Design and Development of Smart Motorcycle Parking System

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***Abstract*—Nowadays, increased number of motorcycles in big cities of Pakistan causes the major issue of parking. The motorcycle parking requires a lot of space in open land. The Automated Smart Parking System requires small area while increase the parking number. A smart motorcycle parking system is an electro-mechanical system designed to reduce the space required for motorcycle parking. To minimize the amount of space lost in a multi-story parking lot, the smart motorcycle parking system, on the other hand, uses a mechanical system to transfer bikes to and from parking bays (rather than the driver). While a smart motorcycle parking system is more similar to an automatic storage and retrieval system for motorcycle. In a congested parking lot, it is difficult for drivers to manually hunt for a space. Traditional techniques for identifying open or occupied space are thought to be inaccurate and wasteful. As a result, our system provides a full range of parking assistance services, from helping drivers find and reserve a space to providing navigational aid to enable them park effectively at their intended location. In this work, radio frequency identification (RFID) tags are used to detect vacant parking slot and store and retrieve motorcycles. The proposed system results in decrease in land usage, increase the storage of the parking, increased safety of motorcycle, and fully automatic system.**

***Index Terms*— Motorcycle Parking System, Radio frequency identification (RFID), Smart Parking System.**

I. Introduction

At present time parking spots exist as distinct concrete structures where vehicles are parked by the individual or as open concrete squares in basement levels of buildings. The production of motorcycles climbed by 22.34% in the first four months of 2017–2018 compared to the same time the previous year, reflecting the growing number of motorbikes in Pakistan. According to the most recent data from the Pakistan Bureau of Statistics, 2,251,917 motorbikes, including Japanese brands constructed domestically and Chinese-made imports, were manufactured in the first 10 months of 2017. It is observed that at least 2.5 million bikes were produced in the previous year, while in only 10 months of current year (2018), the number of motorcycles produced in Pakistan has surpassed two million [1]. Therefore, this development aims at solving motorcycle parking problems in business center of big cities, theatres, shopping malls, stadiums and universities; at reduction of street parking in crowded areas, at decreasing pollution and at providing safe, secure, clean, economical and fast automated parking spaces for motorcycle. The extreme shortage of parking spaces, particularly in some urban locations such as residential areas, campuses, or street parking is a contributing factor to the difficult parking problem [2].

Developing mechanical parking devices is a workable alternative that directly improves the parking supply based on original space, among other techniques, as the ability of expanding parking areas is restricted [3]. Worldwide, a wide variety of parking schemes are in use. The first multi-story parking structure was built in 1918 for the La Salle hotel in Chicago [4]. In 1992, an automated parking system with a lifting feeder was invented in the United States. This innovation consists of a car lifting feeder and parking rack that automatically places automobiles in parking spots by using a set of wings that resemble combs to match each pair of comb-like platforms on the parking space. Parking lots with several decks are an excellent technique to fit cars into locations with the least amount of land. With the help of that technology, parking spots will be automatically assigned to cars, significantly reducing the amount of land that must be occupied. [5].

In Pakistan, the most common type of parking arrangement is the open one. This system uses a large land for parking. This system has no proper arrangement for parking. It also increases the traffic problem in big cities. As this require land which could be used for many other useful purposes. Open parking system does not have the security of vehicle [6]

Figure 1 Open Parking System[23]

A multi-storey a parking garage is a structure which is designed especially for vehicle parking and where there are a number of floors on which parking occur. It is essentially an arranged parking lot. It gives multiple access and exit system to avoid traffic congestion in and out. In this system driver have to park vehicle by driving himself to the parking lot [7 - 8].

Figure 2 Multi-storey Parking Building[22]

In their 2017 work, "Mechanical Parking System," Feng Yuan Wang and Yi Liu described a rotational system that enabled all of the automobiles to move in a circular motion. All of the automobiles rotated as they were loaded and unloaded. The car could be easily parked and operated with ease, which was a benefit. The fact that each automobile must be turned in order to access one, the high original cost and ongoing maintenance expenses, and Complex Organization [9].

