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Method proposal for the management of geographic information in water and sewer companies

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ABSTRACT

Geographic information has been used in water and sewage companies and currently has worldwide application, in rich and poor countries, from basic actions such as georeferencing points of interest to cross-referencing complex Enterprise Resource Planning (ERP) and Spatial Data Infrastructures systems together with other public services. But has the creation, use and management of this information been carried out successfully harnessed? Considering the constant changes occurred in Information Technology, in the demography of urban areas, in water and sewage systems and in corporate management, we propose a new method for implementing and support Geographic Information Systems (GIS) for water and sewage services in metropolitan areas. The methodology was based mainly on international GIS and/or Project Management standards and propositions in the academic literature including applications, challenges and the role of different stakeholders. The objective was to gather much information and pathways in simplified models to facilitate operators and decision makers in water industry for an overview about what to be considered in a corporate and public GIS. Based on two models, it is possible to elaborate requirements related to the use and management of GIS and guide actions and decisions for their development, considering the organizational management of companies and the regional context in which they operate.

KEYWORDS: Geographic Information Science. GIS Management. Water Utilities. Water Governance.

INTRODUCTION

We are living in a world in which 29% of the population still does not have access to *safely managed drinking water services* and 61% cannot count on *safely managed sanitation facilities* (United Nations, 2018). This means that the technological advancement in water and sewer and in Information and Communications Technology – ICT, cited by governments, companies and scientific articles, has lacked means of access to reach a large part of the world population, due to political, economic, technical or, especially, transfer of knowledge reasons.

The United Nations, in 2015, developed the 17 Sustainable Development Goals (SDG), among them SDG 6, whose complete title states, *Ensure access to water and sanitation for all*, inviting humanity to face this challenge. To manage the advances and setbacks of this SDG, the UN recognized the necessity of constant monitoring of indicators through data and information systems. One method which stood out was *the need to incorporate new and novel sources of data including remote sensing and GIS* to monitor sanitary sewage systems (UN, 2015) and, since 2015, the Inter-Agency and Expert Group on the Sustainable Development Goal Indicators (IAEG-SDGS) Working Group on Geospatial Information, began to function at the UN, to support all SDGs.

In some aspects, SDG 6 intersects with SDG 3 (Health and Well Being), considering that, traditionally, sanitation and water together with hygiene, have been treated as a single sector (...) impacting mortality and morbidity burdens in the developing world and, separate or together, the three components are determinants of health (CAIMCROSS et al. 2010). In this way, water quality monitoring, in particular of distributed water, is fundamental. On an international scale, obtaining shared data through a Joint Monitoring Program (JMP) can highlight opportunities for accelerating that progress on expanding access to drinking water and sanitation (BARTRAM et al, 2014). In Africa, efforts towards universal access to drinking water suggest that the continent may not even attain SGD 6 by 2030 (ALAGIDEDE & ALAGIDEDE, 2016) and that water utilities are not always capable of serving the whole population, with a part being served by NGOs, or remaining without access to the services (NHAMO et al. 2019).

In addition to the challenges that water utility in poorer countries faces in the management of investments and corporate organization, urban areas are also diversified. The growing urbanization and metropolitanization of developing countries, including through informal settlements without the proper water and sanitation infrastructure, can result in the overloading of water and sewer systems and in the pollution of water supply reservoirs (OILIVER et al. 2019). In 2015, around 880 million people lived in informal settlements or slums (UN, 2015).

GISs have already been recognized for being applied to water services in diverse regions of the world to support decision makers, like in the case of Rafah – Gaza Strip (ELJAMASSI & ABEIAD, 2013) for monitoring hydraulic network installations, for planning and use of water sources in Nagpur – India (VARADE et Al., 2017) and for the management and control of water losses in São Paulo – Brazil (SILVA JUNIOR & CABRAL, 2015). In 2018, a partnership entered into by the government of Burkina Faso and the World Bank through the Water Supply and

Sanitation Program was reevaluated and, in the follow-up report, investment proposals were recommended for the operational improvements of the water supply systems, for example GIS and staff training (WORLD BANK, 2018). In spite of the examples of applications such as these and others mentioned in the science bibliography, it is not always that research and projects developed in the academic environment are effectively applied by water utilities, either due to lack of technical or institutional interaction, or due to difficulties with funding and in the scaling up of pilot projects to the corporate scale.

Challenges in the creation, use and management of geographic information platforms date back to the 1990s, when authors such as Somers (1998) and Chan & Williamson (1999) discussed how GISs could be managed on the corporate scale. They considered the diversity of personnel and of the types of tasks and information that would be consulted on a platform, proposing management models based especially on data, stages, actions and equipment.

