International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 8, 2025
https://theaspd.com/index.php

GIS And Participatory Governance For The Modernization Of Urban Street-Sweeping Services: A Case Study Of Oum El Bouaghi

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ABSTRACT
Urban street-sweeping services are a key element of municipal solid waste and environmental management, yet they remain poorly documented in many medium-sized cities of the Global South. This article presents a detailed diagnostic of the street-sweeping service in the city of Oum El Bouaghi (Algeria), based on field observations, semi-structured interviews, administrative data, and spatial analysis using QGIS. The study examines human and material resources, the organisation of work blocks and schedules, and the spatial coverage of the road network. The results show that only about 11% of the urban road network is regularly swept, with a strong concentration of efforts in central administrative and commercial areas, while peripheral districts remain largely underserved. The service relies exclusively on manual sweeping, with 26 sweepers organised into 17 work blocks, operating without mechanical sweepers or purpose-built street-cleaning depots. Using a GIS-supported sectorisation exercise, an optimised scenario is proposed in which coverage could increase to nearly 35% of the road network without additional staff, through a more rational distribution of blocks, the creation of local cleaning stations, and adjustments to day/night shifts. The discussion relates these findings to current debates on GIS-based optimisation of urban services and on collaborative and participatory governance in African cities. The article concludes by outlining operational, institutional, and participatory pathways for modernising the street-sweeping service in Oum El Bouaghi in line with smart and sustainable urban governance.
Keywords: *Urban street sweeping; Public Cleanliness; GIS; Participatory Governance; Municipal Management; Oum El Bouaghi, Algeria*

1. INTRODUCTION

Street-sweeping operations constitute a core but often overlooked component of integrated urban environmental management, with implications for particulate pollution, stormwater quality, visual amenity and urban liveability (Ragazzi, 2023). In large and medium-sized cities, the performance of sweeping services is increasingly assessed through operational indicators such as coverage rates, frequency of passage and user satisfaction, sometimes supported by dedicated software and indicator frameworks (López et al., 2017).

In North African cities, rapid urbanisation, constrained municipal budgets, and institutional fragmentation have made the provision of effective cleaning and solid waste services particularly challenging (Cheniti et al., 2024; Magoura, Dehimi, & Redjem, 2023). In Algeria, recent studies highlight the persistence of uncontrolled dumping and under-equipped local services, despite an evolving national strategy that increasingly emphasises planning, environmental performance and the use of analytical tools, including GIS (Bouchama & Drias, 2025; Hachemi et al., 2024; Hamdi Nasr et al., 2025 ; Yahia et al., 2025).

Geographic Information Systems (GIS) are now widely recognised as powerful tools for the spatial optimisation of municipal solid waste management, including landfill siting, container placement and collection routing (Magoura et al., 2023; Sisay et al., 2025). In Algerian and other African contexts, GIS-based approaches have helped local governments to construct spatial databases, identify service gaps and simulate

alternative allocation scenarios under resource constraints (Djamel et al., 2018; Bouchama & Drias, 2025). However, the specific application of GIS to the intra-urban organisation of street-sweeping services remains relatively underexplored, especially in medium-sized cities.

Parallel to these technical developments, scholarship on urban governance in Africa has emphasised the importance of collaborative and participatory arrangements to improve local service delivery, including waste management (Abdulai et al., 2024; Kubanza & Simatele, 2020). Participatory mechanisms at the local level—such as neighbourhood committees, feedback platforms and co-produced planning processes—have been shown to increase transparency, strengthen accountability and foster co-ownership of services (Ngunjiri, 2023; Check, 2024). However, in many municipal cleaning services, citizen involvement remains limited to complaint handling, and there is little evidence of structured engagement around route design or performance monitoring (Lamine et al., 2025; Fernanda Da Silva Fuzzo et al.,2025; Chaabane et al., 2024 ; LAMINE et al., 2023; LAMINE et al., 2019; Bachari et al., 2019; Lamine et al.,2020; Khidir Abdalla et al.,2019a; Khidir Abdalla et al.,2019b) .

Against this backdrop, the present article focuses on the city of Oum El Bouaghi in north-eastern Algeria. The research pursues three main objectives: first, to produce a detailed diagnosis of the existing street-sweeping service, including spatial coverage, organisation of work blocks and available human and material resources; second, to use QGIS to develop an optimised sectorisation scenario under existing staffing levels; and third, to discuss the institutional and participatory conditions required to implement such a scenario sustainably. The contribution of the paper lies in its combined attention to spatial optimisation and to the governance arrangements—particularly participatory ones—that underpin the modernisation of municipal services in a medium-sized North African city.

