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Use of Multi-Criteria Analysis (MCA) as a means of determining the location of waste management infrastructure and urban cleanliness facilities in Touba Mosque

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Abstract: Marked by a very strong demographic growth, rampant urbanization, and a dynamic economy, the city of Touba is also experiencing new consumption patterns (retail sale, fast food, popular use of disposable textiles, etc.), once prevalent in the world's largest cities. These elements are among other decisive and essentially responsible factors for the significant amount of waste produced in this city. This proliferation of waste, which is accompanied by the multiplication of illegal and recurrent dumping sites, justifies on one hand, the need to disseminate waste management infrastructure in this city so as to maximize waste collection activity, on the other hand to bring the population closer to this public service, which is waste collection. Thus, the usage of solutions offered by GIS seems essential to model a justified distribution of these infrastructures.
The aim of this research is to provide an overview of the current spatial distribution of urban cleanliness equipment in Touba and to concretely explore GIS solutions that will enable optimal distribution of these waste management infrastructures through Multi-Criteria Analysis (MCA).
The methodological approach used in this research is quantitative, with the development of a questionnaire using Kobotoolbox to collect information on the urban equipment deployed in the city of Touba Mosque, but also technical, with the explanation of the various processes used to carry out the MCA.
The results of this study have shown that the city of Touba is facing a high production of waste, hence the presence in several locations of waste management infrastructure (IGD). The audit of the dissemination of urban cleanliness equipment shows that it does not rely on justified selection criteria regarding the locations of the sites where the IGDs should be located. This is why the idea of using the MCA method has been proposed, which makes it possible to identify favorable or suitable sites for the implementation of IGDs and urban cleanliness furniture.

Keywords: Waste management, urban equipment, GIS, multi-criteria analysis, Touba

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Introduction

The management of household and urban solid waste has become an equation with several unknowns. The history of waste management on a global scale shows that it has always been a minor concern in medieval societies, where the growth of industry in the 18th century was seen as the capacity for production of a power or country. These new modes of production have encouraged new consumption trends, which are responsible for the pollution of once pristine natural areas. Most human settlements are faced with environmental degradation due to health and environmental hazards, as well as visual and olfactory pollution.

The proliferation of these forms of nuisances has caught the attention of both decision-makers and populations on the international stage. As this concern returns to the agenda at inter-state meetings, it eventually highlights its importance to the international community. That is why the Johannesburg Summit in 2002 and the United Nations General Assembly in July 2010 resulted in the following provision: "The right to water and sanitation allows everyone to have access to safe, culturally acceptable and participatory water and sanitation services that are provided in a non-discriminatory and responsible manner."

The previous century was marked by the acceleration of solid waste production, which is now seen by most people as a major problem (World Bank, 2012). For experts (naturalists, ecologists, environmentalists, geographers, etc.), the harmful impact of solid waste on the living environment has gone beyond the stage of a problem and is now considered as a phobia. This is confirmed by the publication of several reports (World Bank (2012), UNEP (2015), EU (2013), and that of UN-Habitat in (2021) and several other studies commissioned by the German International Development Cooperation Agency (ACIAD).

Despite all the efforts made by countries and international institutions so far, the world produces 2.01 billion tonnes of municipal waste per year, and without instant action, this figure will increase by 70% to reach 3.4 billion tonnes by 2050[1]. Many cities in Africa produce local solid waste that they cannot dispose of easily. They are almost all faced with a lack of sanitation systems (both collective and individual) and solid waste management (Seidl, 2007).

In Senegalese cities in general, including Touba, solid waste blocks drainage channels and causes stagnation or backflow of fluids. These similar situations are part of the daily lot of the National Sanitation Office of Senegal (ONAS). Almost all the open channels in the Senegalese capital serve as dumping grounds (Diawara, 2009), both in Dakar and Touba, and even in other cities. The Municipality of Touba Mosquée has a high population density, which influences the production of solid waste (468 T/day) and the quantities dropped in landfills (80 T/day), which is 17% of the total production of solid waste (UCG, 2020).

[1] What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 | Groupe de la Banque Mondiale (worldbank.org)

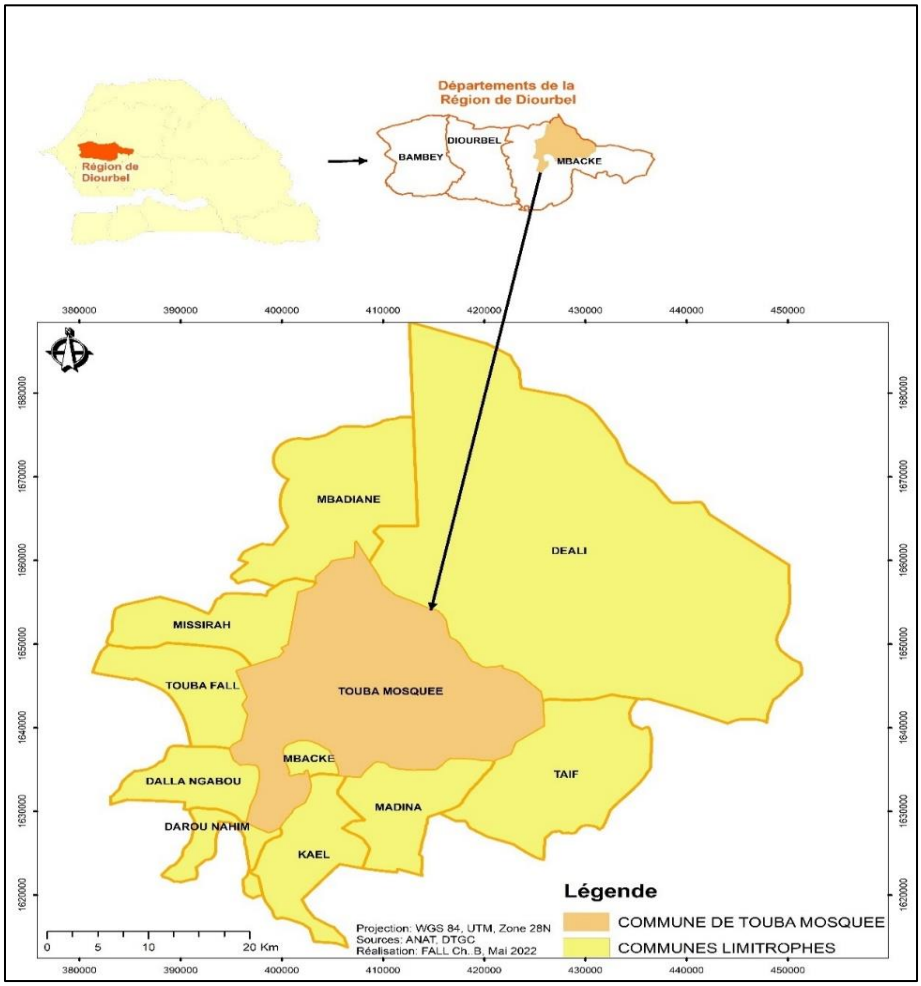
The high production of solid waste and the inability of the municipalities of Touba Mosque and Dakar, for an effective management of waste, justify the proliferation of illegal dumps in urban areas. In light of this observation, which is widespread in almost all Senegalese cities, and in order to preserve the environment, Senegal has embarked on a dynamic of ratifying international initiatives (SDG 11.6[2]), and implementing plans and programs aimed at improving the living conditions. As such, solid waste management has been included in its development priorities, poverty reduction (employment), and improving the living conditions of the population. This initiative is materialized by the creation of the Solid Waste Management Coordination Unit (UCG) in 2013, in order to have a significant and positive impact on waste management, especially operationally. One of UCG's top priorities, shortly after its creation, titled "initiative in contact with interior cities," aimed to eradicate illegal dumps located at the entrances and exits of cities throughout the country. But despite the multitude of actions carried out by UCG, there is a relative inefficiency in waste collection.

