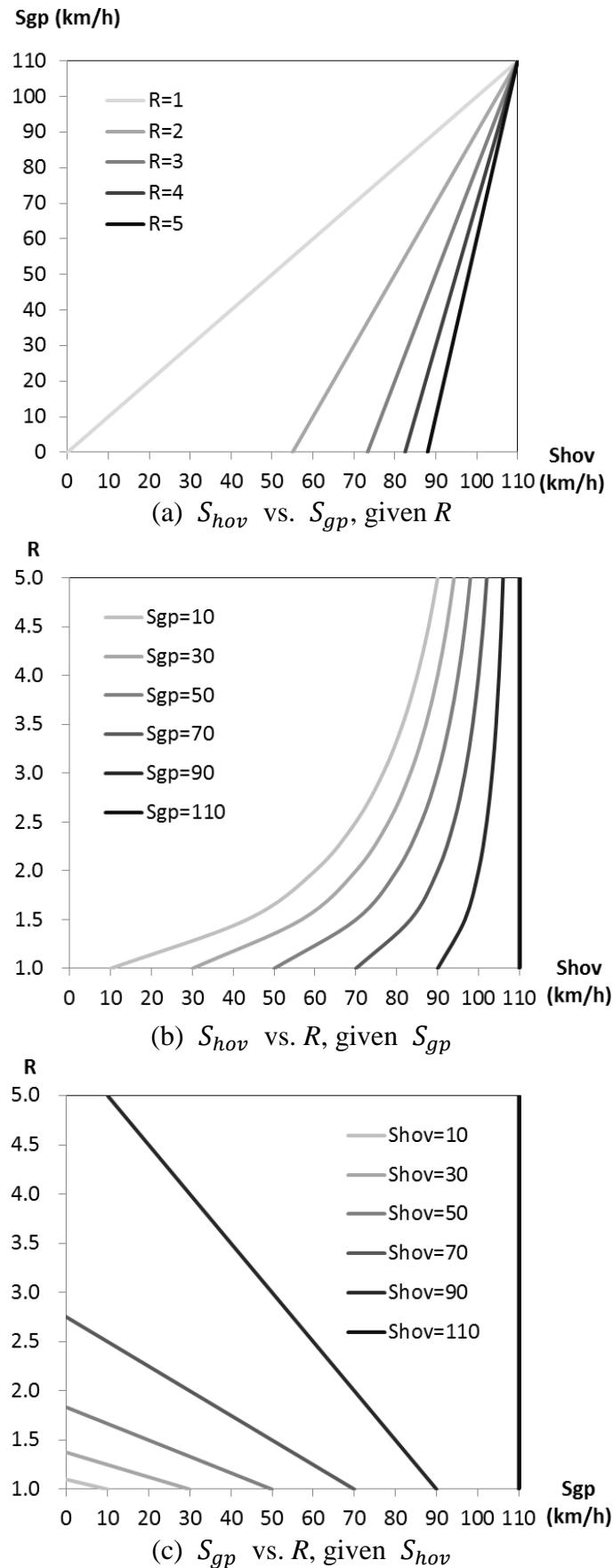


Figure 1. Relationships between different variables under the vehicle occupancy scheme

- 1) Since $R \geq 1$, if the HOV and GP lanes reach speed balance, S_{hov} is not less than S_{gp} , as shown in Figure 1(a). In other words, no HOV priority is granted when $R = 1$, but significant priority would be appropriate for a bus lane with a great R .
- 2) Also in Figure 1(a), the left side of the lines indicates that either S_{hov} is less than its balanced speed due to the over-utilized HOV lanes, or S_{gp} is greater than its balanced speed due to the under-utilized GP lanes. The right side denotes the opposite. No matter what R is, S_{gp} and S_{hov} converge toward 110 km/h and S_{gp} always starts at 0 km/h.
- 3) As shown in Figure 1(b), the curves toward the right axle demonstrate that the HOV priority increases with R . Given $S_{gp} = S_{gp}$, the curves possesses increasing positive slope of $(ffs - s_{gp})/(110 - S_{hov})^2$, and become a vertical line for the extreme condition of $S_{hov} = 110$ km/h.
- 4) As shown in Figure 1(c), the lines toward the left axle signifies that the priority of the GP lanes decreases with R . Different from Figure 1(b), the lines possesses negative slope, and become a vertical line for the extreme condition of $S_{gp} = 110$ km/h.

In addition to the above three variables, the free flow speed could vary with different freeway sections from 110 km/h to 80 km/h that alter the relationship between S_{hov} , S_{gp} , and R . In fact, when ffs is less than 110 km/h, the lines in Figure 1(a) will shift in parallel toward the axle of S_{gp} , or toward the axle of S_{hov} if otherwise. Figure 2 exemplifies a free flow speed change from 110 km/h to 80 km/h. All of the characteristics previously mentioned will be in different scales but identical trends. The proof of the difference is trivial and thus neglected.

