

Development of an audit-based payment system for MRS in the Smart City 311 App

Background & Need of the Pilot

The National Clean Air Programme (NCAP) launched by the Central Government aims to reduce particulate matter concentrations by 40% by 2026, using 2017 as the base year. Lucknow, identified as one of the 131 non-attainment cities, is facing significant air pollution challenges due to road dust.

As part of CAP India, TERI conducted an emission inventory and source apportionment study for Lucknow district, identifying road dust re-suspension as a major contributor to PM_{10} and $PM_{2.5}$ levels. The estimated PM_{10} and $PM_{2.5}$ emissions from road dust resuspension in Lucknow city are 116,733 kg/day and 28,242 kg/day, respectively. The estimated PM_{10} and $PM_{2.5}$ emissions from road dust re-suspension in Lucknow district are 165,768 kg/day and 40,105 kg/day, respectively.

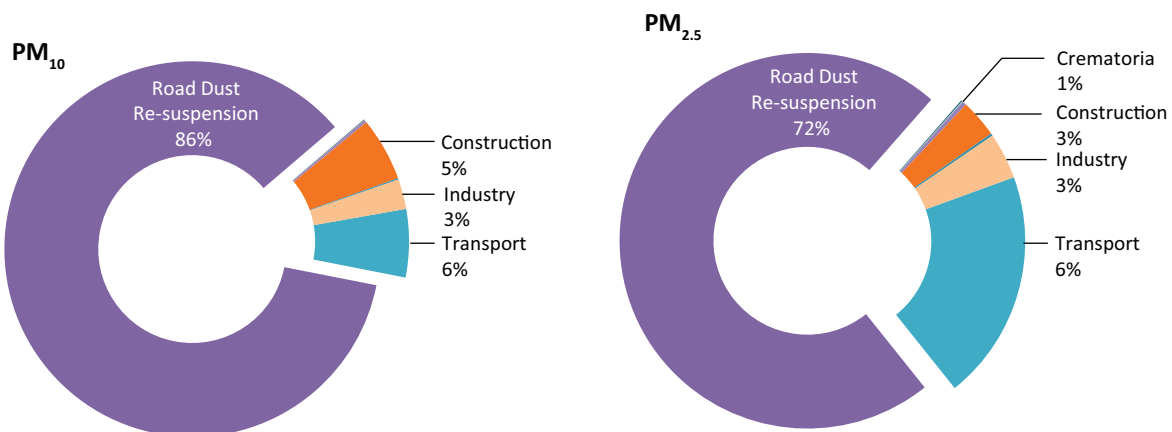


Figure 1: Percentage contribution of various pollutants including PM_{10} , $PM_{2.5}$, NO_x , SO_x emissions in Lucknow city based on the study conducted by TERI

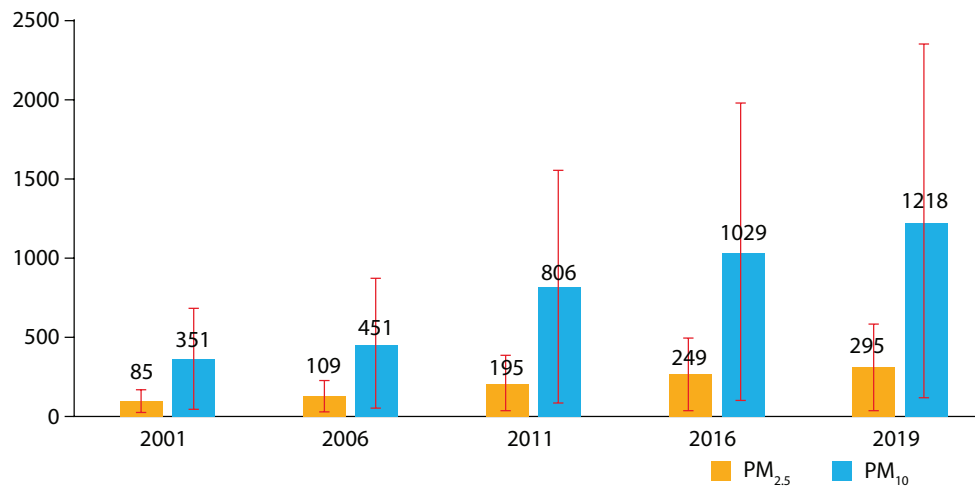


Figure 2: Annual contribution of road dust suspension to atmospheric PM₁₀ and PM_{2.5} during 2001-19 (National Emission Inventory)