In 2004, Tomaselli (2004) went a little farther, and identified that, in addition to purely technical or financial factors, behavioral and cultural matters could become obstacles in the development of GISs. In their view, many Information Systems personnel do not understand spatial data and systems. They tend to be focused on control, not sharing, in addition to eventual misunderstandings between management departments and a lack of clarity regarding management responsibilities and internal staff.

Despite the efforts of the authors mentioned, this is still a real problem. Geographic Information is undergoing a new perspective and the preparation of maps, in recent years, has been radically transformed with the use of geotags in Apps, drones for territorial surveying, the growth of collaborative mapping platforms such as Open Street Map and the availability of free software and codes, including those applicable to water resource management (DELIPETREV et al. 2014) and sanitation. This Era, referred to as Cybercartography (TAYLOR, 2005), with the growing proposal of Public Participatory GIS (CUTTS et al. 2011; MUKHERJEE, 2015) through the use of Volunteered Geographic Information – VGI (ELWOOD, 2008; ELWOOD et al. 2012), and influenced by increased sharing of data and cheap equipment, presents new opportunities and applications as well for the water industry.

The development of a method to guide water utilities in the contemporary world, considering social, environmental and operation matters that involve water and sewer services, should be adaptive to the terminology and context and understanding of the professionals, especially from this sector. GIS area professionals have been specializing in proposals on the demands of specific sectors of the industry, but this does not mean that the intersection of sanitation and geoprocessing knowledge has reached its potential. The integration of GIS and sanitation has become a necessity and there is a lack of management instruments compared to the abundance of technologies.

Considering the importance of such applications and the challenge to manage much information to implement improvements in both water distribution and sewage system in metropolitan areas, the objective was to identify data demand and pathways for GIS in a simplified model. It can support operators and decision makers in water industry for an overview about what to be considered in a project for corporate and public levels. The model considers both new GIS still under planning and those already in use.

METHODOLOGY

The conception of the proposal of methods and indicators for GISs has at its foundation a stream of pre-existing management actions and models, including generic ones for corporative GISs, or ones that are directly related to those in water and sewer companies.

Initially, the first Water Utilities GIS implementation model proposed was that of Shamsi (2005). Based primarily on north-American companies, the author conceived a gradual work flow, ordered in 8 stages, whose end was limited to the beginning of routine operation of the GIS and propagation in the corporative sphere:

1. Identification of interested parties (stakeholders);
2. Dialogue with the interested parties;
3. Resource inventory;
4. Establishment of priority needs;
5. Creation of the project and system design;
6. Pilot project execution;
7. Development of an implementation plan;
8. Carrying out of the final presentation

Drew Clarke also developed a model based on work flow for the implementation of large scale GISs, with 14 steps grouped into four stages, (LONGLEY et al, 2013). The author began with the principle that, to build a GIS, it was necessary to satisfy the requirements, preferably in the order indicated, which were based on stages connected mainly to financial matters, technology and platform usability.

In addition to step-by-step layouts such as those presented, another discussion that emerged in the Geographic Information Science field was how to evaluate the stage of maturity of GISs, named “Maturity Models” (MÄKELÄ et al. 2010; ALRWAYS, 2016). As an objective, the authors aimed to define development stages and requirements for each one of them, in order to identify which stage the GIS of a determined corporation found itself and what were the outstanding gaps, being technological, organizational and/or human capital matters. These proposals were based on previous studies done on information systems in general, such as the Nolan´s Stage Model (NOLAN, 1973), characterized by 4 stages (Initiation, Contagion, Control and Integration), the Capability Maturity Model – CCM and management tools such as SWOT analyses.

Mäkelä (2013) developed a model evaluating public company GISs in Finland based on 15 requirements grouped into 3 Key Areas: Architecture (5), Services and Processes (3) and Capabilities (7). Scores could vary between “0” (minimum) and “5” (maximum), without decimal intervals and which could be characterized with “+” or “-“ symbols. In the United States, the Urban and Regional Information

Systems Association – URISA developed the GIS Capability Maturity Model, for which 23 Attainment Capacity requirements (GIS implementation) and 22 Execution Capacity requirements were selected, totaling 45 requirements. The requirements could receive scores of “1.0” to “0.0”, with intervals of 0.2 points in the case of partial attainment (URISA, 2013). The requirements of both the models deal with questions such as: hardware and software technologies; user support and training; primary data availability; investments, and organizational management.

Despite the models presenting uniform evaluation proposals, in our proposal, aspects indirectly related to technologies can also be considered, which can have great influence on the use and performance of these GISs. Given that this study directed its efforts to water and sewer services, it included peculiar aspects of these services and information that are routinely produced and used, since they can impact the production and use of geospatial data and, yet, they permit crossing with other technologies and with commonly employed database models.

