

# A Device to Improve Collaborative Practices of Sanitation Department Agents of a Territory: The Case of the Lamkansa District in Casablanca

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## Abstract

The aim of this article is to strengthen and improve the collaboration between professional agents of a service that manages one of the technical processes acting on a given territory by synchronizing the spatio-temporal dimensions including all agents assembled for the task. This proposal was tested in the Lamkansa neighborhood in Casablanca, Morocco. The employed approach is based GIS resources and on systemic analysis of communication present in a territory. We were inspired by several methodological developments that carried multi-actor processes in land use planning. We focused our work on strengthening the collaboration between professionals, field agents and office agents, in the process of design and monitoring the liquid sanitation system. The device is based on geolocation and synchronous feedback of topological, geographical, and multimedia data related to the liquid sanitation network. Thanks to a geo-collaborative, participative, and motivating logic, we reduced the management costs of the network and made it faster and more efficient by equally mobilizing another type of non-specialized actors (the inhabitants). This device uses spatial and temporal dimensions to consolidate collaborative work tools through ICT and GIS technologies that thematize and exchange information collected in the field. Furthermore, this device raises great interest as it entails the concept of integration of several actors in a geo-collaborative mode while combining geomatics with communication and information sciences.

## Keywords

Device, ICT, GIS, Collaborative Practices, Spatialized Information, Synchronization, Professional Agents, Technical Processes, Sanitation, Environment, Territory

## 1. Introduction

Previous experiences have shown that, in most cases, it is not easy to master the necessary elements for the design methods that allow the construction of an appropriate stormwater system to the studied territory. In addition, today's territories are evolving: their urban fabrics can become denser, change in shape or in occupation mode, which leads to an evolution of the collected water. Also, the sealing of soils can be increased, leading to rising flows.

The stormwater system is one of the wastewater systems to be seriously monitored as it is a risk factor for occupational hygiene, health, and safety [1] [2] [3]. Moreover, it is a complex system composed of several elements to be controlled and managed, including pipes, ducts, and structures [4]. Its achievement depends on many constraints (technical, land, financial, etc.), and is subject to several criteria (urbanistic, topographic, geological, climatic, urban density, rainfall, etc.).

As sanitation professionals, we have identified that to provide an adequate spatial analysis, communication between field and office staff of the urban sanitation department requires time and a budget. Data collection *in situ* is done through special devices (e.g. GPS). However, to make such data usable, one must transfer it to a computer, sort it, and transform it into geo-localized information. Only then it is possible to produce analysis maps that are needed for future decisions.

Based on this scenario, we believe that collaborative practices on geolocation information are being missed between sanitation professionals. This conclusion was also reported by the European Environment Agency [5].

In this sense, the matter in question is how to organize the activities and analysis required by such professionals, who need methods, tools, and software to better (geo)-collaborate in the exercise of their missions. The association of ICT and GIS allows one to collect and centralize various pieces of information collected *in situ*, leading to improved practices of the service sanitation agents of a territory. This technological coupling, which is the basis of our device, also offers synchronization of spatiotemporal dimensions between users.

In this study, we placed a device within the stormwater sanitation service of the test district, Lamkansa. The first test was to provide aid to the sewerage network design using technology tools and GIS-ICT software. To achieve our goals, we have developed an information system called "Geo-L" that has a database with local spatial reference at its core.

To help designers and technicians maintain and, perhaps, develop the stormwater network best suited for the neighborhood<sup>1</sup>, we established a checklist with spatial reference named "E-Geo-L". The implementation of this checklist was possible thanks to ICTs that constitute a technological gateway from the field

<sup>1</sup>For the design of liquid sewerage networks in the neighborhood using Geo-L we decided to choose stormwater, given the needs of the neighborhood especially in terms of problems related to rainfall in winter. However, for monitoring and follow-up we were interested in all liquid sewerage networks.

information to the information system implemented in the sanitation department.

Through the online interconnection of ICTs and the information system, this checklist strongly linked to the “Geo-L” system creates a collaborative bridge between the agents of the wastewater sanitation service, those in the field and those in the office, particularly in terms of precision and simultaneity of spatialized information. The use of “E-Geo-L” aims to collect and transfer information (*in situ* problems) related to technical processes that can be identified by non-specialist, such as lay citizens or inhabitants.

In the following sections, we will first discuss the design method, and study the functioning of the Lamkansa stormwater network. We will specify the structure and functions of the “Geo-L” information system, since one of its main purposes is to provide good knowledge of the network and its environment. Next, we will focus on the monitoring and follow-up processes of the network operation, which will be possible due to the spatial reference checklist “E-Geo-L”.

## 2. Presentation of the Study Area

The Lamkansa neighborhood (**Map 1**) is located in the southwestern part of the Ain Chock district of Casablanca, in the Casablanca-Settat region of Morocco (between longitude 7°58' West and latitude 33°52' North), covering an area of about 300 ha. It was not urbanized under regulatory measures, or complying with urban planning provisions and regulations in force. Indeed, the area is a spatially isolated urban fabric showcasing a disorganized morphology [6].

In terms of urbanization of this district, the roadway is very narrow and its

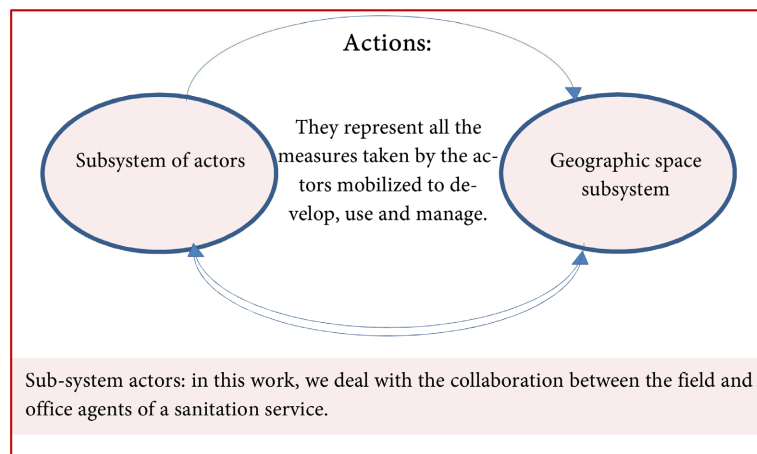


**Map 1.** Geographical location of the Lamkansa district.

right of way does not exceed 2 or 3 meters in the best of cases, which makes any development and restructuring operations difficult. Following the findings in the district [6] [7], it seemed to us that, despite the commendable efforts made, the situation in Lamkansa requires the development of new and more appropriate methods to better manage technical processes, such as those of urban sanitation which is the subject of this article.