Thus, we explored GIS in order to find a technical solution that would allow for better dissemination of IGDs, to contribute to the reduction of waste produced and not collected. As a geoinformation tool whose functions include acquiring, storing, processing, producing, and disseminating information with spatial reference, GIS is an analytical and visualization tool that can ensure the control of spatial information for optimal management of public resources.

The choice of the city of Touba Mosque (map 1) is strategic, as it is the second largest Senegalese city in terms of population; and waste management remains problematic, hence our clear willingness to propose a scheme for the spatial redistribution of urban furniture for better coverage of the communal territory of Touba Mosque. From this fundamental concern arises the following question: would the use of the multicriteria analysis method allow for a better choice of the location of IGDs and urban cleanliness furniture in the religious city of Touba Mosque? The purpose of this research work is to propose a site selection process based on the solutions offered by GIS, which can be of significant contribution to the governance of solid waste. In this case, the exploration of solutions offered by GIS will notably involve the use of multicriteria analysis for the proposal of a better spatial coverage in Touba Mosque through IGDs and urban cleanliness furniture. This research problematic is therefore based on the hypothesis that "the dissemination of IGDs and urban cleanliness furniture does not rely on relevant technical criteria, hence the need to propose a method based on GIS through the use of the multicriteria analysis function (AMC), contained in ArcGis 10.8 Arctoolbox, which should allow for better placement of urban equipment in the religious city."

[2] SDG 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

Map 1: Location of the Municipality of TOUBA Mosque



Source: Fall, 2022

This research is organized around two essential points: the methodology of the study, which discusses the requirements of scientific research work, and explains the technical procedures used during data collection, analysis, and discussion of the results. The latter are structured around the assessment of waste production and spatial distribution of urban furniture in the city of Touba Mosque. The study also considers the introduction of GIS in waste management through multicriteria analysis to determine suitable areas for the allocation of waste collection points (IGD) and urban cleanliness equipment.

1. Methodology

Geographic Information Systems (GIS) through their functions of acquisition, storage, processing, production, and dissemination of spatial reference information, actively contribute to the search for sustainable and innovative solutions in the management of public affairs. These spatial reference data, acquired and processed with methods ranging from the simplest to the most complex on increasingly powerful computer stations, help decision-making, planning, and improving the living environment. GIS thus allow decision-makers to have a powerful source of information of various kinds

to be well-informed for better management and decision-making (CALOZ et al., 1995; LILI CHABAANE et al., 1999, and CRAUSAZ, 2000).

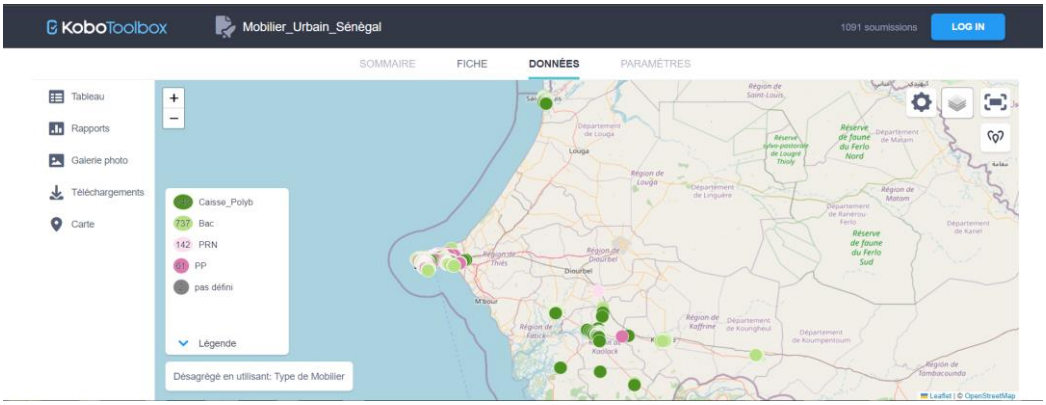
1.1. Literature review

The theoretical analysis involved familiarizing ourselves with basic concepts of waste management from various books, articles, and study reports. We had access to a wide range of literature on waste management in Senegal in general and in the city of Touba in particular. This exercise also led us to visit many public and private structures. This documentation process allowed us to readjust our ambitions, gain a better understanding of the studied reality, and better plan the different stages of this research work.

