EXPANSION OF PARKING AREA USING RIGID PAVEMENT AT COL. ROBERT ATTY BESSING MALINAU AIRPORT

Donni Octaviano Hindarto[1], Linda Winiasri[2], Fahrur Rozi [3]

[1,2,3,...] *Politeknik Penerbangan Surabaya*
Email: [1,*]donnioctaviano4@gmai.com

ABSTRACT
The increasing number of passengers at Colonel Robert Atty Bessing Airport in Malinau, North Kalimantan, has led to parking shortages, with the existing facility accommodating only 28 vehicles. This study aims to plan the expansion of parking facilities using rigid pavement to ensure capacity, durability, and serviceability. Passenger forecasts up to 2035 were conducted using the Holt Linear Trend method, while parking demand was estimated based on forecasted passengers, vehicle ratios, and peak-hour factors. Several layout alternatives were compared to maximize land efficiency. Pavement design followed Manual Desain Perkerasan Jalan No. 03/M/BM/2024, considering traffic load (JSKN), soil strength (CBR 8.88%), and concrete strength (K-300). The results show that by 2035 parking demand will reach 130 vehicles, requiring approximately 6,000 m² of land. The 90° layout was selected as the most efficient option for maximizing capacity. The recommended pavement structure consists of a 20 cm reinforced concrete slab supported by a 15 cm lean concrete subbase. This research provides practical recommendations for sustainable airport landside planning, ensuring that parking facilities can meet long-term demand with durable construction.

Keywords: *Parking expansion, rigid pavement, Holt Linear Trend, airport infrastructure.*

INTRODUCTION

Airports serve as critical infrastructure in supporting mobility, economic growth, and regional connectivity. While runways and airside facilities often receive priority in planning and development, landside facilities play an equally important role in shaping passenger experience and service quality. Among these landside elements, parking facilities are often underestimated, even though they constitute the first and last point of interaction for airport users. Adequate parking space ensures smooth circulation, reduces congestion, and improves the overall image of the airport as a gateway to the region. Conversely, insufficient parking capacity can cause queuing, traffic conflicts, and dissatisfaction among passengers and visitors.

Colonel Robert Atty Bessing Airport, located in Malinau, North Kalimantan, has strategic importance as it connects remote regions with urban centers. In recent years, the airport has recorded consistent growth in passenger numbers. Data show that the total passengers increased from 35,120 in 2019 to 43,215 in 2024, despite temporary disruptions caused by the COVID-19 pandemic. This upward trend indicates that demand for airport services, including ground access and parking, will continue to rise in the coming years.

Currently, the parking area at the airport only accommodates 28 vehicles. This capacity is already insufficient under current demand, leading to congestion during peak hours when vehicles spill over beyond designated spaces. The issue is expected to worsen in the future if no intervention is made. Inadequate parking not only disrupts circulation but also reduces the convenience and safety of airport users. For an airport that aspires to serve as a reliable transportation hub in a developing region, addressing parking shortages becomes an urgent necessity.

Several studies have highlighted similar issues in other Indonesian airports. Panjaitan et al. (2022) analyzed parking demand at Sultan Hasanuddin International Airport in Makassar and emphasized the need for systematic forecasting and efficient layout design. Saputra et al. (2020) studied parking facilities at Raja Haji Fisabilillah Airport in Tanjungpinang and found that rapid passenger growth must be matched with flexible parking planning. Putri et al. (2017) examined Ngurah Rai International Airport in Bali and concluded that insufficient parking facilities significantly affect passenger satisfaction and operational efficiency. These findings underscore the importance of proactive planning for airport parking facilities to accommodate future demand.

Another crucial aspect in parking facility development is pavement design. Unlike typical urban parking areas, airport parking lots must accommodate not only passenger vehicles but also service vehicles and, in certain cases, small trucks. This requires a pavement structure capable of bearing heavier loads with minimal maintenance. Rigid pavement, or concrete pavement, offers advantages in terms of durability, structural strength, and service life compared to flexible pavement. The *Manual Desain Perkerasan Jalan 2024* provides clear technical guidance for designing such pavements, making it a suitable reference for this study.