### 3. Methodology

In the framework of the PhD thesis defended on July 6, 2021 at the DeVisu laboratory in Arenberg Creative Mine, by Abdessalam HIJAB<sup>2</sup>, the author proposed an approach based on the combination of ICT and GIS called “Multi-Actor Geo-Collaborative” to improve the technical processes carried on a territory. The work targeted two scenarios: the first one contributes to strengthen the collaboration between professional and non-professional actors, while the second scenario points the collaboration techniques between the agents of a technical service on a territory [7]. The experiments were conducted on the urban sanitation network (solid and liquid). Indeed, the “Multi-Actor Geo-Collaborative” approach developed and applied in Lamkansa is derived from a systemic analysis of communication [7], based on the territory modeling proposed by Moine to better analyze the subsystems of a territory, which he calls system (Figure 1)<sup>3</sup> [8].



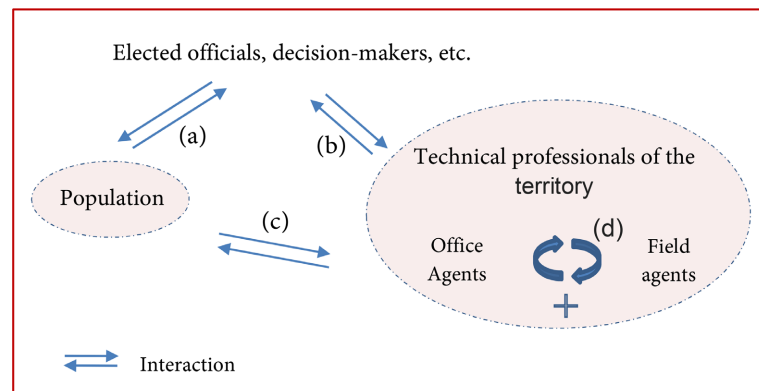
**Figure 1.** Scheme of a territory analysis.

Thenceforth, in this paper we focused on the development of a subsystem of actors inside a territory. **Figure 2** shows the interactions established between the following actors: the elected officials; the population; and the land-use planning department. These interactions are translated as follows:

<sup>2</sup>Hijab, A. (2021). Les TICs et SIG au service d'un dispositif collaboratif multi-acteuriel. Le cas d'un assainissement urbain durable. (Doctoral dissertation, Valenciennes, Université Polytechnique Hauts-de-France).

<sup>3</sup>This diagram represents only a simplified part of Moine's modeling of the territory. For more details, see: Moine, A. (2006). Le territoire comme un système complexe: un concept opératoire pour l'aménagement et la géographie." *LEspace géographique* 35.2 115-132.

- Interaction between residents and elected officials: it allows the public to communicate with the officials expressing their satisfaction. It also allows such officials to ensure there are no land use issues.
- Interaction between elected officials and technical professionals of the territory: it allows the elected officials to give their recommendations or suggestions, possibly resulting from the interaction between themselves and the inhabitants (a).
- Interaction between inhabitants and technical professionals of the territory: it allows the population to be involved in strengthening the technical processes implemented by field and office agents of the territory.
- Interaction between professional agents, office and field, of the territory: this is an internal communication exchange, since it occurs between actors from the same organization.



**Figure 2.** Subsystem of actors within a territory [7].

Partially based on the diagram found in **Figure 2**, we emphasized the communication process established between professional actors themselves, *i.e.*, field and office agents of the sanitation department (d), as well as the interactions with non-specialized actors (c). For the last, we considered that having citizens involved in the monitoring of sewerage systems by providing information on visible elements helps strengthen this technical process. To ease this process, we created a list of options to be assessed by professionals and another for non-specialized actors (*i.e.*, water leaks and network overflows).

In the following section, we will present the elements that fit our project for Lamkansa district and thus are useful for designing and monitoring the stormwater network.

#### 4. Design and Operation of the Lamkansa Stormwater System

The use of GIS tools, including spatial reference databases, in design and analysis of stormwater networks has been increasing. Regarding the design phase, such tools help technicians create analysis and simulation maps of network operation, integrating numerous technical parameters as illustrated in **Maps 2-4** found

ahead.

In order to properly design the stormwater network, one must begin collecting significant basic data, then implement it and perform calculations. This is done through “Geo-L”. It is also possible to simulate the operation of the network, as it can be seen in **Figure 3** and **Map 4**.

Prior to the constitution of “Geo-L”, we followed certain steps:

- Data collection: the collection of useful data must be organized, classified by spatial and/or alphanumeric data, and georeferenced if necessary;
- Digitalize and process cartographic data: to digitalizing all cartographic data and draw primary analysis maps;
- In the first subsection we will describe the structure and functions of the “Geo-L”.

### 1) Structure and Functions of Geo-L dedicated to Stormwater Networks

The spatially referenced database “Geo-L” was initially developed for wastewater network design in Lamkansa and Drabna neighborhoods [9]. The thematic maps use the same national coordinate system (Lambert/Morocco). Based on their original structure, we enriched the maps with more data from different, multi-scale, and multi-actor sources.

The alphanumeric and spatial data collected (maps, plans, restitutions, and statistics) were implemented and spatially analyzed using Arc GIS<sup>4</sup> software with a GIS-type approach.

In **Figure 3** we present a chart of the “Geo-L” dedicated to the Lamkansa stormwater networks. The diagram is applicable to any other area with similar problems. “Geo-L” consists of a database with spatial reference where a set of functions characterized by specific treatments can be associated, as follows:

- Collection and integration of basic data to make it georeferenced;
- Spatial analysis, which allows a cartographic representation of the collected data, and produces a synthesis of the analysis maps;
- Assistance to the design and sizing of the stormwater network, a technical step to delineate the basins and sub-catchments, as well as to trace collectors and interceptors from calculations.

When implemented, these functions take their data from the database and return the results to it. That will serve as input data for iterative processes or different processes corresponding to other functions.

