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Evaluation of parking space efficiency and sustainable land management strategies at Puri Raharja General Hospital in Denpasar

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ABSTRACT

Puri Raharja General Hospital, one of the primary healthcare facilities in Denpasar City, faces challenges related to insufficient parking. This study investigates the parking characteristics and requirements to support the planning of a multilevel parking facility as an alternative solution for optimizing limited parking areas. Data were collected through parking inventories, cordon, and patrol surveys. The analysis revealed the following characteristics for light vehicles and motorcycles in both on-street and off-street parking areas: total parking volumes of 326 light vehicles and 1,646 motorcycles; peak accumulations of 37 and 252 vehicles per hour; average parking durations ranging from 1.034–3.484 hours and 1.289–3.250 hours; peak duration distributions of 74.60% and 77.18%; turnover rates of 0.650 and 1.236 vehicles per parking space unit (PSU) per hour; maximum parking capacities of 18 and 74 PSUs per hour; parking provisions of 265 light vehicles and 1,071 motorcycles; and parking indices of 2.891 and 8.782, respectively. Based on these findings, the total parking area requirements are estimated at 1,090.63 m² for light vehicles and 1,517.89 m² for motorcycles. The proposed construction of a motorcycle parking building on the south side of the hospital and redesign of off-street parking parallel to Gadung Street are expected to reduce the motorcycle parking demand to approximately 1,127.89 m².

Keywords: Parking Characteristics, Parking Demand Analysis, Parking Space Unit (PSU), Hospital Parking Management, Off-Street Parking Design

1. INTRODUCTION

The rapid population growth in Denpasar City has created new pressures on various public services, including healthcare facilities. With the increase in population, the community's need for access to health services has increased in terms of outpatient and inpatient visits. This increase has impacted not only medical aspects but also supporting facilities such as access to locations, transportation, and parking. Recent studies have shown that the development of healthcare facilities in urban areas is often followed by the implementation of inadequate transportation and parking infrastructure, leading to operational and mobility problems (e.g., parking congestion, land searches, and increased traffic jams) (Sochacka et al., 2024).

In hospitals, the need for adequate parking facilities is an integral part of the continuity of health services for patients, visitors, and medical personnel. Limited parking facilities often cause vehicle users to park haphazardly, even on surrounding roads, causing local traffic congestion and reducing the convenience of access to health facilities (Demirtas & Atalay, 2025). This condition is also observed in various developing cities, where hospitals are located in urban areas with high traffic density, and parking provision is often linked to actual demand (Altaher et al., 2020). Therefore, understanding the characteristics of vehicle visitors and parking needs in the hospital environment is crucial for efficient parking space planning.

Puri Raharja General Hospital, as one of the health service centers in Denpasar City, has conditions similar to many other public service facilities: limited parking space that affects visitor accessibility and comfort of the visitors. Although the high number of visits shows the importance of this hospital, to date, no specific research has examined the characteristics and parking space requirements at this location in detail. This situation creates a research gap that can be filled through an empirical study of parking characteristics (volume, duration, turnover) and estimates of the land required for parking. For example, in Denpasar, private hospitals have a parking index that exceeds one, indicating that parking demand exceeds supply (Suthanaya, 2017).

Research on parking characteristics and needs in hospitals is important not only for land provision but also as a basis for planning safe, efficient, and integrated on-street/off-street parking space designs that are integrated with surrounding mobility. For example, parking inventory, cordon, and parking patrol surveys have been used to measure variables such as volume, accumulation, parking duration, turnover, and parking capacity (Demirtas & Atalay, 2025). In addition, recent research has used price-based simulation models and demand elasticity to predict parking needs more dynamically in dense urban contexts (Pavlek et al., 2025). Our study, which combines a survey of characteristics with estimates of parking areas, will make an important contribution both at the local level (Denpasar) and methodologically.

This study aims to analyze the parking characteristics (volume of light vehicles and motorcycles, duration, turnover, and parking index) and parking space requirements at Puri Raharja General Hospital. The results of the analysis are expected to produce estimates of the area of land required as a basis for planning parking facilities, such as the development of parking buildings or the restructuring of off-street parking. By filling this research gap, the research output will provide practical recommendations for hospital managers, city planners, and transportation stakeholders in Denpasar. In addition, these results can form the basis for policies to improve land-use efficiency and reduce potential congestion and parking conflicts in the hospital area.

