University of Tehran

Earth Observation and Geomatics Engineering Online ISSN: 2588-4360

Homepage: https://eoge.ut.ac.ir/

Improving Regional Budgeting: An Ontology-Based SDSS Framework for Fair Resource Allocation

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Article Info

Article type:
Research Article

Article history:
Received 2025-01-09
Received in revised form 2025-03-08
Accepted 2025-03-09
Available online 13 May 2025

Keywords:
Budget formulation, resource allocation, SDSS, Regional equity, recommendatory system.

ABSTRACT

To ensure fair budget distribution across the country, equitable resource allocation is crucial. This involves using budget planning informed by land use data to tailor fund allocation to the unique characteristics of each region. Spatial data has recently become vital in decision-making for various projects, including land use planning and disaster management, enhancing implementation across management domains. Resource allocation is inherently complex due to its dependence on diverse factors, often viewed as semi-structured problems. Addressing these decision-making challenges requires integrating the spatial dimension into the processes. Consequently, technological solutions like Spatial Decision Support Systems (SDSS) have been developed to improve decision-making in budget and resource allocation, which is a sensitive issue across different levels of society. In this study, decision-making techniques based on qualitative analysis have been applied in the field of resource allocation and budgeting. Therefore, using spatial decision support systems (SDSS), the climatic, industrial, natural, political, and other characteristics of various regions in the country have been categorized based on specific qualitative parameters. The resource distribution functions for different regions have been established in the system's inference engine, taking into account various characteristics and using decision-making logic. The results indicate that the use of this system leads to appropriate resource allocation while considering regional features. In particular, it provides recommendations for budget allocation in underdeveloped or border areas to enhance security and, in general, addresses the deficiencies of traditional resource allocation methods that do not take these factors into account.

Cite this article: *Rezaee, Z. and Rabiee, F. (2025). Improving Regional Budgeting: An Ontology-Based SDSS Framework for Fair Resource Allocation. Earth Observation and Geomatics Engineering, Volume 8 (Issue 1), Pages 77-88. http//doi.org/ 10.22059/eoge.2025.388553.1165*

Publisher: University of Tehran.

DOI: http//doi.org/ 10.22059/eoge.2025.388553.1165

1. Introduction

Iran is notable for its diverse geographical characteristics, climatic conditions, and distinctive water and land resources, which collectively generate unique economic capacities across its regions. A significant challenge for officials and economic and social experts has been the recognition of these differences within development programs, especially in the context of formulating annual budgets for various regions. Effective planning methods for budget formulation and resource allocation are critical indicators of growth and development. These methodologies are essential to maintaining the necessary level of services, thereby fostering sustainable community development (Seyedrezaei et al., 2017; Azar et al., 2015; Makhdoom, 2021).

Spatial planning strategies, which prioritize role allocation and feasibility assessments for each area, facilitate the optimal utilization of resources to improve material and spiritual conditions within defined territories. This approach seeks to systematically utilize the advantages of the natural, social, and economic environment, establishing logical relationships between population distribution and activities based on the spatial characteristics of each region. In Iran, development programs spanning various sectors economic, industrial, social, and cultural have largely adhered to a center-periphery model (First Development Plan of 1988, Second Development Plan of 1993, Third Development Plan of 1999, and Cultural Policies of 1999). This has resulted in the concentration of cultural facilities in major cities, notably Tehran, while border and remote regions face cultural deprivation and resource shortages. Historical planning failures can often be traced back to a lack of consideration for local natural and social conditions and the dynamics between behaviors and ecosystems (Sarafi, 1998; Makhdoom, 2021; Iran Land Use Planning Document, 2020).

A vital tool for the Iranian government in promoting equitable development is the public budget, which serves as a primary means for establishing justice within the national geographical framework (Seyedrezaei et al., 2017; Mirzazadeh & Parizadi, 2018). Neglecting regional justice can exacerbate poverty, increase class and regional disparities, and lead to marginalization and environmental crises, thereby heightening social and ethnic unrest. The discourse on regional justice focuses on unfair distribution while advocating for equity for both communities and individuals (Seyedrezaei et al., 2017; Qazi & Taheri, 2014; Schlosberg, 2007). The necessity for accurate and up-to-date spatial data has become increasingly emphasized within various decision-making and management processes. This data is crucial for numerous areas, including land use planning, disaster management, natural resource management, and transportation planning. The effective incorporation of spatial data directly influences the quality of societal management and the overall enhancement of individuals' life quality (Schlosberg, 2007; Cory et al., 2012). Therefore, it is imperative that governments employ effective planning strategies grounded in high-quality data to maximize resource utility and implement optimal resource management.

Iran's pursuit of balanced development is confronted with several challenges, including significant disparities in economic resource distribution. These inequalities have left underprivileged areas without essential economic and social infrastructure, exacerbated by the primary focus on metropolitan development, particularly in Tehran. Geographic disparities complicate equitable development due to varied geological features that impact infrastructure feasibility and service allocation. Furthermore, social, cultural, and climate-related inequalities hinder sustainable growth and development opportunities.

The primary challenge Iran faces in achieving balanced regional development lies in the significant disparities in resource distribution and the lack of effective planning strategies to address these inequalities. Despite its diverse geographical and economic potential, the country has struggled to allocate resources equitably, leading to underdevelopment in remote and border regions. This disparity is compounded by the historical adoption of a center-periphery development model, which has concentrated resources and infrastructure in major cities like Tehran, leaving peripheral regions with limited access to essential services and economic opportunities.

It is important to clarify that resource allocation, as addressed in this study, encompasses a broad spectrum of resources, including economic, environmental, and social resources. This comprehensive approach ensures that the proposed framework is adaptable to various allocation needs, whether financial, environmental, or social. For instance, the framework can be applied to budget and financial resource allocation for regional development, as well as to planning and development programs aimed at managing environmental resources such as green spaces and coastal areas. Additionally, it can be utilized for social resource allocation, ensuring equitable access to community development programs. This versatility underscores the framework's ability to integrate diverse resource allocation strategies, thereby promoting a holistic approach to sustainable development.

