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Smart Vertical Rotary Parking System

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Abstract: *The shortage of parking spaces has become a problem in densely populated cities due to urbanization and the growing number of vehicles. To address this issue, a Smart Vertical Rotary Parking System is proposed, offering an innovative and space-efficient solution by utilizing vertical space instead of conventional horizontal parking. This system aims to maximize parking capacity in limited areas, reducing land usage while ensuring quick and automated vehicle retrieval.*

The proposed system operates on a rotary mechanism, where vehicles are moved vertically and horizontally using a motor-driven platform. The model uses a combination of mechanical, electrical, and IoT-based systems to automate parking and retrieval. The prototype is managed by a website that facilitates the booking, parking, and retrieval of vehicles, making it more convenient for users. Solar panels are incorporated into the model to ensure sustainable energy usage and contribute to environmental conservation.

Key features of the system include efficient space utilization, low operational costs, and reduced carbon footprint due to solar energy incorporation. The design includes safety measures such as obstacle detection, emergency stop mechanisms, and secure locking systems, but they are conceptually included without practical testing. The system's design and functionality are demonstrated through a scaled-down working prototype, showcasing the feasibility of implementing this technology in real-world scenarios.

This project holds potential for future advancements by integrating AI-based parking algorithms and enhancing real-time data analytics, making urban parking systems smarter, safer, and more efficient..

Keywords: Vertical Rotary Parking System (VRPS),Urban Areas, Space Utilization, Vehicle retrieval time

I. INTRODUCTION

A VRPS is an automated parking system that optimizes limited urban space by stacking cars vertically in a rotating system, similar to a Ferris wheel. This type of parking system, also known as carousel parking, uses a rotating platform and a set of interconnected pallets or carriages to efficiently store and retrieve vehicles within a compact footprint.

Once the driver positions their vehicle in the entry bay, the system automatically rotates to place the car in an available slot in the stack. Drivers no longer have to search for parking spaces or navigate within a garage, resulting in a streamlined and time-saving experience.

The VRPS is ideal for urban areas where land scarcity is high and parking demand is continually rising. By reducing the need for expansive ground space, VRPS can significantly alleviate the urban parking problem while minimizing environmental impacts such as traffic congestion and pollution from cars idling or driving within parking structures. The system improves security by restricting access to parked vehicles, which provides greater protection against theft and damage compared to conventional open-parking lots. VRPS has become more popular in cities worldwide, particularly in regions with dense populations, like Japan and parts of Europe.

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Fig 1. Vertical Rotary Parking System

1.1 Research Objectives:-

1. Optimize Space Utilization with AI-based dynamic parking slot allocation, ensuring that available space is used effectively based on vehicle size and type.

2. Reduce Energy Consumption by integrating renewable energy sources like solar panels and using energy-efficient motors.

3. Minimize Vehicle Retrieval Times by incorporating automated vehicle detection and intelligent retrieval mechanisms to improve user experience.

4. Incorporate Safety Features such as obstacle detection and fire alarms (to be conceptually included in the prototype but not tested).

5. Lower Maintenance and Operational Costs by employing a simplified, modular design and durable components, improving system reliability and reducing the need for frequent repairs.

1.2 Methodology

To develop the Smart Vertical Rotary Parking System, the methodology began by identifying the urban challenges of limited parking space, congestion, and high emissions. A solution was proposed to create an AI-integrated, solar-powered vertical parking system. The project objectives were established to maximize space efficiency, automate parking, and enhance sustainability after an extensive literature review identified gaps in traditional parking methods. A small-scale prototype was designed using a rotary mechanism, AI-based slot allocation, and energy-efficient components. Safety features like obstacle detection and fire alarms were conceptually incorporated. The system was constructed using both mechanical and electronic components, evaluated for operational efficiency, and documented extensively to support future advancements in smart urban parking solutions.

