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Design and Fabrication of Smart Washroom Kit with Staircase Trolley

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Abstract:- Hotels and commercial buildings need to maintain standard restroom cleanliness, but the traditional hand-cleaning method takes a lot of time and resources. This study investigates the effectiveness of creative solutions to lessen these difficulties, specifically the combination of a portable pressure washer and a stairway trolley. It usually takes one to one and a half hours and eight hundred to nine hundred liters of water to manually clean eight bathrooms and washrooms. The suggested remedy seeks to streamline this procedure by cutting down on the amount of water and cleaning time. Using a portable pressure washer in conjunction with the staircase trolley setup allows cleaning staff to maximize cleanliness and reduce water usage. The high-pressure stream outperforms conventional techniques in its ability to remove dirt and grime. Additionally, by eliminating the need for numerous trips and heavy lifting, this method allows cleaners to cover multiple floors, improving overall operational efficiency.

Keywords:- *Restroom Cleanliness, Portable Pressure Washer, Staircase Trolley, Water Conservation, Cleaning Efficiency, Commercial Buildings, Time-Saving Cleaning Methods, Operational Efficiency,High-Pressure Cleaning,Innovative Cleaning Solutions, Resource Optimization, Multi-Floor Cleaning, Sustainable Cleaning Practices,Traditional Vs. Modern Cleaning.*

I. INTRODUCTION

Traditional washroom cleaning methods have long been associated with manual labor, requiring significant manpower to meticulously clean various surfaces such as bathroom fixtures, floors, and toilets. This labor-intensive process not only demands considerable physical effort but also consumes large amounts of water, leading to both wastage and increased water bills for commercial buildings and educational institutions. Furthermore, cleaning with these traditional methods takes a significant amount of time, which leads to inefficiencies in the cleaning process. This extended period may cause workers' stress and exhaustion, which may eventually result in health problems and a decline in output. Using contemporary technology, such as a portable pressure washer, can help overcome these obstacles and herald in a new era of efficiency and effectiveness in restroom cleaning. Using a lot less water than conventional cleaning techniques, a portable pressure washer effectively removes dirt, grime, and stains from surfaces by utilizing high pressure. This double advantage helps workers accomplish jobs faster and with less physical strain by saving water resources and cutting down on overall cleaning time. Using a lot less water than conventional cleaning techniques, a portable pressure washer effectively removes dirt, grime, and stains from surfaces by utilizing high pressure.

Apart from the advantages of using a portable pressure washer, conventional floor washing techniques frequently involve the strenuous work of manually cleaning every area of the floor with a bucket of water. This can eventually cause workers' discomfort and repetitive strain injuries. However, the cleaning procedure can be transformed into something more efficient and ergonomic by including a tri-wheel stairway cart that is outfitted with a portable pressure washer kit. The inventive trolley design makes it possible to move around and go between locations with ease, doing away with the need for workers to haul bulky buckets of water from one place to another.

Additionally, the trolley's integrated bucket makes it easier to store water and reach it when cleaning, which lowers the possibility of spills and maximizes productivity. The smooth combination of a pressure washer and trolley not only improves cleaning quality but also drastically lowers the need for manual work, opening the door to a more efficient and sustainable method of maintaining restrooms. Through the integration of contemporary technology and ergonomic design, establishments and companies can realize numerous advantages in their restroom sanitation procedures.An advancement in efficiency and efficacy may be seen in the combination of a portable pressure washer with a tri-wheel staircase trolley, which can save water, cut down on cleaning time, and lessen the physical strain on workers. Furthermore, for businesses in a variety of industries, the improved workflow and lower labor needs result in real cost savings and increased overall production.

II. LITERATURE REVIEW

Dr. P.V. Sanjeeva Kumar et al.(2019) address the ongoing difficulties in moving large objects up staircases. They draw attention to the widespread reliance on conventional production techniques, attributing it to things like technical skills and engineering aptitude deficits, resistance to embracing new technology, and inertia. The project's authors emphasize how important it is to address society's daily demands, especially in addressing the shortcomings of the current hand trolleys when it comes to stair climbing. The suggested stair-climbing hand cart seeks to make it easier to transfer heavy items up and down stairs with less manual labor by integrating Tri-Star wheels.

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Through an emphasis on improving maneuverability across irregular surfaces such as bumps and holes, the authors hope to provide a holistic solution to the problems related to load transportation in a variety of contexts.

