SINERGI Vol. 29, No. 1, February 2025: 97-108
http://publikasi.mercubuana.ac.id/index.php/sinergi
http://doi.org/10.22441/sinergi.2025.1.010

Effect of building designation on parking characteristics, road performance, and zoning regulation

Don Gaspar Noesaku da Costa*, Yulius P. K. Suni
Department of Civil Engineering, Faculty of Engineering, Universitas Katolik Widya Mandira, Indonesia

Abstract
If the capacity of the parking zone on buildings with great trip attractiveness rates is inadequate, it usually triggers on-street parking activity and its unintended derived impacts. Unfortunately, although this unintended situation may decrease traffic and road environmental quality, a similar situation always occurs. The initial field observation's result indicates that a change in building utilization may have influenced it. So, this study aims to assess the effect of parking accumulation rates due to a change in building utilization on the parking index and its impacts on road performance, including traffic accident risk. The existing parking index is influenced by parking accumulation and capacity, while the planning parking index is determined by comparing the parking accumulation and standardized parking space. In addition, the effect of on-street and road performance was assessed using results from similar previous studies. It was found that a change in building function significantly impacts the existing parking index value. It could not accommodate the increased trip rate, resulting in on-street parking activity. It influences a decrease in road capacity, travel speed, air pollutants, and sight distance (increasing accident risk level). This indicates that an institutional strengthening capability represented in an appropriate zoning regulation, which describes the type, number, and scale of activities allowed to be built in a particular corridor, is a compulsory requirement. Consequently, the ladder of urban land use planning should be re-reviewed. Implementing this new concept should be considered, especially in an urban fast-growth corridor.

Keywords:
Building designation;
Land use plan;
Parking index;
Traffic accident risk;
Zoning regulation;

Article History:
Received: February 26, 2024
Revised: April 29, 2024
Accepted: May 21, 2024
Published: January 25, 2025

Corresponding Author:
Don Gaspar Noesaku da Costa
Department of Civil Engineering, Universitas Katolik Widya Mandira, Indonesia
Email: dnoesaku@unwira.ac.id

INTRODUCTION

The availability and adequacy of off-street parking have been a mandatory criterion when proposing the building authorization application because the trip attraction and generation produced might decrease the road capacity and road user convenience [1], decrease environment quality due to inaesthetic view [2, 3, 4, 5], or increase accident risk [6, 7, 8] if the existing parking space is inadequate. Traffic accident is reported to be the primary cause of death [9]. Factors related to road accidents in Indonesia are human factors, environment, and climatic [10]. Indonesian transportation laws [11, 12, 13] stated that each proposal for building licensing permission should be equipped with the Traffic Impact Analysis/TIA document. At the very least, it should explain the effect of trip attraction and generation during the construction and operation stages (until the next five years) on local road network performance, including recommending an accident risk strategy along the road link and surrounding intersections [12].

Thus far, initial building licensing approvement has been given based on location consideration [14][15]. If it is located on a suitable permitted land use pattern, the principal permit would be given as a basis for further design, construction, and operation stages. More intense consideration must be given to the effect of additional activities due to such new buildings, especially in fast-growing urban areas. On the other hand, many buildings change their utilization due to economic considerations, as seen in many trading buildings in Kupang City, Indonesia.

Trading is the primary economic sector that has made the most significant contribution to the gross domestic product/GDP of Kupang City in recent decades. Accordingly, the augmentation of the 2-story building type (the 1st floor is used for a shopping area while the upper floor is used for residence), namely Ruko (Ruko is an abbreviation of Rumah Toko, Rumah is a house whilst Toko is a store), is rapidly, mainly along the arterial and collector roads, sporadically. Unfortunately, several Ruko were converted into a restaurant or an office (mostly a bank office). This type of change could be categorized as an adaptation [16]. Consequently, the trip rate produced is also transformed so that it might be unsuitable for the capacity of the planned parking space. Problems arise when the available parking lot is less than the required parking accumulation rate, causing several vehicles to park on the roadside [3, 17, 18], resulting in road capacity and accident risk due to a decrease in the effective width of roadways and sight distance. Therefore, a safe system approach [19] is employed because the effect of such functional change is multidimensional, requiring it to be addressed organizationally, systematically, and continuously. It offers a shortcut policy for land use based on the potential cumulative negative impacts produced.

This study aims to identify the effect of functional change of Ruko on the capacity of existing parking spaces, assess the effect of trip attraction and generation rates on the parking index, and assess its impacts on road performance and traffic accident risk. The result could be used to consider the requirement of proper zoning regulation or to improve building permitting criteria and mechanisms (including in the monitoring and evaluating stages). Consequently, any parking space management policy [15] developed should consider the socio-economic and environmental needs, mainly when the existing off-parking space is insufficient.

METHOD

Study Approach

The safe system approach model offers the possibility of recognizing the negative impacts that might be caused due to the availability of minimum standardized services required in a region [19]. Since the aim of this study is to identify the effect of building functional shifting on the trip attraction and generation rate and its derived impacts, the presence of problems was measured based on the existing and planned parking index values as well as the effect of on-street parking to the traffic accident risk.

Furthermore, this approach is based on the awakened responsibility of the investor or building operator, the government, and the road user. If a change in building function significantly impacts parking index values, then the government may interfere correspondingly in the parking space management system, including improving the building licensing criterion.

Figure 1 illustrates this research system, which describes the relationship between variables that influence the existing and planned parking index. A problem (the effect of on-street parking) occurs when the $PI_{existing}$ is > 1.0 or if the $PI_{planned}$ is < 1.0. It may decrease road capacity and increase accident risk or environmental degradation as well, so an appropriate strategy has to be recommended to solve it.

