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BIM AND GIS OPEN INFORMATION STANDARDS FOR INTEGRATED WATER SERVICE MANAGEMENT

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Introduction

Integrated water service (IWS) in Italy identifies a service that combines drinking water supply and wastewater treatment. It includes numerous hydraulic infrastructures, and due to the number and diversity of infrastructures that are part of this system, it involves complex data management. For this reason, for the past few years, IWS data management has been done through GIS, which allows geolocation of information in the territory. GIS is not sufficient to manage all the information associated with IWS facilities, however, the recent emergence of BIM, also due to regulatory requirements, has introduced new potential in data management. To optimize the management of civil hydraulic infrastructure within IWS, it is essential to connect and integrate these two tools. The aim of this research is to propose an approach for database-driven BIM-GIS integration for the IWS through the open information standards IFC and CityGML.

GIS, which emerged around the 1960s, is defined as a geographic database management information system. It enables the management of elements in the spatial domain even at large distances, which is why the use of coordinate systems that consider the shape of the earth is essential (Rajadurai and Vilventhan, 2022). This potential in managing many elements limits the ability to go too much into the specifics of each element. A wastewater treatment plant can be geolocated in the territory through GIS with some information associated, but it will not achieve good semantic and geometric detail. However, GIS is perfect for managing the linear elements of the IWS network, i.e., pipelines. These elements do not require complex geometric representations and do not need a lot of associated data. BIM has its conceptual origin around the mid-1970s and is defined as an information model, which can contain information regarding the entire life cycle of typical facilities in the construction industry. BIM allows for precise and detailed management through the association of many attributes. However, the high degree of detail implies a weakness in the spatial extent of its domain (Sharafat et al., 2021). BIM, consequently, is perfect for the management of punctual elements, such as a wastewater treatment plant or a lift station, which require a detailed geometric and informational description.

BIM and GIS integration is a topic of interest, which is why there are several articles in the literature dealing with the topic. In contrast, the literature on integration between BIM and hydraulic engineering is still limited (Liu et al., 2024). A review is conducted to analyse the status of BIM-GIS integration in the water industry. Among the selected studies only a few (Gilbert et al., 2021; Howell et al., 2017; Zhao et al., 2019) integrate BIM and GIS with specific reference to water and sewer pipelines. Most of the other studies found, integrate BIM and GIS with reference to underground utility infrastructure (gas, water, and electricity) in general, without distinctions, or focusing on those not directly related to the water industry. With reference to the totality of the selected articles, some observations can be made. First, no article was found that directly deals with the integration of the pipelines of the IWS (represented in GIS) and the punctual facilities of the IWS, such as a wastewater treatment plant (modelled in BIM). Second, the most widely used software are Revit, ArcGIS, and Civil 3D, but in reference to the methodology that will be proposed there is a little use of QGIS Third, the literature in this field has not deeply discussed the use of SQL database for BIM-GIS data integration through open information standards.

IFC (Industry Foundation Classes) is the ISO standard for interoperability of BIM models. It is maintained and updated by the no-profit organization buildingSMART International. Currently, the IFC data model has a good level of completeness but does not allow it to describe all types of existing buildings, infrastructure or facilities. Unfortunately, this data model does not have a specific discipline for describing the water industry. Various extensions of the IFC data model have been proposed in the literature over the years in various application fields (Yu et al., 2023). Among them, an extension is proposed to better describe a wastewater treatment plant (Söbke et al., 2021), a typical IWS facility. However, in practice, it is more useful to adapt classes already in the data model than to extend the schema with classes that perhaps will be adopted in future versions of the standard (buildingSMART Germany, 2023). IFC can be encoded in various file formats, each of which has advantages and trade-offs in terms of software support, scalability and readability. One of them is the ifcSQL database schema, proposed to store data from various BIM models in a single database according to the official IFC data model (Bernhard Simon Bock and Friedrich Eder, 2020).

CityGML is the most widely used international standard for storing and exchanging three-dimensional models of urban areas with semantics in the geospatial domain. CityGML supports the creation of data model extensions for specific use cases through the standardized mechanism called “Application Domain Extensions” (ADE). The Utility Network ADE is the extension for utility networks, such as electricity, gas, water, and telecommunications (Tatjana Kutzner, 2019). It can be used for a more detailed representation of infrastructure networks, including the water sector. CityGML can also be encoded in various formats, one of them is based on SQL database, called 3D City Database (3DCityDB) (Yao et al., 2018). The advantage of using database-based coding is that databases are built to manage and organize large amounts of data, as is typical in GIS.