A research effort centered on the design and performance assessment of a stair climbing trolley was introduced by Nwe Ni Tun et al. (2019). The creation of a device that will make it easier to move large objects up stairs is at the heart of their project, fulfilling a critical demand in the community. The authors use the beam's bending strength to calculate the shaft diameter with great care, choosing mild steel to guarantee good strength. They choose Bearing No. 204, a single row angular contact ball bearing, and specify an estimated diameter of 0.75 inches in addition to the shaft length of 21 inches. Interestingly, the design factors are optimized to support a maximum load of 60 kg, which corresponds to the capabilities of average humans.The design process's essential elements are covered by the indexed words, which also include stress considerations, bending moment analysis, shaft diameter determination, and bearing selection standards.

P. Jey Praveen Rajet al. (2016) explores how, despite technological developments, moving big objects up stairs continues to be difficult. Lifts are useful in some situations, but they are not universally applicable, especially in places like construction sites and schools. In order to meet the needs of society on a daily basis, the project intends to answer this need by creating a system for the simple transfer of heavy loads up stairs. The writers acknowledge the limitations of hand trolleys when it comes to stairwells, building on their usefulness for ground-level chores. The suggested remedy is for the creation of a stair climbing trolley that can effectively and with little user effort carry large items uphill. Improving usability and efficiency while guaranteeing seamless mobility during stair ascent are important goals.

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In response to the needs of society on a daily basis, Shubham S. Shiwarkar et al. (2018) address the need for a method to assist the simple transportation of masses across stairs. Although hand trolleys minimize strain when lifting on level surfaces, they frequently malfunction when stairs are involved. This led to the creation of a hand cart that can rise stairs and move up to 150 kg of things with less manual labor. In addition to meeting this actual need, the project looks into the importance and usefulness of a product like this. In order to minimize user strain while allowing a non-industrial hand trolley to handle stairs, curbs, and uneven terrain, several design options are investigated.By their effort, the writers meet a variety of societal demands while advancing ergonomic load transportation methods.

In order to meet the everyday needs of society, Mulik Shriniwas et al. (2015) provide a system intended for the simple transportation of heavy goods over uneven terrain. They draw attention to the shortcomings of the current hand trolleys, which have trouble lifting heavy objects over short distances. This has prompted researchers to investigate ways to improve mobility across curbs, stairs, and uneven terrain while reducing user fatigue. Even if the project admits that the mechanism's strength and structure have certain limitations, it nevertheless represents a significant advancement in the field of stair climbing vehicles. After conducting test runs, the authors identify that their design has the potential to move big loads upstairs with efficiency, which points to a promising path for future advancements in material handling technology.

According to Md. A. Hossain Nafis et al. (2010), the main goal is to create a vehicle that can move over uneven ground and climb stairs. Ensuring the vehicle's stability and speed during stair ascent are the main technological concerns. The original design had a wheel arrangement with a frame, a sun wheel, and three planetary wheels. An idler connects each planetary wheel to the sun wheel. This configuration facilitates efficient stair climbing by allowing the planetary wheels to spin in unison with the sun wheel. The idler and sun wheel are positioned in a straight line with the planetary wheels, which are arranged 120° apart. The authors want to develop mobility technology by addressing fundamental issues in vehicle design for stair climbing applications through their investigation of wheel shapes and mechanics.

Tyler D. Master and colleagues (2021) present a novel pressure washer design that integrates a folding handle mechanism. The pressure washer is made up of a frame, a handle, and a motor that powers a pump. The handle and frame are connected by a rotating joint. Interestingly, the rotating joint has a locking mechanism that allows the handle to be selectively positioned in relation to the frame, improving user comfort and dexterity. In order to make room for the engine and pump inside the designated volume, the handle can be rotated between its storage position, which places it next to the frame, and its extended position. This design solves the problems of transportation and storage by enabling easy extension for operation and compact storage when not in use.The creator has addressed the concerns of consumers who are looking for efficiency and convenience in their cleaning activities by incorporating a folding handle feature into electric pressure washers. This practical solution improves the electric pressure washers' usability and storage capacity.