Further, according to the National Emission Inventory (NEI) developed by TERI, PM₁₀ emission from road dust re-suspension on highways in the state of Uttar Pradesh (UP) is 260,822 kg/day.

The Mechanized Road Sweepers (MRS) machine offers an effective solution to road dust re-suspension by using vacuum systems equipped with brooms, holding bins, water sprinklers, vacuum nozzles, filters, and suction inlets. However, there was a gap in understanding the efficiency and efficacy of on-ground MRS operation. In order, to bridge this gap, TERI team along with Directorate of Environment (DoE), UP and Lucknow Municipal Corporation (LMC) has developed a MRS Module in the Smart City 311 App in Lucknow to monitor the MRS operations on a daily basis linking it to the payment of vendor/drivers and workers.

Objective: —○

The objective of this assessment was to monitor MRS operations independently by Lucknow Municipal Corporation. To introduce and explain the development of a performance-based payment system for MRS in Lucknow, highlighting key components:

- Development of SoP for MRS operations in Lucknow
- Development of MRS App- Module in Smart City 311 app
- Installing cameras on MRS for proper monitoring

Methodology —○

Multiple rounds of stakeholder consultations with the DoE, UP, UPPCB, LMC, revealed the need for a comprehensive mechanism to monitor the on-ground efficiency of MRS in Lucknow. The initial module for this purpose was prepared and subsequently refined based on feedback from stakeholders during MRS training and additional consultations with LMC.



The consultations highlighted several key issues:

There was a gap in understanding on-ground efficiency and efficiency of MRS machines.

This system is designed based on a report published by TERI in 2022, under the Municipal Corporation of Delhi (MCD), MRS in Delhi. Ensuring the effective operation of these sweepers was a significant challenge. Factors include the following:

Fuel Efficiency: Assessing how efficiently the machine was using fuel during operation.

Daily Output: Measuring the amount of work completed by the sweepers each day.

Machine Working Conditions: Evaluating the health and functionality of the sweepers to identify any maintenance needs or operational issues which are critical for their performance.

Financial Input vs Output: The payments to the vendor/operator are made based on the fuel consumption and kilometre of cleaning or length of machine operation. Effectiveness of the on-ground financial investments for mitigation of road dust re-suspension done by LMC is required to be facilitated.

Based on the findings, TERI developed an MRS App module for LMC that links the payment of vendors, contractors, and drivers on their performance. This performance-based payment system was designed to incentivize better operation and maintenance practices. Further investigation by TERI, identified that a significant root cause of the inefficiencies was the lack of proper monitoring of supervisors and operators of the MRS. The initial module for this purpose was prepared and subsequently refined based on feedback from stakeholders during stakeholder consultations with officials and workers involved in MRS operation in LMC. Further, a sample audit using the module on 11 MRS was conducted to understand the challenges in using the application and the module was revised. The MRS App module was integrated into the Integrated Command and Control Centre (ICCC) in Lucknow, enhancing the management of MRS operations through optimizing deployment to ensure effective coverage, real-time data collection and analysis for informed decision-making. To address this, the assessment process was structured into six phases:

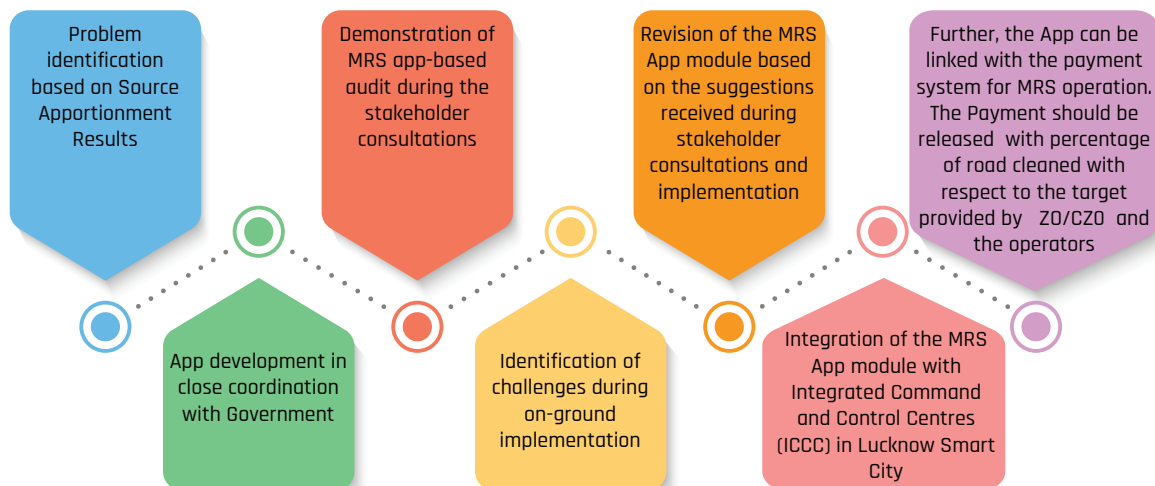


Figure 3: Stages of development of an audit-based payment system with MRS-App Module



1. Problem identification based on source apportionment results and discussions

Source apportionment revealed road dust re-suspension as a significant contributor to the PM_{10} and $PM_{2.5}$ levels in Lucknow. Conclusions from several stakeholder discussions, revealed that though MRS were opted by the Municipal Corporation to address the issue of road dust, for easy and fast sweeping purpose, however, there were still several operational challenges:

- Machine operators were completing time without the operation which does not ensure effective road cleaning.
- If vehicles were moving then brushes were not touching the road.
- Supervisors were by-passing the standards of operation.

Hence, CAP India team along with DOE, UP along with LMC decided to meet these gaps with the integration of the MRS App Module along with strengthening Smart City 311 App in Lucknow.

2. App Development

After the assessment of gaps, with the help of knowledge and experience from the audit that TERI had done for MCD. TERI planned to develop an application based pilot project.

- Information gathered from relevant authorities and stakeholders were mapped.
- Further, an audit questionnaire was developed while conducting a literature survey, and then on-site audit checklist was created.
- Based on the questionnaire, an onsite audit was planned and roads with high dust were identified.
- Municipal Corporation supported and provided the opportunity to assess their machine operation and effectiveness on road.
- The development of this module was done on the existing Smart City 311 app. Civic Solutions Pvt Ltd was offered with this app development.
- The Civic Solution's team continuously engaged with TERI for the development and incorporating inputs in the app.

The screenshot shows the 'SmartCity-311 Officer App for Lucknow' interface. On the left is a navigation menu with options: Road Checking, Project Tracking, Data Capturing, Zonal Officer Module, Road Inspection Report, Notifications, Feedback, Property Request, and Mechanical Road Sweeper (highlighted with a red dashed box). The main screen is titled 'Create New Report' and contains the following fields and options:

- 1. Driver Photo: Capture Image button
- 2. Driver Name: Pradish Acharya
- 3. Name of the Route/Road: Indira Nagar, Lucknow, 226016, Uttar Pradesh, India
- 4. Time of start of shift: (Empty field)
- 5. MRS Model: Select MRS Model Capacity of Fuel Tank (Dropdown menu)
- 5. Meter functionality: Is speedometer working? (Checked YES)
- 7. Condition of the Right brush/broom: Select condition of the right brush (Dropdown menu)
- 8. Is Dust Tank Clean and Working? (Checked YES)
- 9. Is Vacuum Working? (Checked YES)
- 10. Is Sprinkler working? (Checked YES)
- 11. Is it accident prone route? (Checked NO)
- 12. Front Panel Before Photo: Capture Image button

A green 'Submit' button is located at the bottom right of the form.

