Prototype Design of a Data Warehouse for Determining, Mapping, Monitoring and Visualizing Urban Heat Islands: The Case of Zagreb and Split, Croatia

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Abstract

The UHI phenomenon is not visible to the naked eye and its intensity changes depending on the time of day and year. Natural and artificially induced phenomena such as the creation of Urban Heat Islands (UHI) are becoming more frequent and intense in recent years. Data warehouse combined with a decision support system (DSS) are offered as good solutions to this task. Research presented in this paper focuses on monitoring the phenomenon of UHI and providing guidelines for designing a specific data warehouse for that purpose. In this conceptual preliminary communication, theoretical considerations on the design of the future data warehouse for the detection and prevention of the creation of UHI, and decisions on the selection of individual parts in it, were presented. A data warehouse design concept using Online Analytical Processing (OLAP) type is presented with the star schema modelling technique, which will contain a catalogue of data needed to detect new and monitor existing UHIs in the cities of Split and Zagreb, Croatia. The single-tier model was chosen for the data warehouse architecture, due to its specificity and narrow scope, and the Extract, Load, Transform (ELT) tool will be used within it. A data warehouse system designed in this way, in combination with a decision support system (DSS) that should utilize its full potential, should ensure smooth data collection and efficient processing, and provide the possibility of transferring the methodology to other areas of big data processing.

1. Introduction

Humanity is witnessing significant changes in climate parameters around the world that cause or exacerbate many well-known environmental phenomena. Natural and man-made phenomena such as hurricanes, floods, forest fires and the creation of urban heat islands (UHI) are becoming more frequent and intense around the world (IPCC, 2014). The UHI phenomenon is manifested as elevated air temperatures in urban areas compared to their surrounding rural environments. It affects every major city (Yamamoto, 2006), where vegetated areas are covered by built-up areas that absorb solar radiation during the day and emit it at night (Oke, 1982; Quattrochi et al., 2000). The difference in air temperature between the city centre and the suburbs can be from 1 to more than 10 °C (Sen et al., 2019; Wijeyesekera et al., 2012). The largest temperature differences occur in cities with a population of more than 100,000 inhabitants in lowland areas or valleys and in the summer period (Voogt, 2002). Urban vegetation can regulate the microclimate to some extent, mainly through shading (Anyanwu and Kanu, 2006) and evapotranspiration (Li et al., 2013), so, for now, the main and most effective option for mitigating the effects of UHI is to increase the vegetation area (Yu and Hien, 2006).

The research presented in this paper focuses on monitoring the UHI phenomenon (Howard, 1833) and aims to support local authorities in decision-making processes related to its prevention and mitigation. It is a fact that such events greatly affect the quality of life of the population, but it is also a fact that the population itself contributes to the creation and spread of UHI, through excessive urbanization (Jabbar et al., 2023). The UHI phenomenon is not directly visible to the naked eye, and its intensity varies depending on the time of day and year. One of the main factors contributing to the creation of UHI is dense urbanization and the removal of vegetation. The development of UHI is also influenced by the geometry (position and height) of the built-up area. Tall buildings create a canyon geometry that causes heat to be trapped in the lower layers. This reduces the release of heat that is 'trapped' by higher buildings, thus creating an urban canopy (Gartland, 2012; Masson, 2006). Due to the densely distributed tall buildings, less heat is transferred from the surface to the air (buildings reduce the speed of the wind that would otherwise cool the area) (Gartland, 2012; Priyadarsini et al., 2008). The effect of UHI is greatest during calm, clear weather when there is no wind (Tumanov et al., 1999). The increase in temperature is also affected by the distribution of vegetation and construction.

UHIs can be identified using various techniques, including direct and indirect air temperature measurements and physical modelling (Vujovic et al., 2021). The conventional method of measuring air temperature at stationary meteorological stations, located 1.5-2 m above the ground, is one form of direct measurement. The main disadvantages of this method are the high cost and limited coverage of meteorological stations (point data). In addition, meteorological stations are often located outside critical areas (e.g. dense high-rise zones), are too sparse, or are located at heights and locations that are not suitable for recognizing heat islands (Gartland, 2012; Fadhil et al., 2023). Another way to directly determine UHI is to measure air temperature using mobile sensors, mounted on a moving vehicle or balloons for vertical measurement of air temperature changes.

