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Abstract

The aim of this paper is to develop a Multi-Actor Geo-Collaborative Device to improve the processes of household waste collect (HWC) in urban areas. The proposed device will be tested in the Lamkansa district, in the southwestern part of Casablanca city, Morocco. The approach used is a systemic analysis of communication in order to act on a territory. We have been inspired by several methodological developments concerning multi-actor processes of land use planning. We focused our work on the involvement of the inhabitants in the process of household waste collect. The results show that the urban population can help and contribute to the development of complementary solutions to improve the urban environment and their living environment. Moreover, by integrating citizens in HWC processes, as well as decision communication, we can reduce household waste management costs and make it faster and more efficient, through a geo-collaborative, participatory and incentive logic. The approach described in this article is original, not only considering the technologies used to present and share the collected information, but also regarding the concept of integrating several actors in a collaborative/incentive mode. It arouses great interest by combining geomatics with communication and information sciences. It contributes to improve the participation of the inhabitants in the life of their urban environment in order to establish a reinforced dialogue on the future of their city and public health. Also, it involves the development and testing of new devices and tools for multi-actor collaboration.

Keywords

ICT, GIS, Systemic Analysis, Communication and Collaboration Processes,

Population Participation, Household Waste and Urban Environment, Lamkansa

1. Introduction

In *L'entrée dans l'ère écologique* (Entering the Ecological Era) the author, Edgar Morin, discusses the main strategies for developing an ecological thinking that respects our homeland. He begins by noting that the planet is threatened mainly by human polluting activities, which leads us to the present great concern we are facing regarding climate future. This situation calls us to a new planetary thinking based on global solidarity, the exploitation of energy sources, and the emergence of civilizational policies [1].

Here, we join the author in his thinking: we believe we must go through a continuum of restructuring, from small to large scale. Small streams make large rivers, on which it is possible to build dams for flood control, irrigation, industry, hydroelectricity, drinking water distribution, etc. In other words, we could protect our homeland, starting with the protection of the environment of our own neighborhood, our city, our country, and consequently our planet.

Considering the city as a complex system containing several constituent elements (interconnected infrastructures and networks, etc.), protecting the urban environment is not an easy task. This forces managers to invest more in human and technical resources in order to master the technical processes that act on the city.

Our action aims to contribute to the reduction of environmental degradation suffered by several developing or emerging countries, particularly in terms of urban sanitation management. This situation is linked to the weakness or inadequacy of existing sanitation infrastructures and their malfunctions, which are faced with uncontrollable costs and results that do not always meet expectations [2]. Thus, the goal of this article is to establish a shared ownership of the monitoring of sanitation, by promoting the engagement and feedback of the inhabitants of the area and exploring the results of this process. The interest of earlier, closer and better distributed sanitation monitoring should also work for a better protection of the environment.

Today, the mass multiplication of household waste, its exorbitant management costs, as well as its negative impacts on society, the environment and the economy represent at all national, regional and local levels, a serious public problem and, therefore, an important task for all managers involved in this sector. This situation can be even more complex in cases where the government has trouble implementing their local waste management strategies due to uncontrolled population growth and significant urban development [3].

In order to unblock this environmental problem, we took the example of Morocco, where the management of household waste has continuously been the subject of several state efforts through programs that have certainly contributed to

a partial and substantial improvement in the cleanliness of cities and neighborhoods at a national level, however, the problems remain and are not yet definitively resolved [4]. The current situation of household waste shows that all these efforts have very soon shown their weaknesses and limits. It is therefore necessary to carry out an in-depth and rational reflection on this situation in order to conceive and apply other innovative alternative solutions that are especially adapted to the Moroccan context or to that of other countries in a similar context [3].

Based on these different findings, our study is interested in improving household waste collection processes of a city. We propose a Multi-Actor Geo-Collaborative Device based on the association of ICT with GIS tools to create an incentive-collaborative "city/inhabitant" mind space. In this sense, the main goal is to integrate the urban population in the collection processes.

Therefore, this work will focus on citizens' role in HWC processes through a theoretical and empirical study presented in two parts. First, we will outline the context and research question of this theme; later, we will present, discuss, and put into perspective the significant results of a case study carried in the Lamkansa district, located in the southwestern portion of Casablanca city, Morocco.

2. Implication Citizen Involvement in Environmental Protection

In terms of ecological awareness, over the years several organizations (e.g., the Council of Europe) and studies have encouraged the use of ICT to improve citizens' participation in the life of their community and to strengthen dialogues on the future of their environment and city [5]. On the other hand, technological innovations in terms of tools (applications on smartphones, social networks, collaborative sites on wikis, etc.) make it possible to envision different forms of participation and collaboration [2] [6] [7] [8].

Moreover, some results [5] [9] [10] confirmed that the collaborative approach in planning denounces the traditional model of planning that emerges in the line of social movements and is part of the advent of a greater pluralism in society. In doing so, such pluralism opens up space to new actors.

Goodchild showed that the population can be an important producer of geographic information [11]. Another study during the same year [12] also showed that the population has become very comfortable with geolocalized information and electronic participation tools.

Moreover, it is noticeable that nowadays there is a significant number of people in the world who use different types of ICT, including the Internet. For instance, in 2020 there will be 4.54 billion Internet users worldwide (We Are Social et Hootsuite) [13].

In the light of research regarding the use of ICT and participatory dialogist approaches [2], we will study the importance of integrating and involving the urban population in the processes of household waste collection in their urban environment. We will explain how to establish a communication and decision-

making channel between the city and its inhabitants, and how to integrate ICT and GIS tools in the "city/inhabitant" communication processes. We will also discuss the importance of these processes in the development of a waste collection scheme based on participatory mapping and real-time geolocation of information through a GeoWeb and ICT tools (smartphones, internet, social networks, etc.).