Given these considerations, this research focuses on planning the expansion of the parking area at Colonel Robert Atty Bessing Airport using rigid pavement. The objectives are fourfold: (1) to project passenger growth until 2035 using Holt Linear Trend, (2) to estimate future parking demand, (3) to evaluate and select the most efficient parking layout, and (4) to design a rigid pavement structure that ensures durability and long-term serviceability. By integrating forecasting, demand analysis, layout evaluation, and pavement design, this study is expected to provide practical recommendations for airport authorities as well as contribute to academic discourse on airport landside facility planning in regional contexts.

RESEARCH METHODS

This study employed a quantitative engineering approach to analyze and plan the expansion of the parking facility at Colonel Robert Atty Bessing Airport. The methodology consisted of four main stages: (1) passenger growth forecasting, (2) estimation of parking demand, (3) evaluation of layout alternatives, and (4) rigid pavement design. Each stage was guided by relevant technical standards and adapted to the specific conditions of the airport.

(1) Passenger growth forecasting was carried out by collecting and analyzing historical passenger traffic data to identify trends and patterns of growth over the past years. This information was then projected into the future using appropriate forecasting methods, while also considering external factors such as regional economic development, transportation policies, and socio-demographic changes that may influence passenger numbers. The results of this stage provided the baseline projection of passengers up to the year 2035, which served as the foundation for subsequent analyses.

(2) Estimation of parking demand was performed based on the projected passenger data. The calculation followed the guidelines established by the Ministry of Transportation (1998), which recommend the use of Satuan Ruang Parkir (SRP) as the unit of measurement for parking requirements. The formula incorporated critical parameters such as the proportion of passengers using private vehicles, the peak-hour factor to reflect concentrated demand, and the average vehicle occupancy rate. Each SRP was assumed to occupy 35 m², including maneuvering and circulation areas, ensuring realistic spatial planning. This stage quantified the required parking capacity for both current and future conditions.

(3) Evaluation of layout alternatives was conducted to determine the most efficient parking arrangement. Several layouts, including angled configurations (45° and 60°) and the perpendicular 90° layout, were compared in terms of land utilization efficiency, ease of circulation, vehicle maneuverability, and potential for accommodating future growth. Through this comparative analysis, the 90° parking layout was identified as the most suitable option. This configuration offered the highest density of SRP within the available land area, while maintaining operational efficiency and allowing for scalability to meet long-term demands.

(4) Rigid pavement design was undertaken to ensure the structural durability of the expanded parking facility. The design process followed the procedures outlined in the Pavement Design Manual No. 03/M/BM/2024, which considers cumulative traffic load (JSKN), subgrade strength (CBR values), and the design strength of the concrete material. After applying these parameters, the recommended pavement structure consisted of a 20 cm reinforced concrete slab, which provides sufficient capacity to withstand forecasted traffic loads throughout a 20-year design life. This pavement type was chosen for its durability, low maintenance requirements, and alignment with national technical standards.

Through the integration of these four stages, the methodology ensured that the expansion plan addressed both the projected demand for parking capacity and the technical requirements for pavement performance. The systematic approach also guaranteed that the recommendations produced in this study are practical, standards-based, and tailored to the operational characteristics of Colonel Robert Atty Bessing Airport.

Data Collection

Primary data were obtained directly from the airport authority, which included detailed passenger statistics for the period 2019–2024. These data served as the foundation for forecasting future passenger growth and estimating parking demand, ensuring that the projections were based on actual operational conditions of Colonel

Robert Atty Bessing Airport. In addition to passenger data, results from a soil investigation were incorporated, particularly the California Bearing Ratio (CBR) test, which indicated a subgrade strength of 8.88%. This parameter was essential for evaluating the load-bearing capacity of the soil and became a key factor in determining the appropriate pavement design to ensure long-term structural performance of the parking area.