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underscores the framework's ability to integrate diverse resource allocation strategies, thereby promoting a holistic approach to sustainable development.

To overcome the challenges of regional disparities and equitable resource allocation, a comprehensive and participatory approach is necessary. This involves conducting extensive research to understand regional differences and resource distribution patterns. Spatial Decision Support Systems (SDSS) offer a promising solution by utilizing geographic and social data to enhance decision-making and resource management. SDSS provides a structured framework for analyzing resource allocation and its distribution across regions, ensuring equitable solutions that support sustainable development. By integrating ontologies, which organize data and information, SDSS can enable more precise analyses of regional needs, economic potentials, and geographical, social, and economic differences. This allows for optimized resource distribution, improving the quality of life across regions and serving as a practical model for other countries to address inequalities and promote sustainable development. Further research is essential to tailor this framework to the unique characteristics of each region, ultimately establishing an effective system for identifying regional needs and economic capacities. This integrated approach not only advances decision-making but also contributes to sustainable development and regional equity.

This study distinguishes itself from similar research by focusing specifically on the unique geographical, cultural, and socio-economic challenges of Iran, which have not been fully addressed in previous studies. While existing literature often provides generalized approaches to resource allocation and regional development, this study offers a tailored framework that integrates the heterogeneous characteristics of Iranian regions. By incorporating advanced spatial analysis techniques within the SDSS framework, this research provides more precise and context-specific strategies for resource allocation. Furthermore, the study's emphasis on fostering evidence-based decision-making and its practical, policy-oriented approach set it apart from more theoretical or less regionally focused studies. The proposed solutions aim not only to address regional inequalities in Iran but also to serve as a replicable model for other countries facing similar challenges, thereby advancing global efforts toward sustainable and equitable development.

2. Literature Review

Numerous studies have explored regional justice, budget distribution, and resource allocation, involving both international scholars and domestic institutions. There is widespread recognition of the necessity for spatial and regional planning to address the uneven growth and development across regions. Effective strategies must consider regional criteria, capabilities, and limitations. For example, research emphasizing Nancy Fraser's social justice theory highlights systemic factors contributing to inequalities in resource allocation and the importance of tailored policies that reflect local conditions. Studies from European institutions further indicate that persistent regional disparities signal untapped growth potential, advocating for targeted interventions in underperforming areas to enhance economic performance. Similarly, the World Bank emphasizes the significance of recognizing spatial dimensions in economic growth to promote connectivity in weaker regions. In Iran, research underscores the critical role of appropriate budget distribution in achieving equitable development. Findings reveal that neglecting regional justice exacerbates poverty and social inequalities, prompting the need for participatory budgeting that addresses unique regional needs. Additionally, the increasing importance of spatial data in decision-making processes signifies its potential to inform resource allocation and enhance public policy effectiveness. Geographic Information Systems (GIS) serve as essential tools for visualizing spatial trends, aiding policymakers in informed infrastructure and service distribution decisions.
In summary, the studies reviewed highlight the urgent need for comprehensive strategies that foster regional equity and effective resource allocation. An approach grounded in spatial data and an understanding of regional dynamics is essential for achieving balanced development (Van et al., 2020; Kostovicova, 2017; Morello et al., 2002; The Justice Gap Report, 2022). The subsequent section will analyze relevant studies and their implications for improving regional justice and resource management.

Fisher et al. (2006) conducted a study examining the spatial pattern of hazardous industrial sites and the implications of environmental justice in coastal areas of the United States. In this study, they assessed environmental justice across multiple spatial scales using spatial analysis methods. Additionally, by integrating Geographic Information Systems (GIS) with air dispersion models, they were able to identify the number of individuals potentially affected by a specific facility. They also addressed the issue of non-point sources of diesel emissions by analyzing street network data (Fisher et al., 2006).

Silva et al. (2018) conducted a study examining the concept of environmental justice in the distribution of public green spaces in two different study areas: Tartu in Estonia and Faro in Portugal. In this research, they calculated quantitative indicators of public green space in urban areas and assessed the level of access to these spaces. The results indicated that access to public green spaces in different cities is unequal, and urban areas require targeted new green infrastructure development programs to establish environmental justice and achieve a balanced distribution of green spaces across urban neighborhoods (Silva et al., 2018).

In another study conducted in 2020, Kobulov analyzed the key factors in the development of local-level revenue generation strategies. The author emphasized the importance of strategic planning to enhance the revenue potential at the local level, stating that this process can lead

to improved quality of life and public services in communities. The study reveals that the lack of a comprehensive approach in financial resource allocation can hinder the sustainable and efficient development of social services. The paper discusses analytical frameworks and mathematical models, stressing the necessity of financial data analysis for revenue forecasting. The conclusion of the study highlights the importance of understanding the specific characteristics of each region for the effective attraction and allocation of financial resources. It also points to the need for designing projects related to the optimization of local financial structures and the synergies between local governments and research centers to achieve these goals (Kobulov, 2020).

Carvalho et al. (2022) conducted a study on the effects of domain diversity in environmental patterns, addressing the issue of injustice by analyzing the statistical relationships between socio-economic marginalization and environmental vulnerability across three different domains: urban areas, municipalities, and districts. In this research, they created an integrated database utilizing census data and then performed a regional weighted interpolation method. By combining census data with sensitivity data of areas prone to landslides, they conducted a multivariate k-means clustering analysis. The results from this analysis indicate that risk-reduction infrastructure in the environment has a socio-spatially unequal distribution. Therefore, it is crucial for policymakers to consider such complex variables in order to find solutions to address the increasing inequalities caused by environmental changes (Carvalho et al., 2022).