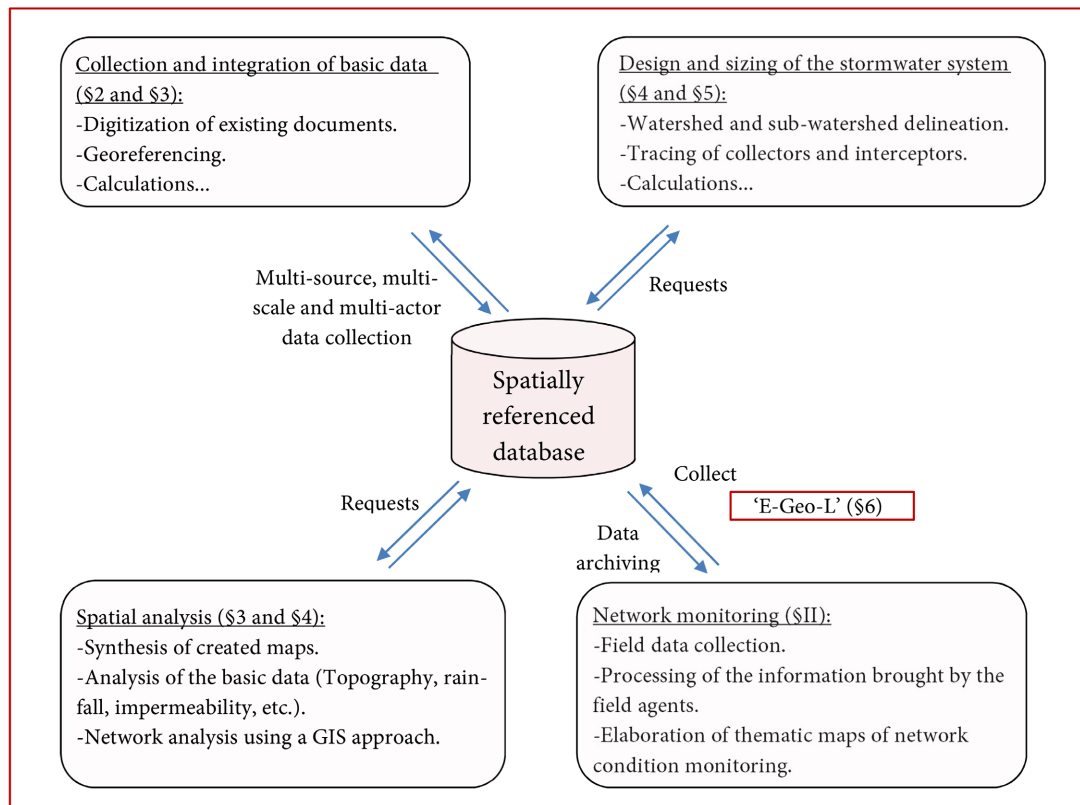
The outline of this sub-section followed the successive description of the “Geo-L” functions, except for “Monitoring of the networks”, which was the subject of a particular section because of its required internet gateway and the improved explicit collaboration between the work of field agents and office agents.

### 2) The Data Integrated in the Spatially Referenced Database

On a general level, factors like the representation of the liquid sanitation system, sustainable management of urban water, protection of receiving environments, the

<sup>4</sup>It is a complete system for collecting, organizing, managing, analyzing, communicating, and disseminating geographic information. The software is developed by ESRI.

Source: <https://resources.arcgis.com/fr> (verified on July 06, 2020).



**Figure 3.** Diagram of the “Geo-L” structure for stormwater management in Lamkansa.

formats used for transferred and exchanged data, the calculation of the cost of the technique used, the deadlines, and taking into account environmental standards, are not obvious to master. Indeed, all these actions require several searches, updates, and information searches from different sources and at different scales [10] [11] [12].

To elaborate an effective design for the stormwater networks in the Lamkansa neighborhood, the spatially referenced database must ensure that several important elements are considered, including [13]:

- Topographic configuration (slope, ridgeline);
- Rainfall and nature of the area’s soil;
- Position and geometry of the groundwater and hydrology;
- Constraints for accomplishing the work;
- Pre-existing different networks, and their current state in terms of capacity;
- Typology of the urban fabric and the nature of urbanization;
- Soil impermeability;
- Development routes, existing public roads, easements, not to build up zones, green space limits, existing buildings, power line routes, and the layout of the restructuring plan;
- The exact outline of watersheds and sub watersheds (area, length, width, etc.) and the selection of the stormwater receiving environment;
- Optimization of project costs and timeframes, as well as environmental

standards and legal references;

- Communication and exchanges between all users (standard and exploitable files), quick availability, and thorough analysis of all data (figures, diagrams, tables, charts etc.);
- Quality of the presentation and display of the project, evaluations, and reports;
- Storage for both cartographic and descriptive data.

The capitalization and mastery of the data found in the “Geo-L” information system allowed us to process information related to the neighborhood in order to perform cartographic analyses. “Geo-L” is a remarkable tool to help better design stormwater network, since with its database it also constitutes a useful archive of alphanumeric and cartographic data to facilitate medium and long-term decision making regarding alternative solutions, evolution, or extension strategies.

### 3) 3D Modeling and Implementation of a Digital Terrain Model

The method consists, initially, in gathering the basic data (development plan, topographic map, restitution plan, statistical data), aiming to guide the intervention to a precise location. Then, this data must be explored with the help of a GIS tool integrating “Geo-L” both to spatialize the information and to update the data. On this tool, we must firstly digitize the urban areas, contour lines, altimetric points, impermeable areas (development paths), and permeable areas (gardens, permeable land, soil, etc.). At last, we can name fields of the polygon type attributes’ table file and, finally, determine the surfaces and their nature, the perimeters, the slopes, etc.

In order to accurately analyze the topography of the terrain, and to define the boundaries of the watersheds and sub-watersheds, 3D geometric modeling of the area is essential. **Table 1** presents the steps to obtain a spatial representation of the terrain that is closely accurate to reality.

**Table 1.** Steps for presenting 3D data on the Arc Scene tool.

Tools used	Implementation steps
Arc GIS	Gather all georeferenced data; Digitize the dimensional points; - Create contour lines; - Use DTM in image format (IMG);
Arc Scene	Add geo-referenced base data and DTM on Arc Scene; Increase the base heights (elevation exaggeration) of all layers of the Scene, up to #4; Navigate and animate with 3D Analyst tools; Exploit, visualize and export 3D maps.

The present means for such actions provide a quality 3D view of the territory,

which allows to improve analysis capacity (Figure 4) and to draw a global perspective of the stormwater network in 3D. The DTM also permits to draw contour lines, visualize the topographic configuration and position the projected or existing networks.

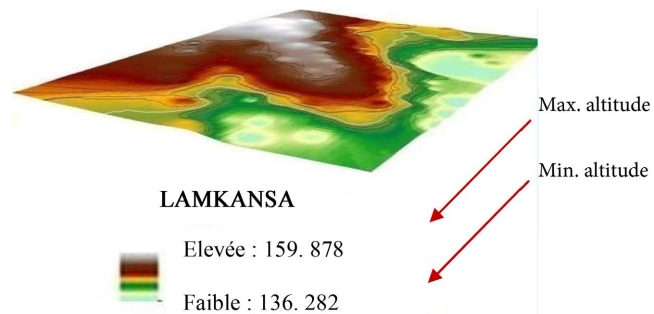


Figure 4. DTM of the study area [14].