Secondary data were also utilized to complement and validate the primary data. These included regulatory and technical references such as the Petunjuk Teknis Perencanaan dan Pengelolaan Parkir (1998), which provided guidance on parking space standards and calculation of Satuan Ruang Parkir (SRP). The Spesifikasi Umum 2017 was employed as a reference for construction materials, workmanship, and technical specifications relevant to rigid pavement structures. Furthermore, the Manual Desain Perkerasan Jalan No. 03/M/BM/2024 served as the principal guideline for pavement thickness design, incorporating factors such as cumulative traffic load (JSKN), concrete quality, and subgrade conditions.

Together, the integration of primary and secondary data ensured the reliability and accuracy of the research process. The primary data reflected the actual operational and geotechnical conditions of the airport, while the secondary data ensured compliance with national standards and regulations. This combination provided a comprehensive basis for calculating current and future parking requirements, selecting the most efficient layout, and designing pavement structures that are both technically sound and suitable for long-term serviceability.

Passenger Growth Forecasting

Passenger projections up to 2035 were carried out using the Holt Linear Trend method. This method is an extension of exponential smoothing, incorporating both level and trend in the data. The mathematical formulation is as follows:

- Level: Lt=αYt+(1−α)(Lt−1+Tt−1)L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1})Lt=αYt +(1−α)(Lt−1+Tt−1)

- Trend: Tt=β(Lt−Lt−1)+(1−β)Tt−1T_t = \beta (L_t - L_{t-1}) + (1-\beta)T_{t-1}Tt=β(Lt −Lt−1)+(1−β)Tt−1

- Forecast: Ft+m=Lt+mTtF_{t+m} = L_t + mT_tFt+m=Lt+mTt

Where LtL_tLt is the level component, TtT_tTt the trend, YtY_tYt the observed value, and Ft+mF_{t+m}Ft+m the forecast for mmm periods ahead. The smoothing parameters (α,β\alpha, \betaα,β) were calibrated to minimize forecast error. Model accuracy was assessed using Mean Absolute Percentage Error (MAPE), with values below 10% considered acceptable for planning purposes.

Parking Demand Analysis

Parking demand in this study was estimated based on projected passenger growth, with the calculation referring to the *Guidelines for Parking Planning and Management* issued by the Indonesian Ministry of Transportation (1998). The required number of parking units, expressed as **Satuan Ruang Parkir (SRP)**, was determined using Equation

SRP=Forecasted Passengers×Vehicle Ratio×Peak Hour Factor/ Average Occupancy

where:

- **SRP** = number of required parking spaces,
- **Forecasted Passengers** = estimated number of passengers during the design year,
- **Vehicle Ratio** = percentage of passengers using private vehicles,
- **Peak Hour Factor** = proportion of daily passengers concentrated in the peak hour,
- **Average Occupancy** = average number of passengers per vehicle.

The SRP value represents the basic unit of parking capacity, with one SRP assumed to occupy **35 m²**, including both the effective parking stall and additional space for maneuvering, circulation, and safety clearances. This assumption follows the Ministry of Transportation guidelines (1998), which recommend the inclusion of circulation factors to ensure operational efficiency in airport parking facilities.

In practical application, the calculation process involves several stages. First, passenger forecasts were obtained based on historical traffic trends and projected growth rates. Second, the vehicle ratio was applied to estimate the proportion of passengers arriving by private vehicles, excluding those using public transport, taxis, or other modes. Third, the peak hour factor was introduced to reflect the concentration of passenger arrivals and departures during the busiest operational periods, which typically coincide with flight schedules. Finally, the average vehicle occupancy rate, representing the mean number of passengers per car, was incorporated to adjust for shared rides and family travel behavior.