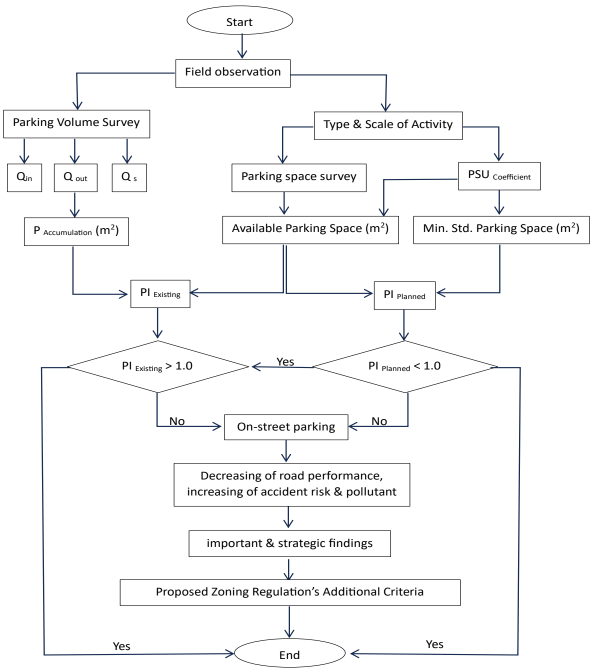

Figure 1. Scheme of Study

Identification of Object Study

The study location was sporadic in the arterial and collector road network of Kupang City, divided into two types of corridors clustered into old and new city regions so that the tendency result could be analyzed. It was chosen based on the need for more parking space capacity recorded during the initial visual observation. In addition, the number of sample buildings is restricted. Only Ruko that has been modified into another function and/or Ruko that influences the great trip rate has been chosen.

Data Collecting

Accumulation of Vehicle Parking Survey

Vehicle parking accumulation describes the number of vehicles parked in a parking zone at a particular time. The parking accumulation survey was conducted for a minimum of 9-10 hours/day, depending on the duration of the peak hour period. The parking vehicles were categorized into motorcycle, light vehicle, and heavy vehicle types. Each entering and exiting vehicle, as well as all recent vehicles that had been parked in the parking zone before and/or during the survey, was observed and calculated using (1).

$$P_a = (Q_{in} + Q_{out} - Q_s)\ x\ VPSU \qquad (1)$$

Where is:

P_a : Parking accumulation (m^2)

Q_{in}: number of vehicles entered the parking zone

Q_{out}: number of vehicles exited the parking zone

Q_s: number of vehicles that have been parked before and/or during the period of the survey

VPSU : vehicle parking space unit (1.5 m^2 for motor cycle; and 12.5 m^2 for light vehicle clustered in the 2nd category)

Existing Parking Area

The dimension of each parking zone in each observed building determines the planned parking index ($PI_{planned}$) value. This value describes the building owner's commitment to providing adequate parking space suited to the type and scale of activity proposed.

Therefore, if the observed buildings were placed on the same site and their services' functions are similar, then the dimension of the parking zone is the sum of the total parking space in each individual building, and vice versa. Consequently, if the type of vehicle is grouped in the existing parking zone, then the parking zone's coverage area in the concerned building should be conducted separately.

Parking Index

The Parking Index (PI) describes the parking space level consumed at a particular time [20]. It could be determined using (2). As previously mentioned, if the PI's $_{existing}$ value is greater than 1.0, then the available parking space is inadequate. Moreover, if the PI $_{existing}$ is ≥ 0,75, then the owner should prepare an alternative parking space to anticipate the augmentation of the trip rate in the near future.

$$PI_{existing} = P_a / P_c \text{ x } 100\% \qquad (2)$$

The PI $_{existing}$ is influenced by parking accumulation (P_a) and parking capacity (PC). Parking capacity (PC) is the available parking area (m^2), divided based on the type of parking vehicle. If the parking zone expanse is not divided for motorcycle, passenger car, or heavy vehicle types, then the parking capacity is the dimension of the whole available parking zone.

In addition, this paper also calculates the planned parking index (3), intended to confirm the suitability between onsite parking zone capacity and the required minimum standardized parking area. Therefore, if the PI $_{planned}$ value is less than 1.0, then it means the building owner has not applied the required minimum parking space as was usually specified in the TIA document.

$$PI_{planned} = \frac{Av_p}{Std_p\ min} \text{ x } 100\% \qquad (3)$$

Where is:

Av_p = available parking area on each building (m^2)

$Std_{p\ min}$ = Minimum std. parking space required for light vehicle = $VPSU_{LV}$ x C_p (see Table 1)

Table 1 shows the parking space unit coefficient (Cp) for each type of activity classified based on the effective floor area, number of students or seats or beds, etc. Therefore, according to Parking Planning Technical Guidelines issued by the Directorate General of Land Transportation in 1996, each building developer should provide a minimum parking space based on its scale of activity [21]. For example, if the effective floor area of a store is 200 m^2, then the minimum standardized parking space that should be provided is 200/100 x 3.5 = 7 PSU. As the PSU for a light vehicle type is 12.5 m^2, the minimum required parking space is around 7 x 12.5 = 87.5 m^2.

Table 1. The Requirement of Minimum Parking Area [21]

Type of Activity	Standardized Parking Space Unit	PSU coefficient (C_p)
Trade center		
Store	PSU 100 m^2 effective floor area	3.5 – 7.5
Department store/supermarket	PSU 100 m^2 effective floor area	3.5 – 7.5
Market place	PSU 100 m^2 effective floor area	3.5 – 7.5
Office		
Nonpublic services	PSU 100 m^2 effective floor area	1.5 – 3.5
Public services	PSU 100 m^2 effective floor area	1.5 – 3.5
Education	PSU / student	0.7 – 1.0
Hotel	PSU / room	0.7 – 1.0
Hospital	PSU / bed	0.2 – 1.3
Cinema	PSU / seat	0.1 – 0.4

Consequently, a change in the building's utilization type of activity or scale of activity should be followed by a change in the PSU coefficient so that the determination of the minimum required parking space is also modified.

