Determining of the Parking Manoeuvre and the Taxi Blockage Adjustment Factor for the Saturation Flow Rate at the Outlet Legs of Signalized Intersections: Case Study from Rasht City (Iran)

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Abstract. The presence of taxi stops within the area of signalized intersections at the outlet legs due to unnatural behaviour of the taxis, sudden change of lanes, parking manoeuvres activities and stopping the vehicle to discharge or pick up the passengers have led to reduction of saturation flow rate at the outlet leg of signalized intersections and increased delay as well as affecting the performance of a crossing lane. So far, in term of evaluating effective adjustment factors on saturation flow rate at the inlet legs of the signalized intersections, various studies have been carried out, however; there has not been any studies on effective adjustment factors on saturation flow rate at the inlet legs. Hence, the evaluating of the traffic effects of unique behaviours on the saturation flow rate of the outlet leg is very important. In this research the parking manoeuvre time and taxi blockage time were evaluated and analyzed based on the available lane width as well as determining the effective adjustment factors on the saturation flow rate at the outlet legs. The results show that the average parking manoeuvre time is a function of the lane width and is increased as the lane width is reduced. Also, it is suggested to use the values of 7.37 and 11.31 seconds, respectively for the average parking manoeuvre time and the average blockage time of taxis at the outlet legs of signalized intersections for the traffic designing in Rasht city.

1. Introduction

Several factors are involved in the disorder of the intersection. The type of area, the number and width of the crossing lane, parking manoeuvres, pedestrian volumes and crossing lane utilization are among the factors causing disorder and the reduced saturation flow rate as a result. The presence of the taxis within the area of the intersections, their manoeuvres to discharge or pick up passengers, sudden change of lanes and the stopping of them in these areas make the moving vehicles delay and reduce the capacity and disrupt the traffic flow [1, 2]. In HCM, the effect of the above factors is involved on the saturation flow rate as an adjustment factor. Also, this book has considered the number of lanes at 75-meter distance from the intersection as the lanes; and affects the parking manoeuvres in this area, as separated factor on the saturation flow rate at the entrance of the intersections [3-4].

The discussed equations in HCM are somewhat complex and difficult to adapt to the conditions of Iran. In this paper, the related equations to the parking adjustment factors and the taxis blockage adjustment factor will obtain by considering the parking manoeuvres and taxis blockage at the outlet
legs stations of the four signalized intersections of Rasht city; and the values of mentioned factors are
determined for the outlet leg of the studied intersections.

The impact of heavy vehicles was not analyzed due to their insignificant percentage at the studied
intersections. In addition, most of the outlet legs of the Rasht city are flat, since it is impossible to discuss
the effect of grade. The grade appears as the start-up lost time at the inlet leg; but does not have any
significant effect on the saturation flow rate, because the vehicles are moving at the outlet leg.

According to high delay at the intersections of Rasht city due to the presence of taxis to discharge or
pick up the passengers and parking manoeuvres near the intersection, evaluating these manoeuvres and
related adjustment factors would be an important issue. By considering the average parking manoeuvre
time and blockage time of taxis at traffic lights timing in Rasht city, more optimal time for crossing
vehicles at intersection and minimum delay to drivers affected by manoeuvres adjacent the intersections
would be provided.

2. Theoretical Foundations
In the Highway Capacity Manual (HCM, 1985), in order to calculate all the effective adjustment factors
on saturation flow rate at the inlet legs of signalized intersections including adjustment factor for
existence of the parking lanes \( f_p \) and blockage effect of local buses at stops within intersection area
\( f_{bb} \), the related tables are used. The maximum and minimum values by considering number of lanes
in lane group for \( f_p \) is 0.97 and 0.7 and for \( f_{bb} \) is 0.99 and 0.83. The maximum number of parking
maneuvers, \( N_m \) equals 40 maneuvers per hour and the number of stops per hour, \( N_B \) is between 0-40. In
this book, there is no discussion about the exact distance from the stops near the intersection [5]. In
HCM 1998 the factors \( f_p \) and \( f_{bb} \) are constant based on the related tables [6].

In 2000 and 2010 edition of HCM, the equations are used to calculate adjustment factors instead of
tables. \( f_p \) and \( f_{bb} \) are calculated from Eq. 1 and Eq. 2.

\[
f_p = \frac{N - 0.1 - \frac{18 N_m}{3600}}{N}
\]

(1)

Where \( f_p \) is adjustment factor for existence of parking lane (\( f_p \geq 0.05 \)), \( N \) is the number of lanes
in lane group and \( N_m \) is number of parking maneuvers per hour. The number of parking maneuvers used
is the number of maneuvers per hour in parking areas directly adjacent to the lane group and within 250
ft upstream from the stop line. The maximum number of parking maneuvers is 180. Each manoeuvre
(either in or out) is assumed to block traffic in the lane next to the parking manoeuvre for an average of
18 s.