By integrating these parameters, the SRP calculation provides a realistic estimate of the required parking capacity. For instance, if the projected number of passengers is 1,000 per peak hour, with a vehicle ratio of 40%, a peak hour factor of 0.12, and an average occupancy of 2.5 passengers per car, the required parking capacity is:

$$SRP = \frac{1,000 \ x\ 0.40\ x\ 0.12}{2.5} = 19.2 = 20\ cm$$

Thus, 20 SRP units would be required, equivalent to a total land area of **700 m²** (20 × 35 m²). This method ensures that the planned parking facility is both adequate and efficient, balancing projected demand with available land resources while adhering to national technical standards.

Layout Alternatives

Five configurations were evaluated: parallel (0°), angled (30°, 45°, 60°), and perpendicular (90°). Each layout was analyzed for land-use efficiency, circulation ease, and total capacity. The evaluation emphasized maximizing efficiency while ensuring operational practicality.

Pavement Design

The rigid pavement thickness in this study was designed based on the *Pavement Design Manual* No. 03/M/BM/2024 issued by the Directorate General of Highways, Ministry of Public Works and Housing (PUPR). The design procedure followed the standard stages outlined in the manual, including determination of design service life, estimation of design traffic load expressed in terms of the **Equivalent Number of Commercial Vehicle Axles (JSKN)**, specification of concrete grade, and selection of subbase type and thickness.
The equivalent axle load was calculated using Equation

JSKN=(∑AADTJK×JSKNJK)×365×DD×DL×R)

where **AADTJK** is the average annual daily traffic for each vehicle type, **JSKNJK** is the axle equivalency factor (Table 5B), **DD** is the directional distribution factor, **DL** is the lane distribution factor, and **R** is the cumulative traffic growth factor.
In this case, the projected traffic volume was 130 vehicles per day, consisting of 60% light vehicles (JSKN = 0.05), 30% light trucks (JSKN = 0.525), and 10% medium trucks (JSKN = 1.610). The daily JSKN was obtained as:

(78×0.05)+(39×0.525)+(13×1.610)=45.305

Thus, the annual JSKN equals:
45.305×365=16,544.325

and the total JSKN over a 20-year design period (DD = 1, DL = 1, R = 1) is:
16,544.325×20=330,886.5

The concrete slab thickness was then determined using Equation:

$$D = \sqrt{\frac{P\ x\ C\ x\ JSKN}{K}}$$

where **D** is the slab thickness (cm), **P** is the functional pavement parameter (150), **C** is the subgrade strength coefficient (2.5), **JSKN** is the cumulative traffic load (330,886.5), and **K** is the modulus of subgrade reaction (400,000 kN/m³). The calculation yields:

$$D = \sqrt{\frac{150\ x\ 2.5\ x\ 330,886.5}{400,000}} = 17.6\ cm$$

According to the manual, the minimum slab thickness is standardized to **20 cm**. This value was therefore adopted as the final design thickness, ensuring structural performance and durability over the 20-year service life.

RESULT AND FINDING

Passenger Data

The historical passenger data from 2019 to 2024 show a positive trend despite disruptions during the COVID-19 pandemic.

Table 1. Passenger Data

Year	*Passengger*
2019	83846
2020	29797
2021	16725
2022	34279
2023	40249
2024	43015

From the table, a decline in 2020 can be observed due to the pandemic. However, recovery began in 2021, and growth has continued steadily. This indicates that the demand for airport facilities, including parking areas, will increase over time.

Passenger Projection

Passenger forecasts using Holt Linear Trend show consistent growth toward 2035.

Table 2. Passenger Projection

Tahun	M	Level (Lt)	Trend (Tt)	Forecast (Ft)
2025	1	63967	5543	69509
2026	2	63967	5543	75052
2027	3	63967	5543	80595
2028	4	63967	5543	86137
2029	5	63967	5543	91680
2030	6	63967	5543	97223
2031	7	63967	5543	102765
2032	8	63967	5543	108308
2033	9	63967	5543	113851
2034	10	63967	5543	119394
2035	11	63967	5543	124936

Parking Demand

Parking demand analysis was based on projected passenger numbers, vehicle-to-passenger ratios, and peak-hour factors.