The participation of interested parties was taken into account, considering those both internal and external to the companies. The guide PMBOK 5th edition (PMI, 2013) for project managers highlights that the Identification Stage involves the process of identifying people, groups and organizations that can impact or would be impacted by the decision, activity or result of the project, analyzing and documenting relevant information with respect to the interests, involvement, interdependencies, influence and potential impact on the success of the project.

RESULTS AND DISCUSSION

Considering the steps, actions and responsibilities concerning the development of a GIS for a water utility, two models were developed that should be applied simultaneously to projects. They were designated "horizontal" and "vertical" due to the fact that they deal with distinct issues and temporalities that, although complementing each other and being partly or totally dependent on each other for each decision, are at the level of a technical team, a corporation, or a government.

HORIZONTAL MODEL: TOPICS AND STAKEHOLDERS

Within the scope of this study, a model designated the "Horizontal Model" was created, indicating issues and stakeholders, whose conception considers 4 fronts, each one subdivided into 3 variables and 2 axes, which connect the fronts that are on opposite sides. The first to be presented is the axis of Reality (Geography) - Represented Reality (Technology); secondly, the axis of the Management relationship (Administration) - Operation (Services) of water and sewage systems will be presented.

The Geography front deals with reality itself, regardless of its digital representation. Environmental, demographic, cultural, topographic and economic conditions and aspects are fundamental to understanding the differences in the presence/absence of water and sewage services between localities, the quality of these services and the satisfaction of the local population. The three variables defined for this front were:

Socio-Spatial Training: The urban and rural reality, the heterogeneity of land use and occupation, zoning regulated by law, demography, access to water and sewage services for the diagnosis of pressure assessment on hydraulic structures (public, community or private). These aspects influence the relationship that exists between companies and the population in different territories, and should be characterized for the base map and actions to include new populations in the systems.

Water Resources and Physical Environment: This knowledge is useful for all hydromeorological studies and, in particular, on aquifer recharge using GIS (BLAKE et al. 2014), bathymetry of water bodies (CEYLAN & EKIZOGLU (2014), environmental vulnerability of recharge areas (MOGAJI, 2018), among other applications, such as the conditions and influences of relief and soil in the construction and maintenance of networks and pipelines (GUERRA & MARÇAL, 2006).

Global Health: This variable begins with the principle that health is a public and global good, whose objective is to make this a good that is not competitive and for which there is no rivalry (FORTES & RIBEIRO, 2014). These are health issues that transcend national boundaries, whose solutions require international cooperation. GISs can be used to map areas of vulnerability and informal settlements (GOVERNMENT OF INDIA, 2011; MAYUNGA et al. 2007) and facilitate the planning and inclusion of these communities in Water Utilities services.

On the Technology front, it was understood that geographical databases and GIS need a series of hardware and software to exist and work. It is in computers, devices, servers and digital platforms that the cybernetic interface occurs between users and managers, as well as the sending and receiving of data and execution of operations. In this case, the three variables are:

Geotechnologies: There is a range of equipment to be used in the field for mapping and measuring coordinates, such as manual GPS, geodetic GPS, total station, unmanned aerial vehicles (drones) and laser terrain readings (LIDAR). In addition to the equipment, the digital cartographic platforms guide the way this information will be viewed and worked with by users.

Digital Systems: A digital system can be understood as a delimited set of conceptual components of data, information and tools, which are based on physical devices (hardware) and programs (software). An example of these would be Supervisory Control and Data Acquisition - SCADA, commonly used for remote monitoring of structures as well as of water and sewage leaks (VUJNOVIĆ et al. 2018).

Data Science: This variable includes modeling, code design and data structure and the importance of maps being understood by their users (CRAMPTON, 2001) through user-friendly interfaces. Since GISs and other digital systems make data available and offer tools for its manipulation, the ability of georeferenced data to integrate with existing data in other corporate systems in the company should also be predicted, as has already done with the Business Intelligence Model - BIM (KARAN et al. 2016; GILBERT et al. 2018; HIJAZI et al. 2018).

The "Administration" front focused on human resources, capacity building, finance, legal and judicial issues, research and development, communication and supplies, all of which are fundamental to support the actions of elaboration, dissemination and exchange of geographic information and technology acquisitions. Three variables were included to identify this context:

Organizational Culture: This is understood as the set of beliefs, values and principles shared by people in an organization, and which undergoes direct interaction with the management model, due to the power exercised by the main managers of the organization (CROZATTI, 1998). The participation of employees (GROEN et al, 2017) has great influence on this aspect, due to the GISs depending on data from different teams within a corporation. A conflictive or cooperative internal culture will directly impact its development and other future projects.