#### 4) Determination of Watersheds and Sub-Watersheds

The distribution of urban surfaces according to their nature and covering was defined based on spatial analyses of existing documents using the Arc GIS tool (through information and data layer). Among the documents analyzed, we found the development plan, the restitution plan of the existing one, the topographic maps, and a high-resolution satellite image of the study area (Table 2).

Table 2. Data collection and calculations of watershed geometric characteristics [13].

	Steps of implementation	Type of data
Collection and acquisition: (Raster images and vectors)	<ul style="list-style-type: none"> <li>- Satellite image (High resolution);</li> <li>- Restitution plan (1/2000);</li> <li>- Development plan (1/2000);</li> <li>- Restructuring plan;</li> <li>- Topographic map.</li> </ul>	Spatial
	<ul style="list-style-type: none"> <li>- Climate and Rainfall;</li> <li>- Runoff coefficient;</li> <li>- Other statistics.</li> </ul>	Alphanumeric
Digitization and calculations	<ul style="list-style-type: none"> <li>- Slope (%);</li> <li>- Drainage width and length (km);</li> <li>- Watershed and sub-watershed area (m2)</li> </ul>	Spatial and Alphanumeric
Production	Analysis and synthesis cards.	Spatial and Alphanumeric

Based on the steps described in this table, we produced an analysis map (Map 2) that represents the permeable, semi-permeable (greenbelt, green spaces, etc.) and impermeable surfaces in residential, industrial, and road areas.

This spatial representation allowed us to calculate the urbanization surfaces and to determine the permeable and non-permeable zones. It also allowed us to divide the watershed into sub-watersheds based on the topography and current



**Map 2.** The distribution of areas on watersheds (BVs) according to zoning [13].

morphological state of Lamkansa. This will be discussed in the next section.

### 5) Sizing of the Stormwater Collection System

For the design and sizing of pipes or other stormwater collection systems, the most commonly used rainfall/flow model in urban areas is the Caquot model<sup>5</sup> (Equations (1) and (2)).

These equations give the maximum flow at the outlet of a watershed for a given frequency, *i.e.*, knowledge of the peak flow of the flood hydrograph [15] [16]. However, its field of application is limited to homogeneous basins of less than 200 ha in area.

The Caquot model is the most recommended by the sanitation department of the study area. According to our experience, we agree with such recommendation because it is the most appropriate for this type of study due to the hectare surface of the area and due to the simplicity of its application. One must simply calculate and introduce the values to the respective components of the formulas. This can be easily done using the results of the calculation and analysis performed by the “Geo-L” (e.g., **Map 2** and **Table 3**).

$$QT = K \times Ix \times Cy \times Az \times m - t \quad (1)^6$$

<sup>5</sup>The best-known method for urban and rural hydraulic calculations (surface method).

<sup>6</sup>The choice of Caquot method is justified by several elements:

- the method is adequate for neighborhood area;
- positive opinions on Caquot method from professionals, given that it is not limited by watershed concentration time estimate and is based on water mass balance.

$$m = [L^2 / (40000 \times A)]^{1/2} \tag{2}$$

$Q$  = Stormwater flow in l/s for the selected return period.

$C$  = Coefficient of imperviousness.

$I$  = Slope of natural terrain (m/m).

$A$  = Watershed area (Ha).

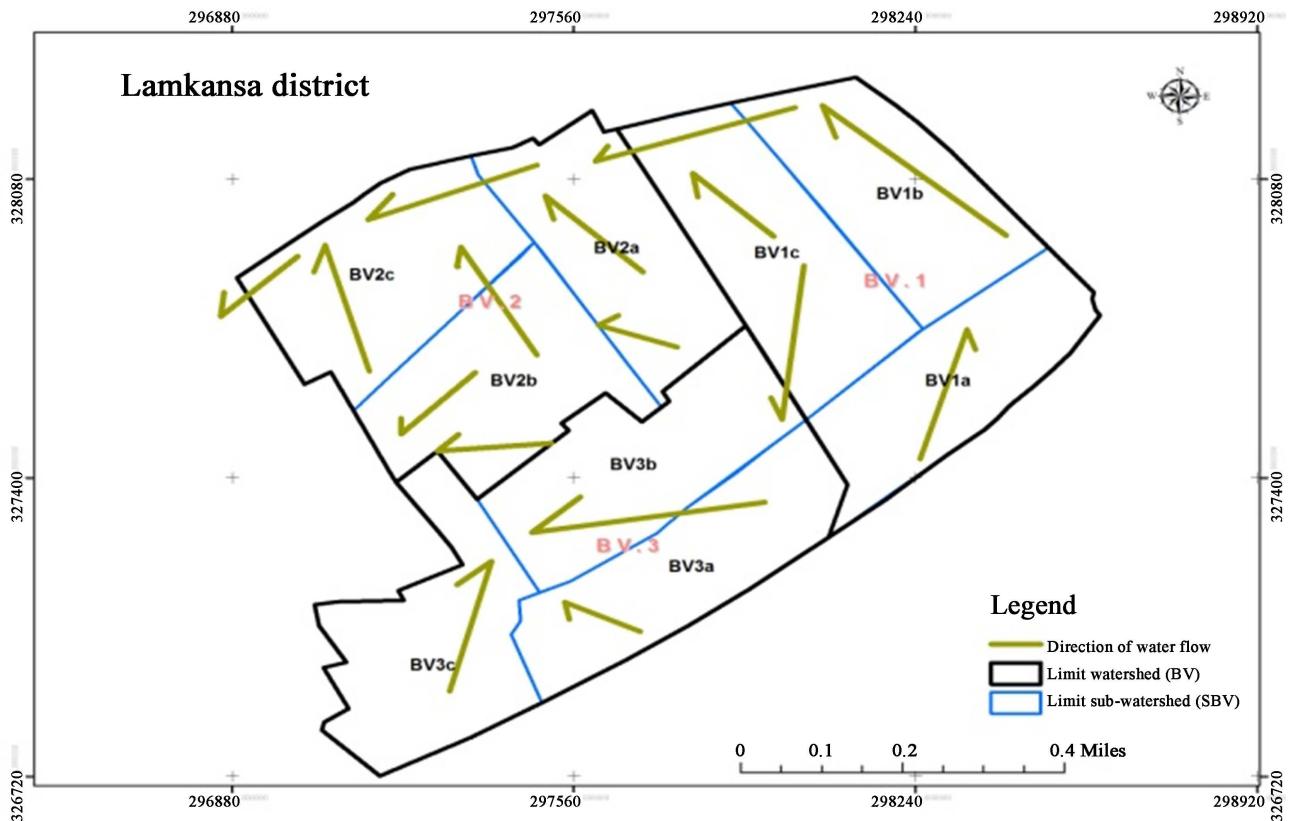
$L$  = The length of the longest hydraulic path.