Table 3. Parking Demand

No.	Vehicle	Percentage (%)	Index vehicle per day
1	small vehicle	60%	78
2	Small truck	30%	39
3	Medium truck	10%	13
	Total	**100%**	**130**

With one SRP equal to 35 m², the total land requirement by 2035 reaches approximately 6,000 m². Compared to the current capacity of only 28 SRP, the gap between supply and demand is significant and requires immediate planning.

Layout Evaluation

Five layout options were analyzed: parallel (0°), angled (30°, 45°, 60°), and perpendicular (90°).

Table 4. Layout Evaluation

Layout	Capacity	Maneuverability	Efficiency
0°	Low	Easy	Inefficient
30°	Medium	Good	Moderate
45°	Medium	Good	Moderate
60°	High	Fair	Efficient
90°	Very High	Difficult	Most Efficient

The analysis shows that the 90° layout provides the highest capacity, which is critical in maximizing the use of limited land at the airport. While maneuverability is somewhat reduced, this drawback can be managed with proper circulation design. Which we can see on picture below.

Figure 1. Layout 60⁰

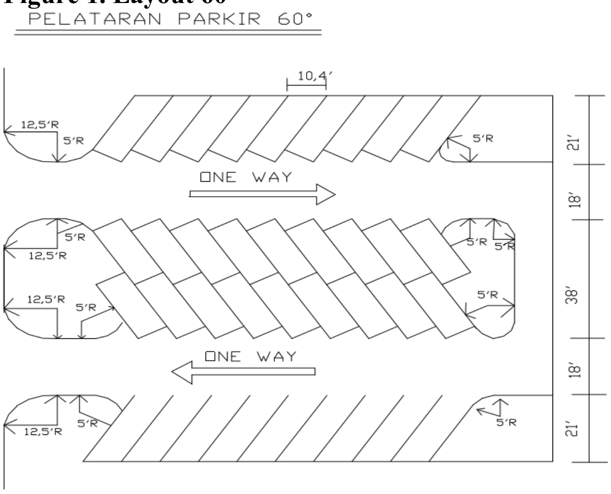


Figure 2. Layout 45⁰

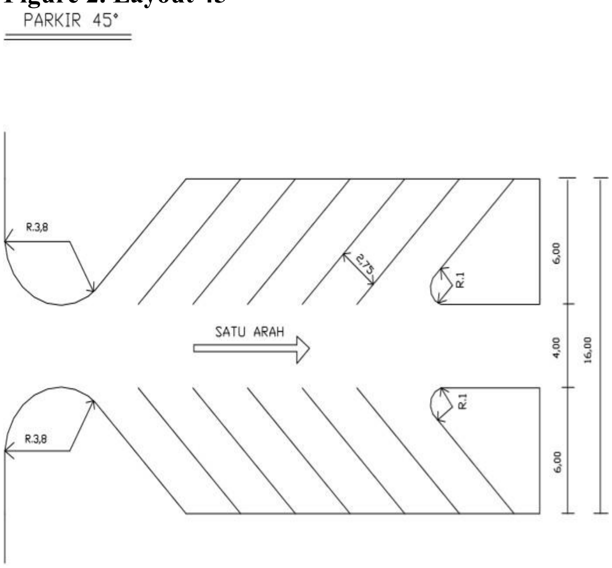
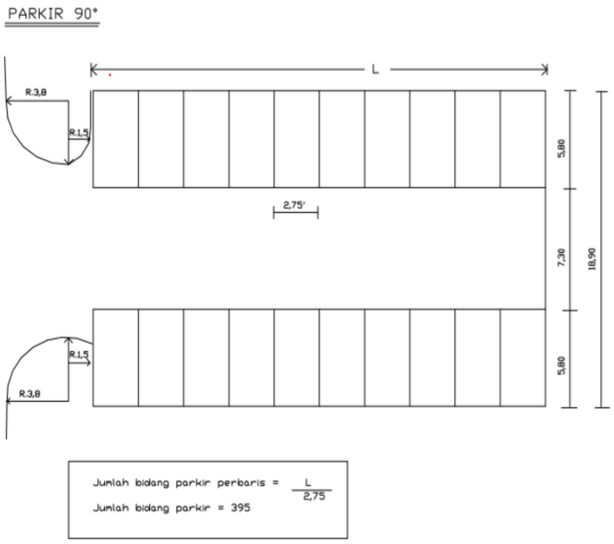


Figure 3. Layout 90⁰



Vehicle Composition and JSKN

Traffic load, expressed in terms of JSKN (Jumlah Sumbu Kendaraan Niaga), was calculated from vehicle composition.