Capacity Building and Innovation: The system is only beneficial if employees and other users are aware of their functions and apply them on a daily basis. Sharing knowledge in a corporation means transferring, disseminating, exchanging experiences, skills and useful information from one individual to other members (SAJEVA, 2014; KATHIRAVELU et al. 2014). In the case of the GIS, there are still highly skilled professionals on the subject for more complex and critical analysis (BEARMAN et al. 2016).

Finance and investments: The initial capital of GIS for the digitalization of geographic information until the continuous investment for constant improvement requires planning and vision. In a Return on Investment (ROI) assessment in GIS, the amount of users, data, applications and time, labor and resource savings are critical (JOFFE, 2015).

And, at the end of this stage we find the "Services" front that includes water and sewage, through which routine operations, planning of actions to implement structures and enterprises, deadlines, maintenance and service areas are determined.

Sanitation Systems: Set of structures and hydraulic equipment that allow for the arrival of water to the citizen and that, once used by the citizen, allow for drainage to a body of water for release. SHAMSI (2005) highlights that any hydraulic or hydrologic modeling must start with the development of the geospatial database, also known as the Technical Register, given that there is a need for accuracy and completeness of these so that modeling can be successfully processed (WATER NEW ZEALAND, 2009).

Operation: The monitoring, in real time, of events and interferences, such as the progress of works, leaks, maintenance services, water quality sampling, flow and pressure measurement, customer service and emergency containment. This data can be georeferenced and provide a panoramic map of the service situation. In this variable, we find the actual events that occur on these objects.

Sanitation policies: Water and sewage services are observed by the sphere of government and public interest. The regulation and supervision of these services are influenced by public policies. GISs enrich debates and analyses by integrating tabular data and highlighting localities and differences at territorial scales. However, this only becomes feasible when geospatial data are organized and available to actors outside the companies.

The model built for this proposal had a two-dimensional geometric design. Considering that GIS projects should have a 360º vision, so that their applications are maximized by the view of their stakeholders, a circle was used to represent them and the four fronts were represented by a sector, as if each one were a dimension, or a plane, on which the variables interact before taking form. Furthermore, the variables converge at the same point, indicating the need for convergence of interests and actions that result in the influence of this front, dimension or plan on the GIS project. The model is found in figure 01:

Figure 01: Horizontal model (topics and stakeholders)

VERTICAL MODEL: DEVELOPMENT, ACCESS AND POTENTIALITIES

In view of the enormous amount of data that a metropolitan water and sewage company holds, it is possible that, for different types of geospatial data, the company will approach differently the steps proposed for two axes.

In the case of Potentialities (vertical axis), it is understood that higher degrees can be achieved after incorporating steps regarding the use and management of geographic information, although the attributes can be worked on separately within a company. As for access (horizontal axis), this is understood as the amount of people who can create, consult and apply this information, which grows in geometric progression, starting from an individual and traversing degrees of sharing that can reach the entire company.

The Potentialities and Access axes have been united in a Cartesian plain graph (figure 02), by which it is proposed that the greater the access by people to certain data and geographic information, the greater the possibilities of use that can be applied because it is available to a wider range of professionals with different backgrounds and interests. To facilitate the influence and actions to be taken in this development, 13 steps have been defined which fit into certain points and are grouped into defined scales for both axes in order to guide efforts and identify strengths and weaknesses.

1 - Information Availability: Information needs to exist, whether it is the knowledge of a single employee or a group of employees, on paper, in digital format or within a system. In addition, it needs to be clear and understandable to staff. In this way, knowledge sharing from an organizational perspective, including from older employees (TAYLOR et al. 2010), technical collections of plants and structures, with location accuracy, and the organization of workflows within a company contribute to the existence and accessibility of information.

2 - Digitalization: Once available, information can be digitized, in alphanumeric format, in images, technical drawings or other types. This step is defined as the ability of technical staff on digital systems (LAAR et al., 2017), the investments (old or recent) in digitizing information previously on paper, and the interest of the water and sewage company in making these fronts move forward.

3 - Base Map: The visualization and location of hydraulic structures depends on background layers, such as aerial images, street, land use and occupation, buildings and other underground structures (subways, tunnels, networks of other utilities), in addition to the physical characteristics of relief, hydrography and drainage. Favelas/slums, where existing, should be mapped to then be included if water and sewage services are not available, and for which alternative mapping methods exist (MAYUNGA et. Al., 2007; INDIA, 2011; PAUL, 2015).