In HCM 2000, 2010 the equation (2) shows the impacts of stopped local transit buses to discharge
and pick up passengers at a near-side or far-side bus stop within 75 m of the stop line (upstream or
downstream).Where \( f_{bb} \) is the bus blockage adjustment factor (\( f_{bb} \geq 0.05 \)) and \( N_B \) is the number
of stopped buses per hour (0 \( \leq N_B \leq 250 \)). It is assumed that the stopping time is equal to 14.4 s for each
bus.

\[
f_{bb} = \frac{N - \frac{14.4 N_B}{3600}}{N}
\]

(2)

The Canadian Capacity Guide for Signalized Intersections (2008), in parking interference section
mentions that, there is a "frictional" component introduced by vehicles moving into and leaving the
parking stalls, car door opening and the generally cautious behaviour of drivers and cyclists as they
proceed along the lane adjacent to parked vehicles. The adjustment factor for the closest lane to the
parked vehicles is given by Eq.3:
\[ F_p = 0.9 - 0.005 N_m \]  

Where \( F_p \) is adjustment factor for parking and \( N_m \) is number of parking maneuvers per hour within 50 meters upstream or downstream of the stop line [7]. In the section of near-side transit stops, the bus stop adjustment factor is calculated as Eq 4:

\[ F_{transit} = 1 - K B T/3600 \]

Where \( K \) is coefficient for the effect of transit vehicle loading during the green time, \( B \) is number of transit vehicle per hour (bus/h, streetcar/h), \( T \) is average transit dwell time during the evaluation period, \( C \) is cycle length and \( g \) is effective green time [8,9].

In Indonesian Highway Capacity Manual, the correction factor for the effect of parking activities is calculated as Eq.5:

\[ f_p = \left( \frac{L_p}{3} - (w_A - 2) \right) \times \left( \frac{L_p}{3} - g \right)/g \]

Where \( L_p \) is distance between stop line and first parked vehicle (m), \( w_A \) is width of the inlet (m) and \( G \) is green time of the approach (s) [8, 9].

In Iranian regulations, in some cases, such as adjustment factor for area type, grade, parking and bus blockage, no study has been carried out separately; and it is recommended to use the values mentioned in HCM85. In Iran's conditions, a model similar to the saturation flow rate in HCM is proposed and in this equation, all variables are based on the definitions of HCM and the values of some factors are not defined [10, 11].

3.  Methodology
In the present paper, in order to specifying the effect of parking manoeuvre and taxi station on saturation flow rate of signalized intersections outlets, 4 different kinds of intersections in city of Rasht (Michael, Shahid Rajaei, Heshmat and Deilaman (Somayeh)) was selected according to figure 1 and field observations were done. This city is located in the central part of Guilan province in north of Iran with the population density of 4340 people per a square kilometre [12].

The intersections with considerable traffic flow were selected between 30 signalized intersections. There are some criteria for selecting the intersections such as important arterial road intersections, its existence in various parts of the city (Eastern and Western exit routes of the city, ring road and etc.), equal distribution of intersections in the city, appropriate geometric and traffic controlling condition for each intersection and existence of saturation flow on at least one leg of intersection’s outlet.

The needed data were gathered to determine the effective parking and the taxi blockage adjustment factor by recording the time at the peak hours in evening using filming methods. Likewise, in order to assess the parking, stopping of taxies for discharging or picking up the passengers in one of the lanes and determining the related adjustment factors, a specific area is needed in which the study of parking and stopping is essential. Since in the most of signalized intersection outlet of Rasht city, one lane is assigned to park vehicles, the information of the area under the parking manoeuvre and stopping vehicles were gathered by long term field observations and checking out the recorded videos. In Tables 1 and 2 respectively, the geometric information and signalized timing on the four intersections are studied.

The values of parking manoeuvre in influenced area of the four signalized intersections were obtained 17, 20, 65 and 85 meters over the beginning of outlet leg based on the conditions of intersections, the number and width of the lanes, however this value in HCM (2000, 2010) is within 75 m upstream or downstream from the stop line at inlet legs.
A. Michaeil (Intersection (1))

B. Shahid Rajaei (Intersection (2))

C. Heshmat (Intersection (3))

D. Deilaman (Intersection (4))

Figure 1. Signalized intersections location studied

Table 1. Profile cross-sectional and geometric information of outlet studied

| Intersections number | Intersections name       | Area type | Outlet name | The number of lanes | The number of park | Lane width | Total lane width | Grade (%) |
|----------------------|-------------------------|-----------|-------------|---------------------|-------------------|------------|------------------|-----------|
| 1                    | Michaeil                | CBD       | Hafez       | 2                   | 1                 | 5.6        | 7.6              | 0.0       |
| 2                    | Shahid Rajaei           | Non-CBD   | Rajaei      | 2                   | 1                 | 8.9        | 10.9             | 2.7       |
| 3                    | Heshmat                 | Non-CBD   | Toshiba     | 2                   | 1                 | 8.5        | 10.5             | 0.0       |
| 4                    | Deilaman(Somayeh)       | Non-CBD   | Ansari      | 2                   | 1                 | 6.0        | 8                | 0.0       |