1.2. Collection of data on urban furniture

The data collection phase took place over several days. For this study, data collectors were sent to the commune of Touba to geolocate all deployed urban equipment. During the collection phase, meetings were held with the coordinator of the SONAGED, the Pôle Centre, and the municipal actors responsible for waste management. This first step facilitated the assessment of the human resources available in the field. By mutual agreement, it was decided to involve the supervisors and chiefs of villages-quarters in Touba in the exercise to maximize the chances of obtaining the right information. The second step consisted of collecting information on urban cleanliness furniture using the Kobocollect data collection tool (photo1).

Photo1: Kobocollect platform interface



Source, Fall 2022.

https://kf.kobotoolbox.org/#/forms/awi9pcSYKYp9Tt58p2oa3F/data/map/Type_de_Mobilier

1.3. Data processing for multi-criteria analysis

Given the proliferation of illegal waste deposits, the development of appropriate spaces to facilitate waste storage before transfer to landfills is an urgent need. This development must essentially be based on a calculated and thoughtful choice, based on specific data processing methods such as multi-criteria analysis (MCA). MCA implementation is a complex technical task that requires mastery of a GIS process involving several stages before achieving the wanted result. The success of the MCA for identifying sites suitable for IGD implantation or reassignment, and urban furniture,

relies on two elements: the choice of selection criteria and the technical processes used to carry out the MCA process.

1.4. Choice of criteria

The optimal dissemination of IGDs and urban equipment through the selected analysis model inevitably relies on the selection of a number of criteria. As a basic element of selection, a criterion constitutes a relevant reference that is measured and evaluated to achieve an objective. A set of criteria provides a reference system for evaluating the suitability of a location to meet one or more objectives (CALOZ, 2001). The choice of favorable sites for the installation of IGDs and waste management urban equipment in the municipality of Touba Mosque is made according to the following procedure.

1.5. Process for modeling the redistribution of urban cleanliness equipment

Based on these observations, we tried to find a way to have a spatial distribution that is justified and based on objective reasons that go beyond visibility. That's when we thought about looking into geomatics and eventually found an approach called "multi-criteria analysis," using the ArcGIS mapping software tool from ESRI. It involves combining remote sensing and mapping, using the Arctoolbox tool from ArcGIS Desktop.

To achieve this exercise, we had to choose five evaluation criteria to determine the areas that are most suitable for the implementation of Waste Management Infrastructures (WMI). These criteria are land use, high production sites, population density, and the city's road network. It should be noted that this process is based on assumptions, but all input data is accurate and reliable.

- ❖ Land use:

For land use, we downloaded a Landsat OLITIRS image from 2020 from the USGS website. Using the remote sensing software ENVI, we classified the land use units, which are built-up areas, bare soils, vegetation, and surface waters. The process is executed using the "raster calculator" function from Arctoolbox in ArcGIS, which provides a result in the form of a "raster" or image.

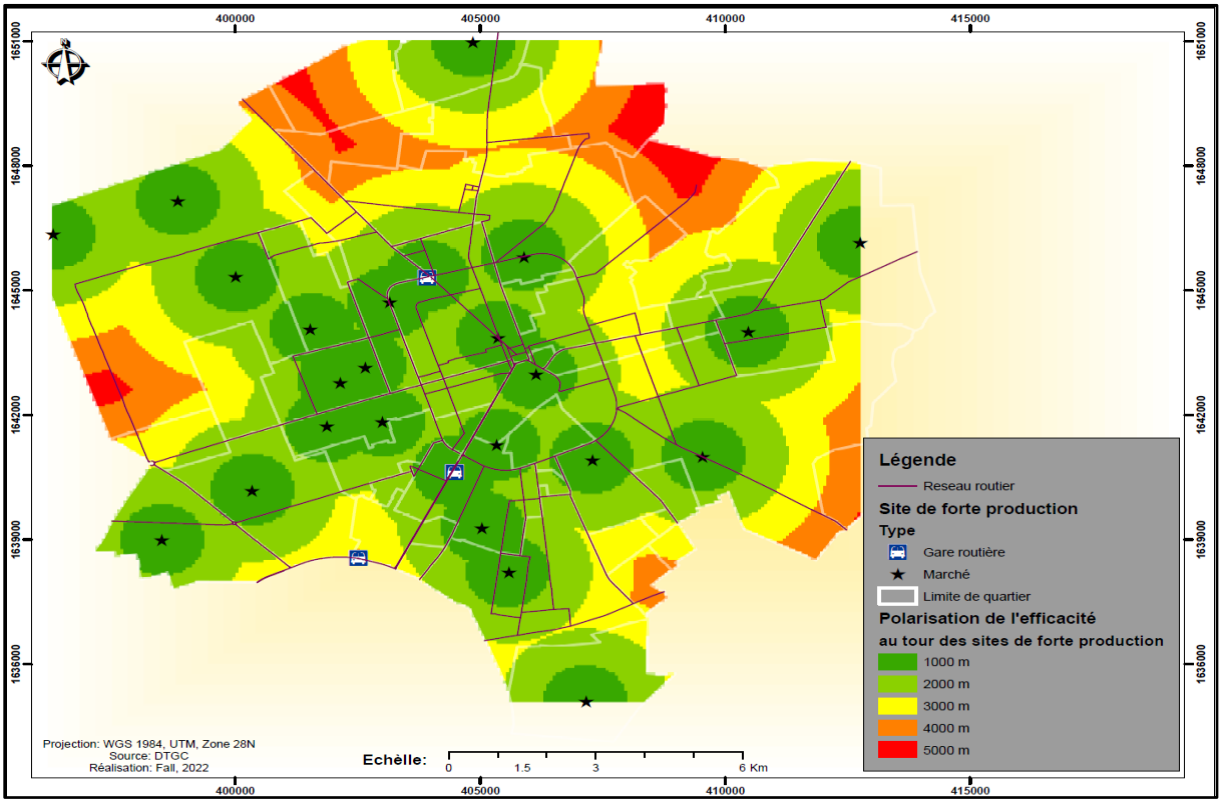
- ❖ High Production Sites (HPS):

The choice of HPS used for this exercise is based on their size and the level of use by the CTM residents. Of the fifty sites listed, twenty-four were selected. The main goal is to determine if the installation of a standardized and functional WMI will have a positive impact and to what level.