4 - Geospatial Modeling: A data model represents a portion of reality expressed in a simplified manner, with the goal of generating an abstraction that can be used in applications for the utilization of this information. This step includes the standardization of geospatial data according to official bodies or ISO, grouping and indexing (LONGLEY et al. 2013) and topological rules for crossing vectors.

5 - Geospatial Data: Once existing and digitized, the geospatial data created in the company itself should follow quality criteria and represent all urban areas in its jurisdiction. For this, it is necessary to have explanatory metadata about the method of data creation, criteria for choosing the software or platform for data manipulation, training of the technical staff for knowledge of cartography of the platforms and assurance of good spatial accuracy of the data produced.

6 - Corporate GIS: The best way to gather geospatial data is by creating a corporate geographic information system (GIS). This step includes the distinction of users according to their assignments, the participation of employees in the system design, the term of reference for contracting the service and maintenance of the platform and the ability to invest and make the project viable.

7 - Simple spatial analysis: The geospatial data produced can be cross-referenced and enable a more integrated view of the hydraulic structures among themselves, with the populations and with the urban and regional infrastructure as a whole. These include studies of alternative locations of enterprises, control of water losses, the degree of satisfaction of the population according to urban districts and data on the pipes.

8 - Automation: When data is frequently produced and there are analytical patterns as a result, it is possible to automate them through workflows. The goals here include the automation of address georeferencing via geocoding, hydraulic supply modelling (SANDOVAL & FLORES, 2013; SITZENFREI et al. 2013), frameworks and integration with Supervisory Control and Data Acquisition (SCADA) systems.

9 - Internal Integration: Different databases in a company can be cross-referenced (financial, systems operation, quality laboratories, human resources, etc.) and the objects to which they refer, when georeferenced, can be represented cartographically. The common coding of the objects in the different bases, interoperability between systems, integrations as done in Enterprise Resource Planning (ERP) and Business Information Management (BIM) and the potential of the corporate GIS itself are all variables that promote this integration.

10 - Complex Spatial Analysis: There are correlations between the supply and depletion systems with issues such as land fragility, water diseases, impacts from construction projects on vehicle traffic and network contamination. Complex analyses require the promotion of RDI in the company, the transdisciplinarity of GIS specialists and other subjects within the company, partnerships with external researchers and, with academia, the application of very high precision equipment and technical-scientific publications of these results.

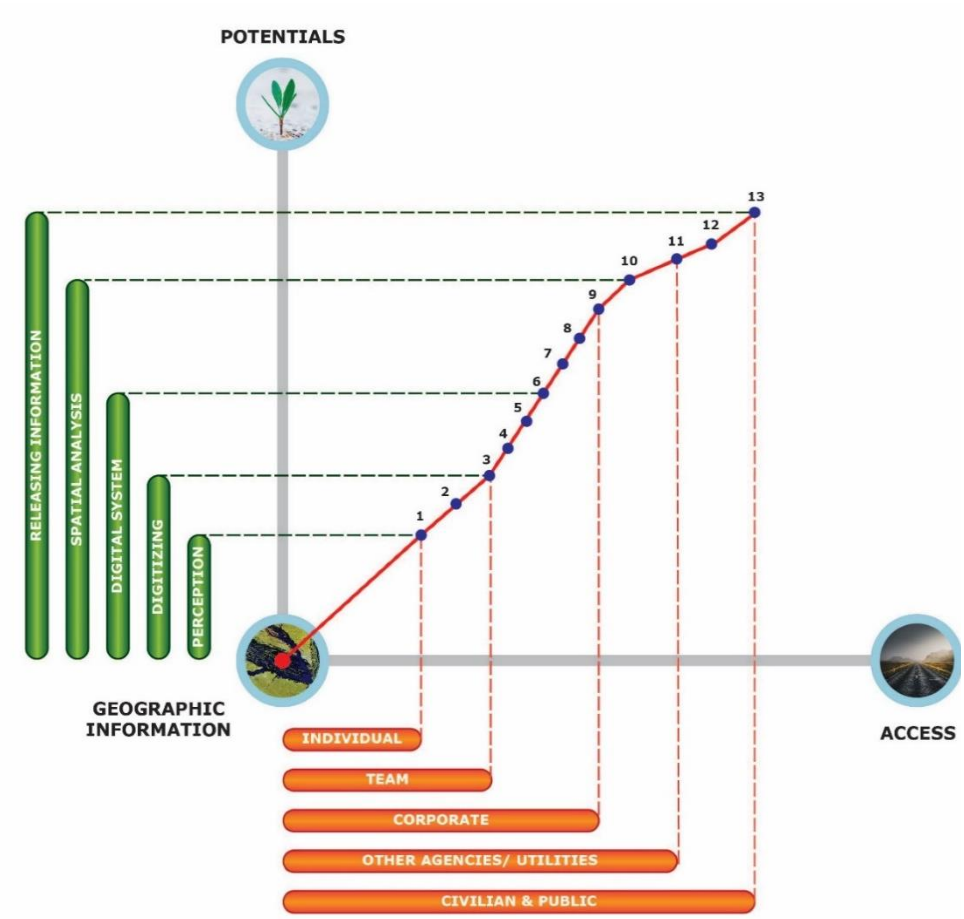
11 - External Integration: Other agencies dealing with environmental inspection, urbanization and construction, electrical systems, gas distribution, transportation and logistics and civil defense, etc. may need geographic information on water and sewage services, while information produced by these may be of interest to water utility. This integration can take place through data sharing (IBRD et. A. 2011) via HDs, the formalization of institutional arrangements, legislation, cloud sharing and feasibility of direct access to the water utility GIS.