2. LITERATURE REVIEW

Parking characteristics are the basic properties that provide an assessment of parking services and issues that occur in the study area. Parking characteristics include the following:

2.1 Parking Volume

In modern parking research, parking volume is understood as the total number of vehicles served by a facility over a certain time horizon (hour/day), which is useful for assessing demand intensity and

mapping peak-period patterns. Recent reviews emphasize a clear distinction between volume (cumulative vehicles served) and accumulation (number of vehicles parked at a given time) to avoid bias in demand-based capacity and pricing. This approach is also used in the latest forecasting models that link volume to price elasticity and user segments (Pavlek et al., 2025).

Parking volume is the number of vehicles entering a parking location during a certain period. The parking volume can be calculated using the following formula:

$$V = E_i + X$$

Note:
E_i = Number of vehicles entering (vehicles)
X = Vehicles already present before the survey time (vehicles)

2.2 Parking Accumulation

Parking accumulation is the number of vehicles occupying parking spaces at a given moment or interval, which is the basis for viewing occupancy and parking load curves over time. In recent literature, occupancy is often defined as the accumulation divided by the capacity; simply put, what percentage of space is occupied at time t. The operational definition and method of calculating occupancy (based on the difference between entries and exits divided by capacity) are explicitly described in a sustainability study (Cai et al., 2025).

Parking accumulation refers to the number of vehicles in a parking location during a certain period of time. Parking accumulation can be calculated using the following equation:

$$\text{Accumulation} = X + E_i + E_x$$

Note:
E_x = Number of vehicles exiting (vehicles)

2.3 Parking Duration

Parking duration is the average time spent per vehicle, and this metric links user behavior to the efficiency of lot circulation. The latest technical literature distinguishes between parking load (veh·hours), average duration, and duration profiles per user category (employees, patients, visitors) to avoid under/over-provisioning. Methodological studies and characteristic reviews emphasize that duration is a key variable that shifts lot demand during peak hours and the performance of progressive rates (Parmar et al., 2020).

Duration (D) is the average length of time that vehicles are parked in a parking space. Parking duration can be calculated using the following formula:

$$D = \frac{(N_x) \times (x) \times (I)}{N_t}$$

Note:
N_x = Number of vehicles parked during the survey time interval (vehicles)
x = Number of intervals
I = Survey time interval (hours)
N_t = Total number of vehicles during the survey period (vehicles)

2.4 Parking Turnover

Turnover measures how many times a space is used in a unit of time (often expressed as vehicles/space/hour). It serves as an indicator of space usage efficiency: the higher the turnover, the more vehicles are served by the same number of spaces. The 2024–2025 on-street and commercial corridor

study in Indonesia shows a consistent method for calculating PTO: the number of vehicles using the facility divided by the number of spaces and divided by the survey time (or equivalent to veh/space/hour) (Satrio et al., 2024).

The parking turnover rate (TR) is the rate of parking space usage. Parking turnover can be calculated using the following formula:

$$TR = \frac{N_t}{S \times T_S}$$

Note:
S = Parking space unit (PSU)
T_S = Length of analysis period/survey time (hours)

2.5 Parking Capacity

Parking capacity indicates the maximum number of vehicles that a facility can serve in a given period, depending on the number of spaces, average duration, and parking turnover rate. In the classical concept, capacity is calculated from the number of spaces and operating hours. Parking capacity can be calculated using the formula:

$$PC = \frac{S}{D}$$

2.6 Parking Supply

Supply refers to the amount of parking services that can be provided during the analysis period, influenced by the number of spaces, turnover rate, time restrictions, and operations (e.g., entry/exit queue management). Recent research combines supply with pricing mechanisms as two key policy levers; elasticity-based simulations show that a combination of supply pricing adjustments can shift some demand or increase space utilization efficiency without building new land (Pavlek et al., 2025). Parking availability can be calculated using the following formula:

$$P = \frac{S \times T_S}{D} \times F$$

Note:
F = Insufficiency factor (0,9)

2.7 Parking Index

The parking index is commonly used as a measure of utilization intensity: operationally expressed as accumulation divided by capacity, sometimes expressed as a percentage. In the 2025 literature (Sustainability), occupancy = accumulation/capacity. This framework is consistent for mapping saturated vs. undersupplied conditions and testing policies (Cai et al., 2025). The parking index can be calculated using the formula:

$$IP = \frac{\text{Parking Accumulation}}{\text{Parking Capacity}}$$

3. METHODOLOGY

3.1 Research Design

This study uses a quantitative descriptive approach to analyze parking characteristics and calculate parking space requirements at Puri Raharja General Hospital in Denpasar. The analysis focuses on six main parameters, namely parking volume, parking accumulation, parking duration, parking turnover rate, parking capacity, parking provision, and parking index. The main objective of this study is to evaluate the adequacy of existing parking facilities and provide a basis for planning the development of parking buildings or rearranging the parking layout.