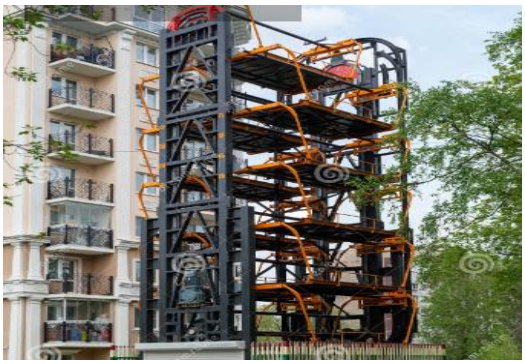


Figure 3 Rotary Parking System[21]

The design of a more straightforward, compact, rotating parking system that takes up vertical parking space. The parking platform is driven by a chain and sprocket mechanism, and a 1/4 horsepower braking motor will be utilized to power the system and index the platform [10].

There are various techniques used in smart parking system. Mostly system requires human interference. Some of the techniques are used to remove or decrease human interference for the functioning. Automated storage and retrieval systems (ASRS) were initially introduced in the 1950s to reduce human interference that accounted for 70% of manual retrieval time [11]. Actually, a typical ASRS is made up of many passageways with storage racks on both sides, as well as conveyors for arriving and departing unit-loads and stacker cranes for storing and retrieving components. This system may significantly reduce labor costs, improve material management, and increase system production. It has great accuracy, speed, and safety. Control system software, however, is crucial to achieving these advantages [12]. A storage system that performs storage and retrieval operations accurately and quickly with a predetermined level of automation is known as an automated storage/retrieval system (ASRS). An ASRS that manages and keeps palletized unit loads. Commercially available ASRSs automate a wide range of tasks. The most advanced level of operation involves complete automation, computer control, and integration with activities in the plant and/or warehouse [13]. A high-tech company called Guangdong AKE Technology Co., Ltd. in China created an indoor, outdoor, and urban smart parking system. The automobile and item are read by the interior parking system using an ultrasonic module and a camera as sensors, which then relay the information to the urban smart parking system. The ultrasonic module and camera are used by the indoor parking system as sensors to scan objects and cars and relay that information to the system [14]. Wireless sensor networks have several uses, including military surveillance, monitoring animal habitat, and monitoring endangered areas. The outdoor parking system operates on the same principle, but it makes use of a geomagnetic sensor to detect changes in the magnetic field inside the designated area. The sensor then wirelessly interacts with the server to update the user on the parking space's condition. The urban parking system monitors the availability of parking in the allocated parking lot using detecting sensors that are comparable to those used by outside systems [15].

Using radio waves, a technique known as radio frequency identification (RFID) can detect objects. It is among the most significant technological advancements that enable wireless data transfer [16]. In July 2022, Shashank Shenoy Basty, Rajeshwari Kiwad, Srikanth Vittal, and Mohammad Moin Ullah presented their study on the RFID-based Smart Parking System, which effectively used RFID technology to expedite parking spot identification. According to their study, the system had an easy-to-use interface that showed real-time parking spot availability information along with a welcome message. Although their method demonstrated the effectiveness of RFID in parking management, it's important to recognize several limitations, especially the heavy reliance on a single-floor design and significant land utilization [17].

The main purpose of this project is to overcome the problem of the parking in the city centers by designing a multi-story automated motorcycle parking system for the customers parking for limited time, which can reduce land usage in front of malls and offices. By the use of this system, we can overcome the parking problems in shopping malls and offices. The purposed system is fully automatic, free from human intervention by which motorcycles can be easily parked on available empty spaces.

II. Methodology

A. Motorcycle Dimensions

From market survey the average dimensions of motorcycle

are obtained. The design and production process of motorbikes can benefit greatly from the precise measurements that have been gained via rigorous market research. The average length of motorcycle is 2300 mm and average width is 900 mm. The average weight of motorcycle is 350 kg. These dimensions are reduced at specific lower scale for prototype manufacturing.

B. Mechanical Design

Initially for the design of the system Creo Parametric 4.0 (Pro/E) software is used. The selection of this software is due to its accuracy as compared to other designing software. It is used for mechanical engineering, design and manufacturing. It is combination of 3D CAD/CAM /CAE solution. It uses constraints, dimensions, features, and relationships to show product behavior and make guidelines, which allow design automation and the optimization of design and product development processes. [18].

There are multiple designs for parking system but we have to select the best, which can fulfill the requirements of the system. As our system require the design which can bear the load as well as give the smooth motion while operation. There are basically three types of motion are required in the system vertical, horizontal and in, out motion from the box. Every design consists of boxes into which bikes will be parked. Due to different sizes of motorcycles, we use the box of the maximum size of the motorcycle (with effective clearance) which provides for better placement of every size of motorcycle. Every box has a pallet on which to park a motorcycle. Pallet with or without motorcycle can be moved through the frame by trolley moving on special guideways which provide supporting structure of the building. The designs are different from each other due to difference in motion mechanisms.