12 - Transparency to Citizens: Citizens have a strong interest in public services, including water and sewage, especially when non-compliance occurs. A map can respond to many of these demands, in addition to supporting the management of trust and improving the citizen satisfaction index. The quality of customer service, the ability of the local population to understand maps, the quality and organization and dissemination of information regarding service interruptions and impacts on traffic, can all serve as valuable tools to expand the communication capacity of companies.

13 - Participatory Citizen: Today citizens can express their opinions through service channels, social media and also through platforms such as participatory GISs.

Strong relationships of trust between the population served and the water utility can be increased in scale through a participatory GIS platform, consultations with the population regarding the implementation of large projects and obtaining assistance and cooperation from populations in favelas/slums for projects that benefit them.

Figure 02: Vertical Model: Development, Access and Potentialities.



CONCLUSIONS

In light of the gradual interest of water utilities around the world to work with integrated systems, it is necessary that the evaluation methods also act in the same way. They should include the way cross-referencing occurs and, in particular, highlight human and organizational aspects that may negatively affect the creation, use and sharing of geospatial data. Also, since these are public services, it is necessary to include citizen-clients as stakeholders in the GIS, since they are those who give purpose to these services.

Although the scientific literature has often defended the use of GIS for water utilities, these organizations always face technical, organizational, or even political challenges, when they need to make decisions through bolder and broader steps with their GISs, even within the corporate scale itself. Conveying information to the outside world, to other public agencies, the press and to citizens, is another challenge, often due to triggering complaints and pointing out structural or operational imperfections of these companies, which can affect trust in them.

The horizontal and vertical models can help companies providing water and sewage services to organize teams, information, tools and operational procedures to support compliance with SDG 3 and 6 in different locations around the world and, certainly, collaborate to achieve other SDG, given the dependence on actions related to water management. The results can be used to plan goals and actions for management improvement, based on participants' actions linked to each requirement and stage of the proposed models. In addition, annual evaluation is recommended to review goals and actions.

The method can contribute to the promotion of joint studies among agencies of other public services, pointing out opportunities for partnerships among them to meet requirements and promote technology and knowledge sharing and transfer. The way this method is applied can be adapted to companies in various ways, for example through the creation of an internal committee of employees capable of creating and analyzing requirements and, together, checking and discussing the results. Or the task can be left to a single professional, internal or external, who should conduct interviews with professionals from various teams in the company and develop indicators and targets for monitoring.

The method supported thereafter the elaboration of a questionnaire, considering all aspects in both vertical and horizontal models. It has been applied in three different water companies, in Fortaleza-Ceara/Brazil (CAGECE), Nairobi (Kenya) and Budapest (Hungary), indicating that aspects can be worked in different realities worldwide. The models are recommended to be applied mainly in case of metropolitan areas due to their high demand on geographic information and harder challenges to manage and systemize them.

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REFERENCES

ALAGIDEDE, P.; A.N. ALAGIDEDE. The Public Health Effects of water and sanitation in selected West African countries. **Public Health** issue 30. 2016. pp 69-63.

ALRWAIS, O.; HORAN, T.; HILTON, B.; BECHOR, T. **Evaluating Local Government Usage of GIS: A New Maturity Mode**l. Pre-ICIS Workshop on Locational Analytics and Big Data, Fort Worth, 2015.

BARTRAM, J.; FISHER, B.M.B.; LUYENDIJK, R; HOSSAIN, R; WARDLAW, T; GORDON, B. Global Monitoring of Water Supply and Sanitation: History, Methods and Future Challenges**.** Internacional **Journal of Environmental Research in Public Health**, 2014, v.11, pp.8137-8165.

BAIRD, G, M. Defining Public Asset Management for Municipal Water Utilities. **American Water Works Association journal – AWWA**. pp. 30-28. 2011.