The problem with such measurements (also, point data) is the high cost of making simultaneous measurements at multiple locations. Indirect methods of determining UHI include remote sensing methods that utilise satellite and aerial imagery to calculate surface temperature estimates. A key limitation of freely available satellite data is their temporal resolution (Gartland, 2012), while commercial imagery offers higher temporal resolution but at significantly higher cost.

In order to make the right decisions to prevent the occurrence of UHI phenomena or mitigate the impacts of existing ones, computer technology (powerful computers) and geoinformatics (results of Earth observations, especially remote sensing

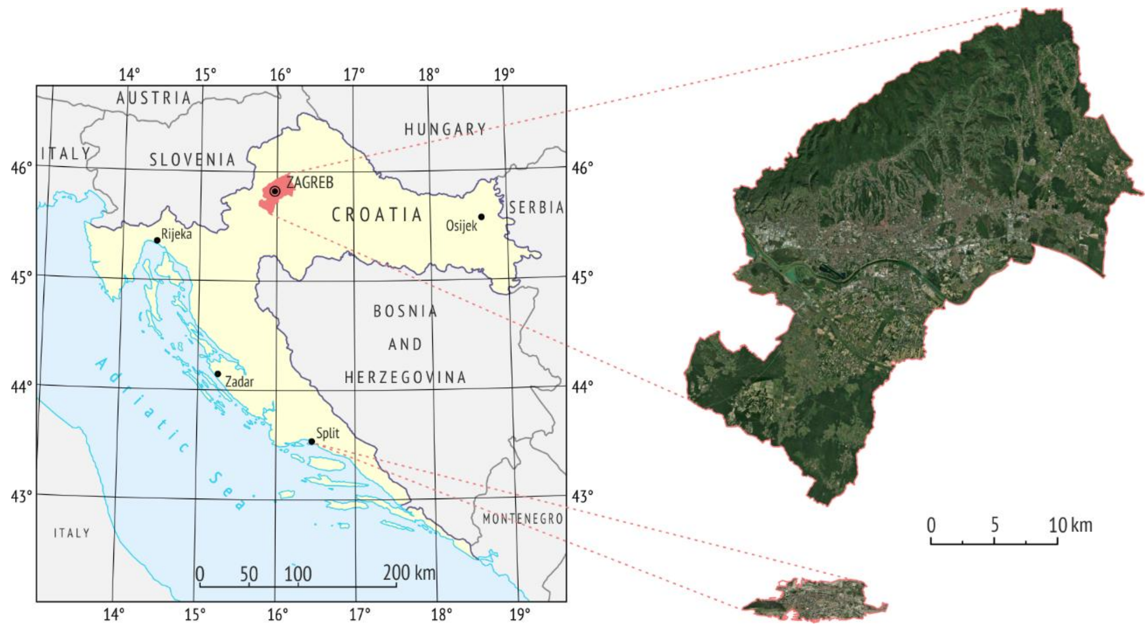

Figure 1. Geographical location and administrative boundaries of the city of Zagreb and city of Split.

methods) can provide ecologists and urban planners with timely information on the basis of which they can make assessments of the state and decisions on environmental conservation in urban areas. Frequently used tools in the environmental protection sector are decision support systems (DSS). The main feature of DSS is the systematic collection of various data on a certain phenomenon and the search for their functional connection to acquire 'knowledge' that is used by experts in various fields for decision-making.

1.1 Solution – Data Warehouse

Data lakes and data warehouse are offered as good solutions to this problem (Jaiswar, 2024; Zhao et al., 2024). Well-designed data lakes (well-structured and defined data) can be the basic building block for various solutions in the analysis of UHI effects. Such data lakes will form a data warehouse for monitoring the UHI phenomenon. Data lakes are filled from various sources. Big data on the environment and the impact of the UHI phenomenon on that environment are available in various types and formats. For any automatic processing, they need to be structured and prepared for common use. The diversity and quantity of data in data warehouses pose major challenges and open issues such as data integration, data quality, and interpretation of data and results (Abadi et al., 2016). Open data can contribute to addressing these challenges by providing adequate data from different domains.