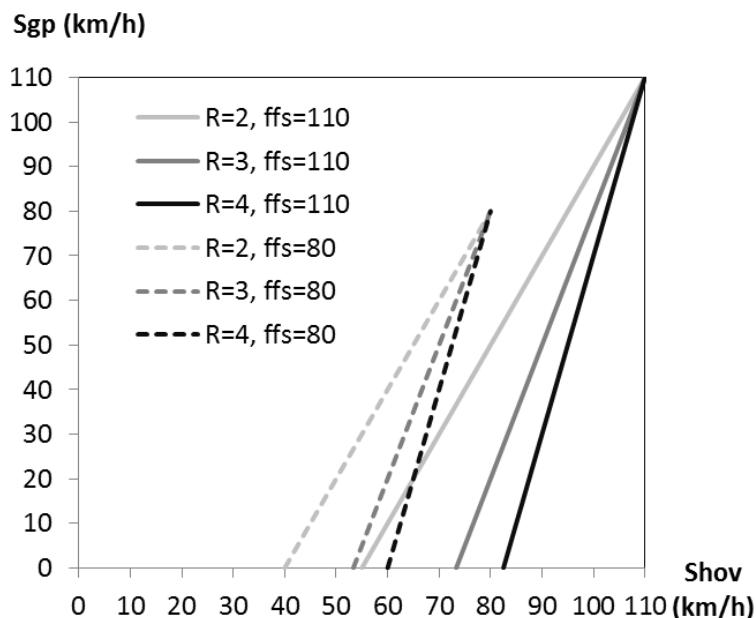


Figure 2. Balanced speed regarding different ffs under the vehicle occupancy scheme

The concept of speed balance is primarily about mobility, leaving the travel reliability issue unsolved. Therefore, speed dispersion is used to measure travel reliability. Chung and Recker (2014) associated speed dispersion with speed, as shown in Eq. (7); this allows using speed to describe mobility and reliability at once. To be specific, a typical indicator of speed dispersion—the coefficient of variation of speed—is adopted. The relationship presented by Eq. (7) can distinguishes whether HOV lanes are more reliable than GP lanes when the speed pairs reach balance under the vehicle occupancy scheme.

$$\begin{aligned}\Delta D_s &= D_s^{hov} - D_s^{gp} \\ &= 36.2e^{-0.023S_{hov}} - 51.6e^{-0.026S_{gp}}\end{aligned}\quad (7)$$

where ΔD_s is the difference of speed dispersion between the HOV and GP lanes; D_s^{hov} and D_s^{gp} are the speed dispersion in terms of the coefficient of variation (in %) of HOV lane speed and GP lane speed, respectively. Three presumed criteria, $\Delta D_s \leq 0$, -5%, -10%, are used for the illustration purpose. As shown in Figure 3, when the HOV and GP lane reach the speed balance, $\Delta D_s \leq 0$ or $D_s^{hov} \leq D_s^{gp}$ can be fulfilled regardless of the values of AVO ratio R . In other words, speed dispersion of the HOV lane is always less than that of the GP lanes. However, should $\Delta D_s \leq -5\%$ be applied to the scheme, once S_{hov} is greater than 86 km/h or S_{gp} is greater than 63 in the case of $R = 2$, the HOV speed dispersion would fail to meet the requirement. Similarly, should $\Delta D_s \leq -10\%$ be applied to the scheme, once S_{hov} is greater than 95 km/h or S_{gp} is greater than 50 in the case of $R = 4$, the HOV speed dispersion would fail to meet the requirement, neither.

According to the 2011 Highway Capacity Manual in Taiwan, dual measures are used for level of service (LOS) of freeway basic sections. One is the ratio of volume to capacity (V/C), and the other one, to some extend for reliability, is the difference between the average speed and speed limit, as shown in Table 1. For example, the LOS of a freeway basic section is “B3” if its V/C is 0.35-0.6 and speed difference is 11-15 km/h. Since speed is the theme of this study, not V/C but speed difference is adopted as the LOS measure. LOS 1-6 in Table 1 are then converted back to A-F for general recognition. Ideally, an HOV lane should typically keep in a free flow state (e.g., LOS no worse than C), and GP lanes would be relatively congested (e.g., at LOS inferior to the HOV’s); this will encourage motorists to carpool. When simultaneously considering mobility in terms of speed balance or Eq. (4), reliability in terms of ΔD_s or Eq. (7), and LOS in terms of speed difference or Table 1, we can find that the preferred condition only accounts for a small portion of the Figure 4 (the upper right corner).