From Table 1, it can be seen that the PSU values range. The lower value describes the minimum parking lot required, while the upper values are the optimum parking lot requirement for each type of criterion. It should be noted that such a PSU coefficient is allowable for light vehicle parking units, so motorcycles and/or heavy vehicles parked in the existing zone should be converted to the standardized parking space unit.

The next step is to evaluate the parking index values. If the PI $_{existing}$ is greater than 1.0 or the PI planned is lower than 1.0. The parking space management should be carried out, especially when the duration of on-street parking occurs due to inadequacy of a certain parking zone is affecting the smoothness and/or the road or traffic safety performance. In this particular case, if the case of an unstandardized parking space problem occurred both in the old and new city's corridors, then it strongly indicates that the building licensing mechanism should be improved by taking into account the effect of a change in building utilization to the novel parking space capacity. Furthermore, it may also indicate the requirement of a shortcut in the land use plan ladder, i.e., by producing an appropriate zoning regulation based on the unintended traffic and road environmental degradation level.

RESULTS AND DISCUSSION

Vehicle Parking Accumulation

Table 2 shows not only the maximum parking accumulation due to a change in building utilization but also the parking area used in each observed building and its scale of activity. It should be noted that the parking accumulation data at Ruko that changed its function was collected after it was transformed to the new function so that it cannot be compared with the former one. This parking accumulation data is used to calculate the existing parking index.

Further, Table 3 and Table 4 show the existing and planned parking indexes of Ruko that have been changing their function. They were classified into two parts: those located in the old city and the new city corridor. If the planning parking index is unstandardized, then it strongly indicates that on-street parking occurs due to the inadequacy of the available parking space, not only due to the parking accumulation characteristic but also poor institutional arrangement.

Subsequently, it also shows that although the PI was planned within the standardized category, the PI $_{existing}$ is adequate. This interesting issue is related to the use of an appropriate passenger car unit coefficient that should confirm the trip attractiveness of each type of building and its scale of activity. The result may explain the correlation between zone attractiveness and parking characteristics produced. This information could be used to determine the appropriate zoning regulation.

It also clearly shows that the used parking space is strongly influenced by the activity type rather than the activity scale. Although the effective coverage floor area is similar, the trip attractiveness is very different, depending on the type of activity offered. This initial finding strongly indicates that the impact of a change in building utilization on parking space capacity should be considered in the future parking space management policy.

Furthermore, from Table 3, it was found that the trip attractiveness is also influenced by Land used characteristics. The building surrounding the center of public daily activity, such as the traditional market, caused the greatest trip attraction and generation as it occurred on the group of Ruko Pasar Inpres or group of Ruko Monginsidi 1_a located in front of Pasar Oebobo.

Table 2. Vehicle Parking Accumulation on the Ruko that Have Been Changed Their Function

No	Name of Building	Max Parking Accumulation (Veh/hour)				Parking Area (m^2)	Scale of Activity
		MC	LV	HV	Tot		
A	**Corridor of Oepura – Kuanino (Old City)**						
1	Glory Restaurant	54	44	2	100	716	Capacity = 110 seats
B	**Corridor of Pasar Oebobo (New City)**						
1	Ayam Gepuk Restaurant	11	2	0	13	41.5	Capacity = 60 seats
2	BRI Branch Office	33	2	1	36	117	Effectiveness coverage floor area = 36 m^2
3	Heppy Mini Market	12	2	2	16	128	Effectiveness coverage floor area = 108 m^2
4	Motorcycle Reparation Center	4	1	0	5	18.5	Effectiveness coverage floor area = 36 m^2
C	**Corridor of Pasir Panjang – Kelapa Lima (Old City)**						
1	Teluk Rasa Restaurant	4	2	1	7	73.5	Capacity = 60 seats
2	Dealer Honda Office	112	12	2	126	403	Effectiveness coverage floor area = 160 m^2
3	Dealer Toyota Office	43	3	1	47	144.5	Effectiveness coverage floor area = 176 m^2
D	**Corridor of Frans Seda (New City)**						
1	Padang 2 Restaurant	10	8	1	19	157.5	Capacity = 60 seats
2	KFC	66	9	0	75	211.5	Capacity = 52 seats
3	Pak Sadly Restaurant	12	3	0	15	55.5	Capacity = 30 seats
E	**Corridor of Piet A Tallo (New City)**						
1	Suka Ramai Restaurant	4	23	0	27	293.5	Capacity = 100 seats
2	BNI'46 Branch Office	23	4	0	27	84.5	Effectiveness coverage floor area = 96 m^2
3	Hungry Boss Restaurant	7	3	0	10	48	Capacity = 91 seats
F	**Corridor of Oebobo – Oetete (Old City)**						
1	Bank NTT Branch Office	116	11	0	127	311.5	Effectiveness coverage floor area = 480 m^2
2	Prodia Healthy Center	27	27	1	55	420.5	Effectiveness coverage floor area = 480 m^2
3	Café Petir	35	8	2	45	237.5	Capacity = 191 seats
4	Koperasi Adiguna Main Office	14	2	1	17	88.5	Effective coverage floor area = 120 m^2

Table 3. Parking Index Characteristics on the Ruko that have been Changed Their Function Located in Old City Corridor