Although the mechanisms that lead to UHI formation are well understood, their spatial and temporal variability remains difficult to detect without integrated, high-quality data infrastructures. Effective UHI detection, mapping and long-term monitoring require continuous, standardized and interoperable datasets that combine satellite observations, meteorological measurements, topographic models and urban morphological characteristics.

Recent advances in the availability of open geospatial data – including Earth observation satellite imagery, land cover datasets, national geoportals, volunteered geographic information and climate reanalysis products – offer new possibilities for building such integrated systems. However, the heterogeneity, volume and differing resolutions of these datasets present substantial challenges for automated analysis and operational decision support.

This paper presents initial research conducted within the UTOMIKA project, which started in 2025, focusing on the conceptual design of a data warehouse prototype for structured management, integration and analysis of geospatial data from multiple sources related to the detection and mitigation of UHI consequences. The study is based on data and data processing results for two major Croatian cities: Zagreb and Split. The aim of this research is not to create a data warehouse per se, but to determine the specific structure of data lakes (for certain types of related data) and data warehouses (a set of synergistic data lakes), and to determine the methodology for designing these systems for the purpose of creating an integral data system and the results of processing these data to assist in decision-making on preventing the occurrence or mitigating the impact of UHI on the environment in the areas of the cities of Zagreb and Split, Croatia.

2. Study Areas and Motivation

Zagreb (Figure 1) is the capital and largest city of the Republic of Croatia (the wider city area has about one million inhabitants). The climate in Zagreb is moderately continental, with hot and dry summers with average temperatures of 20 °C, while winters are cold with average temperatures of 1 °C.

Split (Figure 1) is the largest city in Dalmatia (central part of the eastern coast of the Adriatic Sea), and the second largest city in Croatia. Split has a borderline temperate warm humid climate with hot summers and a Mediterranean climate. Summers are hot, moderately dry, and winters are mild and humid. January is the coldest month with an average low temperature of around 5 °C, while July is the warmest month with an average high temperature of around 30 °C.

For a rapid and spatially explicit assessment of land surface temperature (LST) and the presence of urban heat islands (UHI), advanced remote sensing methodologies are employed. A wide

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UTOMIKA

ID	Data Type	Data Name	Source / Platform	Aim / Purpose	Data Format
1	Satellite image	Landsat mision	EartExplorer, https://earthexplorer.usgs.gov/	spectral indices (NDVI, NDBI), classification, UHI, LST, ECI	JPG, GeoTIFF
2	Satellite image	Sentinel (-2) mision	Copernicus Browser, https://browser.dataspace.copernicus.eu/?zoom=5&lat=50.16282&lng=20.78613&themeId=DEFAULT-THEME&visualizationUrl=U2FsdGVkX1%2FAkVBaPck%2BaS2JmiMdZf5OVXFoLwyRLb3X5LDDsnB0NpprvNXnZupq1V56Tn02kkQxWiDU%2F0vM3WwoKa5%2BgT5483ZwJMfM3SVi9QTGDP9niPQx5yF3ZFXe&datasetId=S2_L2A_CDAS&demSource3D=%22MAPZEN%22&cloudCoverage=30&dateMode=SINGLE	classification, spectral indices (NDVI, NDBI)	JPG, GeoTIFF
3	Satellite image	MODIS	NASA: https://modis.gsfc.nasa.gov/data/	LST	HDF4 / GeoTIFF
4	Vector data	administrative border of the city of Zagreb	Open Dana Portal: https://data.gov.hr/ckan/dataset/grad-zagreb-prostorna-jedinica	vector data for masking	SHP
5	Textual and graphical dana	meteorological data (air temperature, soil temperature, pressure, precipitation, wind)	Croatian Meteorological and Hydrological Service: https://meteo.hr/index_en.php	data analysis	PDF, DOC, JPG
6	Raster data	digital orthophoto, digital terrain models, stereo models,	DGU, Geoporetal: https://geoportal.dgu.hr/	classification, change detection, density and characteristics of objects	JPG, GeoTIF
7	Vector data	LIDAR data, 3D models	DGU, Geoporetal: https://geoportal.dgu.hr/	classification, change detection, density and characteristics of objects	LAS
8	Network data	digital orthophoto	DGU, Geoporetal: https://geoportal.dgu.hr/	better insight into the situation on the scene	WMS/WCS
9	Statistical data	population density, population structure, lifestyle	The Croatian Bureau of Statistics: https://dzs.gov.hr/en	data analysis	PDF, DOC, JPG
10	*In situ* Data	meteorological data (air temperature, soil temperature, pressure, precipitation, wind); temperature of objects (soil, buildings, vegetation)	They are entered manually into the database.	data analysis	PDF, DOC
11	Construction data	building materials and their thermal characteristics		data analysis	PDF, DOC