III. SUMMARY OF THE LITERATURE REVIEW

The reviews of the literature cover a range of creative approaches and developments in the fields of transportation and material handling.The articles and patent reviews draw attention to the ongoing difficulties with conventional material handling techniques, such as hand trolleys' inability to maneuver over curbs, staircases, and uneven surfaces. To overcome these obstacles, scientists and inventors suggest innovative structures and methods that are meant to improve effectiveness, portability, and user-friendliness.The incorporation of sophisticated wheel configurations, such as Tri-Star wheels and tri-wheel mechanisms, to enhance stability and mobility over a variety of terrain is a recurring theme in the literature. Furthermore, the creation of motorized solution like cars and trolleys with stair-climbing capability aims to lessen manual labor and boost load carrying capacity.Moreover, scholarly works underscore the need of attending to pragmatic necessities in the community, like the conveyance of weighty items in diverse contexts like building sites, educational institutions, and daily life. These developments seek to improve usability and user experience in addition to overcoming technological obstacles.

METHODOLOGY

The current bathroom cleaning process, as seen in Figures 1 and 2

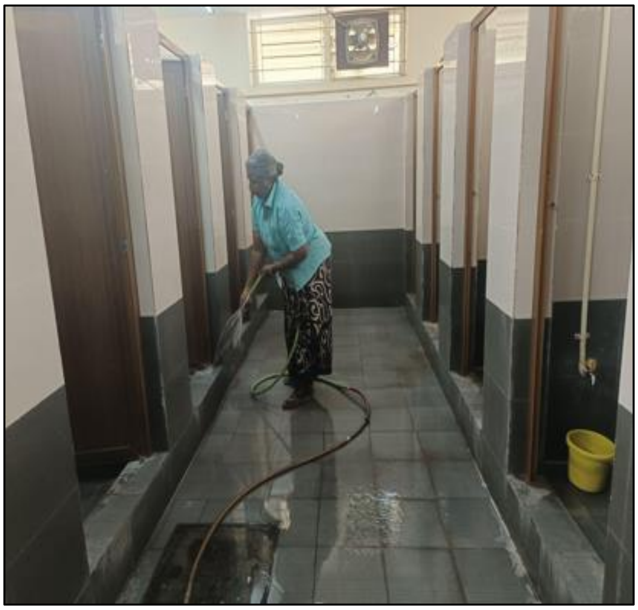

Fig 1: Bathroom Cleaning Process

Fig 2: Bathroom Cleaning Process

The following approach flow chart outlines the individual steps that make up this project. Following a thorough analysis of the literature, numerous viable alternatives were looked at, and the best approach was painstakingly determined. This technique comprises the design and implementation of a tristar stairway trolley that is seamlessly combined with a portable pressure washer, providing a thorough and effective cleaning solution. Figure 3 provides an outline of the steps in the approach that are shown.

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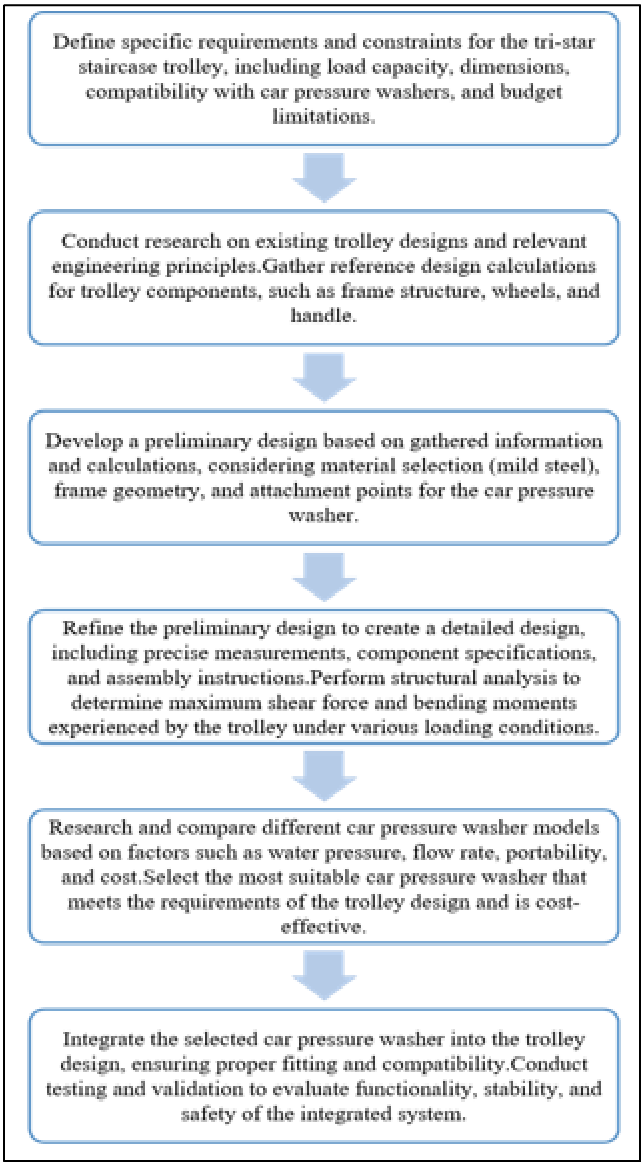