II. NEED OF "SMART VERTICAL ROTARY PARKING SYSTEM"

Urbanization, population growth, and the rise in private vehicle ownership have made the need for a smart VRPS more essential. As cities become more congested, available land for parking decreases, while the demand for parking space continues to grow. Smart VRPS addresses these challenges by maximizing space utilization, reducing environmental impact, and integrating intelligent technology for efficient parking management. Smart VRPS systems are designed with automation and user convenience in mind, reducing the need for manual labour and human intervention. For instance, modern VRPS systems are equipped with sensor-based entry and exit systems, real-time space allocation, and automated retrieval, which not only reduce vehicle idle time but also lower emissions associated with searching for

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parking spots. Smart VRPS complements smart city initiatives by collecting data on parking patterns to inform urban planning and optimize parking availability. By offering seamless integration with mobile applications or touchless entry via RFID, smart VRPS systems improve user experience and are more aligned with the needs of a digital, connected world. Smart parking systems contribute to sustainability efforts by reducing the need for massive concrete structures and minimizing the ecological footprint of urban parking.

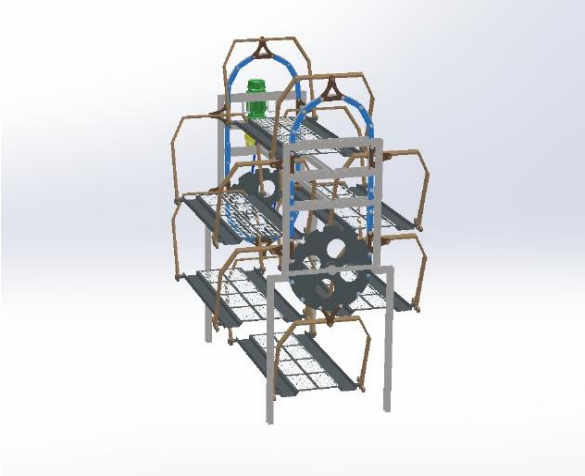

Fig 2. VRPS Assembly

III. GAPS IN PREVIOUS VERTICAL PARKING SYSTEM

- Inefficient Space Allocation: Existing vertical parking systems often assign parking slots on a first-come, first-served basis, leading to inefficient use of space. Vehicles of varying sizes are often placed in inappropriate slots, resulting in wasted space and under-utilization of the parking structure.
- Energy Consumption: Traditional vertical parking systems rely on energy-intensive motors and machinery for vertical movement, leading to high operational costs and increased energy consumption. The use of non-renewable energy further compounds this issue.
- Slow Vehicle Retrieval Times: Problem: Many existing systems suffer from slow vehicle retrieval processes due to inefficient design and lack of smart technologies. This leads to long waiting times for users, particularly during peak hours.
- Lack of Safety Features: Older parking systems often lack modern safety features such as obstacle detection, fire alarms, and emergency response systems. This raises concerns over user safety, especially in high-traffic areas.
- High Maintenance Costs: Traditional systems require frequent maintenance due to mechanical complexity and energy inefficiency. This leads to higher operational expenses and downtime.

Various Types of Parking Systems:-

Urban mobility demands have given rise to several types of parking systems, each with its own advantages and applications:

Conventional Parking:

Vehicles are manually parked in open lots or multi-level structures.
Requires large land area.
Prone to inefficiencies and congestion.

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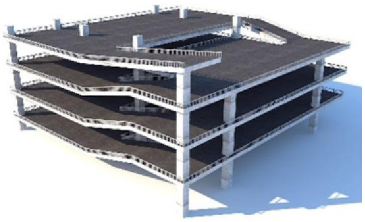

Fig 3. Conventional Parking System

Multilevel Parking System:

Uses ramps or elevators to park vehicles across multiple floors.

Common in malls and business centers.

Fig 4. Multilevel Parking System

Stack Parking System:

Two or more cars are stacked vertically using hydraulic lifts.

Simple mechanism but limited to a small number of vehicles.

Fig 5. Stack Parking System

Automated Guided Vehicle (AGV) Parking System:

Robotic vehicles move cars to designated slots.

Fully automated and efficient but costly.