No	Name of Building and/or Activity	PI Existing	Criteria PI $_{existing}$ < 1.0	PI Planned	Criteria PI $_{planned}$ > 1.0	Average Duration of Parking (min)
A	**Corridor of Oepura-Kuanino**					
1	Glory Restaurant	1.02	Inadequate	0.98	Unstandardized	57
2	Group of Ruko –Oepura Water Spring	1.36	Inadequate	0.76	Unstandardized	18
3	Group of Ruko – in front of Toko Glory	0.79	Adequate	1.78	Standardized	28
4	Group of Ruko – nearby traditional market	1.83	Inadequate	1.27	Standardized	44
5	Group of Ruko – Murah, KN	3.32	Inadequate	0.51	Unstandardized	67
6	Group of Ruko – Soldier Condominium	0.81	Adequate	2.03	Standardized	34
7	Group of Ruko – nearby Koinonia Church	3.72	Inadequate	0.51	Unstandardized	28
B	**Corridor of Pasir Panjang - Kelapa Lima**					
1	Teluk Rasa Restaurant	1.31	Inadequate	3.73	Standardized	65
2	Dealer Honda Office	1.49	Inadequate	9.00	Standardized	44
3	Dealer Toyota Office	0.72	Adequate	6.06	Standardized	52
4	Group of Ruko – TMP Dharma Loka	1.24	Inadequate	1.83	Standardized	27
5	Group of Ruko – Hotel Cristal	1.16	Inadequate	2.00	Standardized	43
6	Group of Ruko – Perfection Accessories	0.44	Adequate	3.20	Standardized	65
7	Group of Ruko – Edison Electric	1.59	Inadequate	1.37	Standardized	44
8	Group of Ruko – on The Rock Hotel	0.78	Adequate	5.00	Standardized	36
9	Group of Ruko – Aston Hotel	1.10	Inadequate	5.71	Standardized	52
C	**Corridor of Oebobo-Oetete**					
1	Bank NTT Branch Office	1.39	Inadequate	1.07	Standardized	76
2	Prodia Healthy Center	1.88	Inadequate	1.07	Standardized	55
3	Café Petir	1.70	Inadequate	1.38	Standardized	46
4	Koperasi Adiguna Main Office	1.26	Adequate	1.33	Standardized	54
5	Group of Ruko – Pegadaian Offce	0.25	Adequate	3.84	Standardized	44
6	Group of Ruko – Robby_Aki Store	0.36	Adequate	6.22	Standardized	22
7	Group of Ruko – Charisma stationary	1.81	Inadequate	3.20	Standardized	32
8	Group of Ruko – Miracle store	0.62	Adequate	3.57	Standardized	22
9	Group of Ruko – Boelan bakery	1.24	Inadequate	1.18	Standardized	20
10	Group of Ruko – Oebobo gas station	1.63	Inadequate	1.71	Standardized	34
11	Group of Ruko – Lourdes	0.97	Adequate	4.29	Standardized	44
12	Group of Ruko – Pemuda intersection	2.25	Inadequate	1.67	Standardized	38
13	Group of Ruko – SMAN 1 senior high school	1.39	Inadequate	0.98	Unstandardized	43

Table 4. Parking Index Characteristics on the Ruko that have been Changed Their Function Located in New City Corridor

No	Name of Building and/or Activity	PI Existing	Criteria: PI existing < 1.0	PI Planned	Criteria: PI planned > 1.0	Average Duration of Parking (min)
A	**Corridor of Pasar Oebobo**					
1	Ayam Gepuk Restaurant	0.74	Adequate	1.78	Standardized	66
2	Bank Rakyat Indonesia Branch Office	4.18	Inadequate	1.78	Standardized	73
3	Heppy Mini Market	1.52	Inadequate	1.78	Standardized	54
4	Motorcycle Reparation Center	0.66	Adequate	1.78	Standardized	85
5	Group of Ruko – Walter Monginsidi Ia	2.81	Inadequate	2.54	Standardized	43
6	Group of Ruko – Walter Monginsidi Ib	1.13	Inadequate	2.29	Standardized	22
7	Group of Ruko – Walter Monginsidi III	0.96	Adequate	1.33	Standardized	47
B	**Corridor of Frans Seda**					
1	Padang 2 Restaurant	1.13	Inadequate	6.22	Standardized	55
2	Kentucky Fried Chicken	1.01	Inadequate	9.33	Standardized	64
3	Pak Sadly Restaurant	0.20	Adequate	23.33	Standardized	44
4	Group of Ruko – BPN	0.72	Adequate	2.96	Standardized	33
5	Group of Ruko – Princes	0.42	Adequate	3.81	Standardized	39
6	Group of Ruko – Ohayo	0.80	Adequate	3.81	Standardized	48
7	Group of Ruko – KFC	1.37	Inadequate	2.67	Standardized	43
C	**Corridor of Pit A Tallo**					
1	Suka Ramai Restaurant	1.83	Inadequate	0.76	Unstandardized	65
2	Bank Nasional Indonesia'46 Branch Office	2.11	Inadequate	0.95	Unstandardized	77
3	Hungry Boss Restaurant	0.60	Adequate	2.29	Standardized	61
4	Group of Ruko – X_2	0.60	Adequate	4.00	Standardized	78
5	Group of Ruko – Suka Roti	1.04	Inadequate	1.60	Standardized	44
6	Group of Ruko – MJ	0.88	Adequate	2.67	Standardized	54
7	Group of Ruko – T-More hotel	1.08	Inadequate	4.00	Standardized	44

Ruko, located near bank offices and/or famous restaurants, also caused great attractiveness trips. This confirms that building licensing should also consider the effect of existing land use characteristics near the proposed new building.

Parking Space Availability

Parking space availability data was collected based on each type of parking vehicle. However, suppose there was no parking lot restriction (motorcycles, light vehicles, or heavy vehicles were free to be parked elsewhere) in the study location. In that case, the parking coverage area is measured precisely as it was, utilizing the existing parking space dimension and/or pattern. Therefore, if the parking lot for each type of vehicle is presented, then the parking vehicle accumulation and the existing parking index for each type of vehicle and each parking zone should be counted separately, and vice versa. In turn, the actual capacity of each parking zone can certainly be calculated.

The Existing and Planned Parking Index Characteristics

In this study, the parking index value was differentiated based on the necessity of its analysis. The commonly existing parking index was calculated based on the parking accumulation of each type of vehicle in each parking zone. In addition, the planned parking index was used to check the suitableness of the available parking zone dimension and the minimum parking zone dimension based on its type and scale of activity.