Fig 3: Methodology

- *List of Components*

➢ *For Maximum Functionality, We Used the Components Indicated Below in Our Project*

- Mild steel hollow square bar and Rectangular mild steel plate
- Roofing sheet
- Portable pressure washer
- Polymer trolley wheel
- TVS Bolt and Nut
- PTA hex self-drilling screws

- *Design Calculations:*

➢ *Dimensions for Frame:*

- Length of the Frame=100cm
- Width of the Frame=50cm
- Normal Height of the Frame=60cm

➢ *Dimension Calculation for Tri-Star Wheel:*

In the design of Tri-Star wheel, four parameters are important,

- Heights of the stairs=a,
- width of stairs=b,
- radius of regular wheel=r,
- radius of Tri-Star wheel, the distance between the center of Tri-Star wheel and the center of its wheel=R.

According to the project requirements, the values of (a) and (b) have been taken as a=13cm;b=29cm.

$R=\sqrt{[(a^2+b^2)/3]}$
$R=\sqrt{[(13^2+29^2)/3]}$
$R=18.3484cm$

The minimum value radius of regular wheel (d_{min}) to prevent collision of the holders the stair is derived as,

$d_{min}=[6R+a(3b+\sqrt{(3a)}]/[(3-\sqrt{3})a+(3+\sqrt{3})b]$
$d_{min}=[(6*18.48)+13[(3*29)+\sqrt{(3*13)}]/[(3\sqrt{3})*13+(3+\sqrt{3})*29]$
$d_{min}=11.6394cm$

The maximum value radius of the regular wheels (r_{max}) to prevent the collision of the wheels together is

$d_{max}=\sqrt{[(a^2+b^2)/2]}$
$d_{max}=\sqrt{[(13^2+29^2)/2]}$
$d_{max}=22.4722cm$

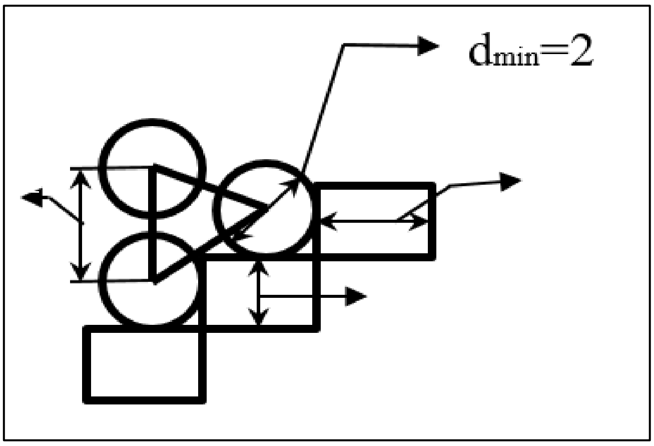

Fig 4: Dimension values of Tri-star Wheel

➢ *Maximum Force Required to Pull the Trolley*

The forces acting on the trolley in x and y directions shown in Figure 6.3.1 When the trolley climbs up the stairs, it is needed to incline at about alpha(α) degree.