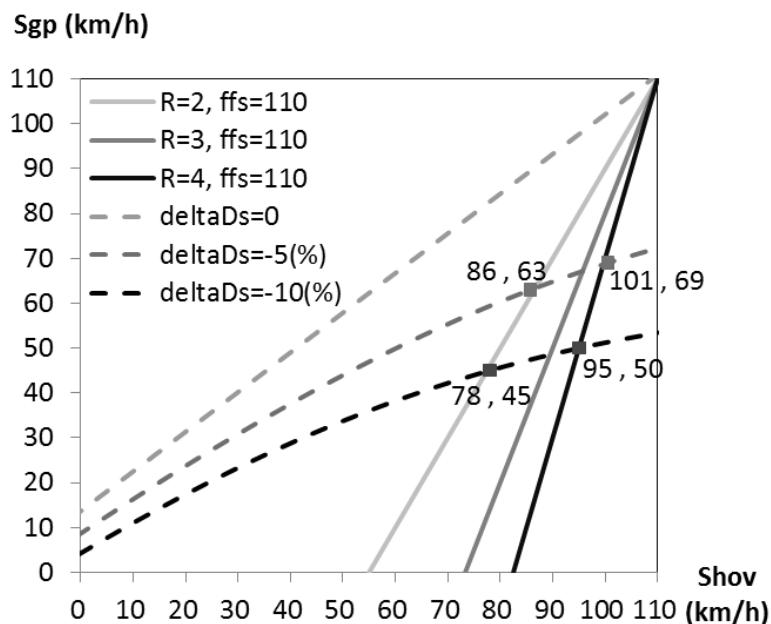


Figure 3. Speed dispersion and balanced speed under the vehicle occupancy scheme

Table 1. Level of service (LOS) criteria

LOS	Volume/Capacity	LOS	Difference between the mean speed and speed limit (km/h)
A	≤ 0.35	1	≤ 5
B	0.35~0.60	2	6~10
C	0.60~0.85	3	11~15
D	0.85~0.95	4	16~25
E	0.95~1.00	5	26~35
F	> 1.00	6	> 35

Source: Lin, K. S., et al, 2011 Highway Capacity Manual in Taiwan.

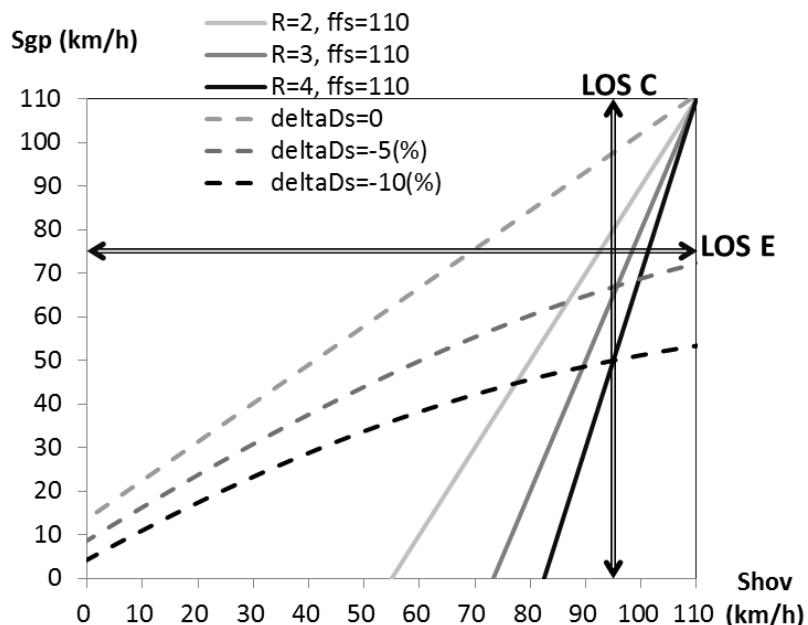


Figure 4. Relationships between speed balance (solid lines), speed dispersion (broken lines), and LOS

By contrast, we employ another commonly used measure, travel time saving, to evaluate the lane relationship because transportation professionals usually set a target value for time saving to ensure the competitiveness and effectiveness of an HOV facility. The existing HOV principle suggests that HOV facilities save at least 1 min per mile and a total of 5-10 min compared to GP lanes (TRB, 1998; Caltrans, 2003). Considered variables include S_{hov} , S_{gp} , travel time saving T (in min), travel distance L (in km), and additional time T_{add} (in min) that those HOV qualifiers, whether they are fampools or non-fampools, may potentially spend on waiting and/or detouring for carpool. To demonstrate the relationship between S_{hov} , S_{gp} , and T , the following traffic settings are used: T_{add} is 3 min, and L is approximately 38 km in southern California (SCAG, 2004) and 13 km in Taiwan (Wu, 2015). We set L as 19 km, corresponding to the length of the HOV lane in Taiwan. To save T min given T_{add} of 3 min and L of 19 km, the speed balance under the time saving principle becomes Eq. (8), as shown in Figure 5.