Alsahli et al. (2022) proposed a multi-criteria model based on GIS to assess environmental justice, which can be used to identify factors influencing the spread of environmental justice, considering the specific nature of the studied region. In this study, the proposed model was applied to the urban area of Kuwait using four criteria: proximity to industrial areas, major roads, high-traffic zones, and green spaces. Additionally, the spatial relationship between these criteria and different demographic groups was examined to assess environmental equity among these groups. The findings of the study indicated that industrial blocks, concentrated and surrounded by residential areas, are one of the most significant factors reducing the environmental justice index and creating inequality in its distribution within urban blocks (Alsahli & Al-Harbi, 2022).

In another study conducted in 2024, Samorodov and Polovynko proposed a scientific-practical framework for optimizing budget allocation to support sustainable regional development based on activity-logistics principles. Their model prioritizes strategic resource distribution to high-impact sectors, ensuring efficiency, regional adaptability, and balanced expenditure across key development domains. The study integrates critical aspects of regional sustainability, including public health, environmental protection, education, social welfare, and economic equity. Findings highlight the significance of data-driven decision-making and adaptive budgeting strategies in mitigating regional disparities and fostering long-term sustainable growth (Samorodov & Polovynko, 2024).

In a recent study, Gumilar et al. (2024) investigated budget allocation disparities within village governance and their implications for community welfare. The study examines the impact of budget inequality on perceptions of social justice, emphasizing ethical considerations and principles of fairness in budgetary decision-making. Findings suggest that inequitable distribution, particularly in direct cash assistance programs, exacerbates social and economic disparities at the village level, highlighting the need for more just and transparent budget allocation mechanisms (Gumilar et al., 2024).

Alogdianakis and Dimitriou (2024) conducted a study examining the equitable allocation of financial resources in public transportation services. This research emphasizes the importance of considering social justice aspects in the budgeting process and explores multi-objective optimization approaches and mosaicking techniques. Initially, the concept of mosaicking (segmentation) is introduced as a tool for dividing urban space into smaller sections, enabling a more detailed analysis of resource distribution and allocation. This method helps planners identify areas with limited access to transportation services. The study also discusses multi-objective optimization techniques, which can help balance various goals such as cost-efficiency, service coverage, and justice. Finally, emphasizing the importance of demographic data and travel patterns, the authors suggest that integrating justice aspects into budgeting models can lead to more equitable resource allocation and improve transportation conditions in less-developed areas (Alogdianakis & Dimitriou, 2024).

Collin et al. (2018) developed a conceptual model to assess environmental justice in the context of flood risk in urban areas of Miami, Florida, and Houston, Texas, USA. The findings of this study indicate that in coastal and port cities, environmental injustices are exacerbated when individuals with higher social status, who have the ability to seek out coastal amenities for choosing residential locations, expose themselves to flood risks. In this process, vulnerable residents of the community are displaced to areas with air pollution and/or the risk of internal flooding. In non-coastal areas, such as Houston, the occupation of coastal lands by petrochemical industries has led vulnerable populations to settle in flood-prone zones, resulting in significant residential and environmental dissatisfaction in these areas. Ultimately, the authors acknowledge that, regarding the complex environmental consequences of flooding, researchers have concluded that multi-scalar perspectives on how injustices are distributed through limiting and powerful forces should be adopted (Collins et al., 2018).

Seyed Rezaei et al. (2017) conducted a study on the factors influencing the growth and development of equitable economic justice in the country. By identifying significant

factors within Iran's budgeting system aimed at achieving regional justice, they addressed semi-structured issues and determined the parameters affecting the budget level and the importance coefficients of these parameters (Seyedrezaei et al., 2017). Perizadi and Mirzazadeh (2018) explored regional development in the provinces of the country using factor analysis and cluster analysis techniques. They classified the provinces hierarchically based on their level of development, taking into account the potential and capabilities of each region, and emphasized the need for appropriate planning to prioritize deprived and less-developed provinces in resource allocation strategies (Mirzazadeh & Parizadi, 2018).

Ghazi and Taheri (2014) conducted a study comparing and contrasting the spatial planning programs of Iran and South Korea. They examined the historical evolution of spatial and regional planning, theoretical frameworks of spatial planning programs, the legal foundations of physical plans, and comprehensive land use plans in both countries using library research methods. The analytical results of this study indicate that Iran has not successfully implemented regional planning programs due to the lack of timely and proper execution of these plans (Qazi & Taheri, 2014). The objective of this study is to consider the budgeting and allocation of the country's public budget in alignment with achieving regional justice, using a recommendation-based approach by employing smart technologies and expert systems.

In the context of regional justice, the regional dimensions that should be prioritized for its development include the establishment of regional infrastructures, taking into account comparative advantage, capacity, and regional potential. Numerous and highly diverse factors related to the capacities of different regions can be considered, each of which may play a crucial role in the formulation of budget and resource allocation strategies (Mirzazadeh & Parizadi, 2018; Qazi & Taheri, 2014; Iran Land Use Planning Document, 2020).

3. Theoretical Foundations: SDSS and its application to resource allocation

Issues such as the appropriate allocation and distribution of resources are highly complex due to their dependence on and interrelationship with numerous and diverse factors, and fall into the category of semi-structured problems. Issues such as the capacity of existing infrastructure and its planning to meet quality of life requirements and necessary improvements require organization and management, where Decision Support Systems (DSS) can play an important role. Effective planning based on high quality information can maximize the benefits derived from the allocated resources by implementing appropriate infrastructure in appropriate locations (Azar & Ghodrazi, 2015; Mirzazadeh & Parizadi, 2018). The use of Spatial Decision Support Systems (SDSS) bridges the gap between policy makers and complex computational models, with evidence suggesting that such integration has a positive impact on the performance of decision makers (Keena & Jankowski, 2019).