From the x-direction,
$\sum F_x = m*a_x$
$F * \cos\alpha - F_f = m*a_x$
$\mathbf{F*\cos\alpha - f*F_n = m*a_x}$

From the y-direction,
$\sum F_y = m*a_y$
$\mathbf{F * \sin\alpha - W+F_n = m*a_y}$

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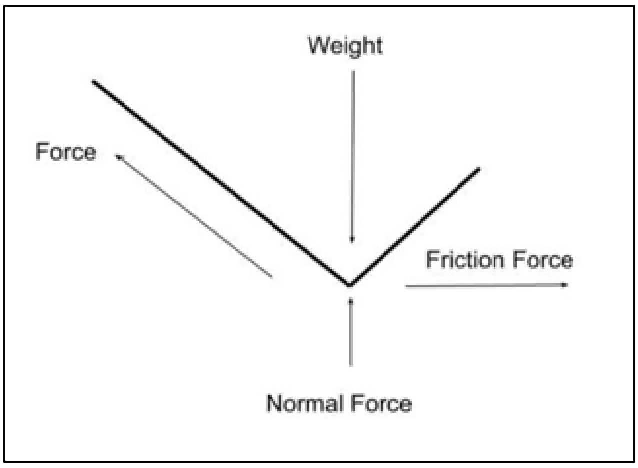

Where,
F = Maximum force required to pull the trolley.
m = Mass of trolley plus carried load.
a = Acceleration of the trolley when load carrying on stairs.
f = Friction coefficient between trolley wheel and concrete.
W = Weight of trolley plus load carrying on stairs.
F_n = Normal force to the trolley.

➢ *Design of Shaft*

Diameter D= 40 mm
Inner Diameter, d =32 mm
Length of the shaft = 476 mm
Shaft Subjected To Simple

- *Torsional Moment:*

Shear strength τ= P/A N/mm²

Assume,
Let's calculate the load force F for a mass of 80 kg We use the formula F=m*g, Where, m is the mass and g is acceleration due to gravity.

load P= 80kg
F=80*9.81=784.8N
F=784.8N

Now, let's determine the cross-sectional area using the formula for the area of a annulus,Area = $(\pi/4)*(D^2-d^2)$ mm² ,where, D is the outer diameter and d is the inner diameter.

Area= $(\pi/4)*(40^2-32^2)$
Area =452.3893mm²

Shear strength,
To determine the shear strength (τ), we divide the load force (F) by the cross-sectional area (Area). Using the previously calculated values:

τ= 784.8/452.3893
τ= 1.7347 N/mm²

Shaft Subjected To Simple Bending Moment,
We begin by calculating the bending moment (M) for a shaft subjected to simple bending. Using the formula $M=[\pi/16]*\tau*[(D^4-d^4)/D]$

where,
τ is the shear strength,
D is the outer diameter, and
D is the inner diameter.

$$\mathbf{M=[\pi/16]*\tau*[(D^4-d^4)/D]}$$
$$M=[\pi/16]*1.7347*[(40^4-32^4)/40]$$
M=12870.0605 N mm

Now, let's compute the bending stress (σ) using the formula $\sigma=[32*M*D]/[\pi*(D^4-d^4)]$
$$\mathbf{\sigma=[32*M*D]/[\pi*(D^4-d^4)]}$$
$$\sigma=[32*12870.0605*40]/[\pi*(40^4-32^4]$$
σ=3.4693N/mm²

Considering that the material selected is mild steel, with a permissible bending stress (σ) of 580 N/mm². Allowable bending moment <permissible bending moment

3.4693N/mm² <580 N/mm²

Since the calculated bending stress is less than the permissible bending stress, the design is safe and satisfactory.

➢ *Pump Calculation:*

- *Power Features:*

Motor Power-2200 W
Power Requirement-230 Volts
(single phase)
Power Rating-2.2 kW
Other Power Features-230 Volts
(single phase)

- *Calculate Current (Amps)*

To calculate the current drawn by the pressure washer, we use the formula:

- *Current (A)=Power (W)/Voltage (V)*

Given the power rating of the pressure washer is 2200 watts and the voltage is 230 volts, we can calculate the current as follows:

Current (A)=2200 W/230 V

- *Current (A)≈9.57 A*

So, the current drawn by the pressure washer is approximately 9.57 Amperes. This represents the flow of electric charge through the pressure washer when it is operating.

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- *Determine Energy Consumption (kWh)*

Energy consumption refers to the amount of electrical energy used by an appliance over a specific period of time. For the pressure washer, we can calculate the energy consumption using its power rating and the duration it operates.

Given that the power rating of the pressure washer is 2200 watts (2.2 kW) and let's assume it operates for 1 hour, we can calculate the energy consumption as follows:

- *Energy Consumption(kWh) = [Power(w) ⁄ 1000]*Time (hrs)*

Substituting the values: Energy Consumption (kWh)=[2200 W ⁄ 1000]*1 hr

- *Energy Consumption (kWh)=2.2kWh*

So, the energy consumption of the pressure washer over one hour of operation is 2.2 kilowatt-hours (kWh). This represents the amount of electrical energy consumed by the pressure washer during that time.

