AUTOMATED SPRAY PAINTING OF WAGONS

South Central Railway

BY

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WAGON WORKSHOP GUNTAPALLI

1. Introduction

Painting of wagons is a crucial activity in the process of overhauling of wagons as it shields the surface metal from corrosion inhibitors. Currently in most of the workshops over Indian Railways, painting is being carried out using manual spray painting or brush painting. These methods have the following drawbacks:

a) **Low production rate**
b) **Non-Uniform Application:** The spray thickness and the evenness of coating layer are the major issues in a painting process. Controlling spraying path is an important parameter in achieve uniformity or evenness of coating layer thickness but it is not possible with manual spray system. Over- coating also results in paint bleeding.
c) **Hazardous Environment:** Vapors of Hydrocarbons in a paint shop are inevitable. These vapors prove to be carcinogenic on prolonged exposures. Moreover, during spray painting, atomized paint droplets repeatedly mask the surface of safety goggles and overcoat of the technicians. Hence, even personal protective gears underperform in such conditions.

An automated painting system can eliminate all of these drawbacks. The following are the tangible benefits enlisted for automated spray painting:

Parameter	Conventional Manual Spray	Automated Spray Painting (Estimated)
Time of Operation	36 min	20 min
Manpower	0.96 per wagon	0.6 per wagon
Health and Environmental Hazard	Extremely High	Low
Coat	Non-Uniform	Uniform

2. Schematic Design of Automated Paint Booth

The painting activity is carried out by atomizing the paint over a nozzle (paint sprayer) connected to a paint pump. The paint sprayers are arranged and movements are configured so as to achieve complete painting of end wall, side wall and roof of a wagon. Figure 1 depicts the general schematic of paint booth