One of the most important applications of GIS and SDSS is the provision of regional justice and assisting in budgeting based on regional justice indicators and service delivery to the population. There is a clear need for a system to support decision-making and offer solutions using GIS technology and knowledge management. The use of ontologies and reasoning engines in SDSS provides an effective tool for optimizing existing conditions and achieving the best possible outcomes (Keena & Jankowski, 2019; Mao & Li, 2011). Consequently, ontology-based SDSS approaches can be applied in budgeting and spatial planning systems. This requires defining ontology rules based on the features and relationships present in the system, which facilitates the extraction of concepts and documentation in this context (Lamy, 2021; Horridge et al., 2009).

In general, ontologies are developed to facilitate information sharing, knowledge reuse, and domain knowledge analysis. The components of these ontologies typically include classes, individuals, attributes, relationships, and rules. Logic in computing plays a critical role in enabling reasoning capabilities, and ontologies provide the means to represent and reason about various forms of knowledge (Lamy, 2021). In this context, spatial planning and its objectives must be examined. The appropriate allocation of resources and budgets, considering the characteristics of different regions, is carried out based on several specific dimensions and criteria. For instance, factors such as deprivation levels and distance from the center are considered fundamental influences in the regional context. The implementation of infrastructure projects in less-developed regions is of significant importance, as these projects serve as the primary channels for creating service capacities within the community and play a crucial role in achieving territorial justice (Seyedrezaei et al., 2017; Azar et al., 2015; Sarafi, 1998). On the other hand, the public budget is one of the key tools for the government in promoting equitable development at the national level. A disregard for regional justice can lead to exacerbated poverty, inequality, and social and environmental crises (Seyedrezaei et al., 2017; Qazi & Taheri, 2014; Schlosberg, 2007).

Finally, the recognition and understanding of the importance of geospatial data in management decision making and planning has gained significant attention. Accurate and timely spatial data are critical for crisis management, resource development, and environmental protection. Therefore, the adoption of spatial planning approaches in resource allocation and budgeting is essential as it can contribute to improving regional equity and ensuring effective resource allocation (Klamroth & Wiecek, 2001; Keena & Jankowski, 2019). In this paper, while considering the aforementioned aspects, the concept of spatial planning and its objectives are examined. Decision-making techniques based on qualitative analysis

are applied in the context of appropriate resource and budget allocation, taking into account the characteristics of different regions from multiple perspectives, as illustrated in Figure 1.

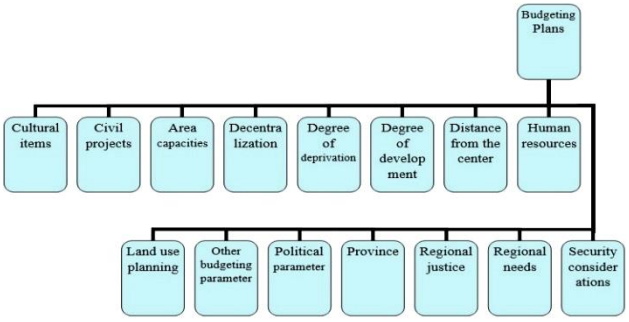

Figure 1.Some parameters considered in the ontology of the budgeting system framework

4. Methodology

4.1. Study Area

To identify strategic planning approaches across various domains, including environmental conservation and industrial development, Gilan and Markazi provinces were selected as case studies due to their distinct characteristics (Figure 2). Markazi province, positioned centrally in Iran, is highly conducive to industrial progress due to its geopolitical location, proximity to major cities and the capital, and access to Iran's western corridor. Resource and budget allocation in Markazi Province is strategically designed to bolster industrial expansion and agricultural investments, alongside addressing environmental concerns such as land degradation. Gilan province, located in northern Iran, is rich in agricultural resources. Gilan serves as a model for evaluating budget allocation strategies focused on environmental preservation and tourism development. Resource and budget allocation in Gilan necessitates optimized management and careful planning, especially for water resources and infrastructure development, to mitigate waste and adverse impacts. Strategic land-use and budget allocation plans for both provinces, derived from logical budget estimation processes, include environmental and natural resource conservation, industrial site selection, and tourism sector development.

Furthermore, the platform is designed to be adaptable to different regions by defining their specific characteristics within the ontological framework. These characteristics may include geographic, political, cultural, industrial, economic attributes, and so on. As long as these attributes are well defined for a region, they can be logically encoded into the system, allowing the platform to be applied to different regions, both within Iran and internationally. This flexibility ensures that the platform's utility extends beyond the selected case studies of different provinces, demonstrating its potential for broader applicability in different contexts.

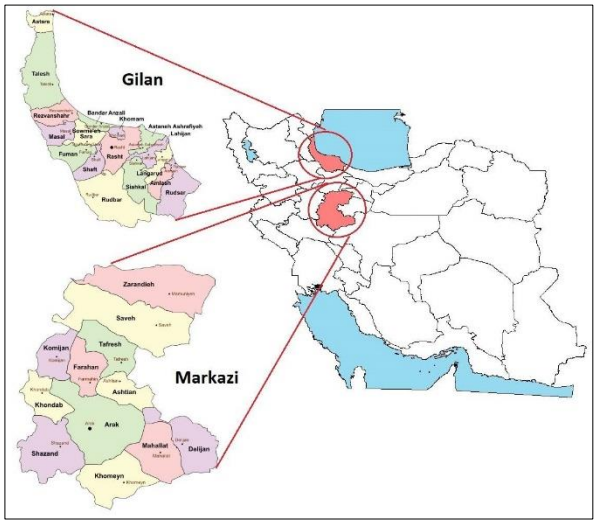

Figure 2. The study area

4.2. Modeling and System Architecture

Given the specifications that the system in this study must meet, the overall architecture of the system, as shown in Figure 3, should initially be based on a client-server architecture.