The assessment of the HPS's influence zone is done by executing the "raster calculator" function based on a buffer or buffer zone of five thousand meters. This resulted in ten classes over a radius of 5000 meters, which were reorganized into five classes. This reclassification is based on the ease of spatial analysis of the obtained information. The resulting map (see Map 2) shows that a good device at each HPS could have a positive impact on waste management, covering a radius of two thousand meters. This means that the device would be able to handle the waste produced by the populations that frequent these HPS (green and light green contours). However, beyond two thousand meters (between 3000m and 5000m), this device will no longer be effective. This is why, beyond the yellow belt (3000m buffer), the remote areas that

are beyond the positive influence of a possible device are located in the north of the city, southeast, and east.

Map 2: Positive influence radius of a waste management infrastructure implemented at a high production site.



Source : Fall, 2022

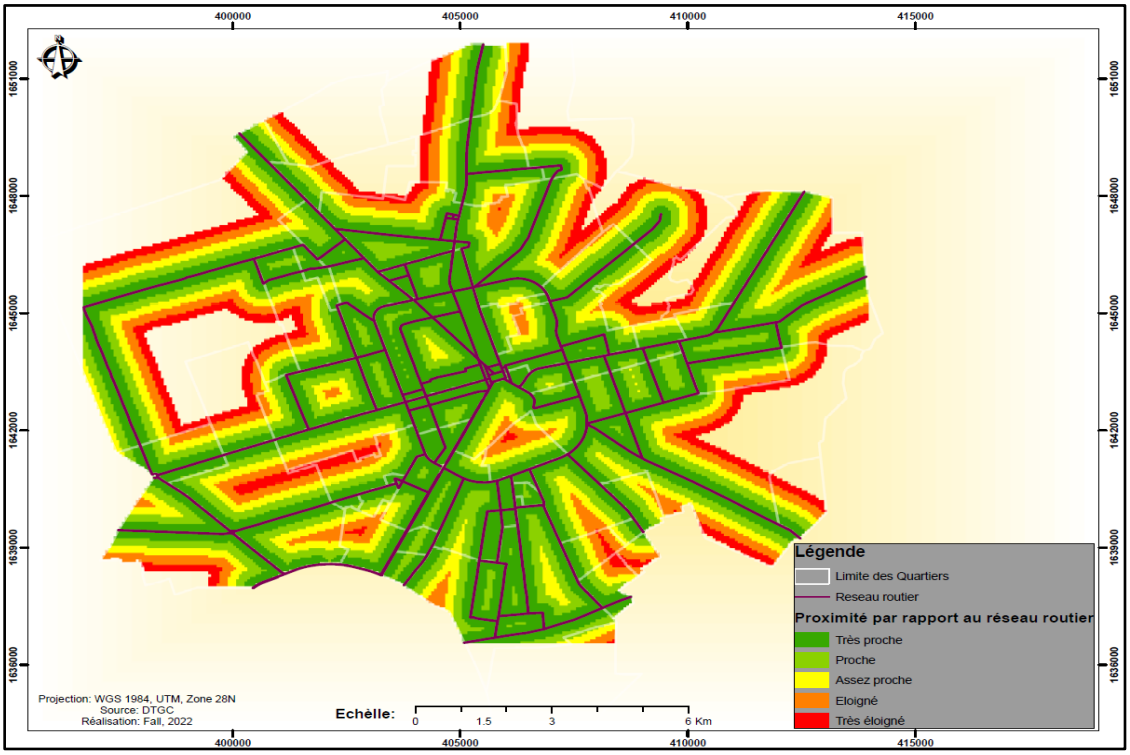
- The road network

Regarding the importance of the road network, the target is the proximity of housing to the road network. We used the "Euclidean distance" function for this indicator and for this exercise, we selected a default influence zone of one thousand meters, as opposed to the 150 meters used by SONAGED. This choice is justified by technological limitations, as selecting too small a buffer zone for this exercise could result in biased or unusable results.

The result obtained presents ten default classes, and we have reclassified it into five classes (buffer of 200 meters per class), and therefore the categorization of proximity ranges from very close to far away, from 0 to 1000 meters (see Map 3). The closer a point is to the road, the higher its eligibility or suitability for the installation of an IGD, as the road's carriageway nature remains imperative for the collection and transportation of waste.

This approach allowed us to see that the majority of remote or inaccessible areas are located in the peripheral neighborhoods, as well as in Guédé Bousso, Touba Guédé, Boukhatoul, Sam Lah, Dianatou, Darou Miname, Khaïra, Keur Niang, and Darou alimoul Khabir.

Map 3: Positive influence zone of the road network.