2. METHODOLOGICAL FRAMEWORK

2.1 Overall approach

The study adopts a mixed diagnostic approach that combines qualitative and quantitative methods to evaluate the organisation and performance of the street-sweeping service. Mixed-method designs are particularly well suited to urban services, where operational indicators must be interpreted in light of staff perceptions, organisational routines and political constraints (López et al., 2017; Bouchama & Drias, 2025). In the field of solid waste management, numerous studies have shown that combining GIS-based spatial analysis with stakeholder interviews and administrative data strengthens the robustness of diagnoses and the realism of optimisation scenarios (Magoura et al., 2023; Sisay et al., 2025).

In Oum El Bouaghi, the methodological objective is twofold. First, the study seeks to describe and map the current state of the service in terms of coverage, resource allocation and time schedules. Second, it aims to construct and evaluate alternative spatial and operational scenarios using QGIS, with particular attention to the balance of workloads between agents and the inclusion of underserved neighbourhoods. The protocol relies on cross-referencing multiple data sources to reduce bias and ensure that the conclusions reflect both observed practices and institutional constraints (Aaron et al., 2018; DIKE Victor et al., 2018; Swati et al.,2018; Lamine et al., 2018; Petropoulos et al., 2016).

2.2 Data collection

Four main categories of data were mobilised. First, semi-structured surveys and interviews were carried out with the head of the cleaning department, team leaders and a sample of sweepers (n = X interviews [to be completed by the author]). The interviews focused on working hours, sweeping circuits, daily constraints, equipment availability and perceived performance. Such managerial and frontline perspectives are essential for understanding how formal rules are translated into daily practices (Abdulai et al., 2024; Ngunjiri, 2023).

Second, systematic field observations were conducted in selected sectors representing different urban situations, including the city centre, peripheral districts and market areas. Standardised observation sheets were used to record the frequency of passage, the visible state of cleanliness and operational practices such as sweeping directions, use of equipment and interaction with residents. Field-based assessments of cleanliness

and operations have been shown to complement indicator-based approaches by capturing contextual and behavioural dimensions (López et al., 2017).

Third, administrative and technical data were collected from municipal technical services, including staff lists, block assignments, inventories of equipment and analogue or digital road plans. In line with recent Algerian studies on solid waste management, these administrative datasets provide a starting point for constructing spatially referenced databases and for calculating performance indicators (Cheniti et al., 2024; Bouchama & Drias, 2025).

Fourth, geospatial data were compiled in the form of a road network layer, municipal boundaries, the location of work blocks and waste evacuation points. These data were completed and verified through GPS readings during field visits. The resulting dataset is comparable to those used in other GIS-based analyses of solid waste and environmental services in Algerian cities (Magoura et al., 2023; Djamel et al., 2018).

2.3. Data Processing And Analysis

Qualitative data from interviews were transcribed and thematically coded, with particular attention to recurrent problems reported by staff (e.g., equipment shortages, difficult circuits, coordination with collection teams) and to their suggestions for improvement. Thematic coding is widely used in studies of local service governance to identify patterns in stakeholders' perceptions (Ngunjiri, 2023; Check, 2024).

Observational and operational data were quantified to derive simple descriptors such as frequency of passage, number of agents per block and approximate distances walked per day. Although the exact road length per agent could not be fully standardised due to data gaps, the quantification allowed for comparative assessment of workloads and coverage between blocks, in line with indicator-based approaches proposed in the literature on street cleanliness (López et al., 2017).

All geolocated data were integrated into QGIS. The tool was used to subdivide the road network into segments, calculate total lengths by work block, map the effective sweeping perimeter and identify underserved areas. Building on techniques used for landfill siting and route optimisation, several staffing allocation scenarios were simulated by reassigning agents to redefined blocks while keeping the total number of sweepers constant (Magoura et al., 2023; Sisay et al., 2025).

Performance indicators were defined in line with the literature and the available data: coverage rate (percentage of the urban road network regularly swept), average road length per agent (kilometres), average frequency of passage (per week), and availability of equipment (proportion of agents adequately equipped). Indicator-based dashboards are increasingly used in European and Latin American cities to track the performance of street-cleaning services and waste collection (López et al., 2017; Ragazzi, 2023).