- *Estimate The Operating Cost*

To estimate the operating cost of the pressure washer, we can multiply its energy consumption (in kilowatt-hours) by the cost of electricity per kilowatt-hour.

Given that the energy consumption is 2.2 kWh (as calculated earlier) and the cost of electricity per kilowatt-hour is 6.70 Rs, we can calculate the operating cost as follows:

- *Operating Cost (Rs)=Energy Consumption (kWh)*Electricity Cost per kWh (Rs/kWh)*

Substituting the values:
OperatingCost(Rs)=2.2 kWh*6.70 Rs/kWh

- *Operating Cost (Rs)=14.74Rs*

So, the estimated operating cost of the pressure washer for one hour of operation is approximately 14.74 Rs.

➢ *Water Power (kW):*

Water power is the power generated by the water flow through the pressure washer. It's calculated by multiplying the pressure (in bar) by the water flow rate (in liters per hour) and converting the result into kilowatts.

- Water Power (kW)=Pressure (Bar)*Water Flow Rate (L/h)*0.0001

Substituting the given values: Water Power (kW)=145Bar*600L/h*0.0001

- Water Power (kW)≈8.7kW

➢ *Energy Efficiency:*

Energy efficiency measures how effectively the pressure washer converts electrical energy into water power. It's the ratio of the water power output to the electrical power input.

Energy Efficiency=Motor Power (kW) ⁄ Water Power (kW)

substituting the given values:

Energy Efficiency=2.2kW ⁄ 8.7kW

Energy Efficiency ≈ 3.9

IV. CONCEPTUAL DESIGN AND ANALYSIS

The conceptual Frame model of our tri-stair wheel trolley, designed for enhanced mobility and stability, is presented in the following figure 5.

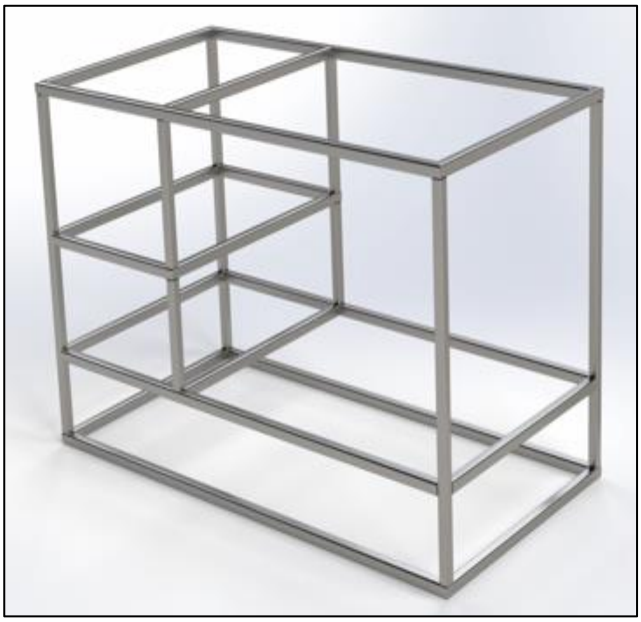

Fig 5: Design of Frame Model

The assembly view showcases the intricate configuration of the tri-stair wheel and its corresponding wheel rim, highlighting their seamless integration within the trolley design shown in figure 6.

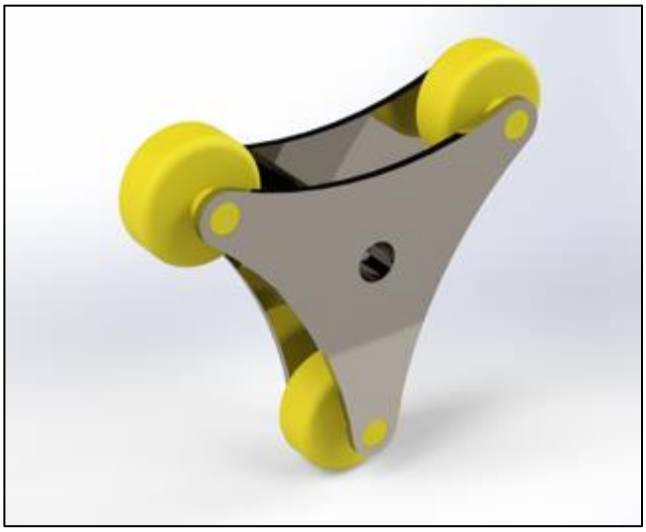

Fig 6: Design of Tri-Star Wheel

The thorough assembly view offers a thorough look at the staircase trolley as a whole, demonstrating how the tri-stair wheels, wheel rims, and other necessary parts are integrated, guaranteeing the design's endurance and functionality see figure 7.