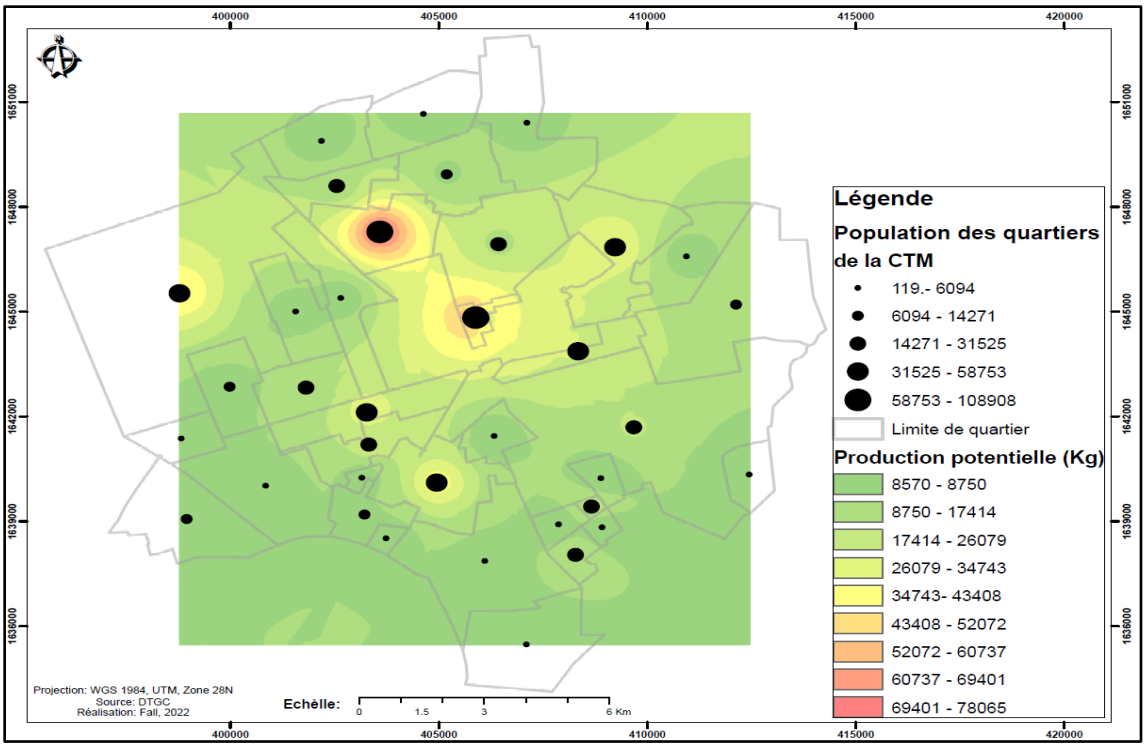
Source : Fall, 2022

❖ Potential waste production

As for the suitability of IGD implantation based on the potential production of solid waste, depending on the population size, we reclassified the result obtained by linear interpolation using the Inverse Distance Weighting (IDW) algorithm of ArcGis. The principle is simple: the higher the potential production, the more eligible it is for IGD implantation. To quantify the potential production, we used the correlation between population size and potential waste production. According to a very basic understanding, densely populated neighborhoods or villages logically produce more waste than less densely populated ones. The reference value used here is the potential waste production per day, per inhabitant, which is 0.72 kg (UCG, 2015). Apart from the neighborhoods of Touba Guédé and Gouye Mbind in the center, there are those in the

periphery (Darou Karim, Diakhaye, Touba HLM, Tindody, Boukhatoul, Sam Lakh, Keur Niang extension, Solbock, Darou Rahmane Santhie, TOUBA fall), which have a very high production of solid waste. The areas of high, medium, and low production cover an area of 1448.7 Ha, 4389.2 Ha, and 3004.5 Ha, respectively (see Map 4).

Map 4: Classification of neighborhoods according to the potential production of solid waste

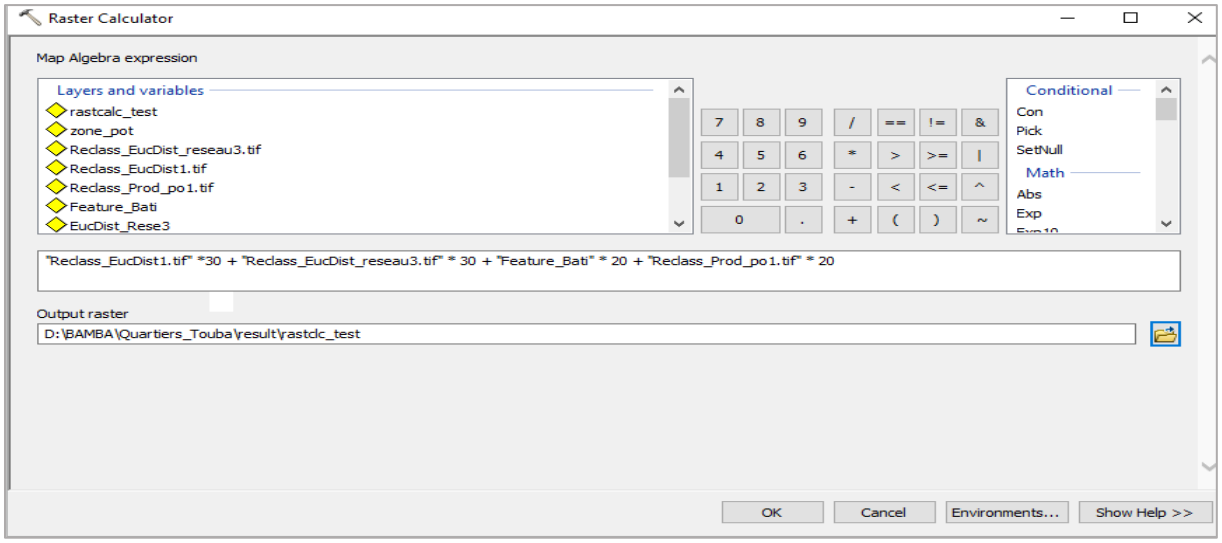


Source: Fall, 2022

Once the different indicators were mapped, the final result was obtained using the Analytic Hierarchy Process (AHP) classification method, and composite weights were assigned to the criteria maps (image format), based on their importance in a waste management system. After analysis, a final map, which summarizes all the previous processes, was generated.

The coefficients assigned to the different indicators are in order of importance, 30 for the SFP, 30 for the positive influence zone of the road network, 20 for the built-up area, and 20 for the potential production of waste based on population size, making a total of 100. It is only after introducing the obtained rasters with their coefficients that the raster calculator can execute the Analytic Hierarchy Process (AHP).

Photo 2: Raster calculator execution process.



