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Internet of Things Enabled Adjustable Ramp System for Productivity Enhancement of Micro, Small and Medium Enterprises †

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Abstract: The industry usually faces a problem during the loading/unloading of finished products and raw materials from one place to another when both places are at different elevations. As trucks are of variable height and industry loading bays are at different elevations, it is not possible to drive the pallets effectively into freight, which results in decreasing loading/unloading efficiency of small concerns. In this paper, an adjustable height ramp system for increasing production efficiency and improving the industrial working environment was developed using a linear actuator and automation system for the safe loading and unloading of pallets. This adjustable ramp will help to increase the productivity of micro, small and medium enterprises (MSMEs), and it will provide a safe working environment. Using an adjustable ramp will help create a bridge between industry loading bays and freight, and it will also resolve the issue of different heights of both by making a path between them. The Internet of things (IoT)-enabled lifting and downward movement of the ramp is attempted for oil/air filter MSMEs.

Keywords: IoT; sensors; relay pallets; ramp

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1. Introduction

The contribution of MSMEs to the Indian economy is 30% of its GDP. Economists are expecting that this figure will reach up to 35% by 2022. MSMEs contribute to 40% of the total exports from India. Additionally, 45% of the total manufacturing output comes from the MSME sector [1]. Productivity gives a quantitative measure of comparing performance. Productivity helps the manufacturing enterprise see present performance and determine what measures they should adopt to improve their productivity. Some factors that affect productivity is controllable or internal factors, including plant and machinery, technology, work method, and material handling [2]. Efficient material handling offers time utility and area software via the garage, as well as the management of material. Material handling is different from production (i.e., fabrication and assembly operations), which provides us with "shape software" by means of converting the shape, form, and outlook of material [3,4]. Industrial automation can generally be defined as the method of following a predetermined collection of operations with very little human exertion and the use of specialized systems and devices that carry out and manage manufacturing strategies [5]. Automation is executed by way of using a spread of gadgets, sensors, actuators, strategies, and devices that might be capable of estimating the production method, making selections concerning the modifications that need to be made within the operation, and manipulating all of the aspects associated with it. Internet of Things integrates diverse technologies like

PCs, wireless devices, and sensors, bridging cyber and physical realms for Industry 4.0. It lowers costs, boosts performance and quality, and offers predictive maintenance through data-driven services, aiding in digital transformation for industries [6]. There is a problem in industries with the loading/unloading of finished products and raw materials from one place to another when both places are at different elevations, as trucks are of variable heights and industry loading bays are at different elevations. So, it is not possible to drive the pallets into freight; this is often done manually in most industries. It is observed that this is too time-consuming; as the worker lifts more boxes, his efficiency will drastically reduce, and he will start to take much more time to lift more boxes.

2. Methodology

A field survey was conducted to increase productivity in oil/air filter manufacturing MSMEs. This research paper was influenced by research questions such as the existing productivity of an MSME with manual loading and unloading of cartons, the possible solution for replacing the manual loading/unloading problem, and the potential benefits of an adjustable ramp system and efficiency calculations for industry before and after its implementation.

The height of the loading bay from the ground is calculated as 0.95 m, and the height of the freight bay from the loading bay is calculated as 0.45 m; there is a difference in height between both the loading bay and the freight bay, as shown in Figure 1. This causes problems in loading and unloading and also results in decreasing the efficiency of the industry.

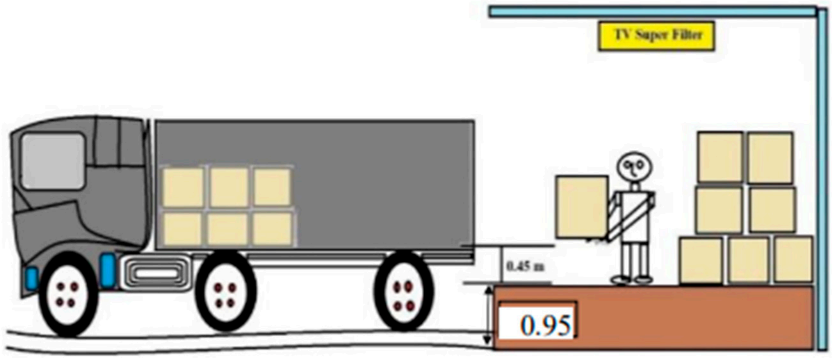


Figure 1. Difference in height between loading bay and freight bay.