2.4. Methodological limitations

Several limitations must be acknowledged. First, the data collection period does not fully capture seasonal variations in waste generation and litter accumulation, which can be significant in cities with marked climatic or touristic seasons (Cheniti et al., 2024). Second, the absence of continuous operational data, such as GPS tracking of sweepers or digital time sheets, limits the precision of workload and frequency calculations, as noted in comparable GIS-based studies of municipal services (Bouchama & Drias, 2025; Djamel et al., 2018). Third, citizen perceptions of cleanliness were not directly surveyed, so the analysis focuses on operational performance rather than perceived service quality, despite evidence that user satisfaction is a key dimension of urban cleanliness governance (Abdulai et al., 2024; Ngunjiri, 2023). The optimisation proposals, therefore, emphasise incremental and testable adjustments that can be refined in future work, particularly through participatory mechanisms.

3. STUDY AREA AND ORGANISATION OF THE STREET-SWEEPING SERVICE

3.1 Urban context of Oum El Bouaghi

Oum El Bouaghi is the capital of the wilaya of the same name, located in the north-eastern High Plains of Algeria on the strategic Constantine–Batna axis. The city occupies a nodal position between major regional centres and has experienced sustained urban expansion, particularly through the growth of peripheral districts. According to municipal data compiled for this study, the resident population is estimated at around

108,000 inhabitants, reflecting a steady upward trajectory linked to demographic growth and the extension of the built-up area. This urban dynamic has significantly increased demands on municipal services, notably in relation to hygiene and public cleanliness, and has accentuated territorial disparities between well-equipped central districts and more modest peripheral neighbourhoods.

3.2 Organisation of the cleaning service

The municipal cleaning service, attached to the technical department, is in charge of manual street sweeping within the entire urban boundary. The human resources consist of 26 sweepers, divided into a day group of 22 agents and a night group of 4 agents. The day group is responsible for 14 work blocks, concentrated mainly in the central and high-traffic sectors, while the night group covers three blocks along major central arteries. In addition, a reinforcement team intervenes on an ad hoc basis during exceptional events or when accumulations are reported.

The current organisation has the advantage of ensuring a daily presence on the most visible axes, but it also reveals major imbalances. The division into 17 blocks does not correspond to homogeneous workloads: some agents are responsible for large areas with dense road networks, while others operate on more compact circuits. This unequal distribution, combined with the limited number of staff, helps explain the low overall coverage of the urban network and the variability in the frequency of intervention between districts.

3.3 Human and material resources

In terms of human resources, the service relies exclusively on the 26 sweepers mentioned above, with reduced management staff consisting of a head of department and team leaders. There are no staff members dedicated specifically to GIS-based monitoring or to medium-term operational planning.

Material resources are predominantly manual. Sweepers use brooms, shovels and wheelbarrows, with limited provision of personal protective equipment such as gloves, reflective vests or masks. The fleet of equipment is both insufficient and often unavailable when needed, which constrains productivity. No mechanical sweepers or light support vehicles are currently in operation, despite evidence from other contexts that such equipment can substantially increase the productivity and ergonomics of sweeping services (Ragazzi, 2023).

Infrastructural support is also weak. The city lacks purpose-built street-cleaning depots where agents could store equipment, rest between rounds and access water or sanitary facilities. Waste is often temporarily deposited in informal depots or on vacant plots before being collected and transported by other municipal or contracted services. This system of unregulated temporary depots generates logistical inefficiencies. It contributes to the visual degradation of certain streets or open spaces, a pattern observed in several Algerian and African cities facing rapid growth (Cheniti et al., 2024; Kubanza & Simatele, 2020).

3.4 Institutional and regulatory framework

The street-sweeping service operates within the framework of municipal competencies in urban hygiene and waste management, as defined by Algerian legislation and regulatory texts governing local authorities. At the operational level, however, the study found limited formalisation of procedures. There is no formally codified system of circuit planning, no written standards for the frequency of passage by type of street, and no integrated protocol linking sweeping, primary collection and final disposal.

Cooperation between the services responsible for sweeping, refuse collection and waste transport remains partial and often informal, relying more on interpersonal relationships than on documented coordination mechanisms. This situation echoes broader observations in the Algerian waste sector, where institutional fragmentation and weak horizontal coordination have been identified as structural challenges (Cheniti et al., 2024; Bouchama & Drias, 2025). Moreover, no formal institutional framework has yet been established for the integration of GIS tools into municipal management, despite their increasing use in related domains such as landfill siting and container placement (Magoura et al., 2023).