Fig 7: Isometric view

A. Analyzing:

The structural components and the load distribution must be taken into account in order to examine the staircase trolley when a uniform distributed load (UDL) is applied. A staircase trolley usually consists of a frame that has rollers or wheels to make stair climbing and stair down easier.

Assume that the staircase trolley is made of a straightforward beam-like structure and that the UDL load is distributed uniformly along its length. Next, we'll figure out the bending moment and shear force at different places along the beam.

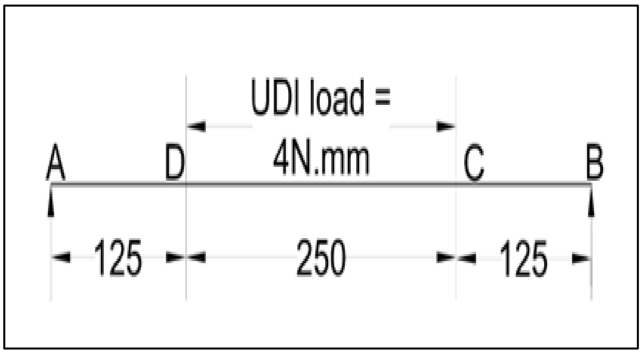

Fig 8: Analyzing the Staircase Trolley: A Beam-Type Structure

To determine the support reactions taking moment about A $\Sigma Ma=0$

$(R_B*500)-(4*250)([250/2]+125)=0$

$\mathbf{R_B=500N}$

Sum of all vertical forces is zero,

$R_A+R_B-(4*250)=0$

$R_A+500-1000=0$

$\mathbf{R_A=500N}$

Shear Force Diagram

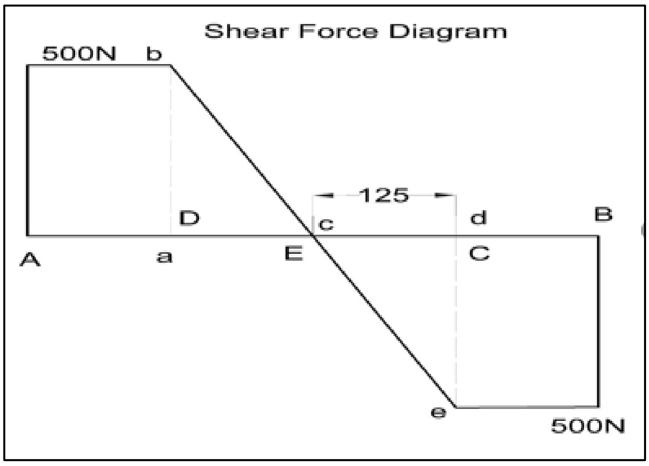

Fig 9: Shear Force Diagram

B. Shear Force Calculation

Shear Force $_{A\text{-}D}$=500N
From D to C S.F changes from 500N to -500N

Shear Force $_{C\text{-}B}$=500N
To locate the point between D and C where Shear Force is zero we have from the similar triangles abc and cde: ab/ac=de/cd
(500)/(250-cd)=(500)/(cd)

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cd=125mm

Bending Moment Diagram
Bending Moment At B=0
Bending Moment At C=500*250
Bending Moment At C=62500N.mm
Bending Moment at the point where Shear Force, is zero is the maximum and is
Bending Moment Maximum =(500*250)-(4*125*(125/2)
Bending Moment Maximum=93750N.mm
Bending Moment At D=(500*375)-(4*250*(250/2))
Bending Moment At D=62500N.mm
Bending Moment At A=0