3. Existing Productivity of MSMEs

It takes approximately 22–24 s to load one box from the pallet into the truck by a laborer. The approximate weight of one box is 60 kg, although there are some other boxes that are different in size and weight. As the laborer lifts five boxes, he gets tired. Subsequently, he takes more time, such as 30–34 s instead of 22–24 s. There is also a chance of injury to the laborer while lifting weight continuously. The entire loading of boxes on a truck consists of three steps, as follows:

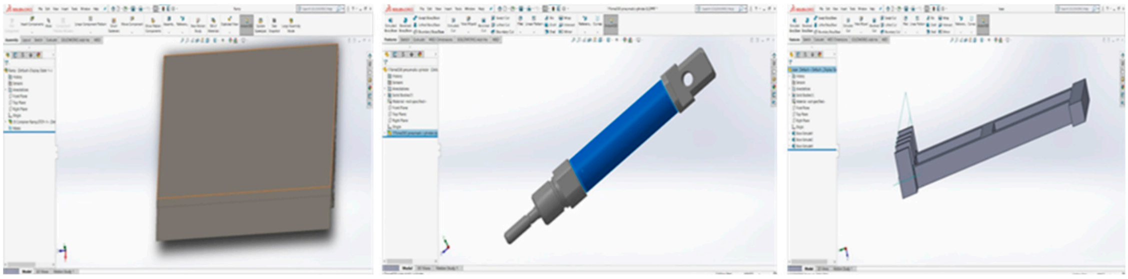
- The laborer bends and lifts the boxes from the pallet.
- The boxes are moved into the truck from the loading bay.
- The boxes are placed into the truck and then stacked.

This entire process of manual loading takes 22 s to lift one box. Based on industry surveys, a typical truck container bed measures 7.5 m long and 2.45 m wide, while cartons are 0.45 m long and 0.6 m wide. Each row and column accommodate 24 boxes, totaling 288 in a truck. Stacking takes time—22 s per box. The time for loading/unloading of one truck was calculated as 110.6 min, considering a rest allowance of 5 min. Streamlining this process is crucial to optimize operations and reduce time-consuming stacking and unloading procedures in the logistics chain.

The proposed adjustable electro-hydraulic/pneumatic ramp system addresses the industry's problem to boost production efficiency and safety during pallet loading and unloading. It enhances MSME productivity by reducing manual labor, creating a seamless bridge between loading bays and freight carriers, and eliminating elevation differences. It operates like a dock leveler, compensating for space and height variations and ensuring secure and efficient freight transfer [7–9]. This innovation offers a safer working environment, increased productivity, and streamlined operations for industries [10]. Designing an adjustable-height ramp helps to achieve objectives such as reducing human intervention and increasing productivity by reducing time to load/unload, with the possibility of minimizing injuries/accidents, thus providing a safe working environment.

4. Design of Adjustable Ramp System

The drawing of sub-parts of the adjustable ramp system was designed in Solid works (Version 2019) and Ansys was used to carry out the analysis, after visiting the industry and taking dimensions. The design with the original dimensions required for industry was designed using a Software named Solid works, 2019 version. Figure 2a,b,c, illustrate, respectively, the ramp with lip, the design of the pneumatic cylinder, the side view of the base, and the Computer Aided Design Model of the adjustable ramp system.

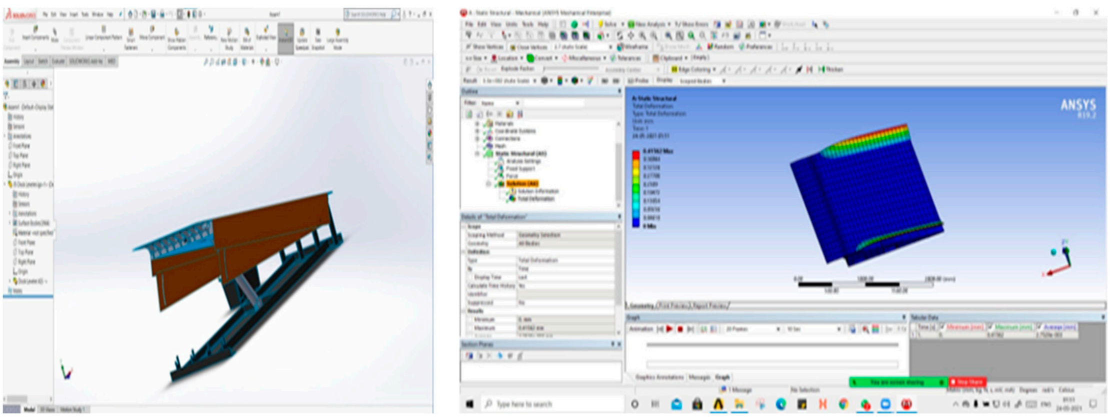


(**a**) (**b**) (**c**)

Figure 2. (**a**) Top view of ramp with lip. (**b**) Design of pneumatic cylinder. (**c**) Side view of base.