Furthermore, we show how the association of ICT with GIS tools can simplify the use of GIS for a non-specialized public, allowing it to be used by all people, from "experts" to "non-experts". Such concern is necessary because the first applications of GIS were dedicated to technicians and professionals, not only in terms of domain and usage, but also in terms of ergonomics, software design, and data models [14].

3. Systemic Communication Analysis to Improve Household Waste Collection

The approach used in this article is a systemic analysis of the communication to act on a territory. We were inspired by several methodological developments concerning multi-actor processes of territorial planning, in particular the analysis of Moine [15] who represented a territory as a systemic schematization by considering it a system that integrates various interacting elements.

3.1. Systemic Approach of the Territory by Moine

Moine models the territory in subsystems (geographical space and actors), actions and constraints-amenities, intercepted by filters "**Figure 1**".

When applying Moine's model to our study, we consider that a territory has three entrances where a geographical space and two interdependent subsystems are found. They develop over time, in a loop and continuously, according to construction/deconstruction modes [15]:

- A geographic space is a social product developed and explored by humans in which there are neighborhoods, land and air transportation routes, dams,

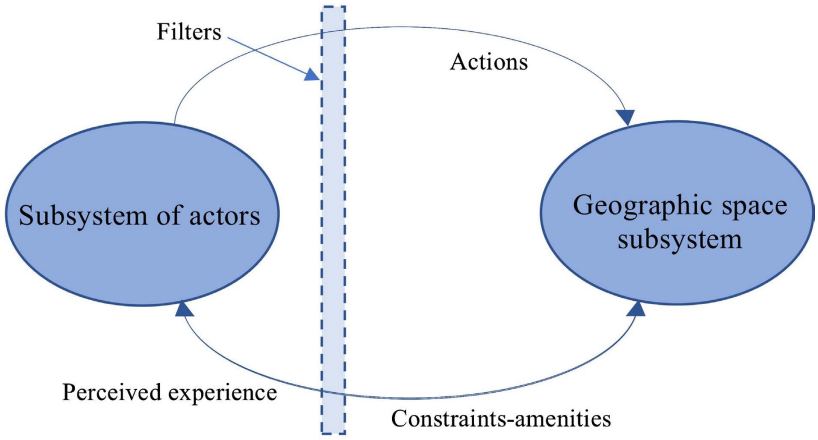


Figure 1. Scheme of analysis of a territory.

mountains, and rivers, etc. It is also a space where many interactions occur based on the relationships between the subsystems that constitute the space (natural, anthropized, social and institutionalized subsystems).

- The system of representations of geographic space is a set of filters (individual, social, ideological) that influence actors in their decision-making and all individuals in all their choices. According to Moine, this process can be classified in two stages: during the observation of the geographic space, and during the projection after the choice of action.
- The system of actors (elected officials, professionals of field and office staff, population, etc.) act in multiple ways in and on the geographic space, influencing it through filters according to their position in this system (territory).

In addition, regarding the systemic analysis of a territory, one can distinguish certain factors that influence and link the subsystem of actors and the subsystem of representations of a geographical space, namely [15]:

- Actions that represent all measures taken by the actors mobilized to develop, use, and manage a city or territory.
- Constraints accounting for elements that impact a given territory and must be considered, such as: orientations already taken by other actors, spatialized socio-economic functioning, preservation of the local culture, community values, the environment outside the territory, etc. At the same time, there are also natural amenities that interact with the actors and impact the organization of the geographical space.
- Living and a perceiving represent feelings of belonging in the film of our past through human relations carried in a local framework that goes from the building to the neighborhood through multiple networks; the shell fills up but does not always give something coherent that can be brought forward for interpretation.

The territory modeling described above allows us to understand and analyze the structure of a given territory, the interactions established between the different actors of a technical process on a territory, and to place the proposed device in the global structure of a territory. Indeed, in order to develop a device aiming to improve the existing solutions and to solidify the collaboration between the mobilized and/or incited actors during the processes of household waste collection in urban areas, our work focused on involving the inhabitants by developing the subsystem of actors acting on a territory "**Figure 1**".

3.2. Development of the Household Waste Management System

As previously stated, the proposed system considers the development of ICT and GIS tools and their uses, with aiming to strengthen the subsystem of actors by integrating the inhabitants in the processes of household waste collection in urban areas "**Figure 1**". The coupling of ICT and GIS tools and their implementation is achieved at moderate costs and remains quickly deployable and functional. This was possible because we developed a household waste management sys-

tem, as it can be seen in the diagram below "Figure 2". The device as we have imagined it follows a two-step process:

- First, the identification of problems observed by the contributing user (citizen - inhabitant, or any other participant) through an ICT. Through online mapping, which can be displayed on his device (GIS), the participant sends a geo-localized alert message to the waste collection service at the sanitation department through a photo, video, descriptive text, or all three at once.
- Second, the transmission of the geolocated message to the household waste manager, later forwarded to the treatment department. This message contains an alert, and will be read, archived, and processed by the technical department. After receiving the message, analyzing it, and handling the problem in the field, a thank-you notification will be sent to the collaborating sender. This feedback is important and, perhaps, necessary to stimulate a larger number of people to get involved in the participative enrichment of the system.

For these reasons, the system we propose in this article is called Multi-Actor Geo-Collaborative Device (MAGCD).