Figure 2. Extract from the data catalogue.

range of sensors acquire heterogeneous datasets that enable the evaluation of urban thermal conditions and their impact on the quality of life of city inhabitants. However, these data are typically distributed across multiple platforms, stored in different formats, and used for specific, isolated purposes. As a result, their full analytical potential remains largely underutilised. To overcome these limitations, the integration of diverse data sources is essential. This forms the core objective of the UTOMIKA project, which focuses on the detection and temporal analysis of UHI development in the cities of Zagreb and Split over the period from 1991 to 2026. By analysing long-term spatiotemporal patterns of UHI, the project aims to generate insights that support the conceptual design of a data warehouse prototype for the systematic detection, monitoring, and mitigation of UHI phenomena.

3. Methodological Framework and System Concept

The system being developed for UHI analysis and monitoring should be based on a workflow in which different data sets are first collected in their original form and then gradually harmonized and organized. Satellite imagery, land cover information, elevation models, meteorological data and urban morphology descriptors are fed into the system through unified input procedures that consider their different resolutions, formats and temporal characteristics.

After acquisition, data need to be aligned and standardized to address the inconsistencies typical of multi-source geospatial datasets. This includes coordinate transformations, transformations of different spatial resolutions, formatting of similar data, temporal alignment, alignment of land cover classifications and thematic attributes. The result is a coherent database suitable for integrated analysis. *In situ* data are used as true country data for internal validation of the obtained results and analysis of the usability of the results of remote sensing methods.

Remote sensing methods were used to calculate Normalized Difference Vegetation Index – NDVI (multispectral channels), LST (thermal channels of Landsat satellite systems) and Environmental Climate Index – ECI. In order to validate these results, during the satellite flyover over the study area (Zagreb and Split), *in situ* meteorological data (air temperature, temperature of individual objects on the scene, air pressure and humidity) were collected.

In order to make timely and adequate decisions to mitigate the impact of existing and/or prevent the creation of new UTOs, decision support systems (DSS) provide ecologists and urban planners with timely information and assist in sustainable development (Qureshi and Rachid, 2021; Mahdiyar et al., 2019). These systems rely on models and algorithms for multi-criteria analysis and data processing. Some of them are based on analytical hierarchy processes and other multi-criteria decision-making techniques or are combined with various management strategies (Jajac et al., 2019; Ivić et al., 2020).

3.1 Data Catalogue and Big data

As part of this study, a data catalogue (Figure 2) was created that contains all the necessary information for a purposeful system of monitoring, detecting and analysing UHI. The catalogue is the result of integrating geospatial, meteorological, urban, technical and administrative data with a defined metadata structure. It lists all the necessary data and their sources that are needed for this purpose. To create such a catalogue, it was necessary to define the goals and objects and phenomena to be monitored and analysed. In this case, these are: land surface temperature (LST), area under vegetation, state of vegetation (vegetation indices), urbanization (reduction of vegetation area at the expense of built objects), environmental critical index (ECI), detection of UHI, modelling of the occurrence of UHI. The data catalogue is directly connected to the data warehouse for monitoring and detecting UHI through a metadata module that will be designed by a selected open-source relational database management system (RDBMS), which will organize the data into tables.