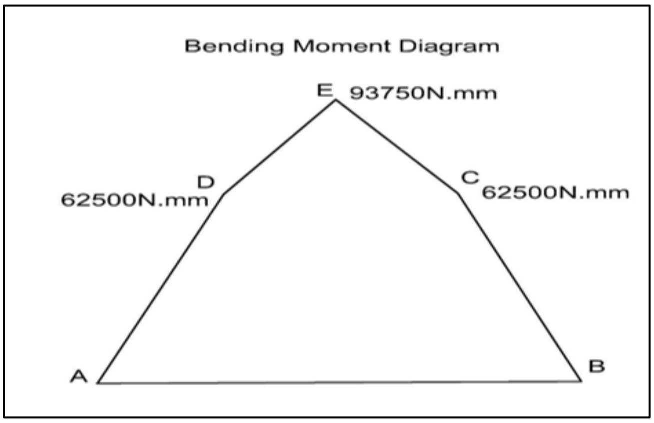

Fig 10: Bending Moment Diagram

- *Fabrication Process*

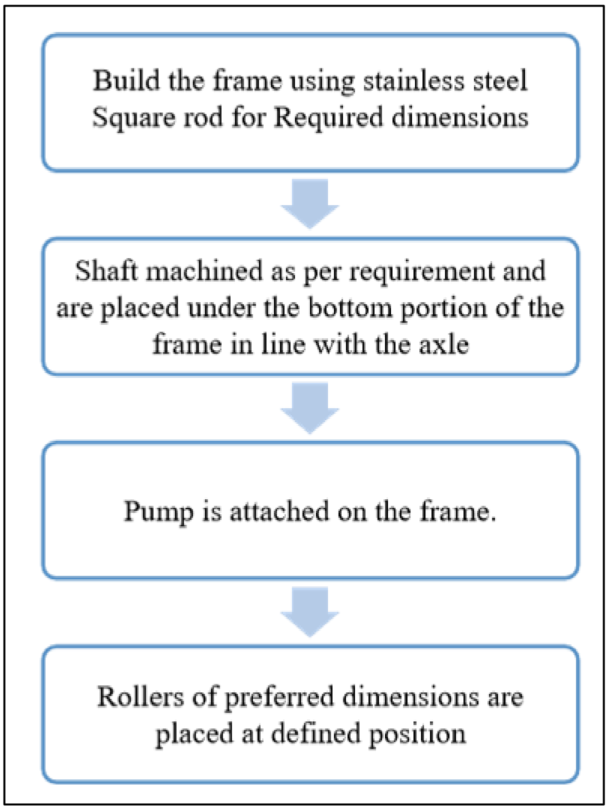

Fig 11: Fabrication Methodology

- *Fabrication Model*


Fig 12: Front View of the Model


Fig 13: Final Model

V. CONCLUSION

In conclusion, our project successfully addresses the drawbacks of conventional methods, marking a substantial progress in restroom cleaning procedures. Cleaning procedures have historically been labor-intensive, time-consuming, and water-wasting, taking up to one hour and fifteen minutes to complete and using 800–1000 liters of water for a long list of facilities, including eight restrooms, eight toilets, and three urine sinks. But a noteworthy change has been made possible by the use of our cutting-edge Smart Washroom Kit with Staircase Trolley. We have effectively reduced the amount of time needed for cleaning to only 30 to 45 minutes, and we have also greatly reduced the amount of water used to 300 to 450 liters.The accomplishment is ascribed to the smooth amalgamation of state-of-the-art technology, such as portable pressure washer kits, with ergonomic design components, like the staircase trolley. Notably, our project relieves the physical strain and exhaustion experienced by cleaning staff in addition to streamlining the cleaning procedure. Additionally, the trolley's portability and comfort optimize the cleaning process, raising productivity and efficiency levels all around. Our initiative contributes to water conservation efforts and lowers operating expenses for businesses and institutions by providing a long-term, sustainable solution for restroom upkeep. Furthermore, a shorter cleaning schedule results in more operational efficiency and better resident and user utilization of the restrooms. We've verified that our approach works to increase cleaning productivity and reduce worker fatigue through extensive testing and evaluation in actual hostel settings. Furthermore, taking into account the car pressure washer pump's hourly operating cost of Rs 14.74, our project guarantees both cost-effectiveness and efficiency in restroom maintenance procedures. In addition, we have finished our design calculations and analysis, which has led to the project's manufacture. All in all, our project presents an eco-friendly, economical, and ergonomic alternative that successfully lessens the drawbacks of conventional techniques and promotes improvements in restroom upkeep procedures in a variety of contexts.

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