Hence, the proposed MAGCD allows the collection of hybrid (differentiated expertise of participants) and collaborative ideas concerning the state of household waste and urban environment. It provides a collaborative communication process between the inhabitant and his city.

Regarding the communicative process established during the processing of information between the collaborative inhabitants and the household waste collection service, two types of communication can be pointed according to the schematization in "Figure 3".

- External communication, consisted of the exchange of information between

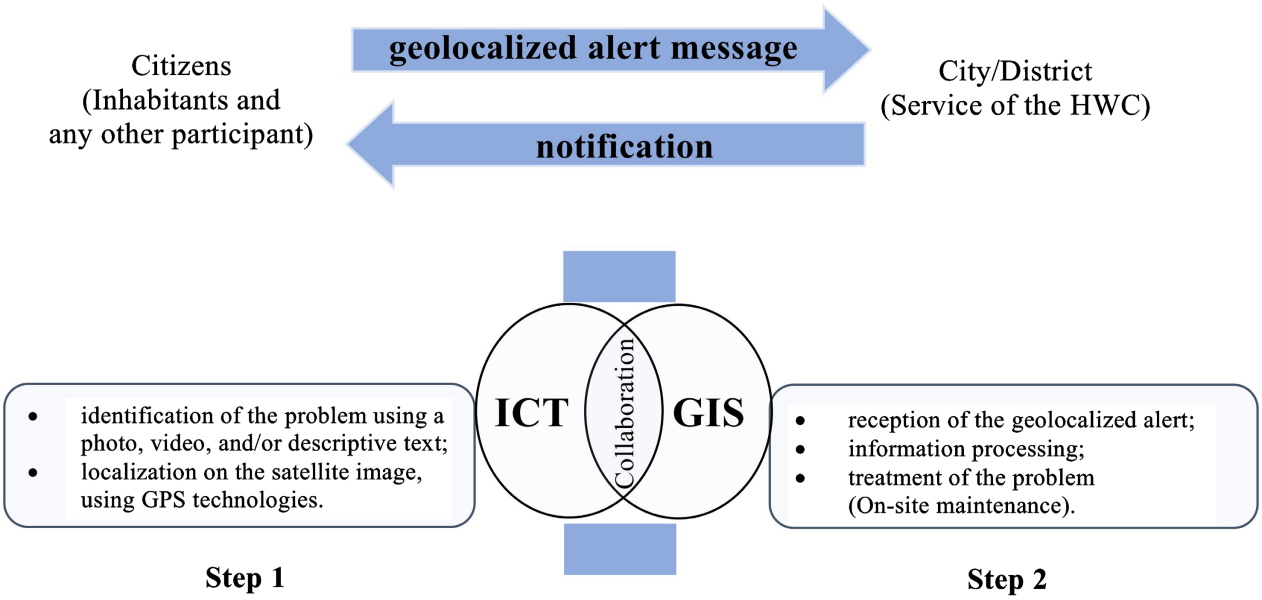


Figure 2. Structure of the MAGCD for HWC.

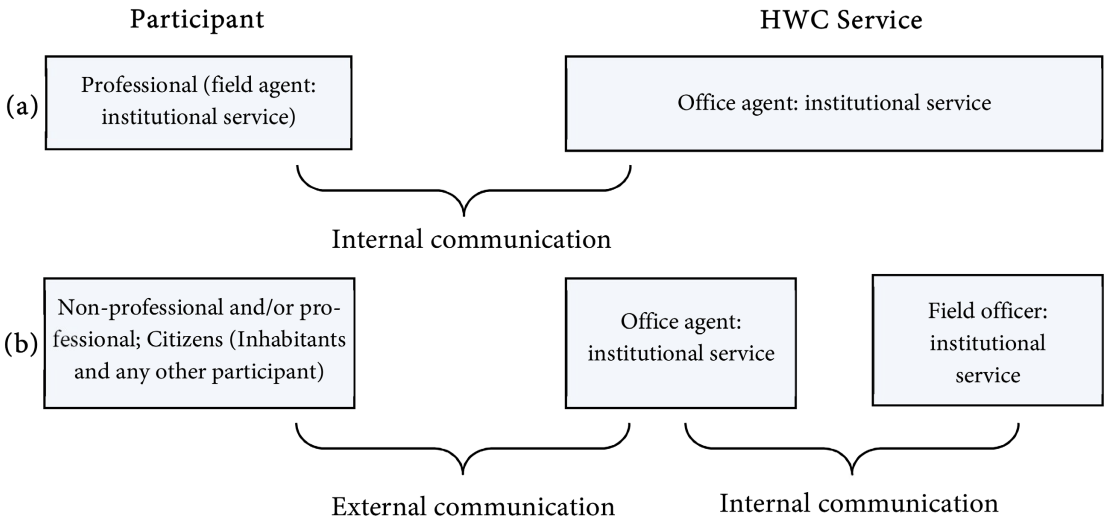


Figure 3. Communication interaction in MAGCD for HWC.

the collaborative participating citizens and the manager (waste collection service).

- Internal communication between the internal actors of the collection service (the office agents and the field agents), which will result in an adapted intervention in the field.

To test our MAGCD and improve the quality of life of the urban population by developing the waste collection process, we will use a neighborhood called Lamkansa, situated in the city of Casablanca, Morocco. This choice was motivated by several observations—the existing situation, the population, the use of ICT, etc. (see section 4), but mainly because the scenario of the district represents the problems of household waste collection found in many districts and in the state. Thus, it is a very good example for the experiment. In this sense, the application developed in this work could include other areas with similar problems.