$$S_{hov} = \frac{1140S_{gp}}{1140 - (T+3)S_{gp}} \quad (8)$$

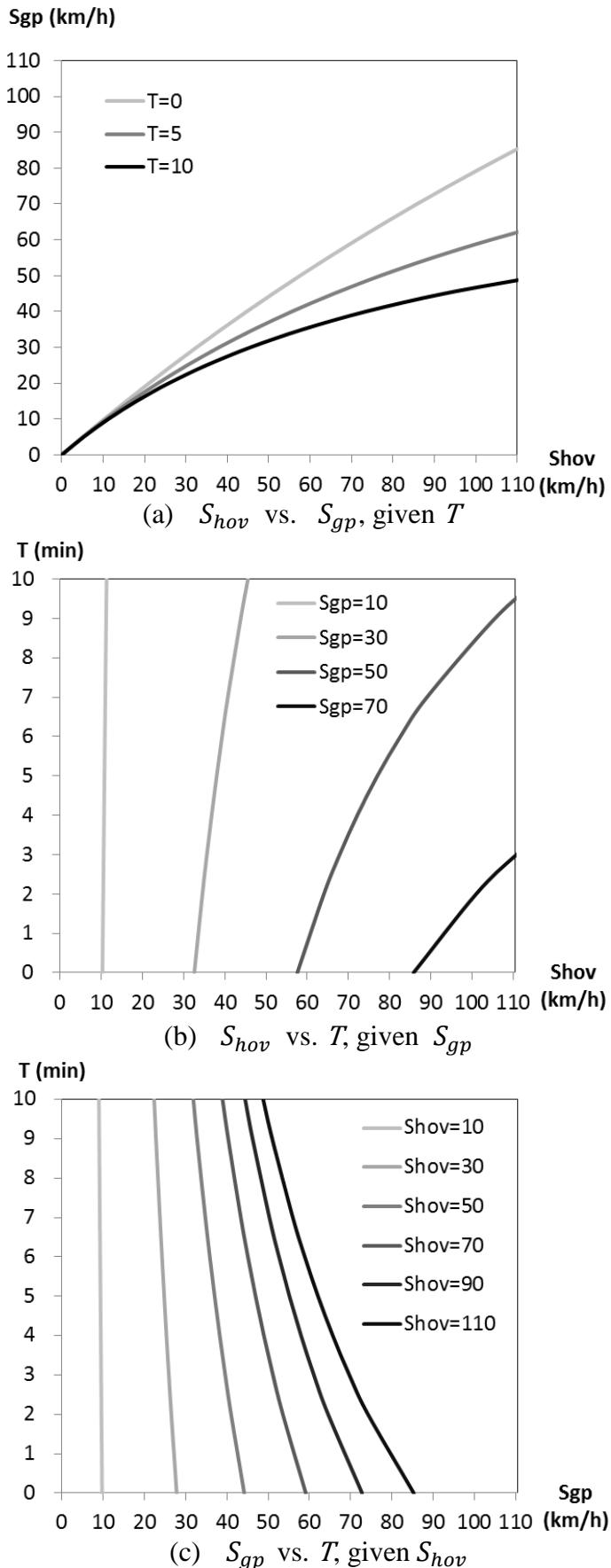


Figure 5. Relationships between different variables under the time saving principle

Figure 5 presents Eq. (8) in the boundary of S_{hov} and S_{gp} from 0 to 110 km/h, and T from 0 to 10 min. Although T is suggested in the guidelines be approximately 5-10 min, the scenario of $T=0$ is still included because some people (e.g., fampools) would carpool without the time saving incentive, or for some others, sharing the commuting expenses is the major concern. Some characteristics of Eq. (8) are listed as follows:

- 1) To sustain travel time saving and compensate the additional waiting/detouring time, S_{hov} is no less than S_{gp} when the HOV and GP lanes reach speed balance, as shown in Figure 5(a). Also, S_{hov} and S_{gp} perform non-linear relationships. To facilitate the application of the S_{hov} - S_{gp} relationship, two-stage linear approximation can be used as T increases.
- 2) S_{hov} and S_{gp} start at 0, and diverge to the right axle with S_{hov} of 110 km/h and S_{gp} of 85 km/h or less. As T increases, the speed difference ΔS ($= S_{hov} - S_{gp}$) increasingly goes up with S_{hov} .
- 3) In Figure 5(b), the S_{hov} - T curves perform positive slopes. However, when both S_{hov} and S_{gp} are small (e.g., ≤ 30 km/h), the balanced speed is not sensitive to travel time saving T . Afterwards, the speed difference increases with S_{hov} and T , given $S_{gp} = S_{hp}$.
- 4) In Figure 5(c), the S_{gp} - T curves perform negative slopes, signifying that S_{gp} decreases with T , given $S_{hov} = S_{gp}$.

In instances of different L or T_{add} from the exemplary values of 19 km and 3 min, the new curves will shift toward the axle of S_{hov} if a smaller L or a greater T_{add} is considered, as shown in Figures 6 and 7. It is self-explanatory that a smaller L or a greater T_{add} relies on greater S_{hov} to accomplish the targeted time saving. All of the characteristics mentioned above are valid, but on a different scale.