That parking index was calculated using (2) and (3), respectively, and the results show some important and strategic issues as follows:

1. The unstandardized parking zone occurred in the old city corridor (29.17%) and the new one (9.52%), i.e., at the Piet A. Tallo corridor. This indicates that the supervising or controlling activity during the parking space construction was inadequate.
2. Although the planned parking index is in the standardized category level, the existing parking zone is inadequate to accommodate the accumulation of parking vehicles (28.57% and 14.29% at old and new corridors, respectively). This strongly indicates that 1) the use of minimum PSU coefficient needs to be suited to the type and density of land use. 2) the trip attractiveness might be influenced by zone attractiveness. The presence of a certain type, number, or scale and density of land use in an area might be the factors that influence it.
3. Inversely, although the $PI_{Planned}$ in some new Ruko is unstandardized category level, the existing parking index is lower than 1.0 (adequate). This might be due to the lower attractiveness of such buildings and/or zones

based on the type, number, scale, and density of activities offered.

4. Although the existing parking index is at an adequate category level, some (20%) require periodical monitoring action because the parking index value is already greater than 0.75. This strictly confirms that the minimum PSU coefficient should always be suited to the effect of zone attractiveness. This would be the near future work.
5. Around 38% of the parking zones need immediate handling. However, most of them (63.16%) are located in the old city corridors, so the additional parking zone cannot be built due to restricted road geometry (unavailable space to be developed).
6. Consequently, parking policy intervention should be undertaken, such as applying a parking progressive tax or using a drop-off and pick-up zone model (kiss and ride parking type). Moreover, the scale of activity should not be increased, or the increasing number of activities on that certain zone should not be allowed. This should be managed in the zoning regulation planning product, and the development of each corridor should be referred to.

From the parking characteristics, it could be implied that institutional capability should be improved, especially during the procurement and construction stages. Moreover, monitoring of parking space construction should also be conducted to ensure adequate parking space capacity is required, suited to the type and scale of activity proposed. Furthermore, it was found that zone attractiveness played a major role in parking characteristics, rather than the type and scale of activity. This strongly indicates that a zoning regulation determination should consider it proportionally.

The Effect of On-Street Parking on Road Performance

Indicators usually used to describe urban road network performance are the degree of saturation (DS) [22], accident risk, and environmental quality [23]. The degree of saturation is a ratio of traffic volume and road capacity. Accident risk is a function of accident probability and its possible consequences [24], while air pollution is greatly influenced by traffic volume, vehicle speed, etc. [25].

In this study, the effect of reducing the effective width of roadways due to on-street parking is assessed using the results of previous related studies. The effect of on-street parking at an arterial street was simulated, and it was found that on-street parking influences road capacity and degree of saturation, so it should be limited [26]. On-street parking on two sides of the roadway reduces the road capacity by up to 37.81% and free flow speed by up to 29.42%. As a result, road performance may be reduced from C to D or even E level of service. Subsequently, several previous studies reported that adequate sight distance is required to detect the presence of hazardous objects and/or conditions on the roadways [27][28]. Since on-street parking vehicles reduce road user visibility, this situation may trigger a risk of traffic accidents.

Understandably, since on-street parking may reduce road capacity, travel speed, and road user visibility and trigger the increase in accident risk, the possible location allowed to be used as an on-street parking zone should be determined by considering not only road capacity and the type of parking or the type of vehicle allowed to be parked at the road shoulder [26], but also traffic accident risk.

Furthermore, regarding the effect of on-street parking on travel speed, a previous study reported that air pollutants increase along with the reduction in travel speed [25], as mentioned above. This confirms that on-street parking should be managed comprehensively by proportionally considering technical and environmental aspects. These prove that a change greatly influences road performance reduction in building designation.

The Important and Strategic Findings

The following important and strategic issues are obtained based on concerned study results and discussion:

a. Although the minimum standardized parking space is available ($PI_{Planned}$ < 1.0), the existing parking index in several building functions, which has been modified into another type, is in the inadequate category. This means the built parking space is unsuited to the parking accumulation rate. This strongly indicates that a modification or adaptation in building function might only be allowed if: 1) trip attraction and generation rate are quite similar and/or less than the initial building type, 2) the owner and/or building operator provide additional parking space and/or apply suitable parking type appropriately.
b. Suppose the duration of parking at the insufficient parking space location, particularly at the building that has modified its function, is long enough to trigger on-street parking activities due to the inadequacy of the existing parking space capacity. In that case, this strongly indicates that each changing plan in building function should be coordinated with

the authority so that the necessary suitable parking space can be recommended properly.

c. The type, number, scale, and density of activities within a great trip attraction and generation rate category should be managed in such a way that the accumulation of parking produced does not affect the inadequacy of the surrounding available parking space. Therefore, a micro-zoning regulation should be proposed, particularly in corridors with high accelerated growth and increased, in accordance with [23][29]. Such needs for flexibility, specification, and steering instruments are also discussed for a sustainable urbanization issue [30]. However, until now, the criteria needed to apply zoning regulation proposals are unavailable. The result of this study could be bridged.
d. The use of the parking space unit coefficient should be suited to the trip attraction and generation rate as well as the average parking time due to the varying attractiveness of activities in each region or corridor.
e. Because the on-street parking activities occur on both sides of road segments, the constructed pedestrian crossing might increase the likelihood of an accident due to the lack of pedestrian crossing facilities nearby. The unintended problems due to on-street parking were also reported by a similar previous study [3], so it is necessary to strengthen institutional capability in a sustainable manner. Moreover, since on-street parking occurs on both roadsides, the traffic volume accumulation, as well as traffic density, may reduce travel speed and environment quality (air and noise pollution) and road aesthetics, unsuited to the goal of sustainable transport or smart city agendas [3][17].
f. Some pedestrian paths are occupied by parking vehicles, so pedestrians tend to walk on the street. In addition, from the field observation, it was found that several pedestrians were using handphones while passing the shoulder and/or crossing the street. According to previous research, this may increase the likelihood of an accident since their walking speed is faster than that of a non-distracted pedestrian. [31], but some of them crossed the street instantly, so this unexpected condition may trigger a longer stopping sight distance, especially when the distance between pedestrian crossing and passing through a vehicle is around 20 m, and the speed of such vehicle is greater than 60 km/h [24]. This unintended situation should be anticipated because some drivers, particularly motorcyclists, tend to exceed the speed limit [32] due to time-saving and sensation-seeking purposes [33][34], so the restricted sight distance due to on-street parking vehicles might increase the accident risk.