We believe that the MAGCD can also allow professional actors to contribute to the improvement of many technical processes in a territory by strengthening their collaboration through geocollaboration. However, in this case study, we addressed the population as participants in the collection process, given the importance of the district in the region and the limited number of professionals in the test area.

4. The Study Area

In this section, we present the geographical location, the household waste problem and relevant demographic data of the study area. Next, we give an overview of the education level of the inhabitants and the use of ICT.

4.1. Geographic Location of the Area

The test district is located between longitude 7˚58' West and latitude 33˚52' North in the south-western area of the Aïn Chock district of Casablanca city, Morocco

"Figure 4", covering an approximate area of 300 ha. It developed itself in a non-regulatory manner, in other words, not in accordance with urban planning provisions and regulations in force; the inhabitants settled there at their own choice.

4.2. Household Waste Status

In the Lamkansa district, as in the Aïn Chock district in general, household waste management is not directly provided by the municipal service: it is subcontracted to a private company. Since 2004 the management mission has been entrusted to several private operators, following agreements signed with the city council and the province (in Morocco, the provinces are called wilayas).

Household waste management is carried out in several stages, from its collection to its discharge in authorized public landfill. Statistics estimate the production of household waste in the entire prefecture reaches nearly 280,000 tons per day, meaning the daily average per person is of 0.95 Kg while the national daily average is of 0.75 Kg per person.

Despite the commendable efforts made, the problem of household waste is still at the center of municipal authorities' concerns. In fact, according to our analysis concerning the situation in the test district, it appeared to us that the HWC currently in place is insufficient, leading to degradation of both urban

Figure 4. Geographic and administrative location of Lamkansa district.

environment and population's health [2].

4.3. Demographics and Future Projection

The study area has a large population size "Table 1" due to several economic and social factors, as well as the proximity to job offering areas—it extends from the offshoring area (Sidi Maarouf) to rich housing areas (Califoria, Couline, etc.). These factors also favor the growth and settlement of new residents in Lamkansa district.

According to HCP [16] statistics the population of Lamkansa is characterized by its youth. Approximately 25.1% of the population is aged under 15 years, and 53.3% is under 30, a lower percentage compared to the national statistics of 38.4% and 57%, respectively.

4.4. Population Education Level and Use of ICT

In our test district the education level of the population aged 10 years up is represented in "Figure 5". We can see that 25.6% of the population has a primary level and 11.2% has a higher level of education. At a regional scenario, these numbers are 28.2% and 9.1%, respectively. The figures vary by gender for all levels of education, as shown in the figure below[1].

Table 1. Population projections for the territory [17].

Zone/year	2011	2040	2060
Arrondissement Aïn chock[a]	-	814,639	1,471,330
Lamkansa district	29,802[b]	60,987	99,934

a. Source: High Commissariat for Plan in Morocco (HCP); b. Source: Lyonnaise des Eaux of Casablanca (LYDEC).

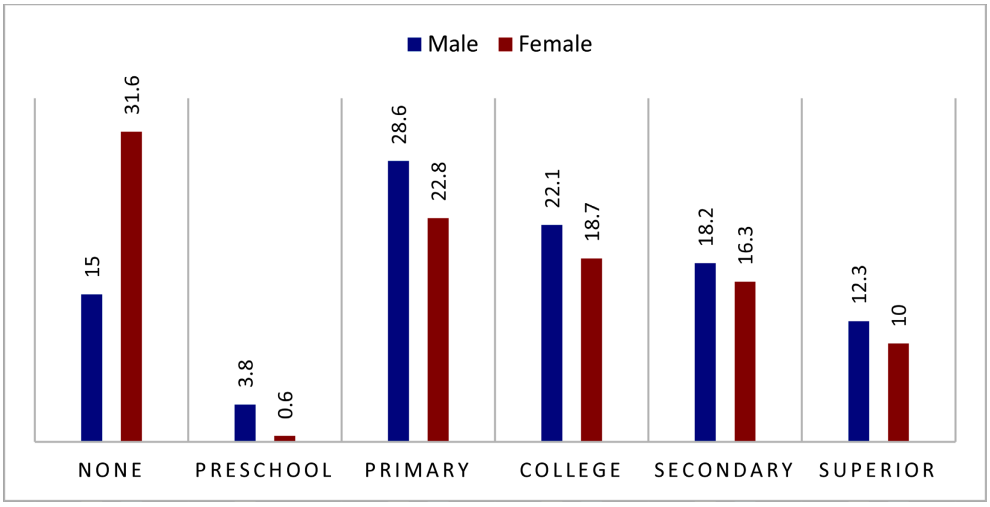


Figure 5. Education level of residents of Ain chock district prefecture, by gender [16].

[1]The education levels in Morocco according to their ages are, in general: Collége—12 - 14 years old; Secondaire—15 - 17 years old; Superieur—18 and older.

Regarding the use of ICT in our study area, a survey published in July 2019 by the ANRT[2] on the collection of ICT indicators of households and individuals in year 2018 revealed that almost all households are equipped with smartphones—the number rose from 90.2% in 2017 to 91.1% in 2018. In addition, this survey showed that about 82.4% of households had access to the Internet in 2018.

Based on an environmental analysis of the neighborhood, we identified that household waste impacts the inhabitants' health because the collection is still insufficient. In fact, despite the commendable efforts made, the issue of household waste remains particularly central to the concerns of municipal authorities.

The problems in this neighborhood cannot be solved in a short time. To ensure improvement in its living environment it is essential that we consider its present situation (regarding demographics, urban planning, economy, etc.) and move towards a sustainable development policy of its infrastructures and complementary solutions.