Prepared results are available for visualization and application in decision support, including maps, interactive displays and scenario modelling. The overall system is designed to ensure consistency, repeatability and long-term operability – qualities essential for reliable urban climate monitoring and mitigation planning. Creating a catalogue is one of the contributions of this work. This enables transparent documentation of data availability, format, spatial and temporal resolution. The catalogue is organized into following thematic categories:

- Earth Observation Satellite Data – Thermal sensors from the Landsat 8 and 9 (NASA/USGS) and Sentinel-3 (Copernicus) satellite systems provide the ability to calculate LST (Figure 3) with resolutions of 30 and 1000 meters; multispectral sensors provide ability of calculating spectral indices (NDVI).
- Databases on land cover and land use – Cadastral plans, digital orthophoto, results of land use/land cover classifications already carried out that enable the differentiation of urban areas like buildings, asphalt, vegetation. Useful data for analysing existing UHIs include building height, materials, building density. This information is key to calculating the Environmental Criticality Index (ECI, Figure 4, Krtalić et al., 2020).
- Digital surface and terrain models – Digital surface models (DSM), digital terrain models (DTM) provide insight into urban morphology (density of buildings, street shapes and orientations, terrain slope and other factors that affect natural ventilation and heat accumulation. Data are available through the State Geodetic Administration (DGU).
- Meteorological data – The Croatian Meteorological and Hydrological Service provides meteorological data collected through its network of permanent stations throughout the Republic of Croatia.
- Administrative data – data on administrative boundaries of cities, population density, traffic, energy consumption and similar data.

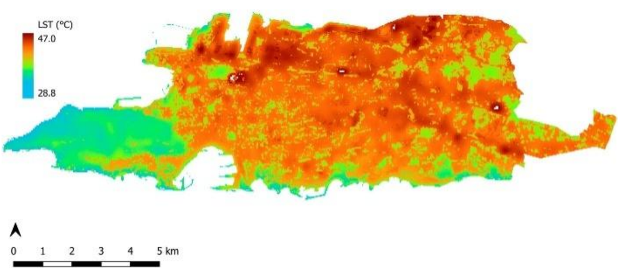

Figure 3. Spatial distribution of land surface temperature (LST) in the city of Split on the 19 July 2024 (Ćesić et al., 2025).

The catalogue defines metadata standards, data formats (GeoTIFF, NetCDF, GeoJSON, WMS/WCS), access methods (API endpoints, direct download), data sources, temporal coverage and licensing conditions, supporting sustainable long-term operation of the data warehouse.

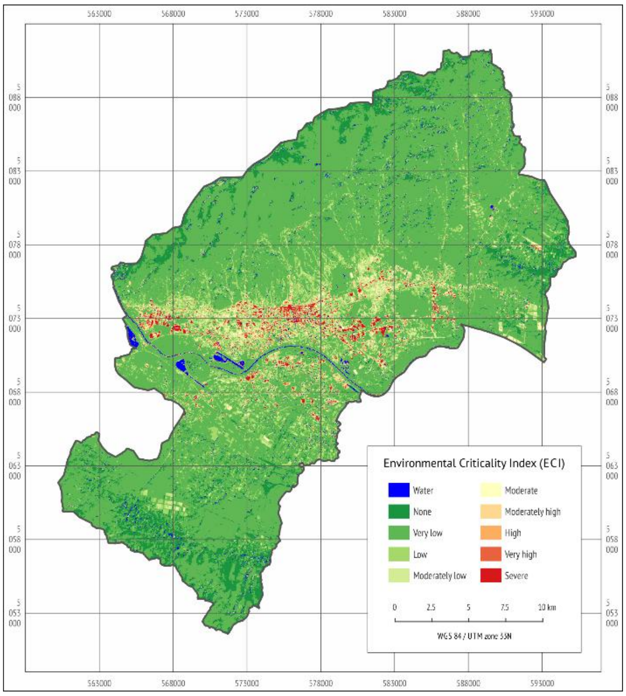

Figure 4. Environmental criticality index (ECI) in the city of Zagreb during 2017 (Krtalić et al., 2020).