After designing the assembly, analysis software was used, i.e., Ansys R 19.2, to analyze our design. The load of 900 kg on the stainless-steel material is applied (as 700 kg was the industry's requirement and 200 was the safety factor) to check the amount of pressure absorbed by the adjustable ramp.

As shown in Figure 3, the blue color denotes the minimum pressure, and the red color denotes the maximum pressure.



(**a**) (**b**)

Figure 3. (**a**) CAD model of adjustable ramp system. (**b**) Analysis of design on Ansys.

Fabrication of Adjustable Ramp System as Prototype

The fabrication of an automatic industrial ramp was performed by using wood material for its ramp and lip and two ultrasonic sensors (HC SR04). The main purpose of these sensors is to properly position the truck, properly align the platform on the truck, enable the IoT lift, and enable downward movement of the truck. A linear actuator over a pneumatic cylinder is used due to cost and availability constraints. Other key components included a Node MCU for IoT applications, an HC-SR04 ultrasonic sensor for distance measurements, and a 24 V DC linear actuator with an 801 kg lifting capacity, converting rotational motion into linear motion at 4 mm/s. A 5 V dual-channel relay to control powered loads through a microcontroller was used, as well as an active buzzer for audio signaling. Additionally, a DC-DC buck converter that usually down the voltage with a potentiometer for adjustment was used. These adaptations allowed us to create an automated adjustable ramp system, optimizing resources and addressing challenges presented by the COVID-19 situation.

Figure 4 show the pictures of the fabricated prototype, which is made using wood. Figure 4a depicts the side view of the prototype with its lip seated on the truck trolley, and Figure 4b shows the linear actuator mounted on the table for lifting and the downward movement of the ramp. List of dimensions used for our prototype see Table 1.

(**a**) (**b**)

Figure 4. (**a**) Side view of ramp with trolley. (**b**) Side view of actuator mounted on the table.

Table 1. List of dimensions used for our prototype.

Description	Value
Length of ramp	0.45 m
Width of ramp	0.25 m
Length of lip	0.05 m
Thickness of ramp	0.01 m
Height to be lifted for small truck	0.102 m
Height to be lifted for larger truck	0.15 m
Angle of cylinder to be fitted as follows:	
Height of cylinder to the base	0.32 m
Total length of cylinder with maximum stroke	0.36 m
So, angle of cylinder placed will be	0.906
Sinθ = 0.32/0.36	Sinθ = 0.906
θ	65°

5. Operation of Adjustable Ramp System

The parking of incoming trucks in an industry sometimes causes accidents because the driver lacks knowledge about the safe distance from the loading bay [8]. Due to this lack of knowledge, sometimes trucks collide with the loading bay, resulting in injuries to the drivers and supporters. To overcome this, an ultrasonic sensor, buzzer, and a red LED are used for the prototype. After the truck has been safely parked, the second ultrasonic sensor will come into play. The second ultrasonic sensor is used to detect or measure the height of the truck that is safely parked, as shown in Figure 5. When the ultrasonic sensor 1 reading is greater than 10 m, the green LED will be ON. If the sensor reading is less than 10 m, the red light and the buzzer will be ON. The purpose of using this ultrasonic sensor is to provide a signal to the truck driver that he is crossing a dangerous distance of 10 m towards the loading bay.

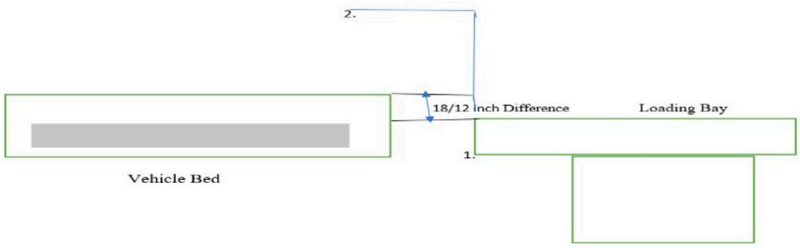


Figure 5. Positioning of sensors.