4. RESULTS

4.1 Spatial coverage of the service

The spatial analysis of the street-sweeping service, carried out in QGIS on the basis of the digitised road network and block assignments, shows a low level of coverage of the urban road system. Only about 11% of the total road length within the urban perimeter is regularly swept. This figure reflects a marked imbalance between the central areas and the peripheral districts.

The administrative and commercial city centre benefits from a high frequency of intervention, often daily. These areas correspond to the majority of the day and night blocks, which effectively overlap around the main boulevards, public facilities and markets. In contrast, several peripheral neighbourhoods—particularly recent subdivisions and peri-urban extensions—lie entirely outside the formal sweeping perimeter. In these zones, the presence of sweepers is at best occasional and often limited to major access roads, leaving secondary streets without regular cleaning.

Maps produced in the framework of the study (Figure 1 – Coverage rate of the sweeping service, source: GIZ and authors, 2024) illustrate this spatial inequality, with a strong concentration of activity in the central work blocks and numerous uncovered road segments in the outer districts. The combination of a limited workforce and the absence of a rationalised spatial planning of circuits thus results in a fragmented and highly selective service, inconsistent with the scale of the urbanised area.

Figure 1: Map of the Coverage rate of the sweeping service. *Source: GIZ and authors, 2024.*

4.2 Staff performance and constraints

The analysis of staff organisation confirms the existence of major imbalances between the day and night services. The 22 daytime sweepers cover the majority of the urban perimeter, with a focus on main thoroughfares and high-traffic zones, such as institutional areas, commercial streets and market surroundings. The night service, composed of only four agents, intervenes essentially on central axes in order to limit interference with traffic and to manage waste generated by evening activities **(Figure 2).**

Figure 2: illustration of the major imbalances between the day and night services.

Despite the commitment of staff, the average yield observed in the field remains limited. The exclusively manual nature of the sweeping operation, combined with the absence of mechanical support, increases the physical burden on agents and restricts the total length of road that can be maintained under existing working hours. The irregular availability of basic equipment, such as brooms, shovels, wheelbarrows and protective

gear, further reduces efficiency. In some instances, agents reported having to share or improvise tools, which slows work and discourages adherence to planned circuits.

The working conditions themselves contribute to physical fatigue: agents must cover long distances on foot, often with limited protection against adverse weather. The absence of rest areas and storage spaces near their zones of intervention obliges them to travel to central facilities at the beginning and end of shifts, increasing dead time and reducing the effective cleaning time. Supervision capacity is also constrained; the reduced number of supervisory staff does not allow systematic monitoring of individual performance or consistent adjustments to circuits based on observed needs (**Figure 3).**

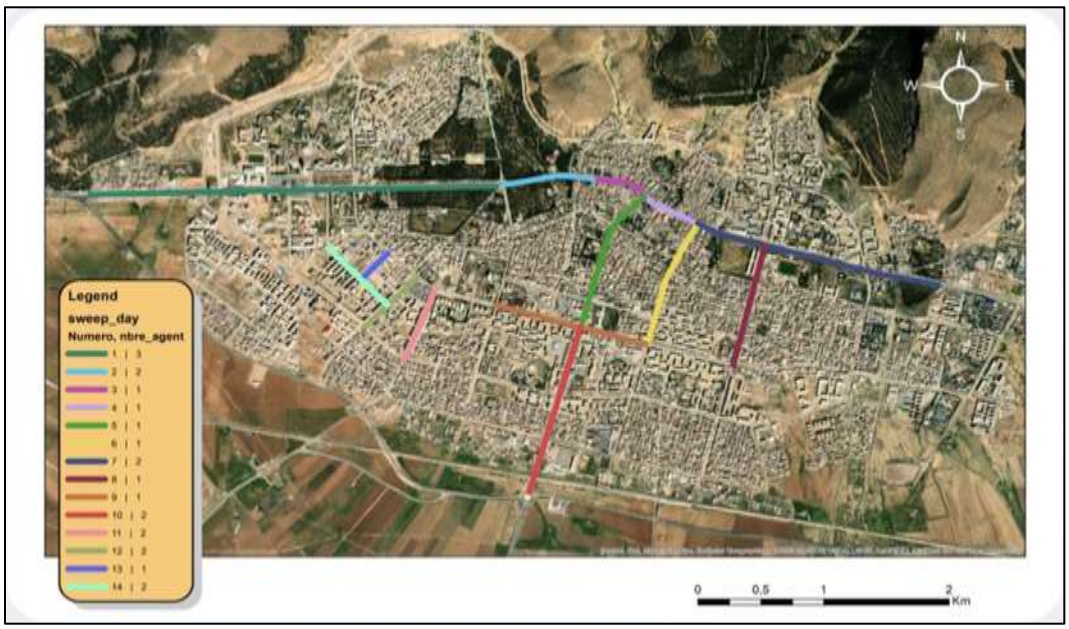

Figure 3: Map of the Coverage rate of the sweeping service for day, *Source: GIZ and authors, 2024*