Today's technological advancements in computer development enable the use of machine and deep learning applications with large amounts of data (Big Data) which is becomes the foundation of an intelligent society (Rao et al., 2019, Ribeiro et al., 2020). However, to facilitate the process and shorten the processing time (due to time efficiency) of this advanced technology, it is advisable to create smaller data sets for special purposes; in this case, for monitoring UHI. Special purpose data warehouses are a good choice for this purpose. Data storage enables the selection and processing of large amounts of data from various sources, the results of which are provided to experts for analysis and decision-making for UHI manipulation.

3.2 Data Warehouse and Decision Support System

Data warehousing is one of the most active branches of database research, development and application and plays a major role in the quality use of DSS (Zhao et al., 2024). In their paper, Salinas and Lemus (2017) show the differences and areas of convergence between big data and data warehousing and explore the convergence in the strategies of the two technologies. DSS, unlike data warehouses, use summarized information, the results of appropriate processing (in this case metadata: meteorological data, population density, building density; calculated data: LST, NDVI, ECI), patterns and trends in multi-criteria analyses whose results are intended to assist ecologists and city authorities in the decision-making process on mitigating or preventing the occurrence of UHI. The most used DSSs are oriented towards databases with well-structured data, such as data warehouses (Gupta and Sahayadhas, 2020).

Based on the nature of the data it processes, the data warehouse will be designed in the Online Analytical Processing (OLAP) type. The database formed in this way will be used to analyse current and historical data (historical data on the creation and changes of UHI, and current data on the state of UHI). It uses a data warehouse. In an OLAP database, most tables are in a non-normalized form. A top-down approach was chosen for designing

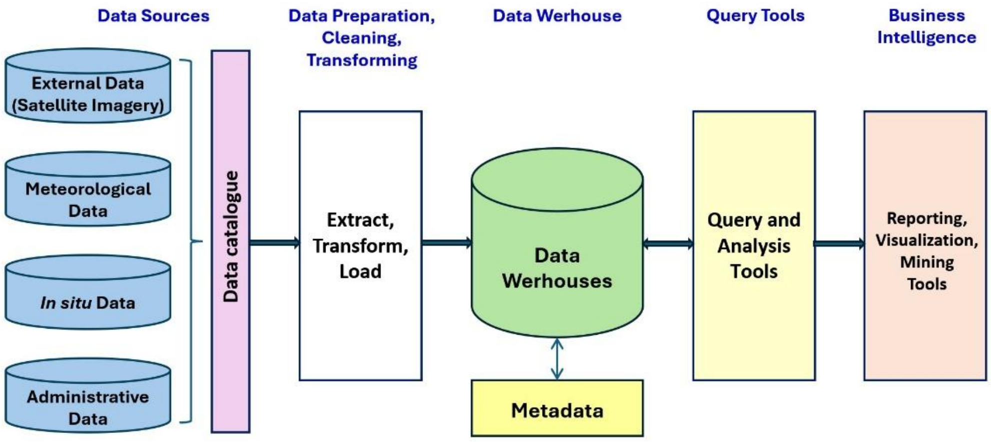

Figure 5. Data warehouse architecture.

the data warehouse. This approach was chosen because data and results are the most important part of the system that can later be transformed for other purposes. The first and main process is the collection and integration of data as a centralized repository, and then, according to the requirements of experts in ecology, urban planning, agronomy, this data is classified and structured and stored. The advantage of this approach is to support a single integrated data source that can be used for other areas (besides UHI management, for example, for monitoring urbanization, the state of urban vegetation, transport infrastructure).