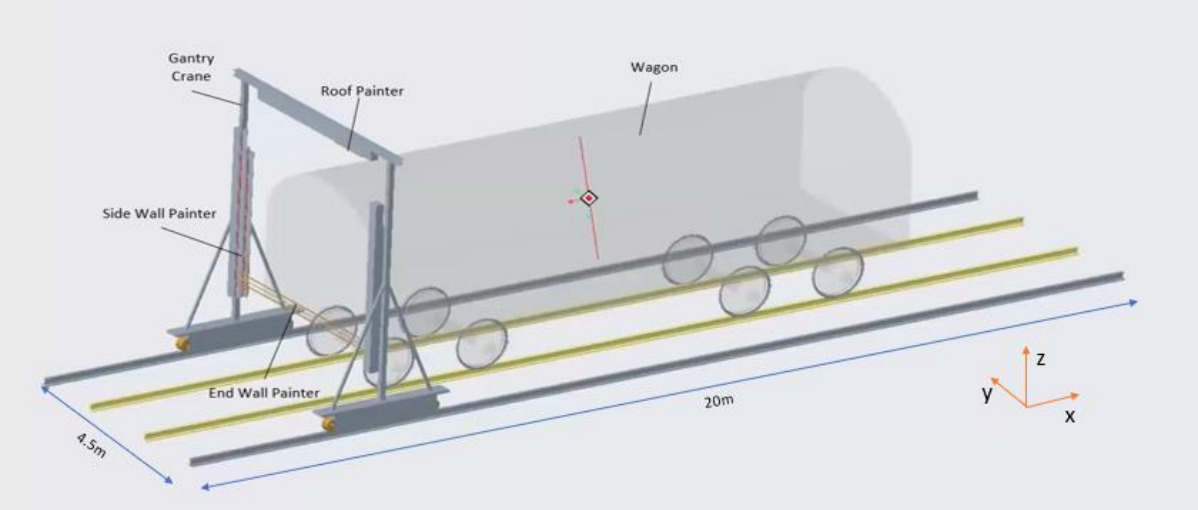


Figure 1: General Schematic of Automated Paint Booth

- All the painting mechanisms are mounted on the gantry crane, that can move along the rails spaced at 4.5m in the longitudinal direction (X direction).
- As shown in the figure, there are four painting mechanisms:
    a) Left Side wall painter (comprising 3 sets of sprayers)
    b) Right Side wall painter (comprising 3 sets of sprayers)
    c) End wall painter (comprising 10 sets of sprayers)
    d) Roof painter (comprising 4 sets of sprayers)
- The movement of these 4 mechanisms are achieved with the help of screw drives as in CNC machines controlled by servo motors for precise position control
- The following is the direction of movement of the mechanisms:
    a) LHS side wall painter- Vertical Reciprocation (Z direction)
    b) RHS side wall painter- Vertical Reciprocation (Z direction)
    c) End wall painter- Vertical Reciprocation (Z direction)
    d) Roof painter- Lateral Reciprocation (Y direction)
- The operation timings and position of various motor and paint sprayers are controlled with help of Arduino microcontroller/PLC.

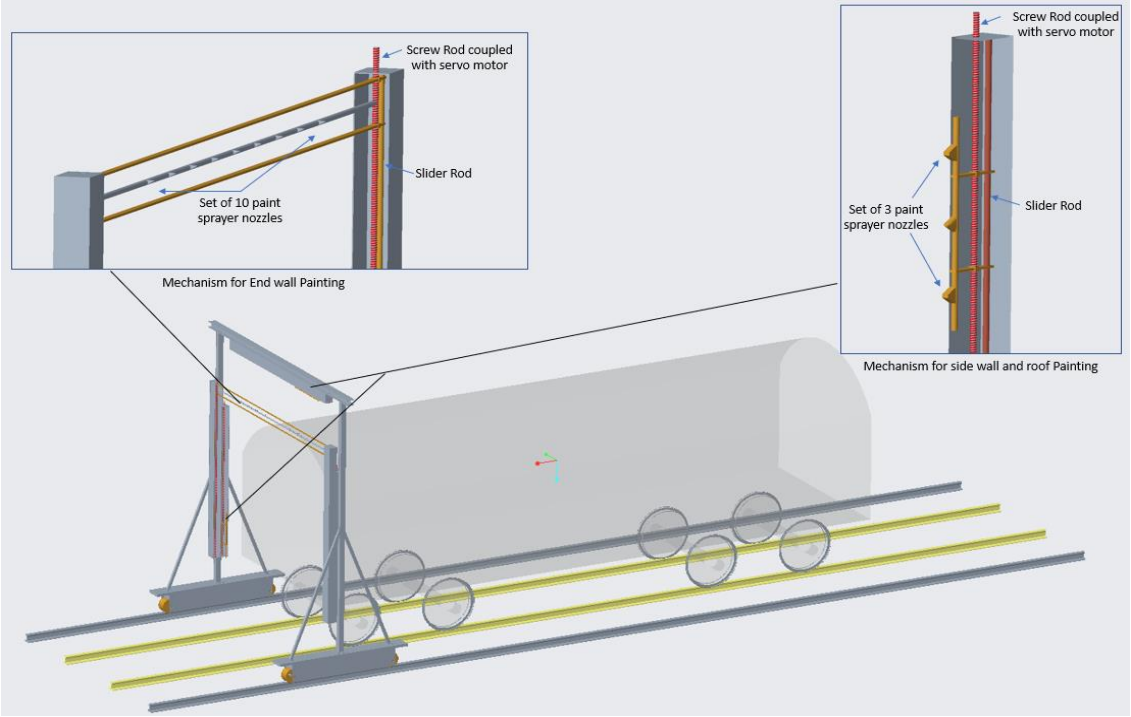


Figure 2: Exploded view of Painting Mechanisms

The entire painting mechanism is enclosed in a civil infrastructure (Figure 3) consisting of:

a) A grated mesh flooring for dripping of excess paint
b) Roofs equipped with paint filters
c) Roof mounted exhaust fans to expunge hydrocarbon fumes within the booth after filtration