As for speed dispersion, similar to the vehicle occupancy scheme, the time saving principle would result in the HOV lane more reliable than the GP lanes. Given the identical relationships in Eq. (7) and the three criteria for ΔD_s , the balanced speed curves do not intersect $\Delta D_s = 0$ in Figure 8; this ensures that the speed dispersion of the HOV lane is less than that of the GP lanes. A greater T , or 10 min for example, would grant a smaller ΔD_s that is less than -10%, making the HOV lane even more reliable than the GP lanes. Back to Figures 6 and 7, a smaller L or a greater T_{add} would also leads to the same condition of a smaller ΔD_s .

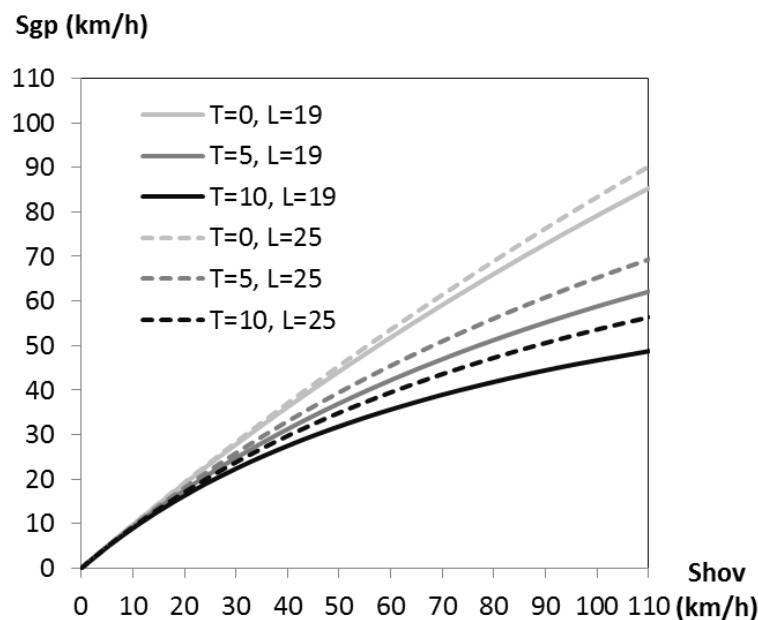


Figure 6. Balanced speed regarding different travel distance L

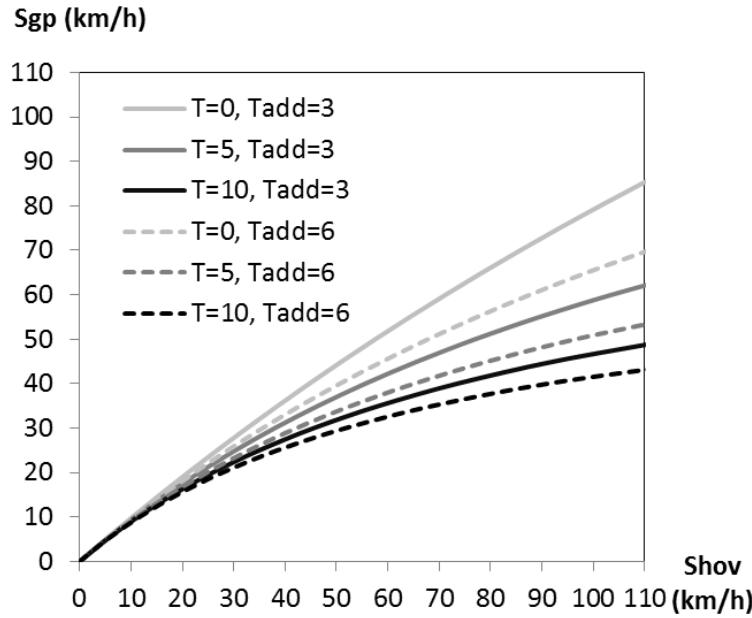


Figure 7. Balanced speed regarding different waiting/detouring time T_{add}

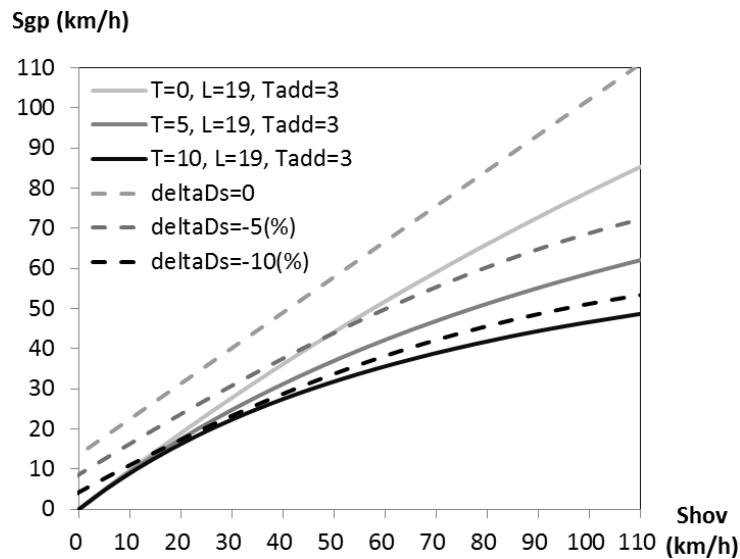


Figure 8. Speed dispersion and balanced speed under the time saving principle

3. DISCUSSION

The distinction behind the vehicle occupancy scheme and the travel time saving principle is obvious: the former, which can be regarded as equity-oriented, prioritizes HOV mobility and reliability based on the person movement capacity; whereas the latter, which can be regarded as policy-oriented, secures HOV incentives based on the time saving set by decision makers. Chung and Recker (2012) also proposed another two schemes regarded as utility-oriented. These schemes highlight the need for developing prospective tools that clarify how much HOV lane performance should be better than GP lanes. Depending on which is used, different results follow:

- 1) The balanced speed of the vehicle occupancy scheme features varied initial conditions but ends at the free flow speed, while that under the time saving principle starts at the jam

speed but ends up variously. In other words, the vehicle occupancy scheme treats HOV and GP lanes similarly during heavy traffic, but the time saving principle does the same during light traffic.

- 2) The speed difference between HOV and GP lanes increases with R , but decreases with S_{hov} and S_{gp} in the vehicle occupancy scheme. The speed difference increases with T , S_{hov} , and S_{gp} under the time saving principle.
- 3) The relationships between any two endogenous variables of the vehicle occupancy scheme are linear except for $S_{hov}-R$; the variables of the time saving principle, instead, are all nonlinear functions.

The vehicle occupancy scheme and the time saving principle also share some characteristics in common:

- 1) S_{hov} is greater than S_{gp} to ensure the HOV priority of mobility. Such priority of mobility simultaneously guarantees the HOV's travel reliability.