In design 1, we have two fixed guide tracks for vertical movement of elevator on both side of the horizontal trolley guideway. In this design the elevator moves with the help of pulley system. Pulleys can be driven by electric motor as motor control the up and down motion of elevator. While horizontal motion can be carried out with screw mechanism

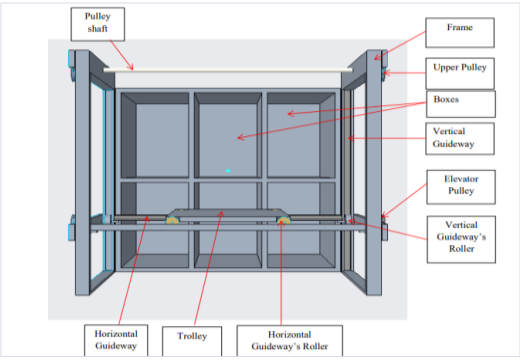


Figure 4 Design Alternative 1

In design 2, we have single guide track for vertical movement of the elevator. In this design vertical guideway moves in horizontal guideway for the movement of trolley. Vertical guideway moves along with the trolley. In this design, horizontal motion can be carried out through screw mechanism or rack and pinion system. While in vertical movement, the rack and pinon system can be used.

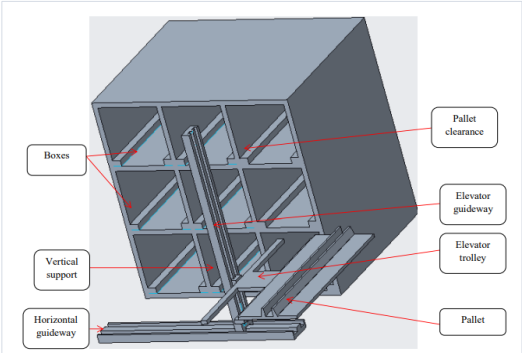


Figure 5 Design Alternative 2

In design alternative 3, we have used lead screws for horizontal and vertical motion. Two steel rods with each lead screw are used to provide support for load and smooth motion. The vertical lead screw and rods along with motor are fixed on a plate, which is attached with horizontal lead screw with the nut and bolt. Elevator trolley is used to store and retrieve the motorcycle from parking slots. Rack and pinion mechanism in used in elevator trolley.

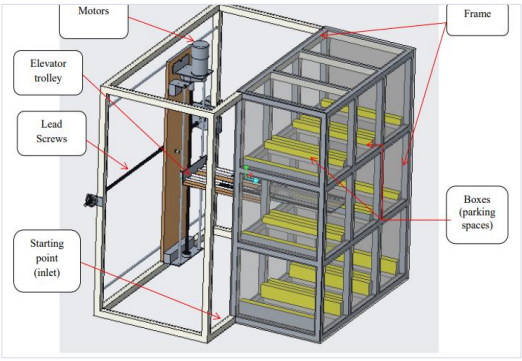


Figure 6 Design Alternative 3

. Design alternative 3 is more stable and feasible as compared to other proposed designs. So, design alternative III is selected for fabrication

C. Fabrication

For manufacturing of the selected design, it is important to select the material which can withstand load under different circumstances. Iron is good choice for manufacturing of whole system frame instead of wood structure. There are less chances of wear and tear in iron as compared to wood. Wood may be affected by weather and may not be able to carry load for long time durations. Iron gives good strength to the system against different circumstances of the weather. For more safety from corrosion, we paint whole metal frame. Also iron is used because it is easy to repair if any part is damage or require any maintenance as compared to other non-metallic material like wood or concrete.

Transparent acrylic sheets are used due to their long-lasted property and also due to light weights as compared to glass, around the boxes so the parking slots easily visible during experiment. The yellow-colored steps or strips in selected

design as shown in the figure 6 shows where palates will place.

III. Technical Details Of Sytem

A. Description of Mechanical Equipment

1) Lead Screws

The selected system consists of two lead screws which provide the guideway for vertical and horizontal movements of the system. Each lead screw has 10 mm diameter.