Users dealing with the problem of the UHI phenomenon need certain specific types of data (satellite images, spectral characteristics of objects, certain meteorological data, land cover) but also some general ones, which are also used by other users (administrative boundaries of cities, digital orthophoto, digital terrain model). The type of data also defines specific processing methods and analytics. The data used to monitor UHI has all the characteristics of Big Data. The amount of data for this purpose is growing exponentially (this mostly applies to satellite data) and results are intensively produced from endogenous and exogenous sources. Endogenous data is collected from operational systems, test results, sensors, meteorological stations, satellites and agricultural equipment. Exogenous data refer to external sources (for example: government agencies, construction sector). The data used in this system comes in various forms and formats (structured and unstructured data, images, geospatial data, mathematical formulas and text. The amount of data produced and collected is growing rapidly (existing sensors that are freely available collect satellite images 24/7, and there are many commercial sensors and those that are yet to be launched). In addition, existing data must be validated and harmonized with newly generated data, as well as removed if they are no longer needed. Since the huge amount of data comes from different heterogeneous sources, is prone to uncertainty, inconsistency, ambiguity and errors, the data entering this system must be validated before standardization and storage. Because of all the above, the future data warehouse must be 'elastic' so that it can be quickly changed and supplemented with new data and results.

3.3 Architecture of a Data Warehouse

A common data warehouse architecture consists of: a central data repository surrounded by key data warehouse components for a specific purpose. This makes the system functional, manageable, and accessible. Such a system contains historical and current data from multiple sources (Nambiar and Mundra, 2022). There are basically three types of data warehouse architectures (Software Architecture, 2026):

– Single-tier architecture – all the required components for the working of application are available under the same package.
– Two-tier architecture – the user interface layer and the database layer are located in two different machines.
– Three-tier architecture – the business layer and the database layer are located in separate machines. Unlike 2 tier architecture, 2 servers perform the major tasks in this application. One server is for the business layer and the other is the database layer.

The single-tier model minimizes the amount of data stored and helps eliminate data redundancy. Although this type of data warehouse architecture is not often used in practice, because its disadvantage is the lack of a component that separates analytical and transactional processing (Nambiar and Mundra, 2022) it was chosen for this purpose.

The main idea is to design a specific centrist system for a specific purpose: determining, mapping, monitoring and visualizing UHI. Only micro location results will be stored in the system, and data from external sources will be used. For example, Google Earth Engine applications will be used for NDVI and LST calculations only in the administrative boundaries of the cities of Split and Zagreb (with open satellite data) and will be stored in the database. Therefore, the storage of existing external databases will be used, and the data will be entered into the system via the data catalogue, which is an integral part of the database of the data warehouse.

The proposed data warehouse architecture for managing UHI consists of a central information repository surrounded by key components (Figure 5):

– Data Sources: data catalogue – list of input data for all necessary calculations and analyses (mostly satellite images in open access (Landsat missions, mostly) that would take up a lot of space in the database, and are already stored in external repositories),
– Extraction, Transformation, and Loading (ETL) tools – conversions, compressions, and changes required to transform data into a uniform format within the data warehouse (Nambiar and Mundra, 2022),
– Data Warehouse Database – central unit for storing data and processing results,

- Metadata – define data and data warehouse (Rousidis et al., 2014),
- Query and reporting tools – allows users to query the data warehouse and generate reports and visualizations,
- Reporting, visualization, mining tools – dissemination and visualization of processing results.

The foundation of a data warehouse environment is a central database that houses transactional databases and routines for data storage methods, since a traditional Relational Database Management System (RDBMS) is optimized for processing transactional databases, not for data storage (Phaneendra and Reddy, 2013). At this stage of the project research, and thus in this paper, attention will not be paid to detailed considerations of technical details and methods for creating databases. This will be approached after collecting the planned results and experience in achieving them. However, since the priority in building a data warehouse is optimized query performance with simplified retrieval and analysis of heterogeneous data and that relational databases need to be implemented for data storage, a star schema was chosen as the schema model (Kimball, 1996). Star schema is more commonly used in data warehousing environments compared to snowflake schema due to its simplicity and better query performance with simplified data retrieval and analysis. In this way, it can better respond to the challenges of data warehousing for the management of UHI and their environmental impacts.