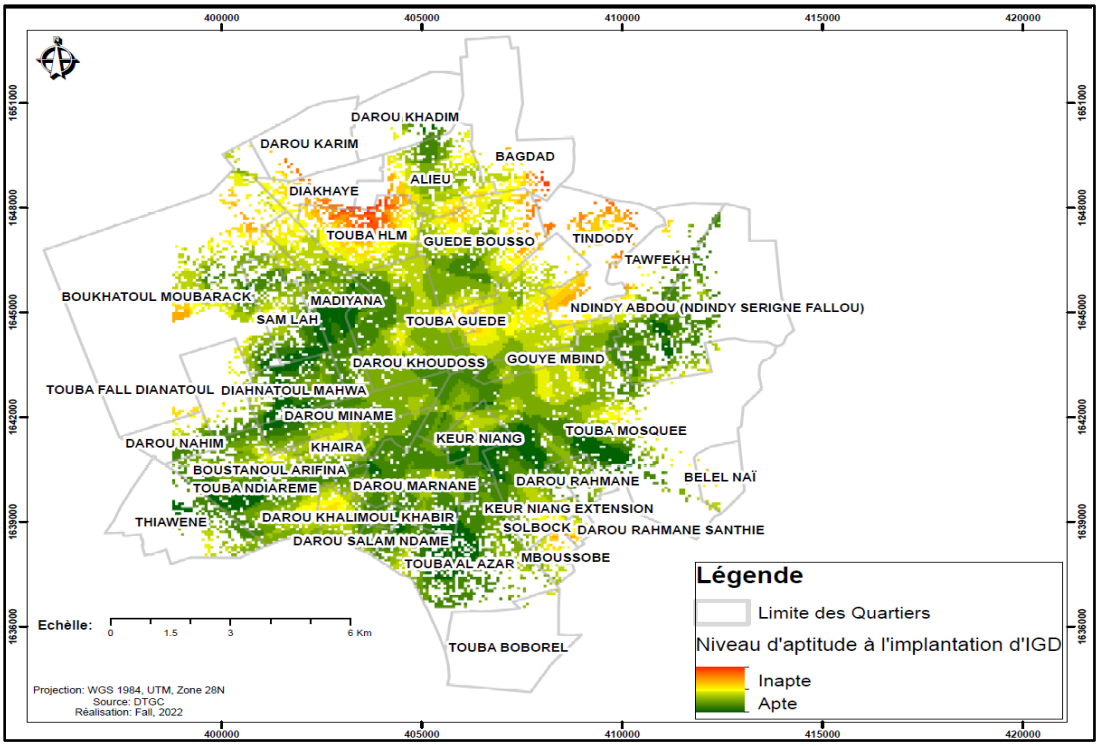
Source: Fall, 2022

The result obtained presents three categories of IGD implementation zones. These zones, according to the logic of the multicriteria approach, are those where the SONAGED office in Touba Mosque should install any type of IGD or urban cleanliness equipment, such as poly-bins, garbage cans, and Normalized Grouping Points (PRN). They also represent areas to target in case of spatial redistribution of existing equipment, which is often highly concentrated. The selected mentions are unfavorable, slightly favorable, and favorable. The final result obtained for the suitability map (Map 5) reveals that the strongly suitable areas are concentrated around sites with high production, in areas close to the road network, and also in areas covered by buildings (see Map 2).

However, areas located on the outskirts (periphery) that are not far from SFP and the road network remain less favorable for the installation of PRN or garbage cans. Areas far from SFP and the road network, or areas with very low waste production, can be considered unsuitable for the implementation of IGD.

In summary, for this exercise, suitable spaces for the implementation of IGD were determined through a Multicriteria Evaluation (EMC). To do this, a number of criteria favorable to the implementation of IGD in Touba Mosque had to be identified. Then, through the AHP method, the reclassified layers were superimposed with their respective weights to determine the suitable and unsuitable areas for the implementation of IGD (see Map 5).

Map 5: Areas suitable for the implementation of IGD in Touba Mosque.

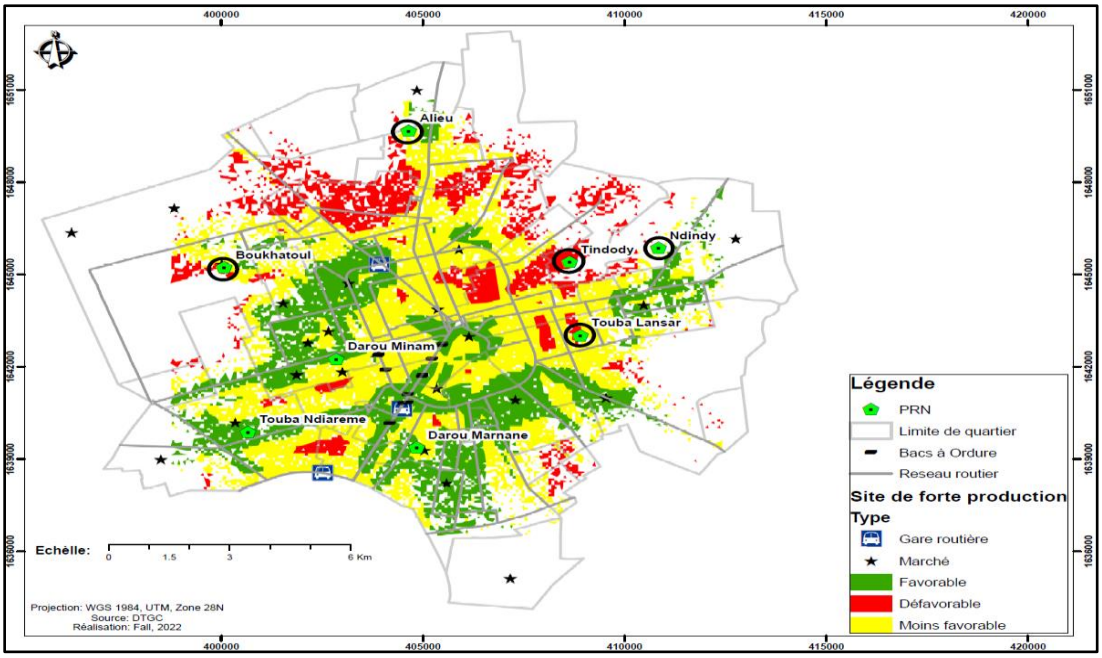


Source : Fall, 2022

The outcome of this multi-criteria analysis exercise has certainly provided results that deserve attention, but we had the feeling that there was a sense of incompleteness. Therefore, we had the idea of adding the spatial reference point data of IGD from the PGDSU and existing urban equipment to refine the information on areas suitable for receiving IGD in the CTM space.