- 2) R and T both decrease with S_{gp} , but increase with S_{hov} .
- 3) S_{gp} is positively proportional to S_{hov} , for specific values of R and T .
- 4) Both ensure more consistent speeds in HOV lanes, relative to GP lanes.

To meet the time saving principle, GP lanes would generally be at LOS F throughout the entire traffic scheme, even when HOV lanes remain at LOS A with excess capacity. In such a case, however, freeway authorities may consider to turn the HOV lanes into high-occupancy toll (HOT) lanes. This, to some extent, explains the limitation of applying the time saving principle to HOV operations. The vehicle occupancy scheme, on the other hand, is free from the above concern and thus relaxes the limitation of the current HOV guidelines exemplified in the introduction.

To better understand what empirical traffic might reveal under the vehicle occupancy schemes, National Highway 1 (NH-1) in Taoyuan, Taiwan, and State Route 60 (SR-60) in Los Angeles, California, were selected for case study, as shown in Figure 9. Traffic data at 44.5 km northbound (NB) of NH-1 were collected from the National Freeway Bureau of Taiwan. A 19-km HOV3+ lane has been configured on NH-1 since 2013; the section has one innermost full-time HOV lane with limited access along with two GP lanes in each direction. As for the SR-60, traffic data at 17.0 mile westbound (WB) were retrieved from Performance Measurement System (PeMS, 2014). PeMS collects and analyzes real-time traffic data from over 39,000 detectors across the freeways in California. SR-60 has one 39-km HOV2+ lane westbound and one 66-km HOV2+ lane eastbound. Similarly, the innermost full time HOV lanes have limited access. Each direction of SR-91 primarily has four to five GP lanes.



Figure 9. Case study site (Left: NH-1, Taiwan; Right: SR-60, California)

Obviously, it would be ideal but difficult to comply exactly with the balanced speed conditions. Speed buffers, $S_{hov}^* = S_{hov} \pm \alpha$, are thus suggested for practical applications, where S_{hov}^* is the balanced HOV speed S_{hov} under Eq. (4) but with a tolerance of α . Let R respectively be 1, 2, and 3, ffs be 110 km/h, and α be 5 km/h, Figures 10 and 11 show the balanced speed buffer and S_{hov} - S_{gp} pairs of the study sites. The black dots are 5-min-based speed pairs from 6:00 through 22:00 on a weekday (April 1, 2014), and the white dots are those on a weekend (April 6, 2014). Each site has 192 black dots and 192 white dots. Those within the corresponding speed buffers indicate that the HOV lane is well prioritized, while those beneath/beyond the buffers indicate the HOV lane is over-/under-prioritized.