We have noticed that the population is little involved in the collectiveness of the neighborhood. Despite having a rather low level of education, the population has considerable access to ICT due to the large distribution of smartphones.

In order to improve the quality of urban environment by involving citizens in the sustainable development of their neighborhood, we raised the following hypothesis: does the development of MAGCD require a combination of ICT and GIS tools?

5. Application and Results

We will now describe the implementation steps of the Geo-Waste platform for household waste collection. Then, we show an interactive interface with spatial reference named Geo-Waste-L intended for waste collection in the Lamkansa district "Figure 6" brings an overview of the articulation between the device, the platform and the interface.

5.1. Implementation of a Solid Waste Management Platform

To manage the implementation of our MAGCD, we believe it is also necessary to create a platform composed of ICT and GIS interconnected by a link generated through a GeoWeb mobile application. Such process will lead to improvements

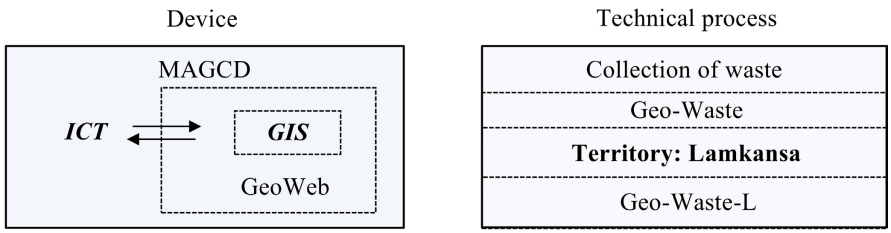


Figure 6. Overview of the interaction between the Geo-Collaborative Device, the Geo-Waste and the Geo-Waste-L.

[2]"*Agence Nationale de Réglementation des Télécommunications*" is a Moroccan public institution aimed at regulating telecommunications in Morocco.

in the processes of HWC and will contribute to the development of complementary solutions to the existing MAGCD. Participants are provided the access link to the platform by the HWC service via website.

The platform has been named "Geo-Waste". The ICT are used as information entry points, as they are simple, intuitive, suitable, and well distributed over the territory and mainly in places of passage. Hence, the city dweller will contribute to a mesh monitoring of the urban sanitation system disfunctions by reporting tangible problems and their precise location in the HWC's service tracking system using the GIS created and developed within it. The process described can be seen in "**Figure 6**".

The chosen ICT is a smartphone or connected tablet. Through the mobile application the user can inform the problem to be traced from a multiple-choice list and indicate the geolocation information.

Cities or districts interested in adopting the household waste information processing service platform must follow two steps: first, create an account in a GeoWeb tool—in this case, the testing platform was Google Mymaps[3]; second, add a plot of the study area in KMZ[4] format so that the area of intervention is clearly limited. Finally, the plot is shared widely on the internet, or specifically in social media, thanks to a link generated via ICT.

5.2. Verification and Incentive Process

As mentioned before, the proposed scheme follows a two-step information management process (see paragraphs in section 3.2). Here we focus on the second step, which should require a verification of the message transmitted to the waste collection service. The receiving operator must check whether the problem has not already been reported by another collaborating participant. It is important that the receiver of the alert (office agent of the collection service) ensures the reliability of the message received on the basis of the input (video, image, text) and the geolocation sent by the participant before giving the green light to the field agents for an intervention on site. In the case of an unreliable message, the collection department will deny the received alert with an explanatory denial notification to the participant, as shown in "**Figure 7**".

When the problem is solved by the field agents, the collection service sends a notification to the participant containing a thank-you text, photos of the post-intervention site, and a payment to the participant's account through a compensation system. This payment system adds bonus and reward points to the employee's profile for each participation "**Figure 8**". This should encourage the participant to continue in this partnership for the benefit of the urban environment.

[3]Google MyMaps is an online service launched by Google in April 2007 that allows the creation of online maps for personal or sharing purposes.

[4]KMZ format is a compressed KML file (Keyhole Markup Language; in French: *"langage à base de balises géo-locales"*). It is a set of characteristics for online display in geospatial software, such as location of marks, images, polygons, 3D models, text descriptions.