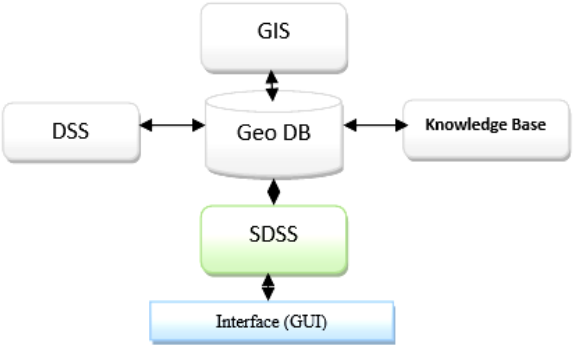

Figure 3. The overall architecture of the system, integrating GIS, geodatabase, and SDSS components

This study presents an innovative ontology-based SDSS for optimized budget allocation. By leveraging logical relationships among regional equity, land-use indicators, and spatial dynamics, the system enhances resource distribution. It utilizes OSM data for mapping and the Owlready library for ontology-based reasoning. Budget distribution is guided by user-defined parameters, including geographic location and land-use priorities, structured using the Analytical Hierarchy Process (AHP). Logical relationships between spatial factors and budget levels are established through Semantic Web Rule Language (SWRL) within an OWL knowledge base. The system generates

budget recommendations and spatial allocations based on user inputs and predefined criteria (Table 1).

Table 1. Criteria and Sub-Criteria for Resource Allocation

Criterion	Sub-Criteria	Description
Geographical Characteristics	*Administrative Divisions (Province, County), Political Stability, Security Situation, Governance Effectiveness*	*These characteristics are considered political factors affecting the security and well-being of budget distribution.*
Political Characteristics	*Administrative Divisions (Province, County), Political Stability, Security Situation, Governance Effectiveness*	*These characteristics are considered political factors affecting the security and well-being of budget distribution.*
Social Characteristics	*Population Density, Education Levels, Income Levels, Employment Rates, Social and Cultural Attributes, Health Indicators, Access to Services (Healthcare, Education, Infrastructure)*	*These factors relate to the social and economic conditions of the population in each region.*
Industrial Characteristics	*Existing Industries (Type, Size), Industrial Potential, Infrastructure (Transportation, Energy), Investment Climate*	*These factors relate to the current industrial landscape and the potential for future industrial growth in each region.*

The budgeting parameters based on spatial planning factors and regional justice (such as provinces, proximity to the center, spatial planning, etc.), as shown in Figure 1, are provided to the user, who can select or adjust any of these values. Finally, the system returns the appropriate budget levels based on the user's request, taking into account the factors provided by the user. Figure 4 illustrates the components of the system architecture for this research in greater detail.

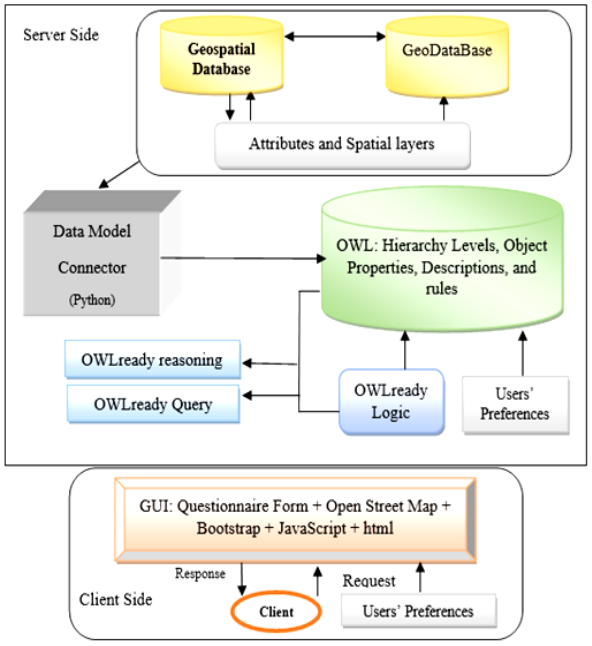

Figure 4. Architecture of an Ontology-Based (SDSS)

Owlready enables ontology-based programming, which is object-oriented programming where objects and classes represent entities within an ontology. This library offers the following capabilities (Lamy, 2021):

- *Representation of formal ontologies, in other words, the ability to address complex details of knowledge, their interrelationships, and knowledge reasoning.*
- *Fast access to relational databases with rapid storage and search capabilities.*
- *Support for object-oriented programming languages, such as Python, to execute essential lines of code to instruct the computer, a capability that cannot be achieved solely through the use of an ontology or a database.*

Furthermore, in the client-side section of the system, OSM data, along with Bootstrap and JavaScript, are utilized for mapping and displaying the geographic locations of the centers under review. Using these tools, the system's design and graphics are managed, enabling the display of the locations of the centers on the map. Ultimately, the selected output is presented to users in the form of marked points with specified locations and associated descriptive fields.

4.3. Implementation and execution

This study addresses regional inequality in Iran by implementing a Spatial Decision Support System (SDSS) that optimizes resource allocation. The proposed SDSS leverages an ontology to structure knowledge regarding regional characteristics and their influence on resource needs. A participatory approach, facilitated by a user-

friendly interface, promotes transparency and allows stakeholder input, ensuring that resource allocation is responsive to local needs. The SDSS utilizes this structured knowledge and stakeholder input to generate targeted budget recommendations. Pilot tests demonstrate the effectiveness of this ontology-driven, participatory SDSS in reducing regional disparities and promoting balanced development. The methodological framework of this research is summarized in the flowchart presented in Figure 5.