Figure 2 clearly shows the result of this study, i.e., that trip attractiveness due to a change in building utilization influences parking accumulation and results in on-street parking activity due to the inadequacy of the available parking space capacity. This may reduce road performance (road base capacity, degree of saturation travel speed), increase traffic accident risk, and the road's environmental quality). It also shows the proposed appropriate strategy to solve it. Therefore, it could be inferred that unintended impact due to on-street parking should be strictly controlled by limiting the type, number, scale, and density of high-attractive social-economic activities along a fast-growth corridor through a micro zoning regulation model.

The Implication of Study Result (Recommendations)

From the study result, it could be implied that:

1. The accident risk, as well as the smoothness and convenience of travel, could be managed if:
   a. The preventive action needed to anticipate an unintended similar situation in the future is to strengthen the institutional capacity prioritized in the following aspects: 1) The building licensing certificate should be equipped with adequate information about the type of building allowed to be utilized on it 2) the zoning regulation should describe clearly about the type, number, scale of activity as well as the density allowed to be built on a certain corridor (road segments)
   b. The negative impact on high-risk corridors and road segments should be managed by focusing on minimizing on-street parking due to insufficient current parking space and providing parking attendants in each specific area suffering from insufficient parking space.
   c. A long-term solution is required to halt the increasing scale of problems by enacting a policy reform [35] addressing identified vulnerabilities. In this particular case, it is necessary to establish an institutional body comprised of local citizens and concerned government officials to control inappropriate building utilization and implement complementing administrative sanctions.

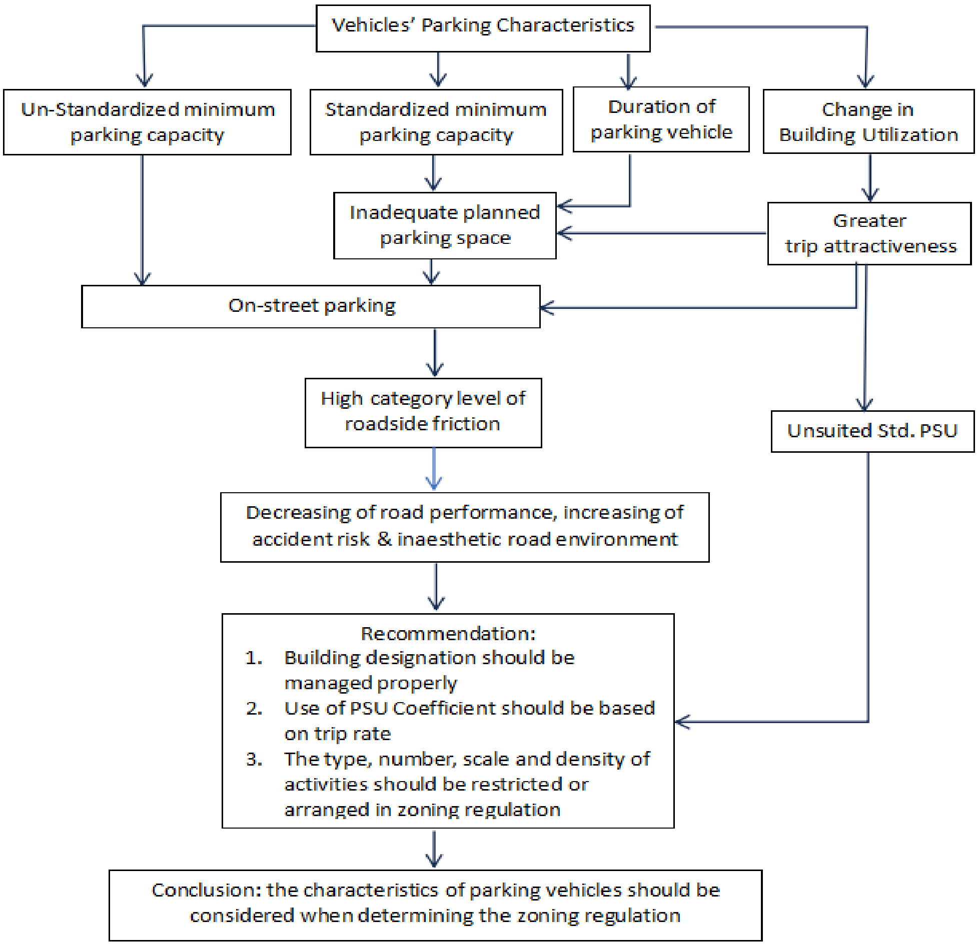

Figure 2. Summary Scheme of Study Result

2. Specific actions needed to avoid socio-economic conflicts during the management of parking spaces at high-risk corridors or road segments are:
   a. A parking attendant is required to handle the effect of right turn maneuvers at the entering-exiting gates and when entering the roadside parking space, particularly in certain locations categorized as having inadequate parking spaces.
   b. Positioning of parking patterns is required to manage whether on-street parking is allowed on both roadsides or only on one side or even is restricted on both sides, in accordance with [17]. Moreover, if on-street parking is allowed, then the pattern of the parking lot should be defined clearly, such as parallel or angle parking. Furthermore, a type of kiss-and-ride for passenger car users should be applied at certain inadequate parking zones. Therefore, the owner should provide concerned signed or road markings as well as a parking attendant or the drop-off and pick-up zone to ensure proper parking activities. In relationship with this term, a previous study reported that total floor area, land category, number of parking lots, type of land use, and population are variables affecting the change of use of a parking lot [15].
3. Suppose the degree of saturation and the existing parking index value is ≥ 0.75. In that case, a specific intervention is required, such as introducing the drop-off and pick-up zone model or significantly applying the progressive parking tax. Another type of intervention that could be carried out is to withdraw the building licensing certificate, especially when the owner refuses to provide such road sign, road marking, parking attendant, or the drop-off and pick-up zone as a consequence of roadside friction arising due to the inadequate of their available parking space capacity.