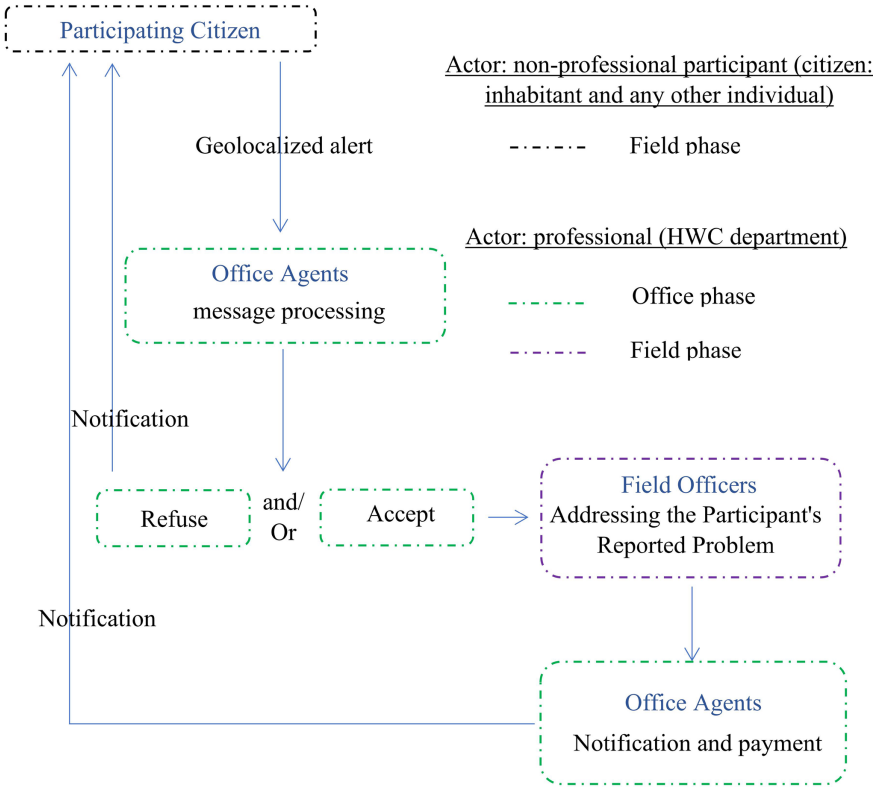


Figure 7. Explanatory diagram of the participant reward information processing system[5].

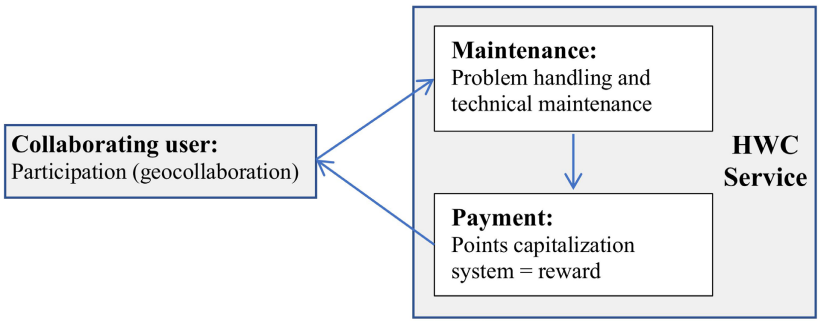


Figure 8. Reward system to motivate the participation of urban population.

Based on several works and recommendations of specialists about involving the population in participatory approaches, we chose some incentive techniques to include the citizens/inhabitants in the HWC service of their district. First, we will use advertisements such as newspapers ads, social media ads, and flyers; also, information points, like caravan parking, will be placed to raise awareness and encourage them to participate. Second, participants will be motivated to participate by a points & rewards system (obtaining a sum of money or purchase coupons, for example) integrated to the MAGCD.

In the present study we limited ourselves to the use of the first incentive technique—advertising and profit-sharing. The points & reward system strategy will

[5]Refusal by the office agent in case a false message or scam sent by a participant is identified, in which case a justified refusal is sent.

be integrated and tested in another work because this system requires programming efforts, a higher budget, and a significant amount of time to be accomplished[6].

5.3. Geo-Waste-L for the Collection of Household Waste in the Lamkansa District

Thanks to the interface of the spatial referenced interactive platform, Geo-Waste-L "**Figure 9**", city dwellers can recommend, geolocate and send alerts to the household waste collection service (View a) for analysis, treatment and intervention on site (View b). This device could eventually feed a data capitalization system (alphanumeric and cartographic data) and generate useful reports for management analysis and decision support. Thus, the spatial representation of the capitalized data in the form of thematic maps improves the identification of risk areas, the analysis of causes and the simulation of phenomena.

We would also like to point that the type of communication content established between the participant and the household waste collection service is different from that usually established during participatory processes aimed at involving the general population (in most cases, it is only texts). In our case study, the messages communicated by the geo-collaborator participant can contain spatial data (geographical coordinates), multimedia data (photos and images) and descriptive data (texts and figures).

The geo-localized messages sent by the participant regarding the identified problems allow the manager to intervene in a more functional way to collect the waste found in the neighborhood; they also make possible to establish a cartographic balance by spatially representing all the alerts on thematic maps "**Figure 10**". This representation enables the diagnosis of the urban sanitation state as it evolves and facilitates the establishment of new perspectives and strategic plans for the future in the intervention area.

In the Lamkansa district, thanks to the help of several participants (inhabitants) and the use of the MAGCD on the "Geo-Waste-L" test interface, we were able to establish a thematic map that represents the geolocalization of the problems identified in situ "**Figure 10**".