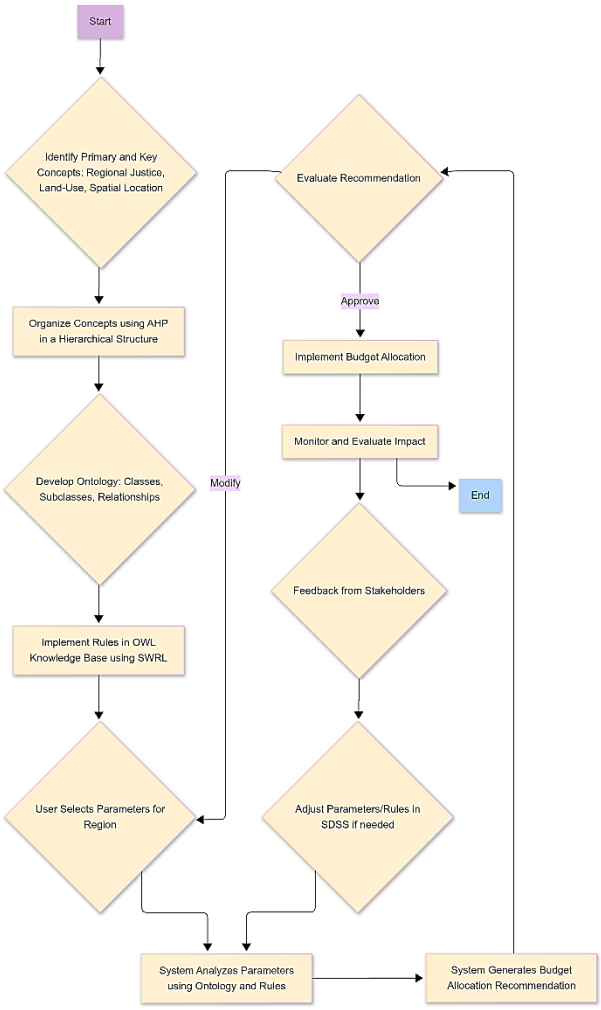

Figure 5. The flowchart of the methodological framework

In the developed ontology, some parameters related to regional justice, land-use planning indicators, geographic location, and other relevant factors are used as influential elements in the allocation of budget levels that correspond to regional characteristics. Specifically, through this system, users can select parameters associated with each province and specific region, which then guides them to an appropriate budget allocation level based on the chosen parameters. The ontology concepts are structured using the Analytical Hierarchy Process (AHP) in a hierarchical classification framework. Parts of the designed ontology, represented as a hierarchy of classes and subclasses, are illustrated in Figure 6. In the first phase of ontology creation, the primary and key concepts must be identified. These concepts are organized using the Analytical Hierarchy Process (AHP) within a hierarchical classification structure. To evaluate decision-making options, a set of rules is implemented in the OWL knowledge base using Semantic Web Rule Language (SWRL). These rules are expressed as a combination of OWL concepts and their properties (Horridge et al., 2009).

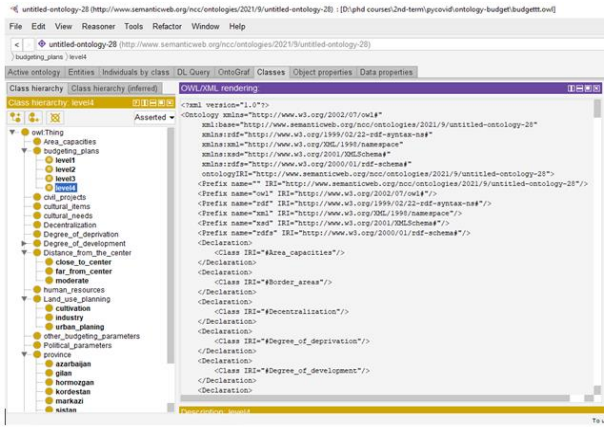

Figure 6. Representation of class hierarchy, subclasses, and entities in the ontology of the budget formulation system

For instance, in this paper, based on spatial parameters such as land-use planning and the political indicators of each region, logical relationships are established between these parameters and the corresponding budget levels through the ontology. Portions of the designed ontology, including both the hierarchical display of classes and subclasses as well as their graphical representation and logical rules, are shown in Figure 7.

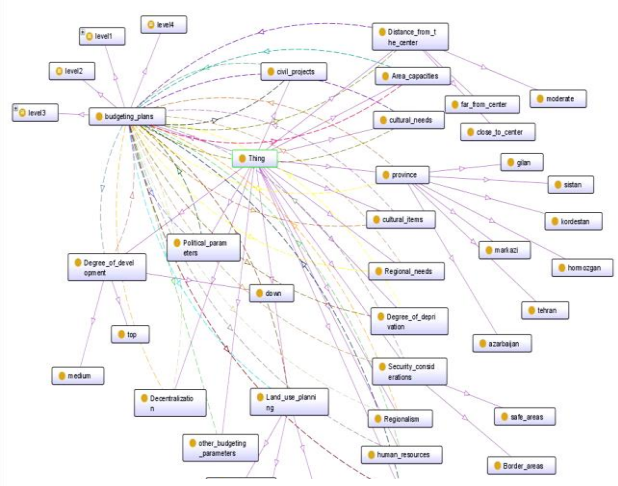

Figure 7. Ontology entities graph

In Figure 8, the user inputs the parameters of the desired region, along with the spatial priorities for budgeting, as a request into the system. Upon receiving the user's request and transmitting it to the server and the ontology reasoning engine, the system returns the desired result as a response on another page, as shown in Figure 9. This response includes the geographical location of the requested area, along with information regarding the appropriate budget level for the region based on the selected characteristics.