As shown in Figure 10, S_{hov} on average was close to S_{gp} , resulting in no travel time saving for using the HOV lane. The majority of the NH-1 speed pairs (74% on the weekday and 81% on the weekend) are within the speed buffer under $R = 1$. However, $R = 1$ is valid for per HOV lane with person throughput approximately the same as per GP lane. It is unlikely to happen in NH-1's HOV3+ lane. Instead, the speed buffer with $R = 3$ is more appropriate, but no speed pairs fall on this buffer. In other words, S_{hov} was lower than warranted, or the HOV lanes were under-prioritized. There are two possible reasons. First, the HOV motorists likely overestimated the travel time saved when using the HOV lane, and they chose to stay in the HOV lane without knowing the actual traffic conditions, as mentioned in previous research (SCAG, 2004; Liu et al., 2004). Second, certain dots falling beyond the diagonal indicate that the HOV lane had lower speeds than the GP lanes. These situations are not uncommon because HOV motorists can become "trapped" in the HOV lanes with limited egress/ingress points as a result of misjudgment, lane overflow, and/or slow vehicles that govern the HOV lanes (Varaiya, 2007). S_{hov} close to S_{gp} also implies that the HOV lane and per GP lane carried similar amounts of vehicles. Even during the heavy traffic condition, both speeds could remain at about 70 km/h and more. To differentiate S_{hov} from S_{gp} , the NH-1 HOV lane may possibly raise its occupancy requirement from three passengers and more (HOV3+) to four and more (HOV4+), especially on the weekend. This will cause fewer vehicles eligible for the HOV lane, and thus increase S_{hov} and decrease S_{gp} . As for SR-60 shown in Figure 11, the majority of its speed pairs (64-68% on the weekday and 61-68% on the weekend) are within the speed buffer under $R = 2$ and $R = 3$. According to the HOV annual report (Caltrans District 7, 2011), $R = 2$ fit the traffic condition of SR-60. Although 26-29% of speed pairs fall beneath the buffer of $R = 2$, and 10-11% beyond the buffer, SR-60 generally followed the vehicle occupancy scheme. The HOV was well-prioritized under the existing HOV settings.

The speed balance buffer can be used for HOV policy adjustments. In the case of NH-1, the HOV/GP lanes are under-/over-prioritized. The policy maker may adopt such measures as fewer HOV access points, stricter HOV eligibility requirements, or additional HOV lanes to increase HOV speeds. Contrarily, if the HOV/GP lanes are over-/under-prioritized, like the certain situations of SR-60, adverse measures and high-occupancy tolls (HOT) may apply to enhance lane utilization. Should most speed pairs be less than a specified level, e.g. 70 km/h, the above-mentioned lane management measures will not be able to sustain appropriate traffic operations. More aggressive alternatives should be considered, such as developing public transit, adding new lanes, toll roads (instead of just toll lanes), and so on. Finally yet importantly, it should be noted that the assessment (1) does not intend to analyze lane choice behaviors, (2) is not for HOT lanes because the speed is justified by tolls; and (3) is used for the HOV operational stage. As for the planning stage, HOV lanes serve as an effective Transportation Demand/Supply Management (TDM/TSM) measure regardless of potentially being under- or over-prioritized in the operational stage.