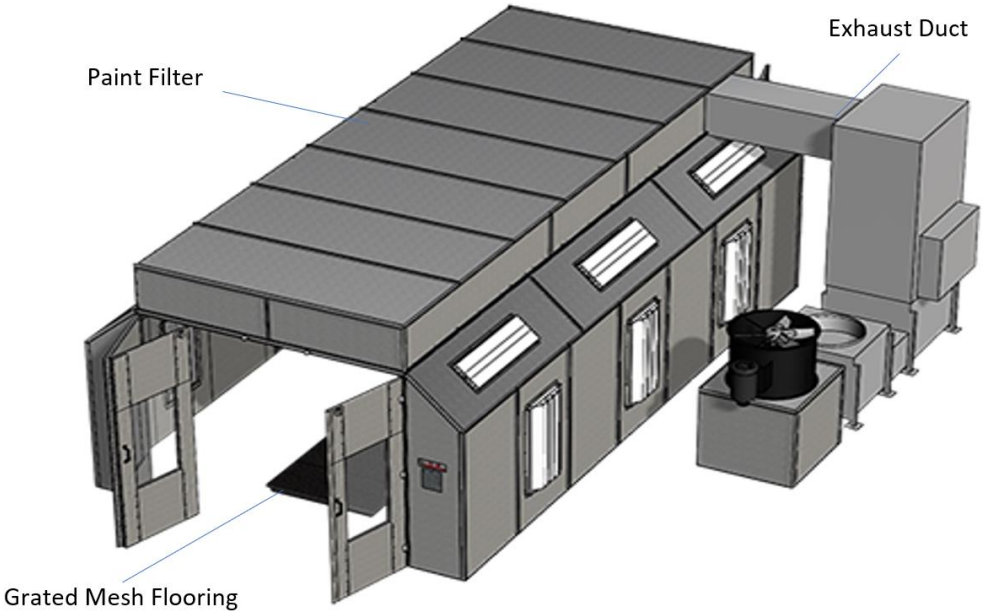


Figure 3: Civil Infrastructure

3. Important Components

	**Rhino Pump:** This is an airless spray pump. The power source is compressed air. The pump generates hydraulic pressure at the paint side by using the energy from compressed air without intermixing air with paint. The pressure ratio is 1:55 (air: paint) and can deliver up to 6.8 L/min of pressurized paint.
	**Automatic Airless Spray Gun:** This is a pneumatically actuated spray gun that atomizes pressurized paint into small droplets and sprays up to a distance of 60cm at a fan width of 300 cm.
	**3 phase AC brake motor:** This motor is used to impart motion to the gantry crane structure. The speed will be controlled using VVF drive. Power:3HP
	**Stepper Motor:** This motor is used to impart motion to various screw drives. The minimum rotation this motor can achieve is 1.8 degrees. Holding torque: 85 Kgcm Step Angle 1.8˚/ pulse Supply Voltage: 24 V
	**Arduino Mega Microcontroller or SEIMENS PLC S7-1500:** This is a programmable microcontroller, that receives input from various sensors processes them and gives command to its peripheral output devices
	**LIDAR Sensor:** This is a distance sensor, that will be used to sense the presence of wagon and the signals will be sent to the microcontroller for necessary commands to be generated to start/stop the spray gun, movement of screw drives and gantry crane.

	**RMCS 1101:** This is a stepper motor driver. Its function is to amplify the low power control signals from microcontroller to required power levels of the stepper motor.
	**3/2 Solenoid Valve:** These valves will pick electrical command signals from microcontroller in order to direct air into the automatic airless spray gun, for controlling the spray of nozzles.
	**Ball Screw Drives:** To actuate the movements of various painting mechanism as discussed before. Diameter: 25mm Pitch:10mm/rev

4. Automation Circuit

Automation circuit (Figure 4) is the low power control circuit that is used to receive signal from sensors and command various motors and pumps accordingly. The circuit consists of the following components:

a. Sensors:

- LIDAR Sensor: This sensor is used to sense the presence of wagon and helps to decide the initiation and halting of painting process.
- PUSH Buttons: Connected on A0-A10 ports of Arduino Mega. These pins will hold specific programs to paint different types of wagons depending on their structure and size. For example, A0 will execute program to paint BOXN and A2 will execute program to paint BCN.

b. Microcontrollers:

- Arduino UNO: This microcontroller is used to continuously read data from LIDAR sensors and send interrupt command to Arduino Mega/PLC to start/stop painting process based on presence of wagon.
- Arduino Mega/PLC: This microcontroller is used to control motion of servo motors, paint pump, gantry crane motors, solenoid valves etc.

c. Actuators:

- RMCS 1101: This motor driver receives signal from Arduino Mega/PLC and drives the stepper motor at preset speeds
- Relay Module: Relay module receives low power control signals from Arduino Mega/PLC and translates it to high power signals to drive gantry crane motor, Paint pump, spray nozzles and process indicator lights.

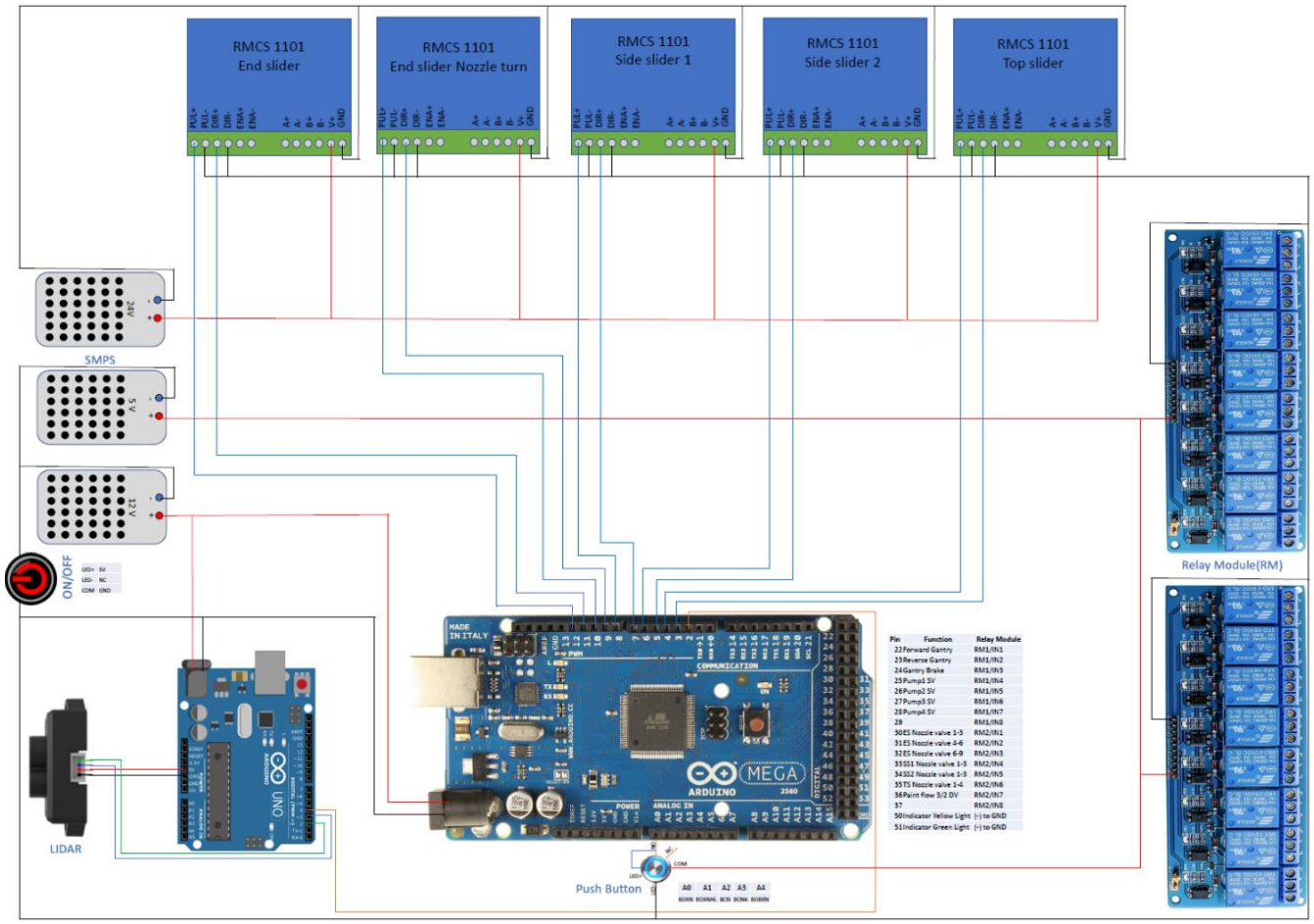
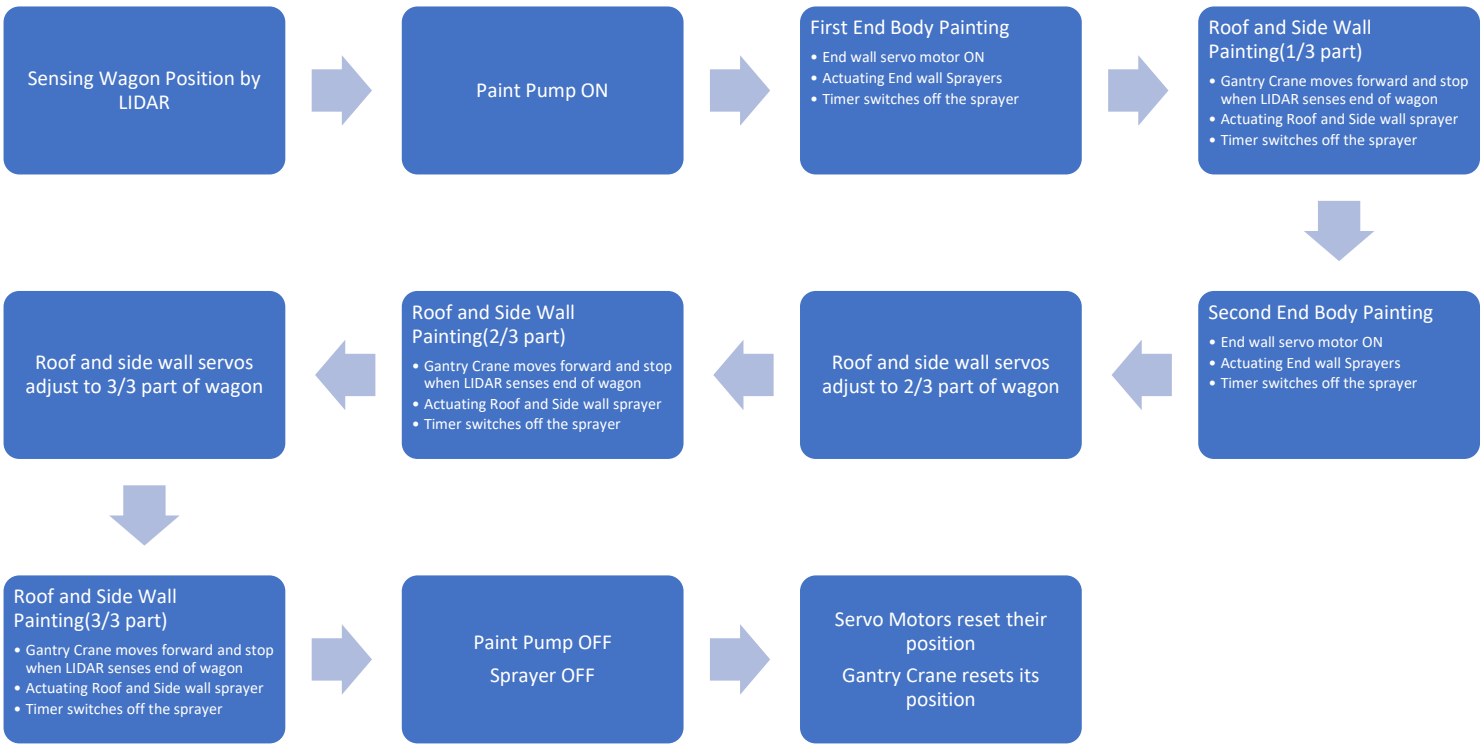
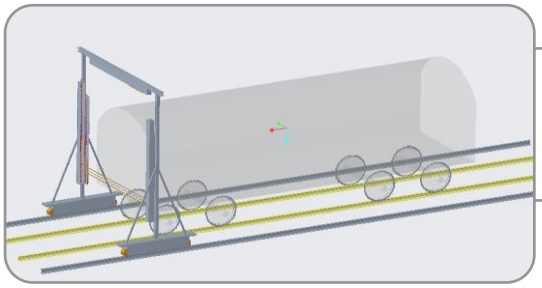