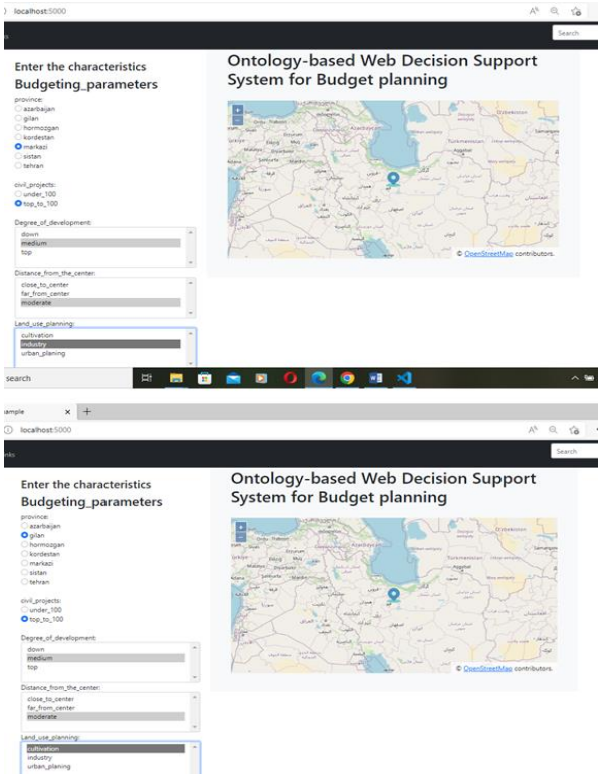

Figure 8. User-defined parameters page in the client section of the system

Therefore, based on the inference engine of the system, which is ontology-based, initially, the appropriate budget level is determined based on the analysis of the user's request and the factors provided by the user. This result is then sent back to the user in the client section as a response.

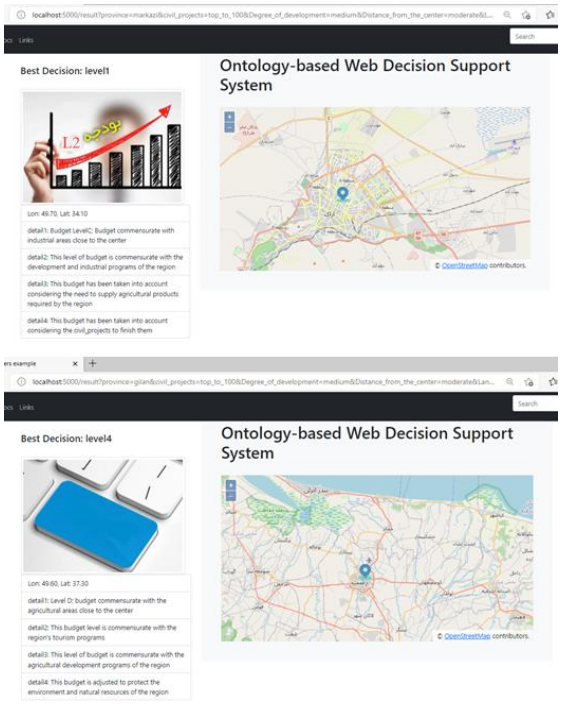

Figure 9. User request submission page in the client side of the system and the response sent to the user by the server

5. Results

Optimal resource allocation and the development of a budgeting system are among the key challenges in improving social and economic infrastructure. Often, planning methods employed in the past have been inadequate in meeting the real needs of society and have failed to provide the necessary assurance for achieving regional equity. Therefore, it is crucial that future planning efforts adopt development models that specifically consider the unique natural, social, and cultural conditions of each region.

In this study, to improve the planning and management process at various levels, a system based on ontology was developed. This system leverages logical relationships between regional justice parameters, land-use planning indicators, and spatial location in order to allocate budget levels that are commensurate with regional characteristics. By selecting parameters relevant to each province, users can access and analyze the appropriate budget allocation tailored to local needs.

The ontology concepts in this system are organized using a hierarchical analytical process, which enables the system to establish sustainable logical connections between parameters and the allocation of financial resources. The rules defined in the OWL knowledge base are designed in a way that facilitates logical and meaningful analysis between parameters and budget allocation.

For Markazi Province, the system responds to requests by

proposing development plans for industrial areas and the allocation of resources required for agricultural development. Additionally, all strategic plans, which are practically applied and considered as case studies in the system's logic engine, are based on the opinions of experts from the National Organization for Planning and Budget. These plans are summarized and presented as logical propositions within the analysis engine.

These examples of selected features have been incorporated as pilot cases into the system. Given the design of this system, all land-use planning aspects and regional characteristics can be expanded in the future. Therefore, comprehensive strategic plans for budget and resource allocation can be developed and generalized in such programs using logical propositions language.

This research justifies the adoption of a Spatial Decision Support System (SDSS) over a generic DSS due to its comprehensive integration of spatial data and analysis techniques. Key spatial dimensions considered include land use, geographic location, spatial planning factors, and regional justice, all underpinned by data from OpenStreetMap (OSM). The SDSS enables a nuanced and context-aware approach to resource allocation, tailoring strategies to the unique spatial characteristics of each region, as demonstrated by pilot studies. The system's spatial focus is further highlighted by its use of maps for visualizing budget allocations and associated regional attributes.

The proposed SDSS, is designed to improve land-use planning and resource allocation, leading to enhanced quality of life and socio-economic infrastructure across diverse regions. The SDSS facilitates scalable and evidence-based resource management, promoting regional equity in budget distribution by addressing the shortcomings of traditional methods. Key benefits include tailored budget recommendations based on regional characteristics, improved strategic planning across sectors, enhanced transparency and stakeholder engagement, and adaptability to different contexts for sustainable development. The system leverages spatial analysis and an ontological framework to support informed decision-making, optimizing resource utilization and contributing to balanced regional growth.