Table 5. Vehicle Composition and JSKN

Vehicle Type	Percentage Composition	Equivalent Axle Load
Small Cars	60%	00.05
Light Trucks	30%	01.00
Medium Trucks	10%	01.05

The calculation resulted in a JSKN of 170,820 for the 10-year design period. This figure indicates the cumulative axle load that the pavement must withstand, forming the basis for structural design.

Pavement Design

Rigid pavement was designed according to *Manual Desain Perkerasan Jalan 2024*, with inputs of JSKN, CBR, and concrete strength.

Table 6. Pavement Design Structure

Layer	Thickness	Material
Surface	20 cm	Reinforced Concrete (K-300)
Subbase	15 cm	Lean Concrete
Subgrade	–	Compacted Soil (CBR 8.88%)

This structure ensures durability and long service life, capable of handling the projected mixed traffic loads with minimal maintenance.

Interpretation of Results

The results of the analysis indicate that the current parking facility is no longer sufficient to meet existing demand. The number of available Satuan Ruang Parkir (SRP) is below the calculated requirement for present passenger volumes, which already causes congestion, longer vehicle queues, and circulation inefficiencies. If no intervention is carried out, this shortage will increasingly hinder passenger comfort, reduce service quality, and negatively impact the overall functionality of the airport.

Forecasts toward the year 2035 show that approximately 130 SRP will be required, which is more than four times the current capacity. This substantial increase highlights the urgency for parking expansion in order to prevent severe capacity shortages in the future. Without adequate expansion, the airport risks facing operational problems such as excessive queuing at entrances and exits, conflicts between circulating and parked vehicles, and reduced accessibility for both passengers and airport staff.

Regarding layout configuration, the 90° parking arrangement was determined to be the most effective solution. Compared to angled layouts, the 90° system provides maximum space efficiency, allowing more vehicles to be accommodated within a given land area. It also enables two-way circulation patterns that are suitable for airport operations. While the maneuvering space required is slightly larger, the gain in overall parking capacity and the more rational use of land makes this option the most suitable for long-term planning.

From a pavement perspective, the study recommends the application of rigid pavement with a reinforced concrete slab of 20 cm thickness, designed in accordance with the Pavement Design Manual No. 03/M/BM/2024. This design offers several advantages, including high structural strength, durability against repetitive heavy axle loads, and lower maintenance needs over the pavement's service life. With projected increases in vehicle movements and the significant presence of commercial vehicles, the use of a 20 cm rigid pavement ensures adequate performance throughout the 20-year design period.

In summary, the findings emphasize the importance of anticipatory infrastructure development. Parking expansion at the airport is not merely a corrective measure for current deficiencies, but also a forward-looking strategy to accommodate future growth. The integration of an optimized layout and a robust pavement structure will guarantee both functionality and sustainability. This approach will allow the airport to continue supporting operational efficiency, passenger convenience, and regional transportation connectivity in line with future development needs.

DISCUSSION

The findings of this study clearly demonstrate that Colonel Robert Atty Bessing Airport is facing an urgent need to expand its parking facilities. With passenger numbers projected to more than double by 2035, the current capacity of only 28 SRP is grossly inadequate. The analysis shows that at least 130 SRP will be required to meet projected demand, necessitating the development of approximately 6,000 m² of new parking area. This confirms that without intervention, the airport will experience increasing congestion and operational inefficiencies, directly affecting passenger satisfaction and safety.