2) Steel Rods

Along with each lead screw there are two steel rods which are connected with the plates moving vertically and horizontally through bearings. The rods provide support in load managing of system. Each rod has 10 mm diameter.

3) Bearings

Two types of bearing are used; linear & circular. Linear bearing is used on steel rod for moving guideway supporting plate. Circular bearings are used at the end of lead screw for smooth rotatory motion.

4) Motor Coupling

Two motor coupling are used to transfer motion from motors to lead screw. Motor side internal diameter is 8 mm and lead screw side diameter are 10 mm.

5) Rack and Pinion

Rack and pinion mechanism is used to move slider for picking and placing of motorcycle in parking slot. This mechanism is used with stepper motor.

6) Slider

Two sliders are used below the lifter. Both move with the help of rack and pinion powered by the stepper motor. Slider provides guide way and smoothness to the motion of lifter for the picking and placing.

B. Description of Electrical Equipment

1) Gear Motors

There are two gear motors are used for providing the vertical and horizontal motion. Motor is connected to the lead screw. Motors have specifications of 24 volts and 465 rpm.

2) Stepper Motors

There is one stepper motor is used in the system. Stepper is used in rack and pinion mechanism for storage and retrieval system from boxes (i.e., parking spaces). Motor is connected to the pinion to provide power. The motor type is 17PM-K502-P2ST

3) Arduino

Arduino is a flexible microcontroller platform that is well-known for being easy to use, adaptable, and accessible for electronics projects and prototyping. From novices to experienced engineers, Arduino's user-friendly integrated development environment (IDE) and extensive range of input/output pins make it simple to design interactive electrical systems and gadgets. Because it is open-source, a thriving community of experts, enthusiasts, and makers contribute to its vast code and lesson library[19]. We have used two Arduinos; Arduino Uno & Arduino Nano. Arduino Uno is used for motor controlling software and Arduino Nano is used for the software of RFID tags and reader system; both are communicating between each other.

Figure 7 Arduino Uno

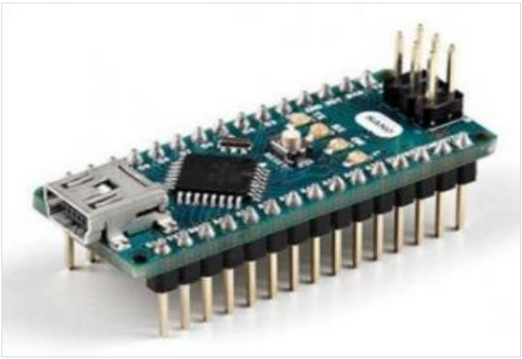


Figure 8 Arduino Nano

4) Motor Driver

L298N dual full-bridge driver, an integrated circuit in a 15-lead Multi-watt and Power. It is a high voltage, high current dual full-bridge driver made to drive inductive loads like relays, solenoids, DC, and stepper motors while also accepting normal Transistor-Transistor Logic (TTL) logic levels. To turn the gadget on or off without relying on input signals, there are two inputs available.[20].

5) RFID System

Radio Frequency Identification (RFID) is the wireless non-contact use of radio frequency waves for the transmission of data. RFID tags are used for automatically identify and tracking record and assets [17]. One RFID tag is allotted to one box. Each tag gives information to the system to park motorcycle in that specific box which is fixed for that tag. Tags are used to park and retrieve from parking.

Figure 9 RFID reader

6) Variable Resistance Sensor

Variable resistance transducers are common types of transducers. The variable resistance transducers are also called as resistive sensors or resistive transducers. They can be used for measuring different physical quantities like displacement, pressure, force, temperature, vibrations etc.[20]. In this system variable resistors are used to measure displacement between boxes and send feedback signal to operate motor according to calculated distance. The resistor we used has capacity of 0-20 kΩ.

IV. DESCRIPTION OF SETUP

This is a prototype experiment. Circuit connections were given through the ports of Arduino Uno, Arduino Nano, L298N motor driver, DC motors, RFID and board and these components are connected together. After Mechanical structure is fabricated, circuit connection was done according to requirement. Description is stated below

First of all, main body frame was made by using iron square pipe, which was cut into pieces then joined by welding. Main body frame consists of two parts; one contains parking boxes and second contains motion mechanism. Each box has 10-inch length, 6-inch width and 8-inch height. Second part has 27-inch length, 12-inch width and 25-inch height.