BEARMAN, N. JONES, N. ANDRÉ, I. HERCULANO, A.C.; DEMERS, M. The future role of GIS education in creating critical spatial thinkers. **Journal of Geography in Higher Education**. vol. 40, no. 3, 394–408. 2016. doi:10.1080/03098265.2016.1144729.

BETHANY B. CUTTS A.; WHITE, D.D.; KINZIG, A.P. Participatory geographic information systems for the co-production of science and policy in an emerging boundary organization. **Environmental Science and Policy**. v14. pp.977-985. 2011.

BLAKE, D.; MLISA, A.; HARTNADY, C. Large Scale Quantification of Aquifer Storage and Volumes from the Peninsula and Skuweberg Formation in the Southwestern Cape. **Water SA**. vol.36 n.2 Pretoria Jan. 2010.

CAIMCROSS, S. BATRAM, J. CUMMING, O. BROCKLEHURST, C. Hygiene, Sanitation and Water. What Needs to be done ? **Revista Plos Medicine**. 2010.

CEYLAN, A.; EKIZOGLU, I. Assesment of bathymetric maps via GIS for water in reservoir. **Boletim de Ciências Geodésicas**. vol.20 no.1 Curitiba Jan./Mar. 2014.

CHAN, T. O; WILLIAMSON, I. P. **Spatial Data Infrastructure Management: lessons from corporate GIS development**. The 27th Annual Conference of AURISA - Blue Mountains, New South Wales – Australia. 1999.

CRAMPTON, J. W. Maps as social constructions: power, communication and visualization. **Progress in Human Geography**. no.25. Vol 2. pp. 235–252. 2001.

ELJAMASSI, A; ABEIAD, A. A GIS-Based DSS for Management of Water Distribution Networks (Rafah City as Case Study). **Journal of Geographic Information System**, vol. 5, pp.281-291. 2013.

ELWOOD,S. Volunteered geographic information: key questions, concepts and methods to guide emerging research and practice. **GeoJournal.** vol. 72,pp.133–135.2008.

ELWOOD, S; GOODCHILD, M.F; SUI, D.Z. Researching Volunteered Geographic Information: Spatial Data, Geographic Research, and New Social Practice. **Annals of the Association of American Geographers**. vol. 102 no. 3 pp. 571-590. 2012.

FORTES, P.A.C; RIBEIRO, H. Saúde Global em Tempos de Globalização. **Revista Saúde e Sociedade**. São Paulo. Vol. 23 n.2 abr/jun 2014.

GILBERT, T.; BARR, S.; JAMES, P.; MORLEY, J.; JI, Q. Software systems approach to multi-scale GIS-BIM utility infrastructure network integration and resource flow simulation. **Journal of Geo-Information**. Vol. 7 n. 8. 2018.

GROEN B.A.C.; WOUTERS, M.J.F.; WILDEROM, C.P.M. Employee participation, performance metrics, and job performance: A survey study based on self-determination theory. **Management Accounting Research**. Vol.36, 51–66. 2017.

GUERRA, A.J.T; MARÇAL, M.S. **Geomorfologia Ambiental**. Editora Bertrand Brasil. 2006. Rio de Janeiro.

HIJAZI, I.; DONAUBAUER, A.; KOLBE. T.H.BIM-GIS Integration as Dedicated and Independent Course for Geoinformatics Students: Merits, Challenges, and Ways Forward. **International Journal of Geo-information**. vol. 7 no. 319. 2018.

INDIA, GOVERNMENT OF. **Guidelines for GIS Mapping, MIS development and Integration of GIS with MIS.** Ministry of Housing & Urban Poverty Alleviation.2011.

JOFFE, B. A personal account of guidelines for estimating GIS for return on investment. **URISA Journal**, vol. 1 n.27. 2015.

KARAN, E. P.; IRIZARRY, J.; HAYMAKER, J. BIM and GIS Integration and Interoperability Based on Semantic Web Technology. **Journal of Computing and Civil Engineering**. Vol. 30 no. 3. 2016.

KATHIRAVELU, S.R.; MANSOR, N.N.A.; RAMAYAH, T.; IDRIS, N. Why Organizational Culture Drives Knowledge Sharing? **Procedia - Social and Behavioral Sciences**. Vol. 129, pp. 119-126. 2014.

LAAR, E.; DEURSEN, A.J.A.M.; DIJK, J.A.G.M.; HAAN, J. The relation between 21st-century skills and digital skills: A systematic literature review. **Computers in Human Behavior** vol. 72 577-588. 2-17.