$m$  = Flow correction coefficient.

In the interest of using the calculation model in the Lamkansa district, the latter was divided into three watersheds, and each basin into three sub-watersheds (less than 200 ha). The division was made according to the topographic configurations, the activities of the private sector, the nature of the surface, the direction and length of the watercourses, the possibility of connection to the network etc.

Thanks to the GIS processing of the IS “Geo-L”, the spatial analysis allowed us to draw and delimit the watershed into sub-watersheds (Map 3) based on the restitution plans of the area at 1:2000. Also, satellite images, the development plan, and regular visits to the area contributed to this step.

The summary of characteristics and results are presented in Table 3 and Map 4.



Map 3. Stream direction and delineation of watersheds and sub-watersheds [13].

In the opening up framework of the Lamkansa district, the local public authorities have proposed a phased restructuring [7]. Having expropriated the area

and after the prospecting phase, a plot of land has been selected to build a rain-water storage basin. This land is located to the northwest of the neighborhood and borders the road to Sidi Massoud (see **Map 4**). Here, we used this basin as an outlet to store all the rainwater (collected by the neighborhood sewers) before

**Table 3.** Watershed and sub-watershed characteristics of the neighborhood [13].

Watrshed	Land use	Watershed area (m <sup>2</sup> )	Perimeter (m)	Runoff coefficient (%)	Undeveloped area in 2018 (m <sup>2</sup> )	Urbanized area in 2018 (m <sup>2</sup> )
<b>Watershed 1</b>  P = 3031 m A = 502,988 m <sup>2</sup> Almn = 135.60 m Almx = 154.14 m	Economic Habitat	57,634	3031	80%	10,1440	213,706
	Industries	257,513		80%		
	Roads	126,446		90%		
	Green belt, green spaces and non aedificandi zones	61,395		20%		
	Subtotal	502,988		68%		
<b>Watershed 2</b>  P = 3733 m A = 505,945 m <sup>2</sup> Almn = 135.04 m Almx = 157.82 m	Economic Habitat	274,471	3733	80%	219,330	92,327
	Industries	37,185		80%		
	Roads	125,186		90%		
	Green belt, green spaces and non aedificandi zones	69,103		20%		
	Subtotal	505,945		68%		
<b>Watershed 3</b>  P = 3084 m A = 511,037 m <sup>2</sup> Almn = 143.72 m Almx = 160.20 m	Economic Habitat	227,422	3084	80%	142,391	171,728
	Collective habitat	74,603		70%		
	Industries	12,094		80%		
	Roads	143,311		90%		
	Green belt, green spaces and non aedificandi zones	53,607		20%		
Subtotal	511,037	68%				
<b>TOTAL</b>		1,519,970	9850	68%	463,161	477,761



**Map 4.** Resulting design of the stormwater networks (REAP).

treating and reusing it.

This map highlights all the components of the Lamkansa neighborhood stormwater collection system. It shows:

- In red: the stormwater main pipes;
- In blue (polyline): the water transport collector;
- In blue (polygon): the boundary of the sub-watersheds;
- In sandstone: the roadway portion;
- In yellow (polyline): the portion reserved for collective housing;
- In orange: the part reserved for economic housing;
- In green: the green spaces;
- In yellow (polyline): the secondary pipes of the stormwater networks.

#### 6) Going from “Geo-L” to the “E-Geo-L” Check List

In order to make this transition from the local database to a mobile database (Table 4), we must use specific formats that function in internet browsers, in particular the KML format. The format used by Arc GIS, the GIS-software applied to the Lamkansa sanitation department, is Shp (shapefile format - Arc GIS).

The necessary steps to convert Shp to KML (Web format) in order to have the “E-Geo-L” spatial reference checklist are the following:

- First, use the “convert Shp to KML” tool contained in the ArcToolbox module of ArcGIS, followed by the “projection and transformation” tool defining

the output projection “GCS\_WGS\_1984”<sup>7</sup>, and Marchich<sup>8</sup> Lambert, Morocco, zone I;

- Second, create a “My Maps” Google account online to implement and make active the file in “KML” format previously created;
- Third, create the “E-Geo-L” checklist online, which will be featured as a table. The attributes of this table are the information, recommendations and descriptions collected in the field by the professionals (condition of the sites, stagnation problems, overflow, etc.) that can be sent back to the “Geo-L”.

**Table 4.** Geo-L/E-Geo-L relationship [13].

GIS (ArcGIS tool)	Transformation	GeoWeb (MyMaps-Google)
“Geo-L”: Local database with spatial reference.	KML/Shp	“E-Geo-L”: Online database to be filled out in the field with a tablet or smartphone.

In the following section, we discuss the development of complementary solutions to the existing one for diagnosis and sustainable monitoring of liquid sanitation through the implementation of “E-Geo-L” on Lamkansa.

## 5. Diagnosis and Monitoring of the Liquid Waste System

We begin this section presenting the framework of the process on which we wish to intervene. Later, we discuss the operating principle of “E-Geo-L” in the test district.

### 1) Geo-collaboration for Diagnosis and Monitoring of Stormwater Management Systems

The stormwater scheme we proposed (**Figure 5**) using “Geo-L” is designed homogeneously to connect all areas of the watershed and sub-watershed, without exception, to the separate network through gravity flows in the pipes (see **Map 4**). These flows end up in the stormwater basin to be stored, treated, and reused.

The designed network requires regular diagnoses by the field managers to ensure proper operation, which can also be useful for redesigning and resizing a new system.

Using the system is relevant because there are two types of actors involved (field agents and office agents). Simple and efficient collaborative work becomes relevant here as we seek to manage the exchange of geolocalized data during interventions in the district.

### 2) Implementation of the “E-Geo-L” Platform

The platform combines ICT and GIS functionalities connected by a link generated through a GeoWeb mobile application that allows to view a cartography enriched by the geographical database of the liquid sanitation service [17]. This link is provided by the office agents to the field agents through an informative email. The link provides the map layout and adhoc interface for the diagnosis and monitoring process.