The addition of this data or spatial analysis indicator highlights the idea of redundancy, which is to be avoided in the exercise of disseminating IGD. That is, we seek to identify areas that are suitable, but do not have IGD or urban equipment. The resulting map has indeed reduced the areas suitable for IGD placement in a more concentrated manner, at the expense of those that are more or less suitable or unsuitable (see Map 6).

Map 6: Favorable locations for IGD placement in the CTM.



Source: Fall, 2022

One of the major findings of this exercise is that all the suitable areas are intersected by roads, which confirms its crucial importance in any waste management system. However, beyond that, the UCG of Touba Mosque would benefit from redistributing the existing urban cleanliness equipment and IGD based on these results. Out of the eight PRNs planned for Touba Mosque, three (Lansar, Boukhatoul, Tindody) are located in areas classified as unfavorable, two are in less favorable locations (Alieuh, Ndindy), and the remaining three are in favorable zones (Darou Marnane, Touba Ndiarème, and Darou miname).

However, since we did not consider flooding as an analysis indicator at this level, the PRN of Touba Ndiarème was deemed eligible, even though it is not (see Photo 2).

Photo 3: Flooded Point de Regroupement Normalisé (PRN) in Touba Ndiarème.

Source: Fall, 2022

In summary, this approach can be used to improve the selection of IGD sites, and could even be replicated on a larger scale for other waste management areas. It's important to understand that a zone must meet all the criteria for analysis to be designated as suitable. The fewer favorable indicators a zone has, the less suitable it is for IGD installation, and may even be unsuitable.

2. Results and Discussion

2.1. Overview of waste production and spatial distribution of urban equipment in Touba

As a necropolis city for the Mouride talibes, the Commune of Touba Mosque (CTM) has a high population density, which significantly influences the production of solid waste (468 tons/day) and the quantities disposed of (80 tons/day), representing 17% of the total production of solid waste (UCG, 2020). This proliferation of waste puts the municipal authorities in a difficult situation due to their lack of resources. Faced with this helplessness, the municipality of Touba Mosquée favors easy solutions by using old sand quarries as landfills. The Bakhya and Darou Salam landfills are starting to show their limits as they will soon be full. The situation prevailing in these landfills led to numerous popular uprisings in 2019. The shortcomings observed in the management of solid waste in Touba are the cause of the strong growth in the production of solid waste. The consistency of the production growth is confirmed by the strong presence of recurring illegal dumpsites and sites of high production (markets and bus stations). Indeed, the conurbation of Mbacké-Touba, which already had 24 permanent markets and 9 weekly markets (ANSD, 2012), is also an aggravating factor.

The municipality of Touba Mosque has 26 collection circuits and changing sweeping circuits, except for the 2x2 lanes that go from the grand Mosque to the Mbacké roundabout. To manage the collection circuits, SONAGED uses 12 compactor trucks, 3 poly-bin trucks, 1 mechanical excavator, 3 dump trucks with a capacity of 16m3, and 9 functional type 2 PRNs. It should be noted that the PRNs of the PGDSU, whose construction is completed, are not yet operational because they depend on the CIVD, which does not yet have its sorting line. It is important to emphasize that the logistics of the municipality for waste management in CTM are limited to two trucks, one mechanical excavator, and minor equipment.

The significant production of solid waste and the proliferation of illegal dumpsites in the Dakar region and the municipality of Touba Mosque justify the deployment of a waste management system by public authorities. To ensure the effectiveness of the spatial distribution of urban cleanliness equipment, it is important to propose a plan for the installation of such equipment by using the functionalities of GIS through the method of multicriteria analysis.

2.2. Proposal of a new waste management model based on the results obtained with the Community Mapping Approach (AMC) in Touba Mosque

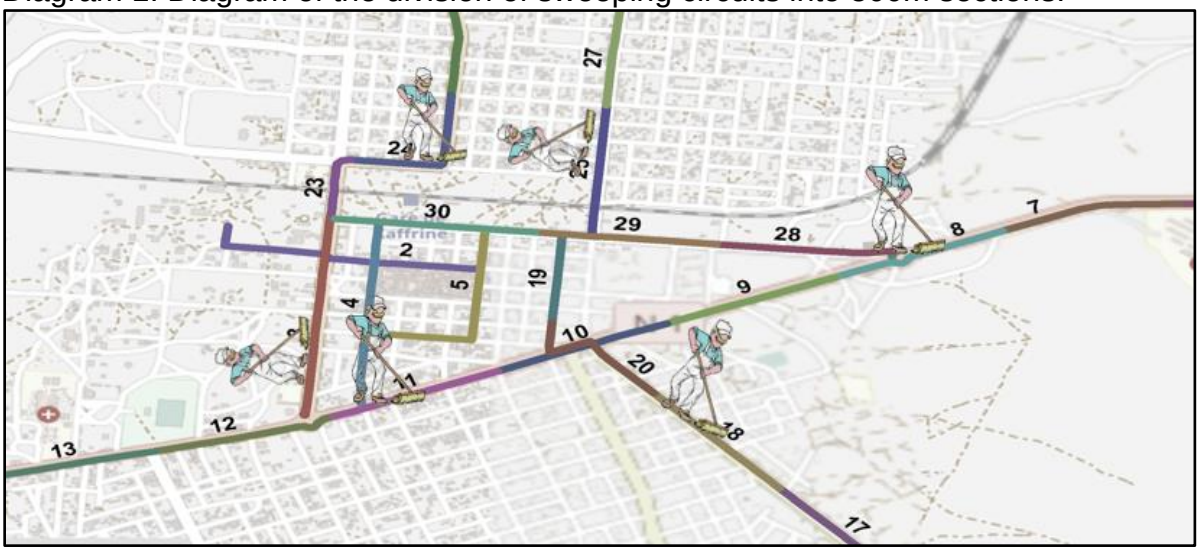
2.2.1. Reorganization of sweeping, pre-collection, and collection in TOUBA Mosque

2.2.1.1. Proposed sweeping method for improved results

For the sake of efficiency, we propose an old practice that involves assigning each sweeper a section to clean. This not only speeds up the work but also avoids the loss

of time caused by the daily ventilation of the sweeping staff. The distance assigned to each sweeper will be 500m, as opposed to the current distance of 1000m per sweeper in Touba Mosque, which we find slightly excessive based on our seven years of experience in the sector, specifically at the Touba Mosque office.