Two lead screws were manufactured of 10mm diameter. Horizontal has length of 27 inch and vertical has 20-inch length. Two motor coupling was made to transfer motion from motors to lead screw. Motor side internal diameter of coupling is 8 mm and lead screw side diameter are 10 mm. After drilling in frame, Horizontal lead screw with motor was installed on frame by nut and bolts at the height of 12.5 inch. Two steel rods were also fixed on frame; each steel rod is fixed at the distance of 2 inch from base and top of frame. A nut on horizontal lead screw was connected with a plate. Plate was also connected with two steels rods with the help of linear bearings from top and bottom.

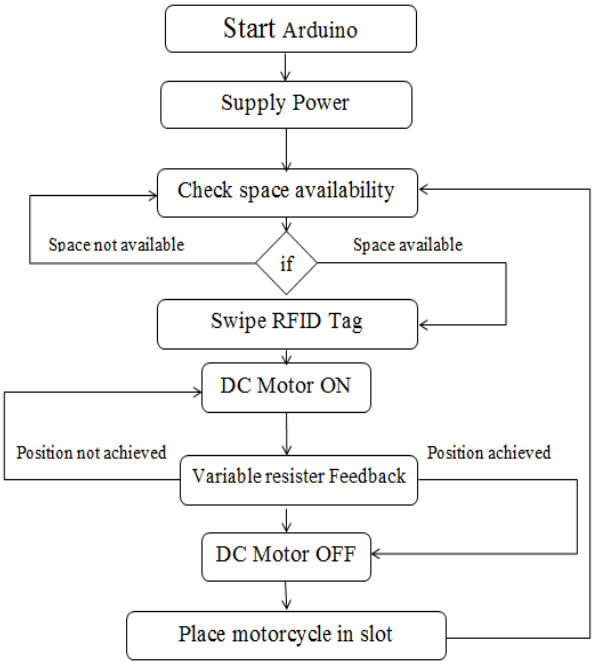
Then elevator system consists of motor, lead screw, steel rod and elevator trolley were fixed on plate connected to horizontal lead screw. Storage and retrieval mechanism had to install on the elevator trolley. Storage and retrieval mechanism was installed on trolley that is consisting of two railings, stepper motor and rack & pinion mechanism. Railings were used as guide track as well as for providing support. Then designed pallet as it was 0.75 inch above box surface so that trolley can pick and place the pallet into parking box. 0.75-inch square pipes were used to place pallet on them.

Circuit network for the automatic parking by using Arduinos, motor driver, relays and RFID reader etc. on Vero board. To operate motors for exacts location of boxes we used feedback of variable resistor sensor. After this we completed programming on Arduino software, such as each box has a specific location, that location was adjusted to a RFID tag. When a tag is read by RFID reader then system starts from picking location and place motorcycle in that specific box.

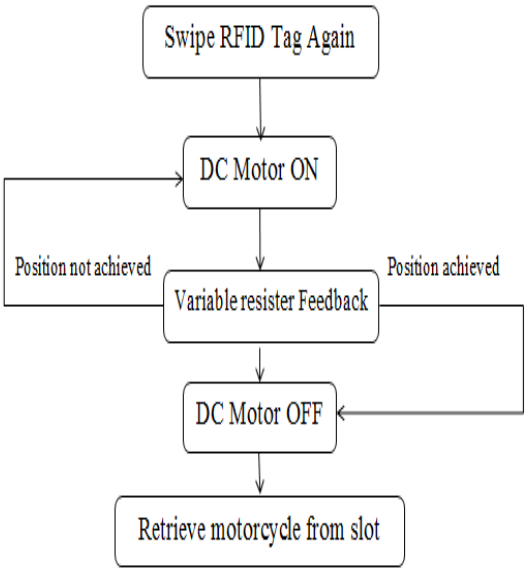
V. WORKING PROCEDURE

Power supply is given to the electric circuit through the power source. Motor cycle was parked on elevator trolley, Then RFID tag was scanned on RFID reader. As card is scanned, DC motor started its operation. DC motors with coupling rotates the horizontal and vertical lead screw. Vertical guideway supporting plate moves forward by the rotation of horizontal lead screw. Elevator trolley moved up by the rotation of vertical lead screw. As trolley reached at the location, stepper motor started and moves trolley in box. Then elevator trolley lowered slightly and stepper motor moves trolley out. The motorcycle on pallet remained in box. After that the elevator trolley returned to entry position. If next card is scanned, above procedure repeated. On scanning a card second time, the elevator trolley moved to that location and trolley picked up the pallet from box and leaves it to exit position.