LONGLEY, P. A.; GOODCHILD, M. F.; MAGUIRE, D. J.; RHIND, D. W. **Geographic Information System & Science**. 13th Edition. 2012

MÄKELÄ, J.; VANIALA, R; AHONEN-RAINIO, P. Competence management within organizations as an approach to enhancing GIS maturity. **International Journal of Spatial Data Infrastructures Research**, 2010, Vol.5, 267-285.

MÄKELÄ. J. Model for Assessing GIS Maturity of an Organization. IN **Spatially Enabling Government, Industry and Citizens Research and Development Perspectives**. GSDI Association Press. 2012.

MAYUNGA, S.D.; COLEMAN, D.J.; ZHANG, Y. A semi-automated approach for extracting buildings from Quickbird Imagery applied to informal settlements mapping. **International Journal of Remote Sensing**. Vol. 28 n. 10. 2343-2357.

MOGAJI, K.A. Application of vulnerability modeling techniques in groundwater resources management: a comparative study. **Applied Water Science** (2018) 8: 127.

MUKHERJEE, F. Public Participatory GIS. **Geography Compass**. Vol.9. no. 7 pp.384–394. 2015.

NHAMO, G. NHEMACHENA, C. NHAMO, S. Is 2030 too soon for Africa to achieve the water and sanitation sustainable development goals ? **Science of The Total Environment**, 2019, Vol. 669,15th June 2019, Pages 129-139.

NOLAN, R."Managing The Computer Resource: A Stage Hypothesis". **Communications of the ACM**. 16 (4): 399–405. 1973.

OLIVER, S. L.; CORBURN, J. ; RIBEIRO, H. Challenges Regarding Water Quality of Eutrophic Reservoirs in Urban Landscapes: A Mapping Literature Review. **International Journal of Environmental Research and Public Health**, v. 16, 2019.

PAUL, S. Analysing and Mapping Urban Poverty of English Bazar Slum: An Approach of Micro Level Planning Perspective from a Developing Country (India). Bangladesh. **E-Journal of Sociology**. Volume 12, Number 2. July 2015.

PROJECT MANAGEMENT INSTITUTE - PMI. **A Guide to the Project Management Body of Knowledge – PMBOK**. 5th Version. 2013.

SAJEVA, S. Encouraging knowledge sharing among employees: how reward matters. **Social and Behavioral Sciences**. Vol.156 pp.130 – 134. 2014.

SANDOVAL, L.C.; FLORES, J.R.R.Z.; LEÓN, A.B.J. Sistema para control y gestión de redes de agua potable de dos localidades de Mexico. **Revista Ingenieria Hidraulica y Ambiental - RIHA**. Vol. 34. 2013.

SHAMSI, U. M. **GIS applications for Water, Wastewater and Stormwater Systems**. Editora CRC Press Book. Estados Unidos. 2005.

SILVA JUNIOR, E. G; CABRAL, R. C. Indicador de vulnerabilidade da infraestrutura – uma proposta para o diagnóstico e tomada de decisões no combate às perdas reais. **Revista SANEAS** ano XIII edição 55. São Paulo. 2015.

SITZENFREI, R; MÖDELR, M; RAUCH, W. Automatic generation of water distribution systems based on GIS data. **Environmental Modelling & Software**. 47 pp. 138-147. 2013.

SOMERS. R. Developing GIS Management Strategies for an Organization. Journal of Housing Research. Vol. 9, No. 1 pp. 157-178. 1998.

TAYLOR,D.R.F.**Cybercartography:Theory and Practice**. Elsevier Science.2005.

TAYLOR, P.; BROOKE, L.; MCLOUGHLIN, C.; DI BIASE, T. Older workers and organizational change: corporate memory versus potentiality. **International Journal of Manpower**. Vol. 31 Issue: 3, pp.374-386. 2010.

UNITED NATIONS - UN. **Wastewater management: A UN-Water Analytical Brief.** 2015.

UNITED NATIONS - UN. **The Sustainable Development Goals Report**. 2018.

VARADE, A.M; KHARE, Y.D; DONGRE, K.P; MULEY, S; WASNIK, G. Integrated geographical information system (GIS)-based decision support system (DSS) approach to identify the site-specific water conservation structures in a watershed of Nagpur district, Central India. **Sustainable Water Resources Management** vol. 3, pp.141–155. 2017.

VUJNOVIĆ, G.; PERIŠIĆ, J.; MILOVANOVIĆ, M.; RADOVANOVIĆ, L. Using Scada Applications in Water Supply System. **Acta Technica Corviniensis – Bulletin of Engineering**. Tome XI. 2018.

WATER NEW ZEALAND. **National Modelling Guidelines – Water Distribution Network Modelling**. 2009.

WORLD BANK. **Report - Burkina Faso water supply and Sanitation Program** (P164345). Program for Results (PforR). 2018.

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