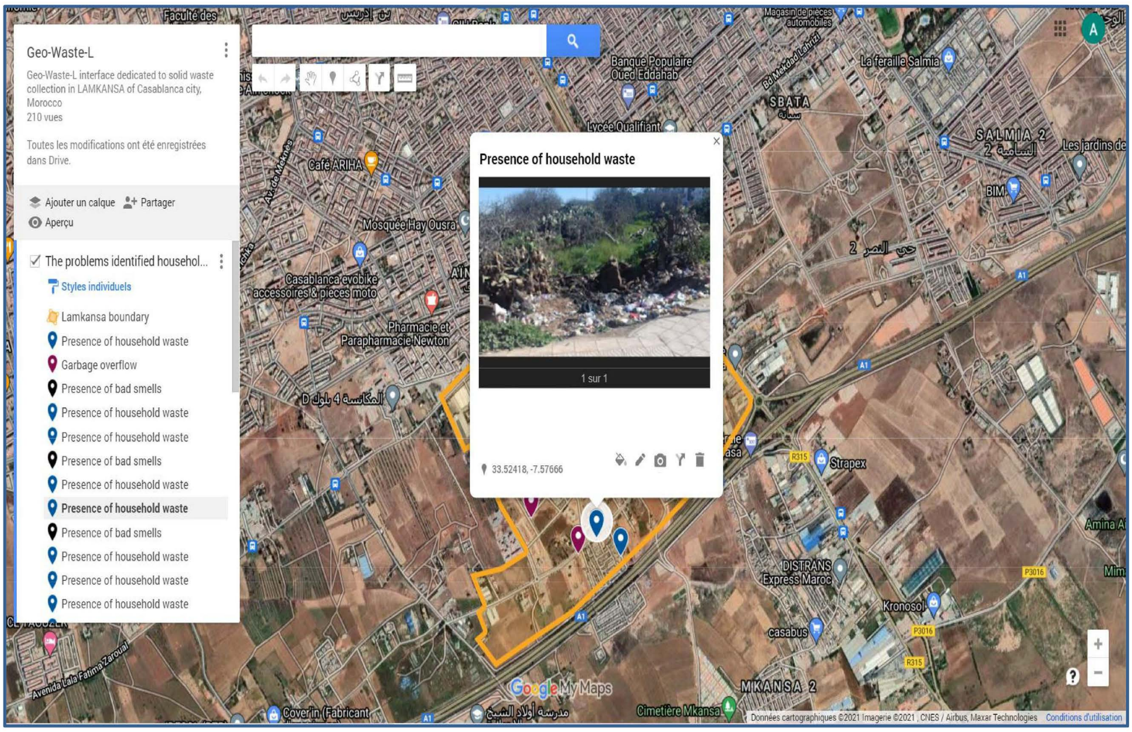
In order to verify the population's interest in the MAGCD, we conducted interviews with 40 residents of the Lamkansa neighborhood.

The results we obtained were encouraging:

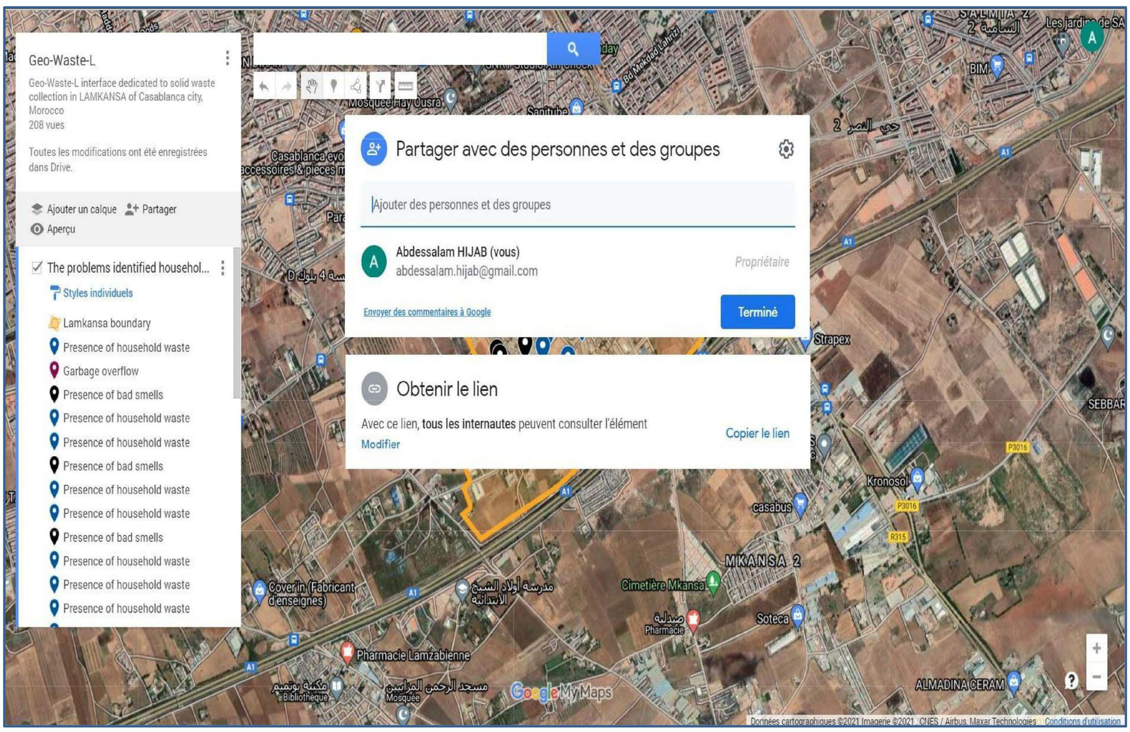
- 36 participants believe they have enough knowledge to work on the application and are willing to collaborate with the household waste collection service of the neighborhood using the proposed platform.
- The satisfaction score given to the platform by the residents is 91.63/100.

As mentioned before, in this study we limited ourselves to the use of incentive techniques based on publicity and pedagogy. The point accumulation system

[6]It is important to note that we do not have the necessary computer development for this purpose, so we used a simplified version of Google MyMaps as a test interface. In this article we will be able to propose specifications to IT developers to create a complete, original, and more profitable application.



View a: Screenshot of an alert entered and shared by a collaborating inhabitant.



View b: Screenshot of a reception alert regarding the treatment of a problem within the HWC department.

Figure 9. Screenshots of the Geo-Waste-L platform on MyMaps-Google.