The selection of a 90° perpendicular layout was a critical decision. Although maneuverability is somewhat reduced compared to angled layouts, the primary advantage lies in land-use efficiency and capacity. Airports often face land constraints due to surrounding development and environmental limitations. In this context, maximizing capacity within available land becomes the overriding priority. Similar studies have reached comparable conclusions. For example, Saputra et al. (2020) at Raja Haji Fisabilillah Airport found that perpendicular layouts offered the highest capacity despite maneuvering difficulties, making them preferable for high-demand scenarios. Likewise, Panjaitan et al. (2022) emphasized that maximizing land efficiency should take precedence in rapidly growing airports. These parallels validate the findings of this study and demonstrate consistency with broader research in the field.

From the perspective of pavement design, the adoption of rigid pavement (concrete) provides multiple benefits. Compared to flexible pavement, rigid pavement offers higher structural strength, lower maintenance costs, and longer service life. This makes it particularly suitable for airport environments, where loads are mixed and sometimes unpredictable. In addition to small passenger vehicles, service vehicles and light to medium trucks also use the parking area, requiring pavement that can withstand higher axle loads. The JSKN value of 170,820 indicates a significant cumulative load over the design period, justifying the need for reinforced concrete pavement. Previous research by Putri et al. (2017) and Yuliani et al. (2019) also highlighted that rigid pavement in airport parking areas significantly reduces long-term maintenance costs while providing better performance under high traffic intensity.

Another important implication is the strategic alignment of this expansion with long-term airport development. As regional airports are expected to play larger roles in supporting connectivity, ensuring that landside facilities keep pace with airside developments is crucial. While investments in runways and terminals often receive priority, neglecting parking facilities risks creating bottlenecks that undermine overall efficiency. In this study, by integrating passenger forecasting, parking demand analysis, layout evaluation, and pavement design, a comprehensive solution is provided that addresses both capacity and durability concerns.

Beyond technical aspects, the results also have policy implications. The findings suggest that airport authorities should adopt proactive planning, anticipating future growth rather than reacting to congestion once it occurs. Furthermore, incorporating durable infrastructure such as rigid pavement aligns with sustainability principles, as it reduces the frequency of maintenance interventions, conserves resources, and minimizes disruption to airport operations.

In summary, the discussion reinforces the importance of a holistic approach to airport infrastructure planning. The chosen 90° layout ensures maximum capacity, while the rigid pavement design provides the durability needed to support long-term operations. These findings not only solve immediate capacity shortages but also contribute to the broader literature on airport landside facility planning, particularly in regional airports with growing passenger demand.

CONCLUSION

This research was conducted to address the parking shortage at Colonel Robert Atty Bessing Airport, Malinau, North Kalimantan, through comprehensive planning of parking expansion using rigid pavement. Based on the analysis and findings, several key conclusions can be drawn:

1. **Passenger Growth Projection**
   Passenger numbers are projected to grow steadily, reaching approximately 90,000 by 2035. This more than doubles the figures recorded in 2019, highlighting the increasing importance of the airport as a regional transportation hub. Forecasting with the Holt Linear Trend method proved reliable, with a low error rate, and provided a solid foundation for estimating future infrastructure needs.

2. **Parking Demand Requirement** Analysis of parking demand showed that by 2035 the airport will require around 130 SRP, equivalent to approximately 6,000 m² of land area. Compared to the current capacity of only 28 SRP, the gap is significant, making expansion not only necessary but urgent. Without adequate parking, congestion and circulation problems will increasingly undermine the quality of service and passenger satisfaction.
3. **Optimal Layout Selection** Among the five layouts considered, the 90° perpendicular configuration was identified as the most efficient. While maneuverability is more challenging compared to angled layouts, the superior capacity achieved is critical in making the most of limited land resources. This decision aligns with previous research that also prioritized land efficiency in high-demand contexts.
4. **Pavement Design Suitability** The rigid pavement design, consisting of a 20 cm reinforced concrete surface layer over a 15 cm lean concrete subbase, was selected to withstand the calculated JSKN of 170,820 and the subgrade CBR of 8.88%. The use of rigid pavement ensures durability, reduced maintenance, and suitability for mixed traffic, including service vehicles and light trucks. This design provides a 10-year service life with minimal intervention.
5. **Practical and Strategic Implications** The results provide practical recommendations for airport authorities to anticipate demand growth rather than reacting to existing problems. Expanding parking with durable materials ensures long-term cost savings, sustainability, and improved passenger experience. Strategically, the study underscores the importance of balancing airside and landside development to maintain overall airport efficiency.