Table 2. Signalized timing information of outlet legs studied

| Intersections number | Intersections name       | Outlet name | The number of phase | Cycle length | Green time (second) | yellow time (second) | phase time (second) |
|----------------------|-------------------------|-------------|---------------------|--------------|--------------------|----------------------|---------------------|
| 1                    | Michaeil                | Hafez       | 2                   | 167          | 72                 | 3                    | 75                  |
| 2                    | Shahid Rajaei           | Rajaei      | 3                   | 122          | 31                 | 5                    | 36                  |
| 3                    | Heshmat                 | Toshiba     | 2                   | 86           | 47                 | 5                    | 52                  |
| 4                    | Deilaman (Somayeh)      | Ansari      | 3                   | 65           | 26                 | 5                    | 31                  |
In the present paper, there is a clear distinction between the long and short time of getting on and off. Each taxi driver after stopping by the road, leaving the vehicle to take a rest or to attract passengers has made a long stop; and if he has stopped to get in and off the taxi at the same time, he has made a short stop. According to the above classification, adjustment factor for taxi blockage is calculated based on the short stop times and the adjustment factor for parking is calculated based on the long stop times for taxis.

4. Results and discussions

In order to determine the number of parking manoeuvre, \( N_m \), and average parking manoeuvre time, the taxis are divided into three classes as type A (The taxis heading into the stop, an entrance manoeuvre), type B (The taxis which are dubbed into the park stop, an entrance manoeuvre) and type C (The taxis heading out of the stop, an exit manoeuvre) and the maximum of four samples of manoeuvres were observed for each type. Finally, by averaging these samples, the average parking manoeuvre time was obtained at the outlet legs, that the results are indicated in Table 3. Figure 2 compares these values with the average parking manoeuvre time presented in HCM at the inlet legs of signalized intersections (18s).

| Intersection number | Number of lane | Lane width (m) | The average time of the maneuver A (s) | The average time of the maneuver B (s) | The average time of the maneuver C (s) | The average parking manoeuvre time |
|---------------------|----------------|----------------|--------------------------------------|--------------------------------------|--------------------------------------|----------------------------------|
| 1                   | 2              | 2.80           | 8.72                                 | 13.36                                | 7.88                                 | 8.76                             |
| 2                   | 2              | 4.45           | 4.87                                 | 8.55                                 | 6.59                                 | 6.39                             |
| 3                   | 2              | 4.25           | 5.47                                 | N/A                                  | 6.29                                 | 5.97                             |
| 4                   | 2              | 3.60           | N/A                                  | N/A                                  | N/A                                  | N/A                              |
| **Average**         |                |                | 6.68                                 | 11.70                                | 7.11                                 | **7.37**                         |

N/A: Not Available

The average parking manoeuvre time of studied outlet legs of Rasht city was obtained as 7.37 s. The intersections number one and three had the maximum and minimum average parking manoeuvre time. Among the reasons of the average parking manoeuvre time being maximum are the low width of the outlet lane and the more interference of the parking and the stopped taxis with vehicular discharge that narrows the lane and increases the roadside friction. It is observed the minimum average parking manoeuvre time in the intersection number three due to the reasons such as the high width of the outlet lane, more freedom to manoeuvre and less interference of the discharging vehicles with the stopped and parking taxis.

According to Figure 2, the average parking manoeuvre time at the studied outlet legs of signalized intersections in Rasht is considerably lower than the same content presented in HCM (2000 and 2010) at the inlet legs of signalized intersections.
In Figure 3, the average parking manoeuvre time is show based on their types at the intersections 1, 2 and 3 according to the lane width at the outlet legs. According to this figure, increasing the lane width leads to a reduction in the average parking manoeuvre time A, B and C. Hence, the wideness of the outlet legs leads the drivers to manoeuvre more freely and reduces the interference of the discharging vehicles with the stopped and parked taxis. The intersection number 1 has the maximum average parking manoeuvre time at A, B and C manoeuvres. Among the main reasons for this are the location of the intersection in the central business district (CBD), the low width of the outlet leg and the interference of the discharging taxis with the stopped and parked vehicles.