Diagram 1: Diagram of the division of sweeping circuits into 500m sections.



Source: Fall, 2022

And even if we divide the number of sweepers by the length of the area to be swept, each sweeper would have to clean 833m per day. For a sweeping scheme organized in 500m sections, an additional 59 sweepers would be needed at the UCG office of the CTM. Similar to collection, sweeping activity is absent in nineteen out of twenty-six villages-quarters, which represents 73%. This similarity with the presence of collection in villages-quarters lies in the common denominator of the carriageway.

Therefore, the reorganization of sweeping would help sustain the level of cleanliness of public roads and, by extension, increase the coverage rate of public collection services. Beyond the spatial reorganization of sweeping, a new approach of intermittent intervention should be established, and sweeping personnel should be redirected to neighborhoods without carriageways to increase coverage rates while minimizing occasional interventions on Fridays with associations. It will be necessary to determine drop-off points in these neighborhoods and work together with pre-collection carters and associations. Sweepers will help redirect the quantities of waste produced to these drop-off points while ensuring the urban equipment at the neighbourhood level is maintained.

Regarding logistics, we recommend the use of poly-bin boxes and 16m3 or 20m3 (off-road type) trucks to desilt the initiations and collect the sand from sweeping to transport it to depressional and/or flood-prone areas as landfill, specifically for TOUBA Mosque. It will also be necessary to ensure the transport of waste from drop-off points to the PGDSU PRN and type 2 PRN.

2.2.1.2. Proposal for a new type of collection and pre-collection

The collection of waste, which remains the weak link in the municipality of TOUBA-Mosquée, urgently needs to be reorganized. Therefore, due to the impressive size of the municipality and its urban structure, it is necessary to significantly increase the number of Compacting Bins, tractors, and poly bins. Currently, the CTM has no less

than twenty-six collection circuits, with collection frequencies varying between once and seven times a week.

We cannot conclude our introduction to the analysis of the circuits without drawing attention to the need to carry out an exercise in optimizing the collection service through their reorganization. The optimization exercise consists of minimizing costs while achieving the best results. In Touba -Mosquée, we have two types of circuits. There are those that are over 2 km long (16 circuits), which often require a third rotation to reach the terminus, and those that are less than 2 km long, of which there are 10. Here, we need to find a waste transport vehicle that has a larger capacity to avoid the third trip. Alternatively, the circuit could be divided into two sections, and negotiations could be held with the concessionaire. In general, collection is carried out in the following two distinct zones:

- In the accessible zone

Grouped or door-to-door collection is recommended due to the accessibility of the concessions, up to 250 meters from the carriageways. Thus, ten compactor bins should suffice for the zone within the corniche, where there is the highest concentration of population and activities. Note that up-to-date data on the population by neighborhood or village should facilitate the determination of the number of collection vehicles by calculating the ratio of the amount of waste to the capacity of the vehicles. However, even at this level, the ANSD does not provide population data at the neighborhood level, making it difficult to obtain a precise result.

- In the inaccessible zone

In the inaccessible zone, the low level of population compared to the central zone results in scattered housing, making the system of garbage collection by Tasseuse Bin with group or door-to-door pickup inefficient as the vehicle may travel several hundred meters without collecting waste due to the morphology of the houses. Therefore, to be more efficient and rational, a pre-collection system has been proposed with the placement of poly-benne containers (thirty-four), with a polarizing radius of 400m serving as public bins, in seventeen villages/neighborhoods where collection and sweeping are absent out of nineteen. In this case, households will have to transport their waste to these bins, and the garbage will be collected by polybenne trucks, which are more likely to operate in flood-prone areas where the soil is clayey, to transport them to the waste treatment facilities (PRN, CRC, or CIVD).

The frequency of collection will depend on the filling frequency of the public bins. But for sustainability of this collection scheme, the frequencies should vary between 2 and 3 times per week, and not more. These drop-off points should be subject to small arrangements to prevent rainwater from filling the bins during the rainy season. Finally, to ensure the sustainability of this collection scheme, all locations of poly-benne containers or bins should be chosen in agreement with the municipality of TOUBA Mosquée and be subject to municipal deliberation.

2.3 Implementation process of the proposed Waste Management Model

To have an effective and sustainable waste management system, a concerted and participatory approach is necessary. In other words, the population must be involved at all levels, from the design to the implementation, up to the monitoring and evaluation framework. To do this, all community and institutional actors must be represented in a pilot structure to successfully carry out the different stages of the proposed Waste Management Model (WMM). This structure may also have representatives at the level of each zone to facilitate the work. Therefore, the community of Touba Mosquée, and all other actors involved in waste management, must ensure the proper execution of

the WMM at the local level, with a participatory monitoring and evaluation framework to ensure the sustainability of the model and achieve expected results.
It is also necessary to consider the possibility of a potential public-private partnership through the concession of the public waste management service (collection, sweeping) to formal and competent organizations. As there are now cooperatives of carters in Touba Mosquée, they could benefit from the delegation of the public cleaning service, as originally envisioned by the PGDSU.

3. Conclusion

This research has shown that the municipality of Touba Mosque has a high production of solid waste (468 tons/day), and the quantities sent to landfill are 80 tons/day, representing 17% of the total production (UCG, 2020). These wastes are managed by public services, particularly the municipality and the SONAGED, through the tracing of collection circuits and sweeping circuits and, above all, by distributing urban cleaning equipment (garbage cans and PRNs) to collect waste. However, despite these initiatives carried out by various stakeholders in waste management, it appears that the dissemination of IGDs and urban cleaning equipment at the scale of this municipality suffers from relative inefficiency, hence the proposal of a spatial redistribution scheme of urban cleaning equipment based on the use of the multicriteria analysis method. It is also necessary to emphasize that the efficiency of the waste management system will depend on the mastery and use of such technical tools, and above all, on the adoption of an inclusive and participatory approach that involves all stakeholders.

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