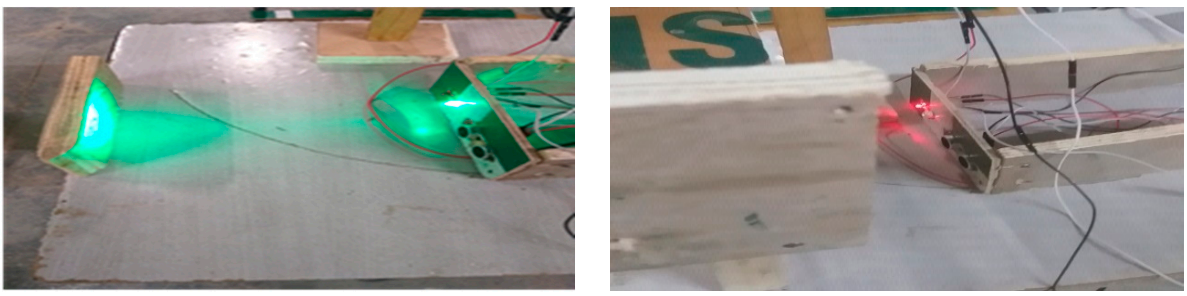
The loading bay stands at 0.95 m, while trucks vary in height, either 56 or 50 inches. The difference is 18 or 12 inches, depending on the truck type. During truck positioning, ultrasonic sensor 2 detects the truck's size. It then signals the electric drive to adjust the ramp accordingly. This adjustable ramp system is remotely operable via a mobile phone app. When a truck that has a height from the ground of 56 inches arrive, the ramp height can be adjusted through the app by toggling Manual Mode OFF and activating Relay 1. When the manual mode OFF is ON, the entire ramp operates automatically, responding to ultrasonic sensor 2 signals. This system offers a flexible and efficient solution for accommodating trucks of varying heights, streamlining the loading and unloading process, and providing control and convenience via mobile technology.

6. Results

The overall working of this IoT-enabled adjustable ramp was made possible through a fabricated prototype, as shown in Figure 4. The reading of the actual design of 10 m is taken here as 15 cm. The working of this adjustable ramp is simplified through the following points:

Ultrasonic sensor 1 exhibits green LED ON when an object is detected beyond 15 cm, ensuring a safe distance and signaling the truck driver to proceed, as shown in Figure 6a.

If the distance is less than 15 cm, the red LED ON shown in Figure 6b warns the driver to halt for loading/unloading safety.



(**a**) (**b**)

Figure 6. (**a**) Working of sensor 1. (**b**) Object at a distance of more than 15 cm.

The red LED may be substituted by a buzzer for a more pronounced warning signal. This system provides a visual cue to proceed or stop, enhancing safety protocols and facilitating the loading/unloading process for the truck driver, ensuring a safer operational environment.

Figures 7 and 8 represent the positioning of sensors with connections and the linear actuator with a stroke length of 6 inches. The ultrasonic sensor 2 is positioned on the pole, which has a height of 15 inches from the ground. For the operation of the prototype, dimensions of 18 inches and 12 inches are taken as 6 inches and 4 inches, respectively, on a 1:3 scale. Ultrasonic sensors 1 and 2 will work simultaneously. When sensor 1 observes the truck is positioned and the red LED is ON, then ultrasonic sensor 2 will measure the height, and our ramp will lift automatically or with relay ON/OFF buttons.

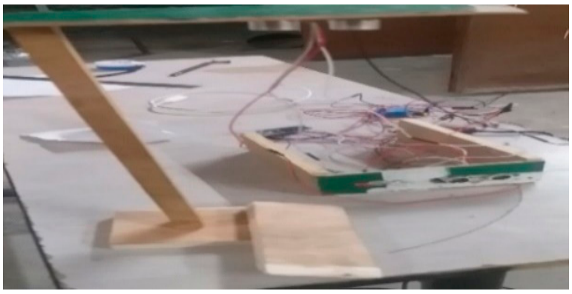


Figure 7. Positioning of sensors 1 and 2.

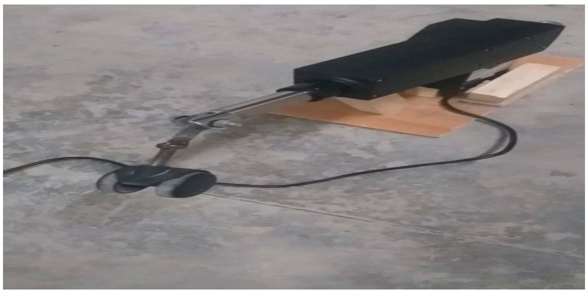


Figure 8. Linear actuator with 6-inch stroke.