4.3 Major dysfunctions in service organization

The cross-analysis of field observations, interviews with municipal officials, and GIS-based mapping highlights several major dysfunctions in the current management of the street-sweeping service. A first dysfunction is chronic spatial undercoverage: large parts of the city, particularly newer residential areas and peri-urban extensions, are not included in the regular sweeping circuits. This undercoverage is directly reflected in the low global coverage rate of approximately 11% of the road network.

A second dysfunction concerns the overall efficiency of the service. The absence of mechanised equipment and support vehicles, combined with the arduous nature of manual sweeping, limits the productivity of agents and amplifies disparities in workloads. Some blocks concentrate long and complex circuits, while others encompass shorter routes. In practice, this leads to unequal returns between agents and variable cleanliness levels between sectors.

A third dysfunction relates to the organisation of waste disposal. The current system relies largely on temporary, unregulated depots, often improvised on vacant lots or roadside spaces, in the absence of properly equipped street-cleaning depots. This arrangement complicates the coordination between sweeping and refuse collection and can contribute to recurrent accumulations of waste at unofficial dumping points.

A fourth dysfunction concerns working schedules. Existing working hours do not always coincide with periods of peak waste generation, such as late afternoon and evening after market closure. The limited night team is unable to cover all areas where nocturnal activities generate litter, particularly in certain commercial streets and around transport nodes.

Finally, there are coordination issues between the sweeping service and the other components of the municipal cleaning system, notably waste collection and transport. The absence of a formal protocol or shared planning tool results in desynchronised operations: in some cases, swept waste remains on the roadside for

extended periods before collection, while in others, collection vehicles arrive at times when streets have not yet been swept.

5. DISCUSSION

The diagnostic for Oum El Bouaghi aligns with recent work on street sweeping and urban cleanliness, which shows a systematic privileging of central areas to the detriment of peripheral districts (Ragazzi, 2023; López et al., 2017). A coverage rate of around 11% of the road network illustrates a highly selective service that contrasts with approaches advocating the extension of cleanliness standards beyond central business districts for reasons of environmental justice and public health.

Exclusive reliance on manual sweeping, in the absence of mechanical equipment and adequate support infrastructure, reflects patterns observed in other resource-constrained municipalities in Algeria and across Africa, where labour-intensive practices coexist with chronic underinvestment in depots and tools (Cheniti et al., 2024; Kubanza & Simatele, 2020). In Oum El Bouaghi, this configuration results in excessive physical strain for sweepers, limited effective cleaning time and difficulties in keeping pace with urban expansion.

The GIS-based analysis demonstrates how spatial tools can partially overcome these structural constraints. By subdividing the road network into more balanced blocks and reallocating sweepers accordingly, the QGIS simulations show that coverage could rise from 11% to nearly 35% without increasing staff numbers, echoing other GIS applications in landfill siting and waste collection routing (Magoura et al., 2023; Sisay et al., 2025). Quantifying road lengths and mapping underserved areas enables more objective decisions on circuit design and workload distribution, in line with recent Algerian experiences in solid waste planning (Bouchama & Drias, 2025; Djamel et al., 2018).

However, optimisation through GIS remains fragile if not anchored in appropriate institutional arrangements. Research on collaborative governance in the waste sector stresses that coordination mechanisms, clear mandates and incentives largely determine service performance (Abdulai et al., 2024). In Oum El Bouaghi, the lack of formal links between sweeping, collection and transport reproduces inefficiencies observed in other African cities, where fragmented responsibilities undermine system coherence (Kubanza & Simatele, 2020). Establishing a cross-cutting municipal unit or working group on urban cleanliness, using GIS outputs as a common reference, would be a key step in transforming the proposed sectorisation into routine practice.