The research framework refers to the Manual of Traffic Engineering Studies (Oppenlander, 1976) and Technical Guidelines for Parking Management (Direktorat Jenderal Perhubungan Darat, 1998), with adjustments to the actual conditions in the urban area of Denpasar.

3.2 Research Location and Time

The research was conducted at Puri Raharja General Hospital, Jalan WR Supratman, Denpasar. This location was chosen because it has a high number of patient visits with limited parking space, which often causes parking to spill over onto the road. Data collection was carried out during 16 hours of observation, from 06:00 to 22:00 WITA, to obtain a comprehensive picture of parking patterns during both busy and quiet hours (Figure 1).

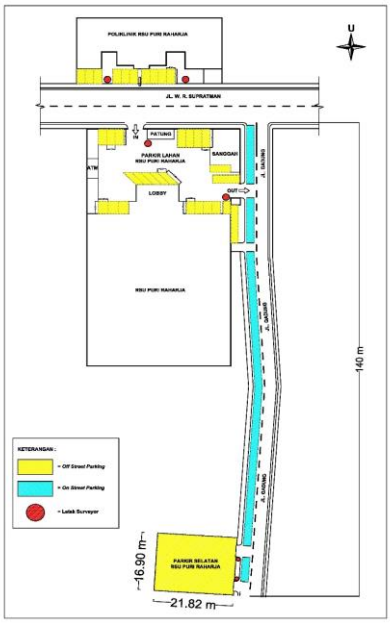


Figure 1. Puri Raharja General Hospital Parking Lot

3.2 Data Collection Techniques

Primary data was obtained through three field survey methods: (1) Parking inventory survey, to record the physical condition of the parking lot, number of parking spaces, vehicle circulation, and road markings; (2) Cordon parking survey, to record vehicles entering and exiting based on type, vehicle number, and time of arrival and departure; (3) Parking patrol survey, to observe the number of vehicles parked at specific time intervals (every 15 minutes) to determine fluctuations in parking accumulation.

All surveys were conducted manually with direct supervision in the field to ensure accurate and consistent observation results.

3.3 Data Analysis Techniques

The data obtained from the survey results is processed quantitatively to obtain values for each parking parameter. The analysis includes calculating the number of vehicles using the parking facilities during the survey period (parking volume), the number of vehicles parked at a given time (accumulation), the average time vehicles remain at the location (duration), and the frequency of use of a parking space per unit of time (parking turnover rate).

In addition, parking capacity is also calculated, which is the maximum ability of the facility to accommodate vehicles; parking provision, which is the number of available spaces compared to actual needs; and the parking index, which shows the level of utilization of parking space relative to its capacity. All calculation results are then analyzed to assess whether the parking facilities at Puri Raharja General Hospital are in ideal, insufficient, or excessive condition.

3.4 Parking Space Requirements Analysis

Parking space requirements are determined based on the results of an analysis of the highest parking accumulation and average vehicle parking duration. From these results, the ideal number of parking spaces for light vehicles and motorcycles is calculated. The number of parking spaces required is then converted into parking area size using the standard dimensions specified in SNI 03-1733-2004.

This analysis also considers land use efficiency and existing conditions in the field so that the results can be used as a basis for planning multi-story parking buildings for motorcycles and rearranging off-street parking areas along Jalan Gadung.

4. RESULT AND DISCUSSION

4.1 Parking Characteristics Analysis Results

Puri Raharja General Hospital provides four parking locations, including off-street parking on the main grounds of Puri Raharja General Hospital, the polyclinic grounds located north of Puri Raharja General Hospital, a special parking area located south of Puri Raharja General Hospital, and on-street parking on Gadung Road. Each parking location has different parking characteristics. Based on the results of data collection and analysis, the parking characteristics at each parking location can be seen in Table 1 below.