Accordingly, 1) local authority should improve building licensing criteria and certification procurement mechanisms by taking into account the effect of a change in building utilization on parking accumulation and capacity 2) building owners need to accept responsibility for obeying the rules and limitations of the system, including by providing certain road traffic management's facilities or efforts required to minimize the effect of on-street parking produced as a result of the inadequacy of available parking space capacity on their building to the traffic smoothness and/or accident risk 3) a proper minimum parking space unit coefficient should be evaluated by local authority so that more suited to the characteristics of trip attraction and generation of each building utilization. Furthermore, local authorities should consider the effect of roadside friction levels produced by a group of socio-economic activities in crowded areas.

CONCLUSION

It was found that a change in building utilization is the main factor influencing the difference in trip attraction and trip generation rate. It contributes to the inadequacy of current parking space capacity by increasing the existing parking index, exceeding its limit, and lengthening the parking period. In turn, this causes on-street parking activities, triggers accident risk, decreases road capacity, increases unsmoothed trips, and creates an inaesthetic roadside environment due to the high level of roadside friction produced, especially when the on-street parking occurs on both roadside surroundings. It confirms the result of previous related studies [3][36]. Consequently, those who are involved in the design, operation, and evaluation system have to accept and share responsibility for the smoothness or safety or the environmental quality of the transport system. In this case, the effect of the type, number, scale, and density of activities in certain corridors on the parking index should be taken when determining the zoning regulation as a mandatory criterion, in accordance with [36][37].

ACKNOWLEDGMENT

Thank you very much to the Student Research Community of Transportation System, Study Program of Civil Engineering, Faculty of Engineering Universitas Katolik Widya Mandira for collecting data during this research.

REFERENCES

[1] P. Stella Belinda Kartika and E. Prahara, “Analysis of the Relationship Between Travel Time and on Street Parking,” *Turkish J. Comput. Math. Educ.*, vol. 12, no. 3, pp. 5252–5264, 2021.

[2] A. Tsakalidis and P. Tsoleridis, “The Impacts of Illegal Parking on the Urban Areas’ Traffic and Environmental Conditions: The Case of The City of Thessaloniki,” *SPATIUM*, vol., no. 33, pp. 41–46, 2015, doi: 10.2298/SPAT1533041T.

[3] A. Kurek and E. Macioszek, “Impact of Parking Maneuvers on the Capacity of the Inlets of Intersections with Traffic Lights for Road Traffic Conditions in Poland,” *Sustainability*, vol. 14, 2022.

[4] D. M. P. Wedagama, “Time Headway Modelling of Motorcycle - Dominated Traffic to Analyse Traffic Safety Performance and Road Link Capacity of Single Carriageways,” vol. 24, no. 1, pp. 27–34, 2017, doi: 10.5614/jts.2017.24.1.4.

[5] Y. Yosritzal, R. Aziz, M. Noer, D. O. Putri, and A. Sani, “Determinant factors in increasing the livability of the city of Padang from the perspective of transportation,” *SINERGI*, vol. 27, no. 1, pp. 73–80, 2023, doi: 10.22441/sinergi.2023.1.009.

[6] M. M. Abdul Manan, “Motorcycles entering from access points and merging with traffic on primary roads in Malaysia: Behavioral and road environment influence on the occurrence of traffic conflicts,” *Accid. Anal. Prev.*, vol. 70, pp. 301–313, 2014, doi: 10.1016/j.aap.2014.04.009.

[7] M. M. Abdul Manan and A. Vrhelyi, "Exploration of motorcyclists' behavior at access points of a Malaysian primary road - A qualitative observation study," *Saf. Sci.*, vol. 74, 2015, doi: 10.1016/j.ssci.2015.01.005.

[8] S. Basu and P. Saha, "Evaluation of risk factors for road accidents under mixed traffic : Case study on Indian highways," *IATSS Res.*, vol. 46, no. 4, pp. 559–573, 2022, doi: 10.1016/j.iatssr.2022.09.004.

[9] GRSP, “Global Plan fo the Decade of Action for Road Safety 2011-2020,” Swiss, 2011.

[10] D. Andarini, A. Camelia, and M. M. Ibrahim, “Factors related to road accidents in Palembang , South Sumatera , Indonesia,” *Int. J. Public Heal. Sci.*, vol. 10, no. 3, pp. 638–645, 2021, doi: 10.11591/ijphs.v10i3.20768.

[11] Pemerintah Republik Indonesia, “Undang Undang Republik Indonesia No 22 Tahun 2009 tentang Lalu Lintas dan Angkutan Jalan.” Jakrta, 2009.

[12] Republic of Indonesia Goverment, “Government Regulation of Republic Indonesian No. 32 year of 2011 about Traffic Engineering and Management, Traffic Impact Analysis and Traffic Demand Management.” Jakarta, 2011.

[13] Transportation Ministry, “Transportation Minister Regulation No.PM.75 Year of 2015

about the Organization of Traffic Impact Analisys.” 2015.

[14] Korlena, A. Djunaedi, L. Probosubanu, and N. Ismail, “Zoning Regulation as Land Use Control Instrument : Lesson Learned from United States of America and Singapore,” *Forum Tek.*, vol. 33, no. 3, pp. 131–139, 2010.

[15] J. Jeong, M.-J. Cho, and M.-H. Lee, “An Analysis of the Effect of Non-Parking Facilities in Parking-Only Buildings on the Traffic Inducement Rate,” *Sustainability*, vol. 14, no. 4250, 2022.

[16] J. M. Kamara, O. Heidrich, V. E. Tafaro, and S. Maltese, “Sustainability,” *Sustainability*, vol. 12, no. 6585, August, 2020, doi: 10.3390/su12166585.