Figure 4: Automation Circuit

5. Programming Logic

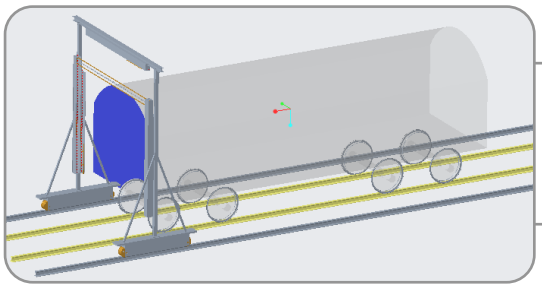


6. Sequence of Operations



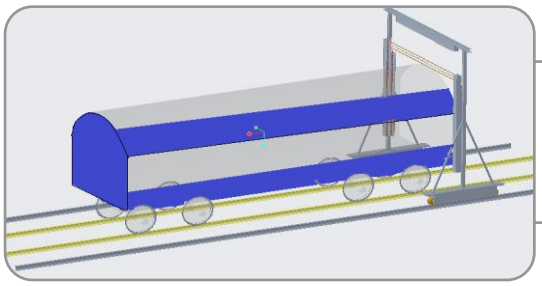
LIDAR Sensor presence of wagon

- End wall painter moves in +Z direction to paint first end wall



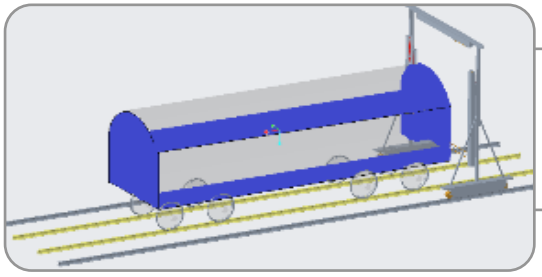
First end wall painted

- Gantry crane moves in +X direction to paint 1/3 part of RH, LH side wall and roof



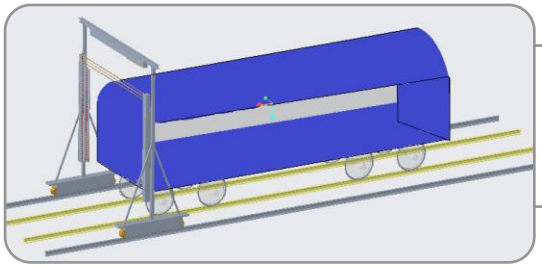
LIDAR senses the position where wagon ends

- End wall painter moves in -Z direction to paint second end wall
- End wall painter moves in +Z direction to clear area for gantry crane movement