Within the database, conversion and transformation tools are used to extract, transform all data of the same type into a single format, and store the data in the data warehouse. These tools generate routines and various programs that regularly update the data in the data warehouse, and help maintain metadata (Nambiar and Mundra, 2022). ETL (Extract, Transform, Load) represents the traditional approach to data warehousing and analytics, whereas ELT (Extract, Load, Transform) is a more recent paradigm (ELT, Gupta and Sahayadhas, 2020). The key methodological difference between these two approaches is the order of the procedures that are carried out. ETL first extracts data from various heterogeneous sources, then transforms it, and after transformation, loads it into the data warehouse database, while ELT first extracts data from various heterogeneous sources, loads it into the data warehouse database, and finally transforms it and forwards it for analysis. Since ELT is more efficient than ETL, it was chosen as the tool to be used in the data warehouse database for processing and preventing UHI. With ELT, users store raw data in one place and can also apply new or different transformations or improve queries according to requirements (Gupta and Sahayadhas, 2020).

Metadata (data about data) defines a data warehouse and helps in building, maintaining and managing a data warehouse (Rousidis et al., 2014). Metadata plays an important role in transforming data into knowledge, as it defines the source, use, values and characteristics of a data warehouse and how to update and process data within it. A category of metadata known as: technical metadata, contains information about the warehouse, and another, called 'business metadata' contains details for end users to understand the information stored in the data warehouse (Nambiar and Mundra, 2022).

Querying tools allow users to 'communicate' with the data warehouse in order to create new data from raw data (in situ data or data from) relevant to the procedures of discovering, mapping, extracting and visualizing the locations and impacts of the UHI phenomenon, so that area experts who are related to this phenomenon (ecologists, urban planners) can make strategic decisions.

4. Conclusion

This paper presents the findings and decisions related to the conceptual design of a data warehouse prototype for the detection, mapping, monitoring, and visualisation of urban heat islands (UHI) in the cities of Zagreb and Split, Croatia, within the framework of the UTOMIKA research project. It establishes the theoretical foundation for the further development and detailed structuring of the proposed data warehouse.

To create a purposeful data warehouse for the detection and monitoring of existing and prediction of the creation of new UHIs (with a focus on the cities of Zagreb and Split, Croatia), it was necessary to well define the needs of the end user, define the list and types of all necessary data, and create a catalogue of providers of this data. The goal of this research is not to create a data warehouse per se, but to determine the specific structure of data warehouses for the purpose of creating an integral data system and the results of processing these data to assist in decision-making on preventing the occurrence or mitigating the impact of UHI on the environment in the areas of the cities of Zagreb and Split, Croatia.

One of the main contributions of this research is the creation of a catalogue of open-access data providers in which the types of data and the results of processing the original data are defined, and structured accordingly and stored in specific data warehouse and offered to experts of various profiles related to this phenomenon as an aid in decision-making, with a special focus on the aforementioned areas (Zagreb and Split). Furthermore, the data warehouse will be designed in the Online Analytical Processing (OLAP) type with the single-tier model architecture. According to the selected architectural design and the need of the data warehouse, a star model was chosen for schema modelling. Within the data warehouse database thus designed, the Extract, Load, Transform (ELT) tool will be used, which was decided to be better suited to the type of task.

In the further research within the UTOMIKA project, connections will be established between the most suitable method of creating a data warehouse and the way to visualize and display the results of data processing will also be determined, based on knowledge of the needs of users and the specifics of the areas of the cities of Zagreb and Split (climatic and meteorological parameters, settlement structures, building materials, terrain configuration, areas under vegetation). Validation of the effectiveness and usefulness of the entire system will also be carried out.

Designed as a foundation for future monitoring mechanisms, planning tools and mitigation strategies, the proposed system also aims to promote the broader use of open geospatial data in environmental and urban climate research. Its reproducibility and transparency should contribute to establishing a stable framework for further research and for practical applications in climate-resilient urban development.

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