The wireless operation of the ramp will be performed through a smart phone that displays three buttons, namely, manual mode OFF, relay 1 OFF, and relay 2 ON. When the manual mode OFF button is pressed ON, lifting operation and downward operation will be automatic with the help of sensor 2. Sensor 2 will sense the truck height from the pole; if it observes that the prototype truck is at 6 inches and positioned for loading, our ramp will lift 6 inches automatically. When sensor 2 observes the prototype truck positioned for loading is at 4 inches, the ramp will lift by 4 inches. This operation will take place automatically without human intervention. When the manual mode OFF button is switched OFF, both the relay 1 off button and the relay 2 ON button come into play. The entire button operation is accessed with the help of a mobile phone; thus, fully wireless operation with the Internet of Things concept is possible with the prototype-based study.

Enhanced Productivity after Installation of Ramp

After implementing the adjustable ramp system, the time to load the cartons into the truck is significantly decreased. There will be a reduction in the time to load from 22 s to 10 s (Table 2). This time of 10 s has been analyzed and compared in various industries that have adopted the dock leveler as their main loading/unloading equipment. As this equipment is a little bit costly when it is employed in much of other industries, this results in less usage in Indian MSMEs. A wooden prototype is used to present a solution for industries facing loading/unloading issues with different elevations.

Table 2. Productivity calculation after implementing adjustable ramp system.

Time taken for one box to be loaded in a truck after implementing ramp system	10 s approx.
No. of boxes	288
Approx. time for 1 box	10 s
Human resting time for 1 truck	10 min
(288 boxes × 10 s) + 600 s	3480 s or 58 min

7. Conclusions

This project aims to automate the loading and unloading process of cartons from an industry's loading bay to a truck's container, addressing the common issue of different elevations between the two. This initiative seeks to reduce manual labor, enhance productivity, minimize injuries, and promote a safe working environment.

1. This implementation significantly reduces loading time per box from 22 s to 10 s and decreases the overall truck loading time from 116 min to 58 min, thereby boosting productivity by 50% and saving 58 min.
2. It ensures precise truck positioning and platform alignment while fostering a safer work environment. The system is also operable via a mobile phone for wireless control.

The fabricated prototype aligns with industrial parameters, demonstrating the feasibility of this adjustable ramp concept for widespread adoption by small- and medium-sized enterprises.

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Data Availability Statement: Datasets are available to download on request. Requests should be directed to the corresponding author: Akhil Sharma, rattanpaulakhils@gmail.com. Although there is not much of data for this study.

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Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Government of India. Economic Survey 2016–17. Available online: https://www.indiabudget.gov.in/budget2017-2018/es2016-17/echapter.pdf (accessed on 1 June 2024).
2. eGyankosh. Productivity. Available online: https://egyankosh.ac.in/bitstream/123456789/31707/1/Unit-4.pdf (accessed on 1 June 2024).
3. Aiello, G.; Enea, M.; Galante, G. An integrated approach to the facilities and material handling system design. *Int. J. Prod. Res.* **2002**, *40*, 4007–4017. [CrossRef]
4. Deepak, B.B.V.L.; Parhi, D.R.; Raju, B.M.V.A. Advance particle swarm optimization-based navigational controller for mobile robot. *Arab. J. Sci. Eng.* **2014**, *39*, 6477–6487. [CrossRef]
5. Gupta, A.K.; Arora, S.K. *Industrial Automation and Robotics*, 3rd ed.; Laxmi Publications Pvt. Ltd.: New Delhi, India, 2007.
6. Sethi, P.; Sarangi, S.R. Internet of Things: Architectures, Protocols, and Applications. *J. Electr. Comput. Eng.* **2017**, *2017*, 9324035. [CrossRef]

7. Titan Material Handling Pvt. Ltd. Electro Hydraulic Dock Leveler. Available online: https://www.titanmhe.com/electro-hydraulic-dock-leveler.php (accessed on 1 June 2024).
8. Abuzaid, M.; Hasnain, M.; Alam, S.; Khan, S.; Agarwal, S. Inbuilt Hydraulic jack in Automobile vehicles. *Int. J. Innov. Eng. Technol.* **2013**, *2*, 76–84.
9. Azib, A.F.B.; Abdullah, S.B.; Hussien, M.S.B. The Extension Hydraulic Wheel Wrench. *Int. J. Appl. Sci. Technol.* **2014**, *4*, 136–146.
10. Okegbile, O.J.; Hassan, A.B.; Abubakar, M.; Onekutu, E.A. Design of an Improved Hydraulic Accumulator for a Truck Loading Lift. *Int. J. Adv. Sci. Tech. Res.* **2014**, *2*, 194–203.