6. Evaluation and Validation of Results

Conventional planning approaches often fail to adequately address societal demands and promote regional equity. To enhance these methods, an innovative system integrates region-specific natural, social, and cultural attributes into the decision-making process. By leveraging rules encoded within an OWL-based knowledge framework, the system enables logical analysis of key parameters and budget allocation strategies. Pilot implementations in Gilan and Markazi provinces selected for their distinct economic and cultural characteristics demonstrate the system's adaptability to diverse regional contexts.

The evaluation and validation of the SDSS and its budgeting framework are essential for assessing its effectiveness and practical application. The study focuses on ensuring the system meets the unique needs of different regions, leading to fair resource allocation and budget distribution. A multi-faceted evaluation approach was employed, featuring both quantitative and qualitative assessments, including pilot tests in Gilan and Markazi provinces, selected for their distinct economic and cultural profiles.

Quantitative data were gathered through surveys measuring resource allocation accuracy, budget alignment, and user satisfaction, alongside monitoring post-implementation performance indicators related to infrastructure and socio-economic development. Qualitative assessments involved expert evaluations and focus group discussions with stakeholders, validating the system's recommendations in context.

Results indicated the SDSS's effectiveness in generating tailored budget recommendations, with Gilan Province receiving strategies to enhance agricultural productivity while protecting environmental resources, and Markazi Province focusing on industrial development and agricultural improvements. Stakeholder feedback highlighted increased satisfaction with the decision-making process due to the system's user-friendly interface and clear recommendations, promoting transparency and collaborative governance essential for regional development.

Furthermore, to assess the effectiveness of the SDSS in improving resource allocation, we conducted an analysis of variance (ANOVA) on the data collected from regions with distinct economic and cultural profiles, particularly Gilan and Markazi provinces. The results revealed a significant statistical difference in resource allocation before and after the implementation of the SDSS.

The ANOVA results yielded an F-value of "15.36" accompanied by a p-value of "0.017". This low p-value indicates that the observed differences in resource allocation are unlikely to have occurred by chance, thereby reinforcing the conclusion that the SDSS has led to significant improvements in resource distribution.

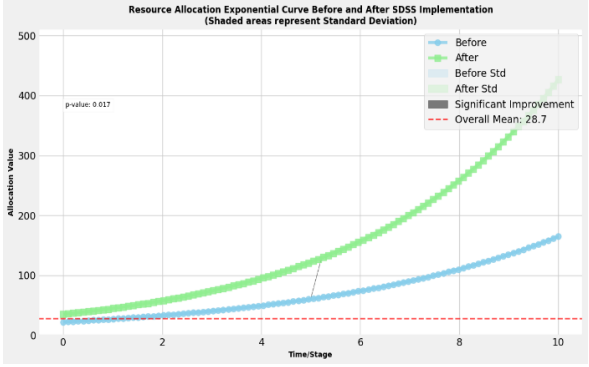

Figure 10. Resource Allocation Exponential Graph Before and After SDSS Implementation

According to Figure 10, further analysis of the data through exponential curve modeling demonstrated that the "after" curve exhibits a faster growth rate compared to the "before" curve. This suggests a marked advancement in resource allocation post-implementation of the SDSS. The assessment of standard deviation highlighted the variability around the mean allocations; notably, the "after" state showcased slightly lower variability, which signifies more consistent and equitable resource distribution across the regions.

These statistical modifications enhance both the visual appeal and clarity of the differences between the "before" and "after" states, effectively underlining the positive impacts of the SDSS. Overall, the findings affirm the system's vital role in optimizing resource allocation and underscore the necessity of robust evaluation mechanisms and continual stakeholder feedback to ensure that the SDSS aligns with regional needs and expectations.

In conclusion, the evaluation process not only validates the SDSS's effectiveness in fostering equitable resource allocation but also serves as a benchmark for other regions or countries aiming to implement similar systems. Understanding the development and validation of the SDSS can facilitate crafting more responsive and equitable resource allocation methods, ultimately contributing to sustainable development and regional equity.

7. Conclusions and Recommendations

The evaluation of the SDSS demonstrated its effectiveness as a decision-making tool for equitable resource allocation and budgeting. The hierarchical structure of the ontology employed in the system allows for dynamic adjustments to regional characteristics, contributing to a more nuanced understanding of budgetary requirements. However, future research should focus on refining the system by integrating more granular regional data, enhancing the ontology definitions, and exploring additional decision-making models. This would further bolster the robustness and scalability of the SDSS, ultimately supporting more comprehensive and equitable development strategies across diverse regions.

Planning methods are deemed optimal when they effectively allocate resources to meet societal needs. Currently, many officials express concerns regarding the capacity of existing infrastructures and plans to satisfy the qualitative requirements of life and facilitate necessary improvements. Thus, it is imperative that development models prioritize regional planning over sectoral approaches, focusing on reducing disparities in cultural and economic development across provinces. The SDSS addresses these challenges by providing a recommendation-based framework that incorporates diverse factors, including land use, regional equity, and geographic context, ensuring that budgeting processes consider all relevant dimensions.

The ongoing adaptation of the SDSS in various contexts can serve as a model for reducing socio-economic disparities, as it harnesses the principles of spatial equity and informed decision-making. By utilizing ontology to organize semantic and hierarchical knowledge, the system equips authorities with the means to make informed decisions regarding budget allocation. This study emphasizes the need for future research to enhance the system's capabilities through the integration of more granular regional data, refinement of ontology definitions, and exploration of additional decision-making models. Such advancements will bolster the robustness and scalability of the SDSS, ultimately contributing to sustainable development and the effective management of resources across diverse regions. The ongoing adaptation of the SDSS holds significant promise for addressing emergent challenges and fostering regional equity.

Future research should enhance system accuracy by integrating detailed regional data, refining ontology structures, and incorporating advanced decision-making models. Further studies are needed to assess infrastructure suitability and improve system adaptability. Continuous refinement of the SDSS, informed by stakeholder input, will support sustainable development and efficient resource allocation across diverse regions.

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