Citizen participation forms a second pillar of such governance reforms. The literature highlights the role of residents in expressing priorities, monitoring performance and co-producing solutions (Ngunjiri, 2023; Check, 2024). Although this study did not include direct citizen surveys, the spatial disparities identified suggest that participatory approaches—such as neighbourhood meetings, participatory mapping of litter hotspots and co-design of pilot sweeping circuits—could help align service provision with local perceptions of critical zones and time periods. Experiences from other African contexts show that structured feedback channels, ranging from neighbourhood committees and public forums to simple digital reporting tools, can contribute to more equitable and responsive waste services (Abdulai et al., 2024; Ngunjiri, 2023).

Taken together, the Oum El Bouaghi case underscores three main insights. First, in medium-sized cities, the central bottleneck is less the number of sweepers than the absence of spatially informed planning and balanced workloads. Second, GIS—particularly open-source platforms such as QGIS—offers a relatively low-cost means to construct such planning frameworks (Magoura et al., 2023; Bouchama & Drias, 2025). Third, lasting improvements depend on embedding these tools within collaborative governance arrangements, rather than treating them as stand-alone technical solutions.

On this basis, several complementary operational proposals can be advanced. A first concern is the institutionalisation of GIS within the municipal technical department through a small internal unit or focal person responsible for maintaining spatial data on roads, work blocks and depots, and for producing operational maps (Bouchama & Drias, 2025; Magoura et al., 2023). A second is the formal adoption of the optimised sectorisation scenario, redistributing the 26 sweepers across 17 redefined blocks whose lengths and functional characteristics are more balanced, so that each agent manages a standardised workload combining

main and secondary streets (López et al., 2017; Ragazzi, 2023). A third proposal is the reorganisation of working hours—shifting some posts to evening and night periods and staggering start times—so that sweeping better follows peaks of litter generation around markets, transport hubs and commercial streets (Abdulai et al., 2024). A fourth concerns the development of support infrastructure through small decentralised cleaning stations near block boundaries, which would shorten non-productive travel, improve working conditions and make the service more visible to residents (Cheniti et al., 2024; Bouchama & Drias, 2025). Finally, gradual mechanisation—based on light sweepers and small electric vehicles or tricycles rather than large machines—could raise productivity and reduce occupational risks while remaining compatible with narrow streets and limited budgets (Ragazzi, 2023).

Modernising street sweeping in Oum El Bouaghi, therefore, requires both technical and governance adjustments. At the municipal level, a priority is to create an integrated framework for urban cleanliness, linking sweeping, collection, transport and environmental units through a coordination platform that uses shared GIS tools to define routes, schedules and indicators (Bouchama & Drias, 2025; Cheniti et al., 2024). A second priority is to institutionalise citizen participation in decision-making, for example, through forums on cleanliness priorities, participatory mapping of recurrent dumping points and co-designed pilot circuits in selected neighbourhoods (Ngunjiri, 2023; Check, 2024). A third dimension is the establishment of feedback and monitoring mechanisms—complaint registers, hotlines or digital reporting platforms—complemented by the public display of simplified coverage maps and schedules to foster transparency and accountability (Abdulai et al., 2024). Finally, these participatory arrangements must be supported by capacity building. As highlighted by studies on local governance in Africa, municipalities often lack both the skills and organisational culture needed to manage inclusive processes (Ngunjiri, 2023). Training municipal staff in facilitation, communication and the use of GIS visualisations in public meetings, together with support for civil society organisations and neighbourhood committees, would help ensure that participation is effective and representative, rather than limited to a small group of vocal actors.

6. CONCLUSION

The analysis of the street-sweeping service in Oum El Bouaghi reveals major structural and organisational weaknesses that severely limit its effectiveness. Only about 11% of the urban road network is regularly swept, with a strong focus on central districts, while peripheral neighbourhoods remain underserved. The service relies exclusively on manual sweeping by 26 agents organised into 17 work blocks, without mechanical equipment, cleaning depots or formal coordination with collection and transport services.

Using QGIS, the study shows that a more rational sectorisation of the road network and a redistribution of agents across redefined blocks could increase regular coverage to nearly 35% without additional staff. Achieving this requires institutional changes: integrating GIS into municipal practices, adapting working hours to peak waste periods, creating decentralised cleaning stations and gradually introducing light mechanisation. More broadly, improving the service depends on stronger local governance, better coordination between municipal services and the involvement of citizens in setting priorities and assessing service quality. The approach proposed for Oum El Bouaghi can serve as a methodological reference for other Algerian and North African cities facing similar constraints, and future work could further explore participatory tools and evaluate the long-term impacts of these reforms on urban cleanliness and quality of life.

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