Table 1. Characteristics of The Four Parking Lots at Puri Raharja General Hospital

Location	Vehicle Type	V (Veh.)	A (Veh.)	D (Hours)	TR (Veh/PSU/ Hour)	PC (PSU/Hour)	P (Veh.)	IP
Main Ground of Puri Raharja	Light Vehicles	176	37	1,034	0,579	18	265	**2,013**
	Motorcycles	732	252	1,289	1,236	29	413	**8,782**
South of Puri Raharja Hospital	Light Vehicles	20	10	3,484	0,096	4	54	**2,680**
	Motorcycles	8	5	3,250	0,083	2	27	**2,708**
Puri Raharja General Hospital Polyclinic	Light Vehicles	104	15	1,139	0,650	9	126	**1,708**
	Motorcycles	273	67	1,496	0,371	31	443	**2,179**
Gadung Street	Light Vehicles	26	8	1,807	0,325	3	40	**2,891**
	Motorcycles	633	184	2,957	0,180	74	1071	**2,473**

Source: Data Analysis (2025)

Table 1 shows that the parking index at all four parking locations is greater than one (IP>1), meaning that the capacity at each location is unable to accommodate the number of vehicles parked there. As a result, many vehicles spill over onto WR Supratman Street and Gadung Street, and many vehicles are parked outside the designated parking spaces.

4.2 Parking Space Requirements

The parking requirements at the main site of Puri Raharja General Hospital, the site south of Puri Raharja General Hospital, the Puri Raharja General Hospital Polyclinic, and Jalan Gadung refer to the number of parking stalls needed to accommodate the large number of vehicles that will park in the area. To determine the number of parking stalls required, a calculation based on peak accumulation is used, where IP<1, i.e., 0.9.

Table 2. Number of Parking Spaces Required at Puri Raharja General Hospital

Location	Vehicle Type	D (Hours)	A (Veh.)	IP<1	Parking Space Requirements S=(A*D)/IP (PSU)
Main Ground of Puri Raharja	Light Vehicles	1,034	37	0,9	42
	Motorcycles	1,289	252	0,9	361
South of Puri Raharja Hospital	Light Vehicles	3,484	10	0,9	39
	Motorcycles	3,250	5	0,9	18
Puri Raharja General Hospital Polyclinic	Light Vehicles	1,139	15	0,9	19
	Motorcycles	1,496	67	0,9	111
Gadung Street	Light Vehicles	1,807	8	0,9	16
	Motorcycles	2,957	184	0,9	604

Source: Data Analysis (2025)

Table 2 shows that the total requirement for light vehicles at Puri Raharja General Hospital is 116 PSU, equivalent to 1,453 m^2, while the total requirement for motorcycles is 1,095 PSU, equivalent to 1,642 m^2.

Table 3. Comparison of Requirements with Available Plots

Vehicle Type	Parking Space Requirements (PSU)	Number of Available Parking Spaces Without On-Street Parking on Gadung Road and Off-Street Parking on the South Side (PSU)	Difference Amount (PSU)	Land Area Requirements (m^2)
Light Vehicles	116	29	87	1090,63
Motorcycles	1095	83	1012	1517,89

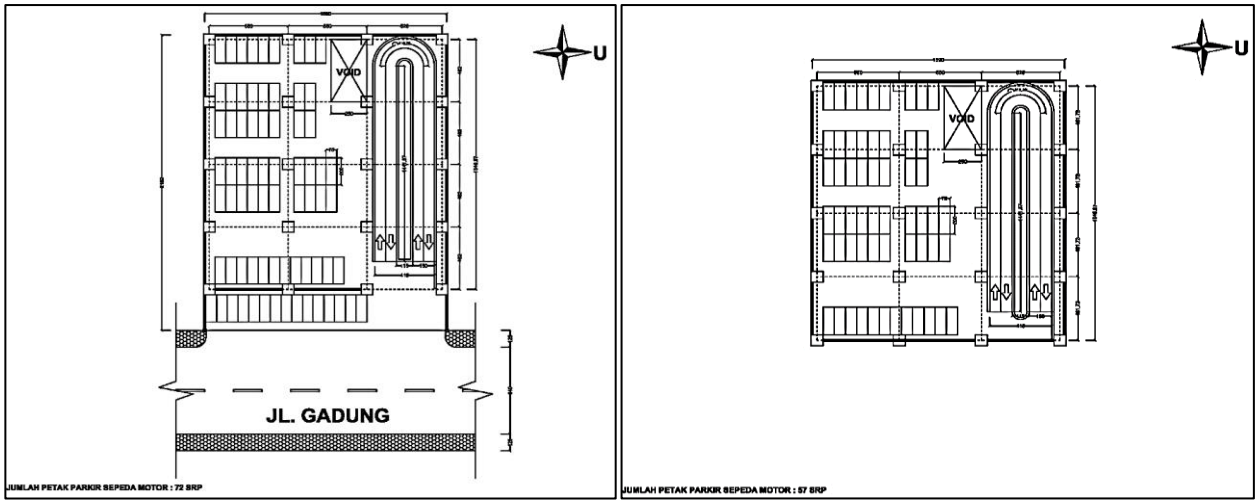
Source: Data Analysis (2025)

Based on Table 3, it can be seen that the parking requirement at the Puri Raharja Hospital site for light vehicles is 116 SRP, whereas currently only 29 SRP are available, resulting in a shortfall of 87 SRP or equivalent to 1,090.63 m^2. For motorcycles, the parking requirement is 1,095 SRP, whereas currently only 83 SRP are available, resulting in a shortfall of 1,012 SRP or equivalent to 1,517.89 m^2.