In conclusion, the expansion of parking facilities at Colonel Robert Atty Bessing Airport using rigid pavement is both technically feasible and strategically necessary. By integrating passenger forecasting, demand analysis, layout evaluation, and pavement design, this study offers a comprehensive framework that can serve as a reference for other regional airports facing similar challenges. Future studies are encouraged to explore environmental aspects and smart technology integration to further enhance parking efficiency and sustainability.

RECOMMENDATION

Based on the findings and conclusions of this research, several recommendations can be proposed for both practical implementation and further academic studies:

1. Implementation by Airport Authority
   The airport management should prioritize the expansion of parking facilities to at least 130 SRP by 2035 in accordance with the projected demand. Early action is necessary to avoid congestion problems that could disrupt airport operations. Implementation should follow the recommended 90° layout and rigid pavement structure to ensure efficiency and durability.

2. Phased Development Plan
   Considering budgetary and land-use constraints, the expansion could be implemented in phases. The first phase should address immediate shortages by increasing capacity to approximately 80 SRP by 2025. Subsequent phases should align with projected milestones in 2030 and 2035, ensuring capacity remains ahead of demand growth.

3. Maintenance and Monitoring
   Although rigid pavement requires less frequent maintenance compared to flexible pavement, routine monitoring is essential to ensure long-term performance. The airport authority should establish a maintenance schedule focusing on joint sealing, crack inspection, and subgrade stability checks. Preventive maintenance will prolong the service life and minimize costly repairs.

4. Integration with Landside Planning
   Parking facilities should be integrated into broader landside planning, including access roads, drop-off zones, and pedestrian walkways. Future expansion should consider passenger convenience, circulation safety, and potential integration with smart parking systems to improve efficiency and user experience.

5. Future Research Directions
   Further research is recommended to incorporate environmental and sustainability aspects into parking design, such as permeable concrete for stormwater management or the integration of solar panels in parking canopies. Additionally, the application of smart technology, including automated parking guidance and online reservation systems, could be explored to optimize space utilization and reduce congestion.

By implementing these recommendations, Colonel Robert Atty Bessing Airport can ensure that its landside facilities evolve in tandem with passenger growth, enhancing both service quality and operational resilience. Moreover, these recommendations provide a roadmap for other regional airports in Indonesia facing similar challenges, contributing to more sustainable and forward-looking airport infrastructure development.

AUTHORS' CONTRIBUTIONS

1. **Donni Octaviano Hindarto**: Main researcher, responsible for conducting the study, data collection, forecasting analysis, parking layout evaluation, pavement design, and preparation of the manuscript.

2. **Linda Winiasri, S.Psi., M.Sc** : Provided academic supervision, conceptual guidance, and technical direction throughout the research process, ensuring the study followed proper methodologies.

3. **Fahrur Rozi, ST. M.Sc :** Assisted in technical review, provided feedback on design calculations, and guided the structuring of the final report.

4. **Dr. Siti Fatimah, S.T., M.T. :** Served as head examiner, validating the feasibility and accuracy of the research results, and offering evaluations on clarity, methodology, and presentation quality.

5. **Dr. Wiwid Suryono, S.Pd., M.M.** : Acted as secretary of the examination board, providing oversight, additional feedback, and ensuring compliance with academic standards.

6. **Linda Winiasri, S.Psi., M.Sc** : Gave expert validation regarding the technical aspects of parking design and rigid pavement structure, as well as feedback on the practicality of the recommendations.

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