Figure 4: MRS-App Module in Smart City 311 App



3. Discussion on MRS app-based audit during the stakeholder consultations

After the initial incorporation of the questionnaire on the Smart City 311 app, TERI has conducted 4-day stakeholder consultations along with the DoE, UP attended by sixty LMC officials, drivers and supervisors for their inputs.

The suggestions and updates received from the drivers/operators and supervisors were further incorporated in the MRS app module and the following key technical points were discussed:

- a) Monitoring of brushes and their condition through cameras and GPS
- b) Accident-prone areas should be highlighted and marked
- c) Plan for verification system and SOP of operation
- d) Speed of vehicle
- e) Run time
- f) Start and end points should be incorporated
- g) Disposal points

4. Identification of challenges in on-ground implementation:

The test runs for 11 MRS machines were selected to understand the on-ground implementation challenges. These are as follows:

Assessing machine maintenance status:

LMC has five distinct types of machines with various specifications, including the Dulavo (Single Unit), TPR, ISER, and TATA (Truck Mounted). Among these, 10 are powered by diesel engines, while 9 are small electric sweeping machines. In this assessment 10 MRS run by diesel engines and one small electric sweeping machine were selected. Throughout the app development process, the variations in machine specifications and statuses were carefully considered. However, only a few machines were fit to run on the road.

Gaps in sweeping operation:

Monitoring and recording of minute-to-minute activities of the MRS operations were done. During this monitoring, it was observed that a few MRS machines were not meeting the standards (speed 22-25km/h and RPM range 1000-6000 covering 1070-2200 kg shift).



Brush/broom condition:

One brush can be used for approximately 1000 km of sweeping operation, after which it must be changed.

Collection and disposal mechanism:

Prior to this assessment, there were no designated disposal sites. During this assessment, two disposal sites for dust collected from MRS machines were allocated.

Identification of training needs:

Drivers were experiencing challenges inputting data due to the lack of English knowledge. Only a few well-trained operators/drivers were there who understood the machine and maintained the machine's health.



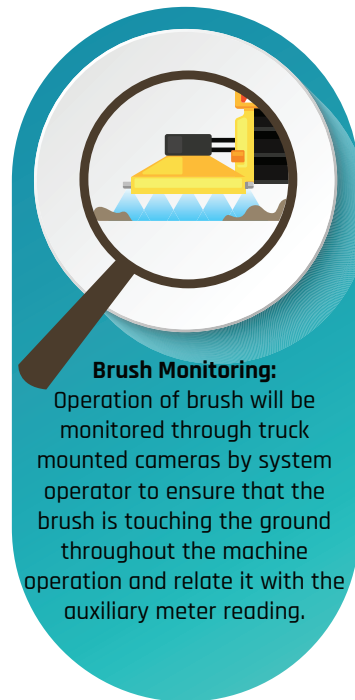
5. Revision of the MRS App Module based on the suggestions received during MRS pilot training workshop

Further revisions were done in the app based on feedback received during the MRS training workshops cum stakeholder consultations. The CPHEEO guidelines, Solid Waste Management Rules, 2016, and manufacturer's guidelines were referred during further revisions of the MRS App Module.

- a) Photographs were taken while filling up the MRS module in the Smart City 311 app while recording the generated report.
- b) Each piece of data that an operator previously had to input manually was automated, reducing the effort required by drivers for data entry.
- c) The photographs were geo-tagged and times stamps for each photograph were recorded.