4.3 Building Design and Parking Layout

The planning of the building and motorcycle parking layout is one alternative to reduce the number of motorcycle parking spaces required at Puri Raharja General Hospital. A special motorcycle parking building is planned on a special parking area located south of Puri Raharja General Hospital with an area

of 16.90 x 21.82 m^2. Meanwhile, the additional parking layout for motorcycles is planned to be parallel to Gadung Road, but not on the Gadung Road itself (Figure 2a and 2b)



(a) **(b)**

Figure 2. (a) Floor Plan of Parking Building 1st Floor; (b) Planning for Floors 2, 3, and 4 of the Parking Building

Based on Figure 2. (a) It is planned that the special parking building for motorcycles on the first floor will be able to accommodate 72 motorcycle parking spaces. Figure 2. (b) For floors 2, 3, and 4, each floor is planned to accommodate 57 motorcycles.

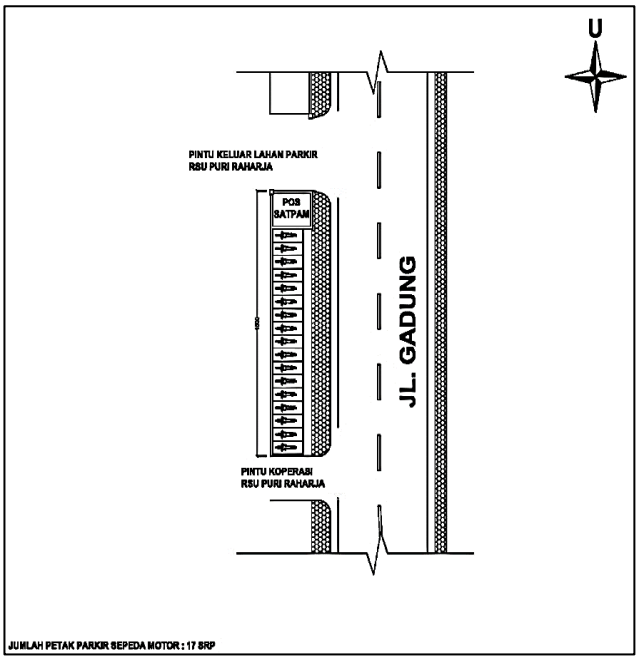


Figure 3. Layout Planning Parallel to Gadung Road

The additional parking layout, which is parallel to Gadung Road, is planned to accommodate 17 motorcycles (Figure 3).

5. CONCLUSION

The results of the study show that the parking facilities at Puri Raharja General Hospital in Denpasar are unable to accommodate all visitor and employee vehicles. Based on an analysis of parking characteristics, it was found that the highest parking volume and accumulation occur during peak service hours, with a fairly long average parking duration. A parking index value exceeding 1 (IP > 1) indicates that the current parking capacity is inadequate, resulting in many vehicles having to park outside the designated area and causing traffic congestion around the hospital.

To address this issue, it is necessary to re-plan and manage a more efficient and sustainable parking system. One suggested alternative is the construction of a multi-story parking building specifically for motorcycles on the south side of the hospital, as well as the arrangement of off-street parking areas parallel to Jalan Gadung. In addition, the implementation of a progressive parking tariff policy and improvements to parking markings and circulation will help optimize the use of limited land and increase the comfort and safety of hospital facility users.

Ethical Approval

Ethical approval was not required since the study involved only field observations of parking behavior without collecting personal or sensitive data. All research activities complied with ethical research standards.

Informed Consent Statement

Informed consent was not applicable because no individual information was gathered. Data were limited to vehicle counts and parking occupancy in public areas.

Authors' Contributions

DCI and DAPAGP contributed to conceptualization and methodology. DATAW and IGFST contributed to validation and supervision. DCI contributed in writing original draft. INIK contributed in writing, review, and editing. All authors approved the final manuscript.

Disclosure statement

The authors declare no conflict of interest related to this study.

Data Availability Statement

All data supporting this study are available from the corresponding author upon reasonable request.

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