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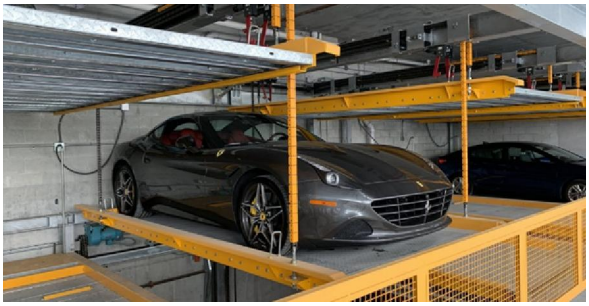

Fig 6. Automated Guided Vehicle (AGV) Parking System

Rotary (Carousel) Parking System:

Platforms rotate vertically like a Ferris wheel.

Saves space and ideal for crowded urban centers.

Fig 7. Rotary (Carousel) Parking System

Puzzle Parking System:

Vehicles move horizontally and vertically in a grid pattern.

Increases flexibility and capacity.

Fig 8. Puzzle Parking System

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IV. COMPARISON BETWEEN VERTICAL ROTARY PARKING SYSTEM AND CONVENTIONAL BUILDING PARKING SYSTEM

Space utilization, operational efficiency, environmental impact, and user experience are major differences between Vertical Rotary Parking System (VRPS) and conventional parking systems. In terms of space utilization, VRPS offers a superior solution, as it stacks cars vertically in a compact arrangement that requires a much smaller footprint compared to the extensive horizontal space needed for traditional parking garages. The land-intensive nature of conventional parking buildings is often due to their need for extensive ground areas, multiple levels with ramps, and vehicle circulation space. Conversely, VRPS minimizes land use by stacking cars and eliminates the need for ramps and driving lanes, saving valuable space. Operationally, VRPS is more efficient as it reduces the time drivers spend searching for parking spaces and navigating through multi-level garages, which is common in conventional systems. This efficiency in VRPS leads to lower vehicle emissions, as cars are not idling or moving around within the parking structure, thereby contributing to reduced pollution levels. In terms of user experience, VRPS offers greater convenience as it is fully automated, often allowing drivers to drop off their vehicles at an entry point without further navigation within the structure. Security is also enhanced in VRPS since access is restricted, reducing risks of theft or accidental damage, which are common in open-access conventional parking. However, conventional systems may be more adaptable for larger volumes but with less space efficiency.

Fig 9. Comparison of vertical parking system with Parking building

V. CONCLUSION

The Smart Vertical Rotary Parking System addresses critical urban challenges by offering a sustainable, efficient, and intelligent alternative to traditional parking. Through effective space utilization, solar integration, and automation, the system minimizes land use, reduces emissions, enhances user convenience, and supports smart city development initiatives. Although the prototype does not test safety features at full scale, the conceptual design lays the foundation for future advancements.

The Smart Vertical Rotary Parking System offers up to 70–80% space savings compared to conventional parking layouts by utilizing vertical rotary space effectively.

It can increase parking capacity by 3 to 4 times per square meter, making it highly suitable for space-constrained urban areas.

In terms of cost, while the initial installation may be higher, the system proves to be 30–40% more cost-efficient over time, owing to lower land costs, reduced manpower, and minimal ground maintenance.

The average lifespan of a well-maintained vertical rotary parking system is approximately 25–30 years, which is 5–10 years longer than many conventional open or basement parking structures, which typically last around 15–20 years before needing major repairs and reconstruction.

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VI. FUTURE SCOPE

- **Integration of Full-Scale AI and IoT:** Real-time monitoring and predictive parking slot management.
- **Advanced Safety Systems:** Real-world integration and testing of obstacle detection and emergency protocols.
- **Scalability Studies:** Implementing and testing larger-scale models in urban environments.
- **Green Energy Expansion:** Larger capacity solar panels and battery storage systems or use of any other Non conventional energy source.
- **Smart City Integration:** Data collection for traffic and urban planning based on parking usage patterns.

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