6. Integration of MRS App Module with the Integrated Command and Control Centres (ICCC) in Lucknow Smart City:

In order to ensure innovative development and making the best utilization of Smart City facility it was decided to integrate the module with the ICCC where, this integration streamlined the operations and management of MRS with the help of system operator at Smart City premises who will observe the following components:

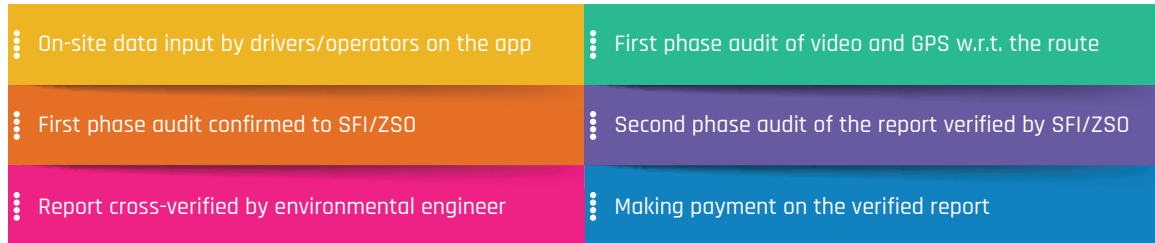


Overall, this integration can lead to more efficient and cost-effective road sweeping operations, contributing to cleaner streets and better urban management in Lucknow.

When the above two steps are verified by the system operators it will be shared to SFI/ZSO of the concerned zone to verify the report. Reports about fuel consumption and kilometres of operation




will be observed to ensure efficiency. In short, the following flow can be used to ensure the effective service-level agreement:



1. Require Fuel	
1	Fuel Before Fueling(in Liters) N/A
2	Fueling Started
3	Fueling Finished
4	Fueling Taken(in Liters) N/A
5	Fuel Panel Photo

2. Emergency: What is the Reason of Machine Stopped in between?	
1	Emergency N/A
2	End Time 7:14 AM

End of Shift	
1	End Time 7:14 AM
2	Speedometer Reading 5207
3	Auxiliary Generator Reading 10982
4	Fuel Remaining After Completion of Shift 35
5	Dust Disposal Sites 16/625, Sector 16, Indira Nagar, Lucknow, Uttar Pradesh 226016, India
6	Front Panel After Photograph 

Start of Shift:	
1	Start Time 6:35 AM
2	Condition of Left Brush Fine
3	Condition of Right Brush Fine
4	Name of the Route/Road 16/1401, Sector 16, Indira Nagar, Lucknow, Uttar Pradesh 226016, India
5	Is Speedometer Working? Yes
6	Is Auxiliary Meter? Yes
7	Is Fuel Meter Working? Yes
8	Is Dust Tank Clean and Working? Yes
9	Is Vacuum Working? Yes
10	Is Sprinkler Working? Yes
11	Is it accident prone route? No

In between shift: (Fueling and Emergency Options)

Figure 5: Audit report generated at the end of the shift of each MRS machine

Outcomes: —○

The assessment helped ensure:

- Regulatory compliance
- Compare current practices to benchmarks
- Generate baseline data
- Review existing practices
- Establish indicators
- Targets for improving mechanized road sweeping operations



Impact of integration of an audit-based payment system for MRS in the Smart City 311 App

Integrating an audit-based payment for the MRS in the Smart City 311 App can enhance the monitoring and efficiency of road dust mitigation efforts. By leveraging technology to track and manage the performance of mechanized road sweepers, cities can achieve significant reductions in PM_{10} and $PM_{2.5}$ emissions, contributing to improved air quality and public health.

This multi-verification system is designed based on a report published by TERI in 2022, under the MCD, audited the MRS in Delhi. The findings suggested that a well-maintained MRS operates for 6.5–6.8 hours at an average speed of 22–25 km/h (RPM range 1000–1600), covering 1070–2200 kg/shift.

However, this efficiency depending on the city may vary. In order to mitigate road dust emissions in Lucknow, a comprehensive strategy has been tested, aiming for 90% reduction in the silt content of road dust by 2035. This strategy includes measures such as roadside plantation and the extensive use of mechanized road sweepers. MRS can achieve a 36% reduction in PM_{10} and $PM_{2.5}$ emissions from road dust re-suspension in Lucknow city and 32% reduction in PM_{10} and $PM_{2.5}$ emissions in Lucknow District when 50% of roads have operational MRS machines.

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