Methodology

To overcome the current limitations, an integration approach based on SQL databases and the open-source software QGIS is proposed (Figure 1). The standard IFC and CityGML formats are used along with related database encodings (ifcSQL and 3DCityDB). Network pipelines are represented through GIS and are based on the CityGML data model, while point facilities are modeled through BIM and exported to IFC. The respective files are then coded within an SQL database. Data visualization is possible through QGIS, which serves as a graphical interface for the SQL databases. In fact, QGIS was originally created to enable graphical visualization of the data contained in the postgreSQL database. Both IFC and CityGML models must be properly georeferenced, through the classes made available in the respective standards, and then displayed in the correct location in QGIS. The result that is obtained is a spatial management of the plants and the pipeline network of the IWS. Finally, it is specified that there is no need for a semantic correspondence between IFC and CityGML since the former is used for the description of the plants and the latter for the pipelines; moreover, the data are contained in different DBs and then displayed contextually within QGIS.

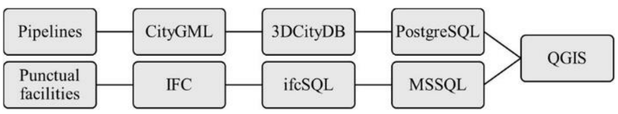

Figure 1:conceptual schematization

Conclusion

Integration between BIM and GIS for Integrated Water Service (IWS) management is a crucial challenge for optimizing the monitoring and maintenance of hydraulic infrastructure. In this study, a different idea of BIM-GIS integration is conceptualized than the classical ones reported in the literature. In fact, BIM-GIS integration is viewed as: punctual elements modelled in BIM and extended linear elements represented in GIS. This is because typically in working practice facilities are designed through BIM methodology, and thus being able to input data into a common environment effortlessly is an advantage. In contrast, typically networks are designed using a methodology that tends more toward GIS. Basing the methodology on open-source software and open formats makes the approach economical and scalable increasing its potential applicability. Very often in the literature, on the other hand, proprietary software such as ArcGIS is used, which is certainly a good tool but being fee-based is not always implementable on a large scale. The use of QGIS as a management interface offers a flexible and customizable open-source option, overcoming the limitations of proprietary solutions. In addition, having all the data in one environment (QGIS) allows them to be analysed to improve the quality, safety, and sustainability of the IWS. The proposed methodology is still at a conceptualization stage and therefore needs direct experimentation on a few case studies to understand what the shortcomings may be.

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References

Bernhard Simon Bock, Friedrich Eder, 2020. IfcSQL [WWW Document]. URL https://github.com/IfcSharp/IfcSQL (accessed 1.10.25).

buildingSMART Germany, 2023. bSD_Whitepaper_Wasserwirtschaft_E-Book-en- bm, buildingSMART International.

Gilbert, T., James, P., Smith, L., Barr, S., Morley, J., 2021. Topological integration of BIM and geospatial water utility networks across the building envelope. Comput Environ Urban Syst 86. https://doi.org/10.1016/j.compenvurbsys.2020.101 570

Howell, S., Rezgui, Y., Beach, T., 2017. Integrating building and urban semantics to empower smart water solutions. Autom Constr 81, 434–448. https://doi.org/10.1016/j.autcon.2017.02.004

Liu, H., Su, H., Li, H., 2024. Study on Digital Twin Technologies for Watershed Information Modeling (WIM): A Systematic Literature Review and Bibliometric Analysis. Archives of Computational

Methods in Engineering. https://doi.org/10.1007/s11831-023-09977-y

Rajadurai, R., Vilventhan, A., 2022. Integrating road information modeling (RIM) and geographic information system (GIS) for effective utility relocations in infrastructure projects. Engineering, Construction and Architectural Management 29, 3647–3663. https://doi.org/10.1108/ECAM-04-2021-0295

Sharafat, A., Khan, M.S., Latif, K., Tanoli, W.A., Park, W., Seo, J., 2021. Bim-gis-based integrated framework for underground utility management system for earthwork operations. Applied Sciences (Switzerland) 11. https://doi.org/10.3390/app11125721

Söbke, H., Peralta, P., Smarsly, K., Armbruster, M., 2021. An IFC schema extension for BIM-based description of wastewater treatment plants.

Tatjana Kutzner, n.d. CityGML-UtilityNetwork-ADE [WWW Document]. URL https://github.com/TatjanaKutzner/CityGML-UtilityNetwork-ADE (accessed 1.9.25).

Yao, Z., Nagel, C., Kunde, F., Hudra, G., Willkomm, P., Donaubauer, A., Adolphi, T., Kolbe, T.H., 2018. 3DCityDB - a 3D geodatabase solution for the management, analysis, and visualization of semantic 3D city models based on CityGML. Open Geospatial Data, Software and Standards 3. https://doi.org/10.1186/s40965-018-0046-7

Yu, Y., Kim, S., Jeon, H., Koo, B., 2023. A Systematic Review of the Trends and Advances in IFC Schema Extensions for BIM Interoperability. Applied Sciences (Switzerland). https://doi.org/10.3390/app132312560

Zhao, L., Liu, Z., Mbachu, J., 2019. An Integrated BIM–GIS Method for Planning of Water Distribution System. ISPRS Int J Geoinf 8, 331. https://doi.org/10.3390/ijgi8080331