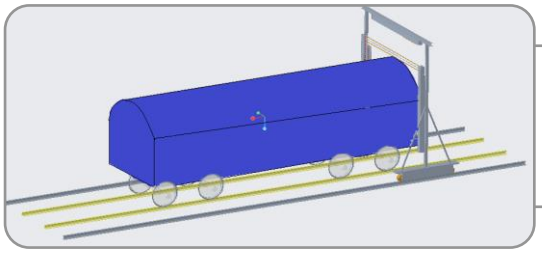
End walls painted and 1/3 side wall and roof

- Servo motor moves Roof and side wall painter in +Y and +Z direction to adjust to 2/3 part of wagon
- Gantry crane moves in -X direction to paint 2/3 part of RH, LH side wall and roof



End walls painted and 2/3 side wall and roof

- Servo motor moves Roof and side wall painter in +Y and +Z direction to adjust to 3/3 part of wagon
- Gantry crane moves in -X direction to paint 3/3 part of RH, LH side wall and roof



Full wagon painting completed

Scan the code to watch the sequence of operations

7. Conclusions

Painting of POH'ed wagons in RYPS workshop is been carried out manually. Introduction of automated spray painting of wagons will reduce the time of painting, manpower required with reduced health and environmental hazards thereby increasing the quality of painting for wagons.

The market rate for a paint booth is around ₹ 7.1 crores. This project is very economical as the In-house manufacturing costs only 8-10 % of the Market Rate at an estimated cost of ₹57.67 lakhs. The following is the estimate of the project:

Cost Analysis

Gantry Crane Structure

S No	Description of item	Qty	Spare Qty	Rate	Value	Remarks
1	3 phase brake motor with gear box(3HP)	2	0	₹ 70,000.00	₹ 1,40,000.00	
2	couplings	2	0		₹ 0.00	Available
3	wheels	4	0		₹ 0.00	Available
4	channels -5 meters length	10	0		₹ 0.00	Available
5	Angular beams	4	0		₹ 0.00	Available
6	VVVF Drive	1	0		₹ 0.00	Available
7	3 Core 4 Sq"mm Copper cable	2	0	₹ 14,000.00	₹ 28,000.00	
8	Control Transformer	1	0	₹ 10,000.00	₹ 10,000.00	
9	MCCB	1	0		₹ 0.00	Available
10	Main Contactor	1	0		₹ 0.00	Available
11	Contactors	2	0		₹ 0.00	Available
12	Pendent	1	0		₹ 0.00	Available
13	OLR	1	0		₹ 0.00	Available
14	Energy Chain	15	0	₹ 8,000.00	₹ 1,20,000.00	
15	Aluminium tray	20	0	₹ 5,200.00	₹ 1,04,000.00	
				Total	₹ 4,02,000.00	

End Wall Slider

S No	Description of item	Qty	Spare Qty	Rate	Value
1	Steeper motor, NEMA 34, 85 kgcm torque RHINO MICRO-STEPPING STEPPER MOTOR	2	0	₹ 7,000.00	₹ 14,000.00
2	DRIVE 18-80V 7AMP	2	0	₹ 3,800.00	₹ 7,600.00
3	1 inch dia,10mm pitch,4 meters length ball screw rod with two Nuts	1	0	₹ 30,000.00	₹ 30,000.00
4	End supports BK20 motor side	1	0	₹ 3,500.00	₹ 3,500.00
5	End supports BF20 other end	1	0	₹ 2,500.00	₹ 2,500.00
6	Supporting Steel tube,25mm OD,14mm ID,length 4 meters with surface finish 8 Ra,Roundnees: 0.008 inch,straightness:0.001 inch per foot	1	0	₹ 4,000.00	₹ 4,000.00
7	Linear Axis ball bearing with block ,Model:SC25UU	4	0	₹ 2,834.00	₹ 11,336.00
8	Support Cross beam and Nozzle rotation rod 4.5 m	1	0	₹ 5,000.00	₹ 5,000.00
				Total	₹ 77,936.00