[17] X. Tang, J. Ma, P. He, and C. Xu, “Parking Allocation Index Analysis of Office Building Based on the TOD Measurement Method,” *Sustain.*, vol. 14, no. 5, pp. 1–14, 2022, doi: 10.3390/su14052482.

[18] B. Xia and Y. Ruan, “Function Replacement Decision-Making for Parking Space Renewal Based on Association Rules Mining,” *Land*, vol. 11, no. 156, pp. 1–23, 2022, doi: https://doi.org/10.3390/ land11020156.

[19] D. S. Usami *et al.*, "Defining Suitable Safe System projects : The experience of the SaferAfrica project in five African countries," *IATSS Res.*, vol. 45, pp. 594–601, 2021, doi: 10.1016/j.iatssr.2021.08.001.

[20] H. Herdiyansyah, Sugiyanto, A. G. Oktavianto, G. E. Aritonang, M. N. Imaduddin, and M. Rilaningrum, “Capacity Analysis of Parking Lot and Volume of Vehicle Toward Sustainable Parking Convenience,” in *IOP Conf. Series: Earth and Environmental Science 88*, 2017, pp. 1–6. doi: doi :10.1088/1755-1315/88/1/012031.

[21] Winayati, F. Lubis, and V. T. Haris, “Analisis Kebutuhan Areal Parkir Gedung Fakultas Teknik Universitas Lancang Kuning,” *Siklus, J. Tek. Sipil*, vol. 5, no. 1, pp. 39–51, 2019.

[22] Direktorat Jendral Bina Marga, “Pedoman Kapasitas Jalan Indonesia Tahun No.09/P/BM/2023.” Jakarta, 2023.

[23] D. G. N. da Costa, R. M. Rayawulan, and S. S. L. M. F. Seran, "Determining the type, number, scale and density of activities in urban areas based on trip attraction and generation," in *Prosiding Simposium Forum Studi Transportasi antar Perguruan Tinggi ke-22*, 2019, pp. 1–10.

[24] D. G. N. da Costa, S. Malkhamah, and L. B. Suparma, “Use of The Safety Factor and Margin of Safety in Motorcyclist Accident Risk Management,” *Int. J. Technol.*, vol. 4, no., pp. 737–750, 2018.

[25] A. Y. N. T. Djen and D. G. N. da Costa, “Identifikasi Tingkat Pencemaran Udara Akibat Aktivitas Transportasi,” in *Prceeding of the 17th International Symposium of Indonesian Inter University Transprtation Studies Forum*, 2014, vol. l, no. August, pp. 1152–1161.

[26] D. G. N. da Costa, M. I. Naikofi, and C. C. Manubulu, “Use of Sustainable Transport System Approach in Tourism Zone Development at Kupang City Use of Sustainable Transport System Approach in Tourism Zone Development at Kupang City,” in *The 3rd Geoscience and Environmental Management symposium*, 2023, pp. 1–6. doi: 10.1088/1755-1315/1233/1/012046.

[27] T. Smith, S. Garet, and J. Cicchino, “The Effect of Sight Distance Training on the Visual Scanning of Motorcycle Riders: A Preliminary Look,” Washington DC, 2013. [Online]. Available: http://www.nhtsa.gov/staticfiles/nti/pdf/811690.pdf

[28] S. S. Smith, M. S. Horswill, B. Chambers, and M. Wetton, “Hazard perception in novice and experienced drivers: The effects of sleepiness,” *Accid. Anal. Prev.*, vol. 41, no. 4, pp. 729–733, 2009, doi: 10.1016/j.aap.2009.03.016.

[29] B. Doe, “Urban land use planning and the quest for integrating the small-scale informal business sector The case of Kumasi , Ghana by,” TU Dortmund University, 2015.

[30] W. Salet, “The Ladder of Sustainable Urbanization,” *disP -The Plan. Rev.*, no. February, pp. 198–200, 2015, doi: 10.1080/02513625.2014.1007650.

[31] H. A. Mohammed, “Assessment of distracted pedestrian crossing behavior at midblock crosswalks,” *IATSS Res.*, vol. 45, no. 4, pp. 584–593, 2021, doi: 10.1016/j.iatssr.2021.07.003.

[32] G. Sugiyanto and S. Malkhamah, “Determining the maximum speed limit in urban road to increase traffic safety,” *J. Teknol.*, vol. 80, no. 5, pp. 67–77, 2018, doi: 10.11113/jt.v80.10489.

[33] D. G. N. da Costa, S. Malkhamah, and L. B. Suparma, “Motorcyclist risk taking behavior,” in *Proceeding of the 19th International Symposium of FSTPT, Islamic University of Indonesia, 11-13 October 2016, ISBN: 979-95721-2-19*, 2016, pp. 77–85.

[34] C. F. Chen and C. W. Chen, “Speeding for fun? Exploring the speeding behavior of riders of heavy motorcycles using the theory of planned behavior and psychological flow

theory," *Accid. Anal. Prev.*, vol. 43, no. 3, pp. 983–990, 2011, doi: 10.1016/j.aap.2010.11.025.
[35] T. B. Joewono, A. K. M. Tarigan, and Y. O. Susilo, "Road-based public transportation in urban areas of Indonesia: What policies do users expect to improve the service quality?," *Transp. Policy*, vol. 49, pp. 114–124, 2016, doi: 10.1016/j.tranpol.2016.04.009.
[36] V. V. Natalia, "Supporting the Integrated Planning for Land Use and Transport Systems by Examining the Distribution of Urban Centres and Public Transit Networks," an der Fakultät VI - Planen Bauen Umwelt der Technischen Universität Berlin, 2021.
[37] R. A. Acheampong and E. A. Silva, "Land use – transport interaction modeling : A review of the literature and future research directions," *J. Transp. lLnd Use*, vol. 8, no. 3, pp. 11–38, 2015.