<sup>7</sup>A global geodetic system.

<sup>8</sup>Geodetic system (DATUM), a point is located in the territory of Mediouna municipality.

The “E-Geo-L” platform on **Figure 6** brings to the field agents the most updated information on the conditions of the liquid sewerage networks known within the service.

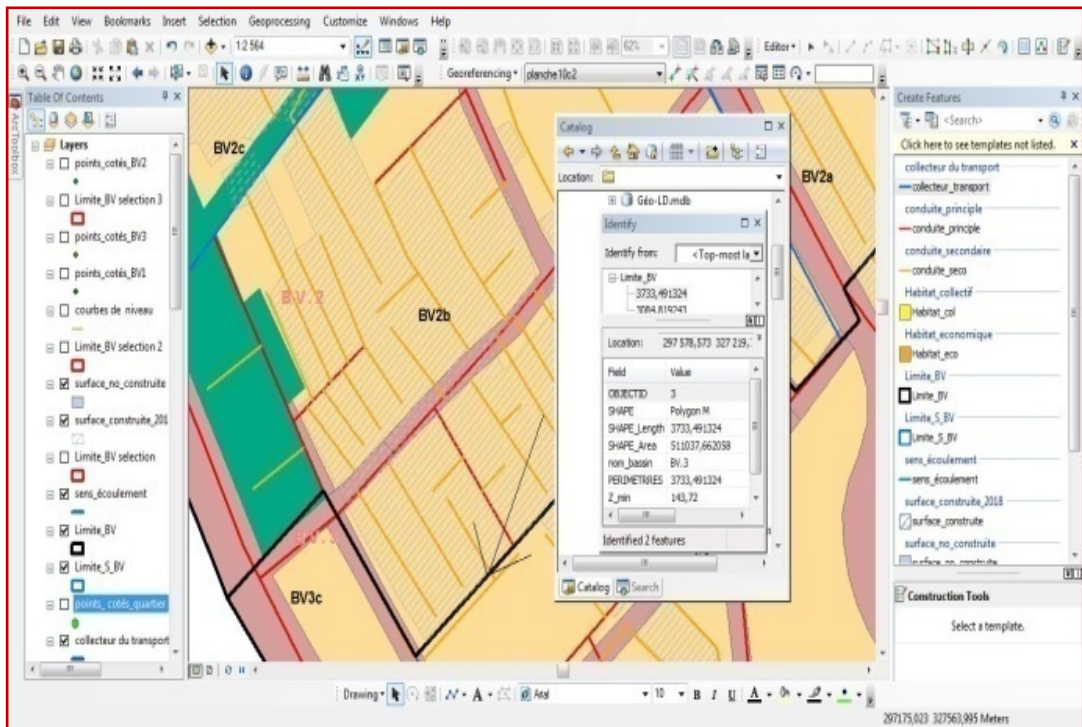


Figure 5. Geo-L interface on Arc GIS [7].

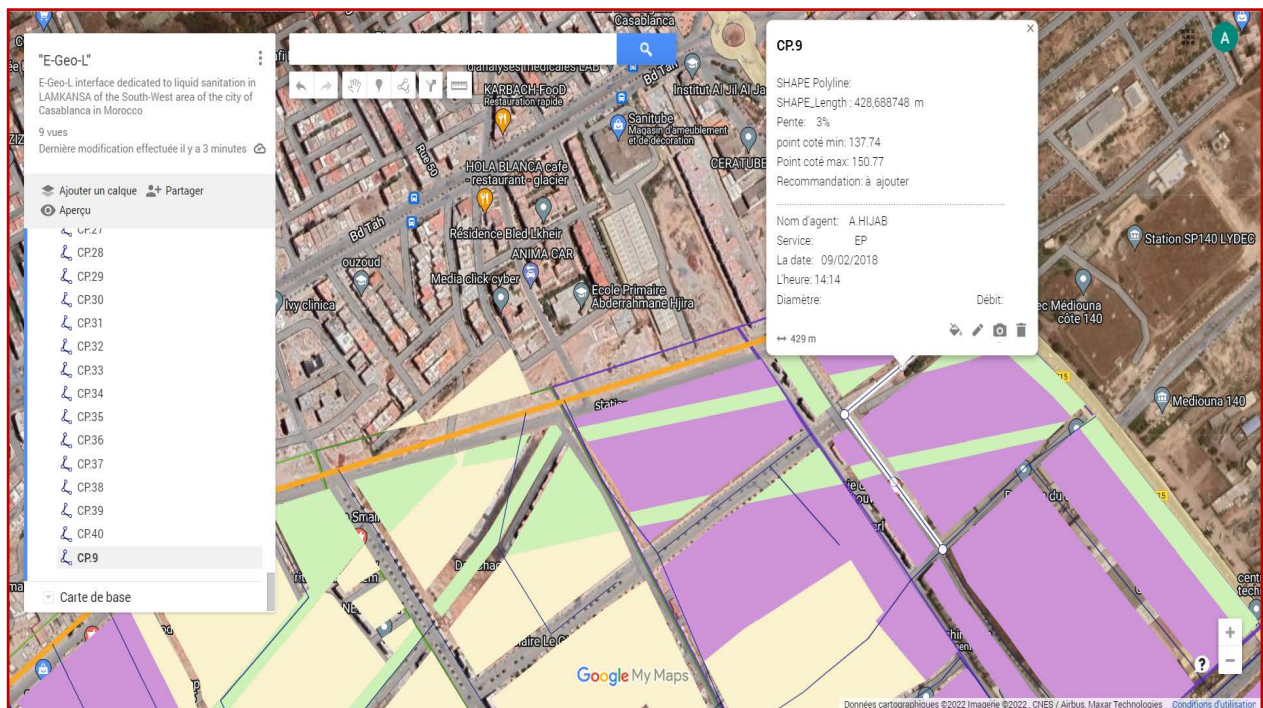
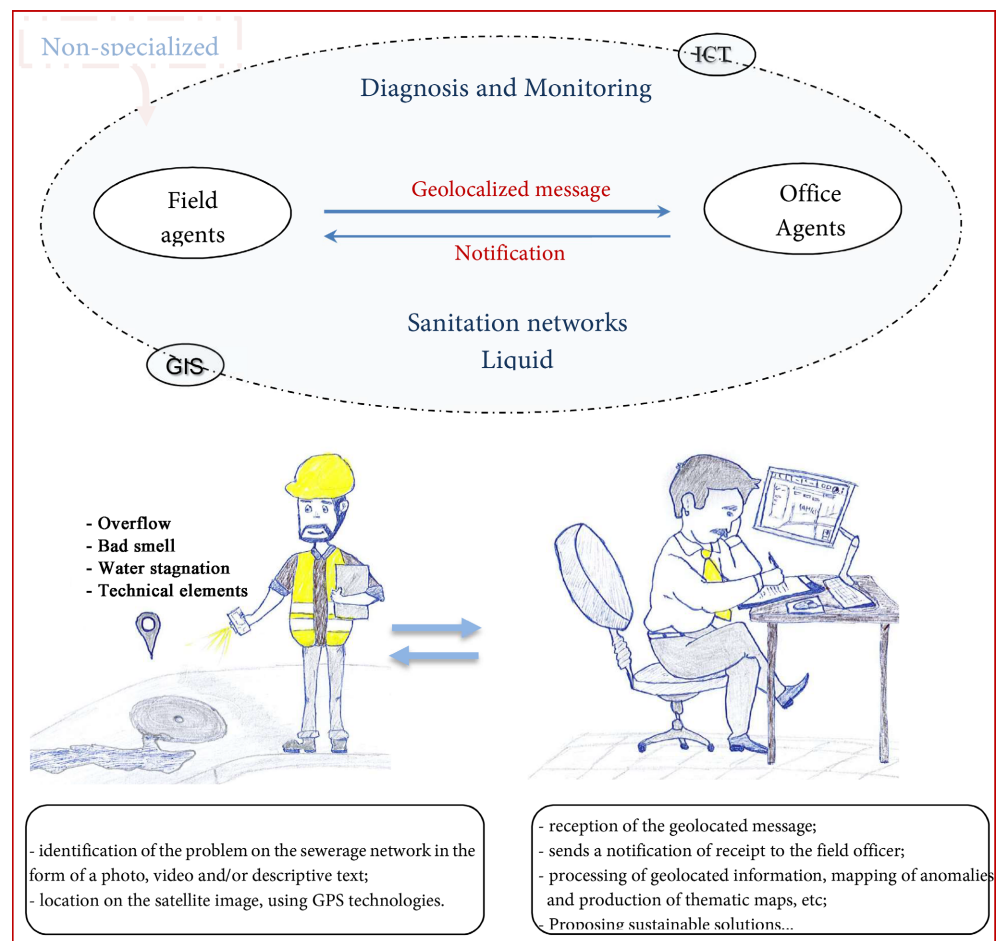