A. Flow Chart for Storage



B. Flow Chart for Storage



VI. COMPARISON WITH REAL TIME MODEL

If a real time model for parking of 50 motorcycles is manufactured. 50 motorcycles will be parked at place of 10 motorcycles.

Two motors are needed which can carry load of almost 450 kg, maximum load of motorcycle is 350 kg and average elevator trolley load is 100 kg. Once you know how quickly and how far you need to raise the 450 kg weight, you can compute power. Put another way, you must determine the speed at which you wish to raise the weight before figuring out the power.

$$Power\ (P) = force\ \times velocity \tag{1}$$

$$Force\ =\ Weight\ =\ Mass\ \times\ Acceleration \tag{2}$$

g is approximately 9.81 m/s 2

$$P\ =\ 450\,kg\ \times\ 9.81\ {}^{m}/_{s^2}\ \times\ velocity$$

If lifting velocity is 1 m/s,

$$P\ =\ 4414N\ \times\ 1\,m/s$$

$$P\ =\ 4414\,W$$

$$P\ =\ 4.4\,kW$$

4.5 kW electric spindle motor, 220 volts can be used in real time model.

VII. RESULTS

The proposed system results in decrease in land usage, increase the storage of the parking, increased safety of motorcycle (i.e.; Secure and reliable), fully automatic system, job creation, income generation, reduced traffic issues. There are nine motorcycles can be parked at the place of almost four motorcycles in this system. The number of parking motorcycles can be increased by increasing the number of boxes.

VIII. DISCUSSION

In big cities of Pakistan population is increasing gradually, due to which land is decreasing. For huge population transportation size increases rapidly. Most commonly vehicle used is motorcycle. Due to shortage of land, enough parking of motorcycles is not available because of that we are parking on roadside. There is no such parking system in Pakistan to solve this issue. There are few points for which validity of this automated smart Motorcycle parking system is suitable for big cities of Pakistan.

This system occupies less space and gives more capacity. It can park 12 to18 motorcycles in space of 6 bikes. It uses less horizontal space (land) and more vertical space. The initial cost of this system is less and has less payback period. It can be constructed in short time. After civil and mechanical work is done, utilization can be done in 6-7 days. The capacity of system can be increased by adding more parking boxes after installation in less time. A smart motorcycle parking system is a time saving system. The maximum time required for storage and retrieval of motorcycle is 100 seconds. The specialty of system is the distribution of parking slot on basis of parking time. Ground floor parking boxes are allotted for shortest parking time (less than 15 minutes). First floor, second floor and upper floors are allotted to the customers according to their parking time. This system is very secure, as every customer have his own RFID card. Customer will able to get his motorcycle after scanning the card. The system is environment friendly, as it produces less noise. It is electrically operated. No air pollution occurs as motorcycle engines are shutdown during parking. Entry and exit in system are easy and simple. Customer does not need to search empty parking slot; he just needs to leave his motorcycle at entry and select & scan his card according parking time. For retrieving motorcycle customer need to scan his card again.

IX. FUTURE WORK

Future research in smart motorcycle parking systems should consider sensor fusion with artificial intelligence (AI) for real-time analytics, dynamic pricing models to maximize space utilization, smart infrastructure design for sustainability and flexibility, integration with larger mobility ecosystems, user-centric solutions for improved experience, accessibility considerations, and strong data privacy and security measures. Researchers can create complete, sustainable, and effective smart parking solutions by focusing on these regions, which will improve urban transportation ecosystems.

X. CONCLUSION

The utilization of RFID technology for motorcycle parking, coupled with the implementation of a multilevel stacking system, represents a significant advancement in smart motorcycle parking solutions. This technology streamlines the parking procedure for users by providing smooth and safe access through the integration of RFID tags into motorbikes and infrastructure. The problem of space constraints is addressed by the introduction of multilevel stacking, which efficiently maximizes parking capacity without expanding the footprint. This creative method maximizes the utilization of urban space while improving accessibility and convenience for users. Moreover, the RFID technology guarantees effective administration and observation, permitting instantaneous tracking of stationary automobiles and expediting their early recovery. All things considered, multilevel stacking and RFID technology have great potential to transform motorcycle parking and open the door to more intelligent, effective, and sustainable urban transportation solutions.

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