To determine the average stopping time of taxis, pick up, discharge, pick up and discharge passengers at the same time, the number of taxis causing the blockage the lane was recorded during the saturated...
phase. By averaging these samples, the average stopping time of the taxis at the outlet legs of intersections was obtained that the results are shown in Table 4. Figure 4 presents a comparison between these values by the average bus blockage time at the inlet legs of the signalized intersections in HCM.

| Intersection number | Number of lane | Lane width (m) | The average parking manoeuvre time |
|---------------------|----------------|----------------|-----------------------------------|
| 1                   | 2              | 2.80           | 8.85                              |
| 2                   | 2              | 4.45           | 11.84                             |
| 3                   | 2              | 4.25           | 12.56                             |
| 4                   | 2              | 3.60           | 9.94                              |
| **Average**         |                |                | **11.31**                         |

![Table 4. The average taxi blockage time at the studied outlet legs](image)

The average stopping time of taxis at the outlet legs of Rash city was obtained as 11.31s. The intersections number one and three had the minimum and maximum average parking maneuver time. As shown by Figure 4, the average taxi blockage time of taxis at the signalized intersections' outlet legs of Rasht city is lower than the average bus blockage time at the inlet legs of the signalized intersections presented in HCM.

5. Determining the adjustment factors

The parking adjustment factor, \( f_p \), is used to interfere the frictional impact of parking manoeuvres on flow in an adjacent lane group. The presence of taxi stops within the area of signalized intersections at the outlet legs due to stopping and parking activities have led to reduction saturation flow rate at the outlet legs. HCM has considered the number of lanes, stopping and parking activities within 75 m upstream or downstream from the stop line; and affects the parking manoeuvres within this area as a separate factor on the saturation flow rate at the inlet legs of the signalized intersections. According to the average parking manoeuvre time at the outlet legs of Rasht city (7.37s), the mathematical equation 6 is suggested to calculate adjustment factor for parking based on HCM2000 model:
Where $N$ is the number of lanes in lane group and $N_m$ is the number of parking maneuvers per hour.

The taxi blockage adjustment factor, $f_{tb}$, accounts for the impacts of taxis that stop to discharge or pick up passengers at a near-side or far-side taxi stop within the area of signalized intersections. In HCM, this factor is defined for local public transport buses stopped within 250 ft of the stop line as the bus blockage adjustment factor at the inlet legs of signalized intersections; and the average bus blockage time is assumed to be 14.4 s. It was observed that the studied outlet legs did not have the bus stops and the number of the stopping bus was insignificant as low as one bus per hour, hence due to the existence of the taxi stops and the effects of taxies stopping on the discharge of queue at the intersection, it is tried to consider the taxi blockage adjustment factor instead of bus blockage adjustment factor at the outlet legs.

According to the average taxi blockage time in Rasht (11.31 s), the equation 7 is proposed to calculate taxi blockage adjustment factor based on the HCM2000 model:

$$f_{tb} = \frac{N - \frac{11.31 N_t}{3600}}{N}$$  \hspace{1cm} (7)$$

Where $N$ is the number of lanes in lane group and $N_t$ is the number of taxi stopping per hour. By using the equations 6 and 7, the adjustment factor for parking and taxi blockage were calculated at the outlet legs and the results are stated in Table 5. In intersection 4 due to the lack of observing the parking maneuver within the time of study, the adjustment factor for parking equals 1.

Table 5. The saturation flow rate adjustment factors at the studied outlet legs

| Intersection | The parking manoeuvre adjustment factor ($f_p$) | The taxi blockage adjustment factor |
|--------------|---------------------------------|---------------------------------|
| 1            | 0.89                            | 0.96                            |
| 2            | 0.92                            | 0.94                            |
| 3            | 0.92                            | 0.95                            |
| 4            | 1.00                            | 0.98                            |

6. Conclusions

The average time of parking manoeuvre is a function of the crossing line width, which increases with reducing of the lane width so that, at the studied outlet legs of Rasht city, increasing of the lane width from 2.8 m to 4.45 m led to reduce the average time of parking manoeuvre. The average amount of each parking manoeuvre time at the studied outlet legs of Rasht city was obtained equal to 7.37 s, which is less than the corresponding value presented in the highway capacity manual at the inlet of the intersections (i.e. 18 s). The average time of parking maneuver at the studied outlet legs are equal to 11.7 s, 6.68 s, and 7.11 s for 3 cases of entering the taxi to the station by head (A), double-park or entering by the back (B), and exiting the taxi from the station by head (C), respectively. Moreover, it is recommended to use from an amount of 11.31 s for the average stop time of each taxi at the outlet legs of signalized intersections for traffic designs of Rasht city.

Based on the results obtained, it is suggested:

- Banning taxis stop and discharging or picking up the passengers by them in the vicinity of the intersections by the help of penalize and physical traffic measures (e.g. the use from traffic barrels);
- Banning parking in the vicinity of intersections by installing traffic signs; “parking is absolutely forbidden”
- Using the correction coefficients, taxis average stop time, and parking maneuver time obtained from this research in the scheduling of traffic lights.
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