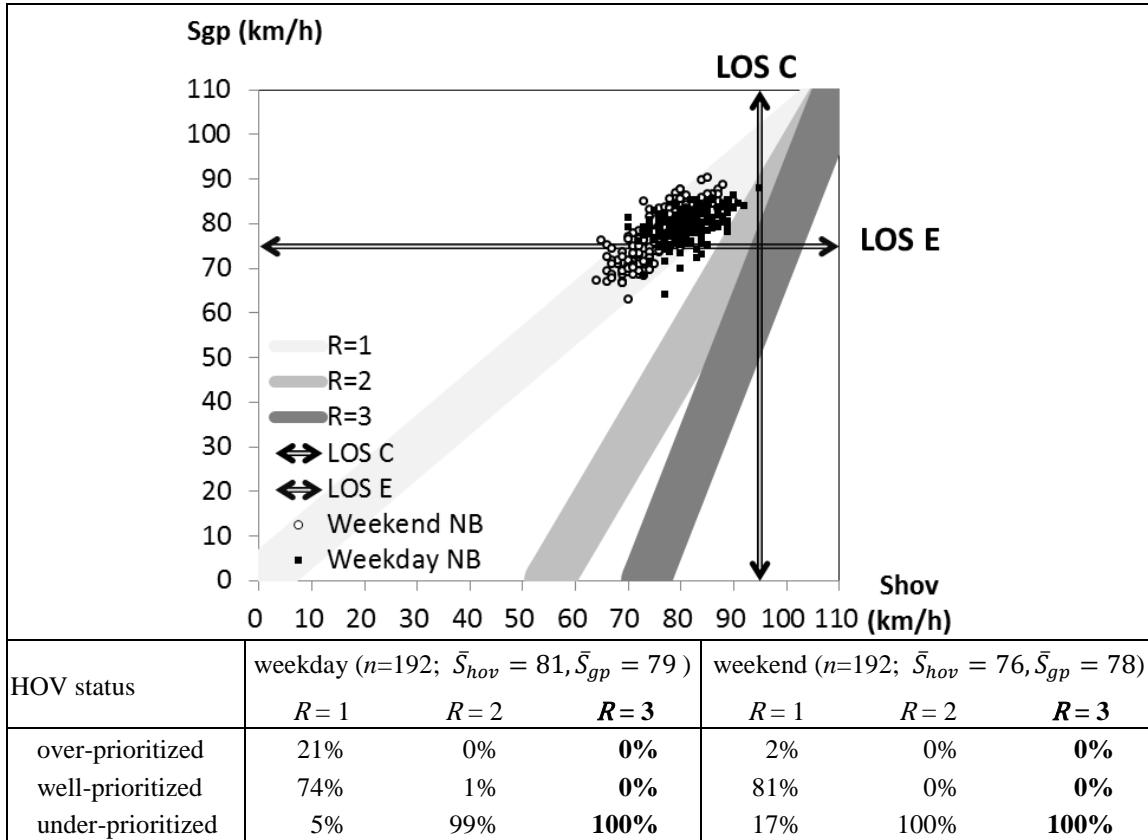


Figure 10. Empirical NH-1 NB speed performance under the vehicle occupancy scheme

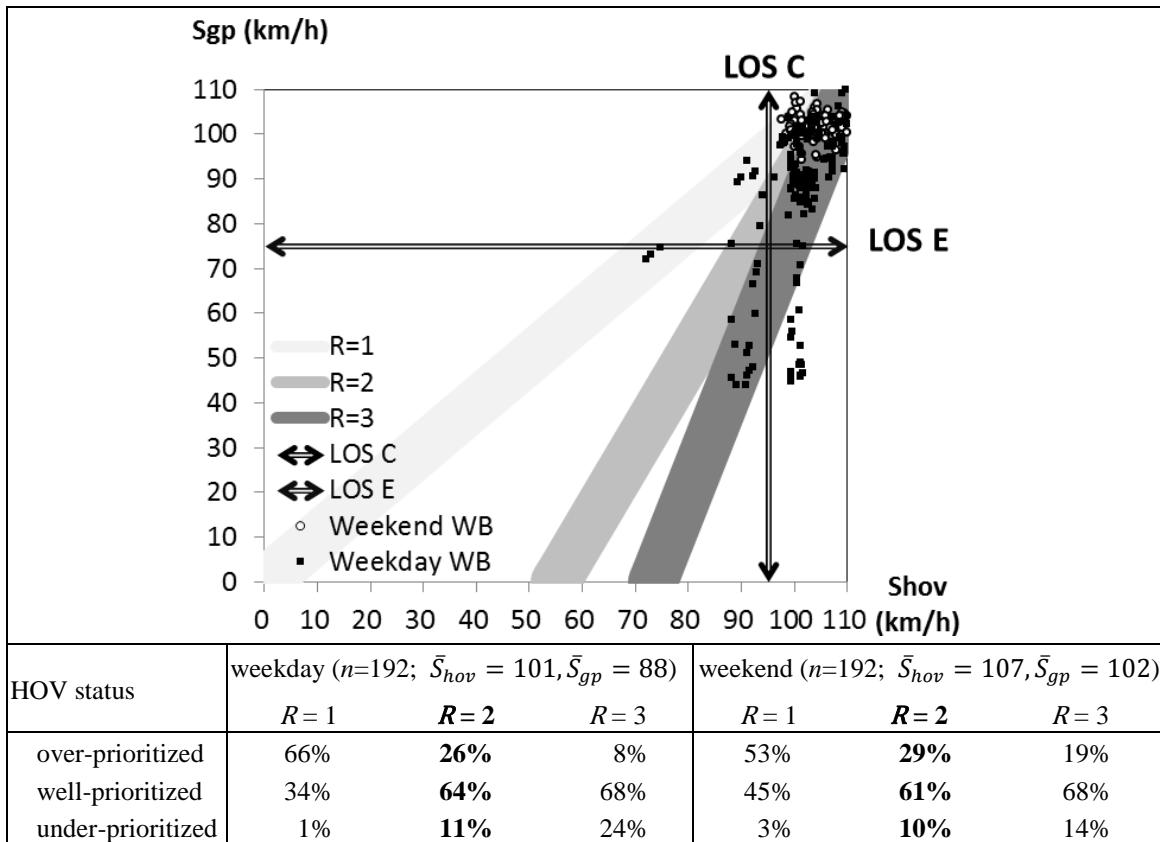


Figure 11. Empirical SR-60 WB speed performance under the vehicle occupancy scheme

4. CONCLUSIONS

This study focused on an undiscovered issue: how much should HOV speed be greater than GP lane speed as traffic changes from the free flow to jam states. The proposed vehicle occupancy scheme highlights HOV's contribution to person movement that grants HOV priority in heavy traffic. The scheme does not try to replace the existing HOV guidelines but serves as a supplement. It can be applied to HOV operational assessment where localized settings of R and ffs are available. The scheme is primarily about travel mobility and somewhat about reliability. The author suggests that future research develop alternative balanced schemes for such objectives as safety, air emissions, or fuel consumption.

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