Figure 6. E-Geo-L interface on Google My Maps.

Google My Maps<sup>9</sup> allows to create and add drawings (points, lines and shapes), to insert images, photos, videos, and to complete them with descriptive information and suggestions related to the disfunctions reported in the field. The input of this new information in real time grants an immediate update of the information with a limited risk of error due to its very close imagery of reality. This way of doing things guarantees a rapid resolution of identified problems, a consequent sustainable management of the networks, besides limiting sustainable impact on the environment.

In fact, the field agents will be able to monitor and report the malfunctions of the sewerage system through precise and explicit description added to their precise localization, as seen in **Map 5**. The preferred ICTs for this application are a smartphone or tablet with connectivity. Through the mobile application, the user can report a problem selected from a multiple-choice list and signal its geolocation information [17].

**Figure 6** and **Figure 7** and **Map 5** illustrate the process of locating and



**Figure 7.** Summary scheme explaining the principle of the spatially referenced checklist (E-Geo-L) aimed at the actors: professionals/professionals [7].

<sup>9</sup>Service launched by Google in May 2007, which allows users to create personalized maps for personal use or sharing.

signaling several problems identified and located *in situ*.

The project was developed in such a way that field agents can exchange geo-located messages and produce thematic maps related to the problems of liquid sanitation systems in the neighborhood. This solution can also integrate other non-professional actors, such as non-specialized city dwellers, security personnel (police, firefighters), or other public services (Figure 7). These are the field actors who can easily spot observable or palpable malfunctioning clues while using their smartphones or terminals placed at different intersections (Figure 8) [7].

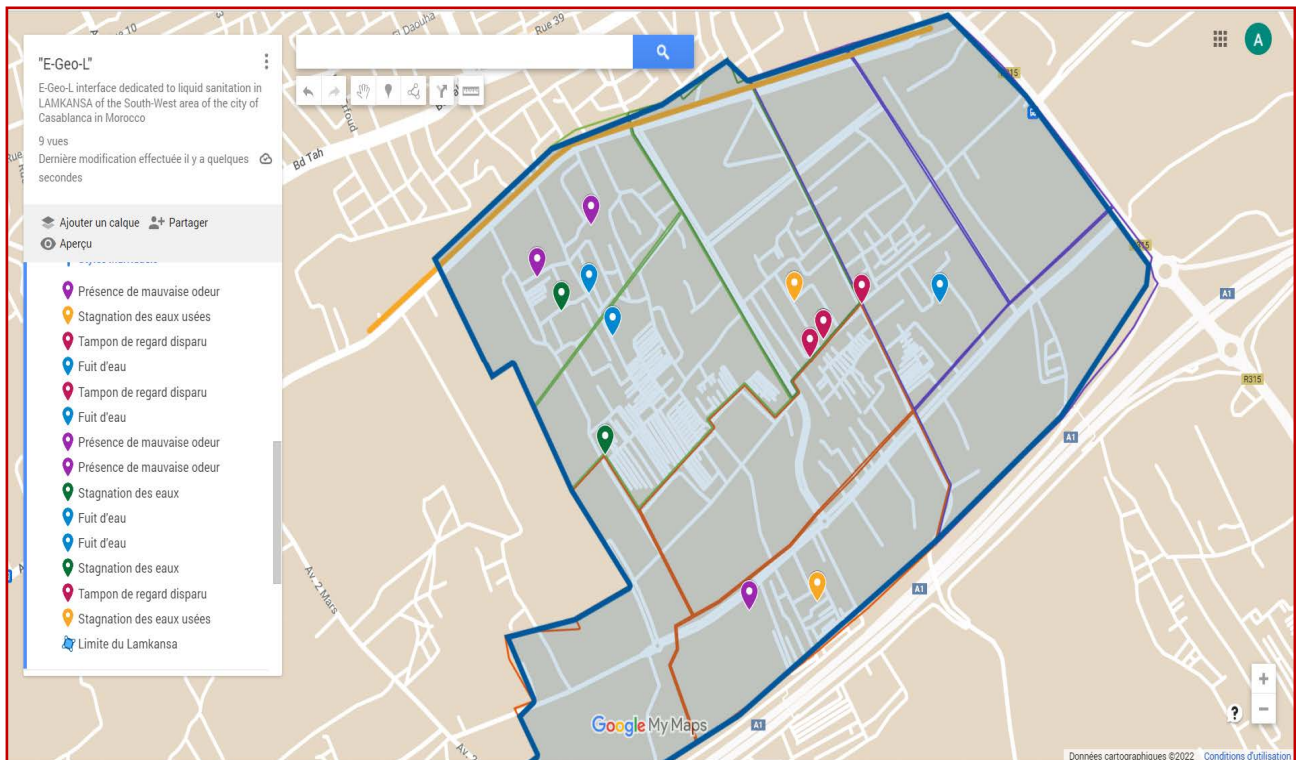


Figure 8. Identification of problems on the liquid sewerage network by the “E-Geo-L”.