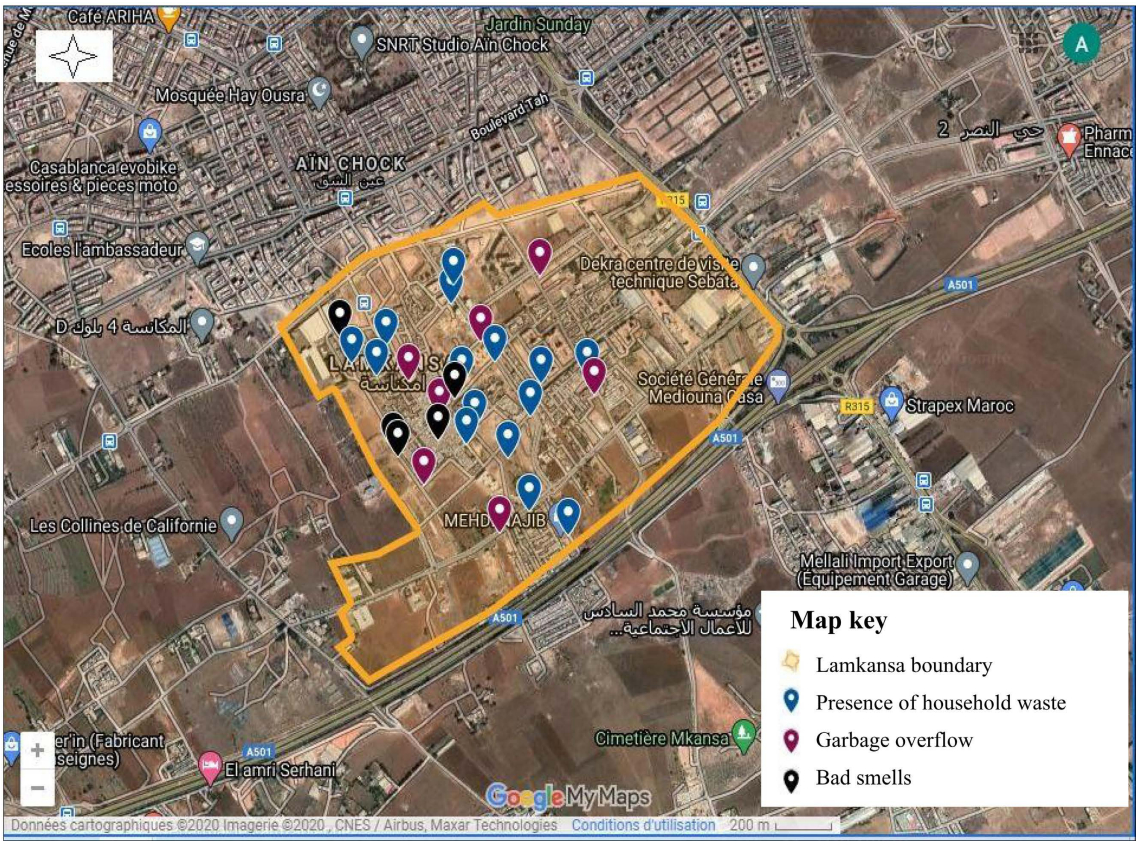


Figure 10. Thematic mapping of problems identified by participants in the Lamkansa district[7].

seen in "Figure 8" will be integrated later. Also, to improve the performance of our application and make it more ergonomic, we formalized a set of specifications, particularly the information processing steps of reward to the participant and the reward system to motivate the participation of the urban population. Future development in response to the specifications will prove inevitable for two reasons:

- The strong involvement of the inhabitants in their neighborhood will limit technical and human investments that would otherwise be on the rise due to the increased requirements for household waste disposal and urban environmental protection.
- The establishment of a sustained collaboration with the population will reduce the time needed to diagnose malfunctions. An immediately triggered and well geolocated alert leads to the production of an accurate traffic plan, saving time and energy in the treatment of the problem by the field agents.

Finally, to ease the access to the Geo-Waste-L platform, we have future plans of developing a mobile application, technologically more trendy and easily downloadable that we plan to name Smart-Waste-L.

6. Conclusion and Perspectives

The originality of this work is due, in the first place, to the multiple approaches

[7]Mapping carried out on December 26, 27 and 28, 2019.

it brings (systemic, systemic analysis of the communication, GIS and collaborative) and to the explored technologies (ICT and GIS tools) by establishing a connection between the contents of ICS and geomatics. It is also original regarding the concept integrating many actors in a collaborative/incentive mode by arousing great interest.

Indeed, the elaboration of the MAGCD required the association of ICT with GIS tools, in order to effectively integrate all partners in the protection of the urban environment, including the participation of the population in the processes of communication, decision making and monitoring of the urban environment. Indeed, these technologies offer sustainable solutions for household waste collection.

As shown, the processes of household waste collection require human and technical investment from the city (household waste monitoring service), with monitoring tools and *in situ* movement means. By integrating the urban population in these processes and adding decisional communication (exchange of messages for successful decision-making) between the field agents and the household waste collection service, we can reduce the costs of household waste management and make it *de facto* more efficient and faster, using a geo-collaborative, participative and incentive approach.

Our proposal can contribute to the transformation of the urban population into an active population and of the inhabitant into a smart inhabitant, which is a pillar of a smart city. It also demonstrates how the combination of ICT with GIS tools can simplify the use of GIS by motivated (non-specialized) actors.

In addition, the MAGCD improves the participation of the urban population in the life of their community's environment by establishing a reinforced dialogue on the future of their city and public health. It also contributes to the development of new methodological tools for multi-actor collaboration.

While considering the limits expressed above regarding the involvement and rewarding of the inhabitants, we emphasize that the expected results represent only the first steps of an approach that must be continued, expanded, and developed. It is important to complete a reference framework by testing our proposal on other sites, perhaps with different characteristics from those presented in the site chosen for this article (notably in terms of type of urbanization, population, etc.).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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