Mechanical System	Civil Infrastructure	Estimated Cost
₹ 27,65,868	₹ 30,02,000	₹ 57,67,868
Market Value		₹7,35,00,000

LHS Slider , RHS Slider, Top Slider

S No	Description of item	Qty	Spare Qty	Rate	Value
1	Stepper motor, NEMA 34,85 kgcm torque RHINO MICRO-STEPPING STEPPER MOTOR	3	1	₹ 7,000.00	₹ 28,000.00
2	DRIVE 18-80V 7AMP	3	1	₹ 3,800.00	₹ 15,200.00
3	1inch dia,10mm pitch,4 meters length ball screw rod with two Nuts	3	1	₹ 30,000.00	₹ 1,20,000.00
4	End supports BK20 motor side	3	1	₹ 3,500.00	₹ 14,000.00
5	End supports BF20 other end	3	1	₹ 2,500.00	₹ 10,000.00
6	Supporting Steel tube,25mm OD,17mm ID,length 4 meters with surface finish 8 Ra,Roundnees: 0.008 inch,straightness:0.001 inch per foot	3	1	₹ 4,000.00	₹ 16,000.00
7	Linear Axis ball bearing with block ,Model:SC25UU	6	2	₹ 2,834.00	₹ 22,672.00
				Total	₹ 2,25,872.00

Paint and Electrical Accessories

S No	Description of item	Qty	Spare Qty	Rate	Value
1	Paint pump,RHINO 55.275	4	0	₹ 2,56,000.00	₹ 10,24,000.00
2	Automatic sparay nozzles	22	0	₹ 18,880.00	₹ 4,15,360.00
3	TC Nozzle 615	22	0	₹ 2,855.00	₹ 62,810.00
4	Pneumatic directional valves	12	0	₹ 1,700.00	₹ 20,400.00
4	3/8 inch Paint hose-20 mtrs	4	0	₹ 6,000.00	₹ 24,000.00
5	1/4 inch paint hose-5 mtrs	15	0	₹ 1,700.00	₹ 25,500.00
6	Manifolds,T joints,Elbows	5	0	₹ 2,000.00	₹ 10,000.00
7	Pneumatic ON /OFF valves	4	0	₹ 1,700.00	₹ 6,800.00
8	Micro-controller-ARDUINO MEGA 2560	2	0	₹ 4,000.00	₹ 8,000.00
9	Micro-controller-ARDUINO UNO R3	2	0	₹ 2,065.00	₹ 4,130.00
10	LIDAR Distance sensor	2	0	₹ 3,399.00	₹ 6,798.00
11	Relay Module 8 channel 5V, 30V DC 10A	4	0	₹ 450.00	₹ 1,800.00
12	Momentary Metal Push Button 5V 2A	10	0	₹ 230.00	₹ 2,300.00
13	Power metal push button 12V 10A 22mm	2	0	₹ 560.00	₹ 1,120.00
14	4 pin Cable connectors IP65	10	0	₹ 698.00	₹ 6,980.00
15	20cm connectors	10	0	₹ 190.00	₹ 1,900.00
16	SMPS 24V, 12V, 5V	3	0	₹ 2,000.00	₹ 6,000.00
17	Wires (Red, Black) Cable 0.3mm2	60	0	₹ 50.00	₹ 3,000.00
18	Wires (Blue Green, Black) Cable 0.3mm2	20	0	₹ 50.00	₹ 1,000.00
19	Pneumatic Pipes	50	0	₹ 55.00	₹ 2,750.00
20	Pneumatic Solenoid valve Fittings	30	0	₹ 50.00	₹ 1,500.00
21	Pneumatic T joint, X joints	20	0	₹ 50.00	₹ 1,000.00
22	Breadboard	2	0	₹ 250.00	₹ 500.00
				Total	₹ 16,37,648.00