Therefore, the analyses maps elaborated through the spatial representations of problems identified in-situ, as seen in Figure 7 and Map 5, allow us to identify the areas at risk and analyze its causes. This operating mode will allow us to have a good control of the existing sanitation’s scene, which could also help us redesign and resize the networks, if necessary.

Furthermore, Map 5 presents a thematic mapping of the problems identified in the liquid sewerage networks. This spatialization was achieved thanks to our own use of E-Geo-L to identify the conditions of the existing networks. In fact, as professionals of this field, we tested the tool ourselves before having it tested by the professionals who manage the network in the neighborhood.

Through the mapping we noticed that a large number of the problems identified in the neighborhood are located in the most complex areas: those with very high density where there are very narrow streets, facts that made the diagnosis and



Map 5. Spatial representation of the problems identified on the liquid sanitation network<sup>10</sup>.

monitoring of the network more time consuming and error prone up to now.

To confirm the success of the project, we performed interviews<sup>11</sup> with twenty local professionals in the field. The results we obtained are encouraging (see tables in annexes A and B):

- All participants are able and willing to use the proposed tools;
- The satisfaction score given by the participants to the proposed checklist is 83.13/100.

In **Figure 7**, we present a diagram of the communication process considering the different situations encountered in the field and the type of exchanges between field and office actors.

The systemic diagram of communication drawn in this same image translates the nature of the exchanges in this context and the support communication tools.

- From the field agent to the office agent: the message aims to identify the problems and anomalies related to existing liquid sanitation networks. For this, the field agents must collect data of various kinds (multimedia, geographical, and descriptive). Also, as mentioned earlier, the population, as a non-specialized actor, can contribute to this stage by identifying palpable problems in the liquid sanitation network (**Figure 2** and **Figure 4**).
- From the office agent to the field agent: the message can serve two purposes

<sup>10</sup>This mapping resulted from a problem identification survey conducted on 14 and 15 September, 2019 in the chosen neighborhood.

<sup>11</sup>To test and verify the validity of the “E-Geo-L”, we submitted the application randomly to a number of professionals in the field, not following a specific methodology).

to confirm the receipt of a reported problem, which must happen fast, or to notify the result of a treatment previously requested by a message coming from the field. The processing may result or not in storage of relevant information. It may also be subject to a situational analysis and solutions proposed by thematic presentations. In any case, this type of feedback, which can be very technical, is not necessarily immediate and must be explored by the field agent.

To better plan and make efficient interventions on the networks, such space for information exchange must be made possible online in an interactive and collaborative manner between the professional actors of the liquid sanitation service.

## 6. Conclusions

In the field of sanitation, good mastery of support systems to management and design, such as those produced from GIS-Software, allows to better comprehend and act on the environment of the urban sanitation system. At the heart of the developed system called “Geo-L” applied to the territory of the Lamkansa district, we constituted a database with well-informed spatial reference. This database contains and organizes all the information necessary for executing or redesigning a liquid sanitation system. The database holds multi-source, multi-scale, and multi-actor local data. By applying the principles formalized in the “Multi-Actor Geo-Collaborative” approach [7], we are convinced that we will consolidate and strengthen a system that will prove to be sustainable because it will better meet the needs of the territory for which the “Geo-L” spatial reference system has been designed.

Moreover, through a technical-spatial analysis of the basic data, and the control of the network design parameters, it is possible to highlight critical functioning of the existing sanitation system in order to consider alternatives to improve and move towards a more sustainable use.

Our experiments let us confirm that GIS is an essential tool for the design of networks because it stores the initial data and calculates parameters related to the flows to be evacuated. The information system, which we have also described as interactive and participatory, “Geo-L”, has made it possible to carry out and improve the stormwater scheme in the test district. Its employment greatly limits the impact of stormwater networks on the city’s environment.

The development and implementation of the spatially referenced checklist “E-Geo-L” in a test area have been successful, according to interviews with professional actors. It facilitates the treatment of problems related to liquid sanitation, contributing to improve people’s life quality by better protecting the urban environment. Synthesis and monitoring maps have been drawn by real time detection and location of all the problems in the Lamkansa networks. This contributes to a better understanding and incorporation of the projected stormwater scheme for the area. We also expected the checklist to be used to set up a mul-

ti-data capitalization system (cartographic and descriptive) related to the networks for further purposes in the medium and/or long term.

## Conflicts of Interest

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

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## Annexes A. Interview from

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Questionnaire regarding the spatial reference checklist (E-Geo-L) for professional actors and professionals related to the Liquid Sanitation Network

1) Sex?

- Man

- Women

2) Years of experience in the field?

3) Your rank within your organization?

4) Do you have any difficulties in collecting data related to the monitoring of the liquid waste system?

5) If question #4 is yes, what solutions do you propose?

6) How often do you use ICT? Would you be able and willing to use our application?

7) Following our demonstration of the E-Geo-L, are you satisfied?

Rate your degree of success and satisfaction on the scale with an (X):

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Not satisfied

Satisfied

Thank you for your participation!

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## B. List of Participating Professionals and Result of the Interview<sup>12</sup>

Participant category and grade	Do you have trouble collecting data and diagnosing the liquid waste network (/20)?	Number of years of experience in the field	Would you be able and willing to use the spatial reference checklist (E-Geo-L) (/20)?	Satisfaction and evaluation of the E-Geo-L (/100)
3 architects		n < 10		
4 engineers		10 < n		
9 technicians		n < 10 and 10 < n		
2 construction managers	-	10 < n	-	-
1 public administration employee		10 < n		
$\Sigma = 20$ participants	15/20 (Yes)	n < 10 and 10 < n	20/20 (Yes)	83,13/100

<sup>12</sup>The interviews performed in this study with a number of local professionals on a random basis are intended to confirm the success of the proposal. They are not based on a specific methodology.