



# Providing land value information from geographic data infrastructure by using fuzzy logic analysis approach



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## ABSTRACT

Effective management of land-related information aids in promoting sustainable land development in both urban and rural areas. Standardised and interoperable data is a key component of achieving successful land administration and applications. When different datasets are produced in an interoperable manner, various thematic applications can be performed easily and reliably. The concept of geographic data infrastructure (GDI) has emerged, with the purpose of developing geographic data standards and ensuring data interoperability. In this study, an extension model was designed using the Turkish national GDI for obtaining reliable land-related information produced by public institutions. In the model design, the thematic factors affecting the land and its value were considered in seven groups and evaluated separately. In this manner, standardised and reliable information regarding land produced by public institutions can be obtained by using a national GDI. Thereafter, a case study using fuzzy logic and geographical analysis techniques was performed to implement the model, as well as obtain thematic information and general value approximations supporting land administration. The resulting maps from the analysis reflected a close and logical tendency towards reality and the applied method was found to be effective for producing reliable and accurate land value maps. Using this model, the general trends and thematic value indexes regarding 23 criteria of land parcels can be determined and added to the parcel information for sharing through e-government services.

## 1. Introduction

The effective management of land information is a rather important issue for governments in order to succeed in sustainable development and progress. Decisions supporting the sustainable development of land are highly influential for establishing a successful land administration and policy for governments (International Federation of Surveyors (FIG, 2002). Definitive and reliable land administration infrastructures promote geographic enablement and efficient information management (UNECE, 1996; Williamson, 2005). A key element to accomplishing comprehensive land administration is enabling reliable and exhaustive information regarding land and real property in every aspect. Governments require appropriate and reliable information about land and real property in order to implement numerous legal practices, such as planning and policy-making, taxation, market capitalisation, property management, real estate investments and funds (Deininger and Selod, 2012). The existence of a comprehensive data infrastructure for both the legal and thematic aspects of land management will promote the effectiveness of the land administration and policy in order to serve social requirements from both the government and citizen perspectives

(International Federation of Surveyors (FIG, 2004; Marwick et al., 2012; Williamson et al., 2010; Rajabifard et al., 2013).

According to the current land development concept, land mapping, registration and valuation functions should be included in the land administration policy for improved and sustainable development (Kalantari et al., 2005). The primary needs for sustainable and effective regional and national land information management are consistent, integrated and standardised data regarding land and property (International Federation of Surveyors (FIG, 2002; Enemark, 2005; Bennett et al., 2007). From this point of view, land-related processes such as real estate valuation, rural-urban transformation, expropriation and land consolidation could be performed effectively throughout government agencies with the presence of standardised and interoperable data.

The interoperability of the data collected from different sources in varying thematic applications is an important factor for successful and sustainable management (UNWDF, 2017). Therefore, governments and public organisations have recently placed particular emphasis on producing and sharing interoperable geographic datasets (European Interoperability Framework (EIF, 2010; Republic of Turkey – Ministry

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of Development, 2012). Only with the existence of up-to-date and interoperable geographic data governments can manage land effectively and provide the opportunity for data sharing among various public institutions and private sector applications (Aydinoglu and Bovkir, 2017). Therefore, the concept of geographic data infrastructure (GDI) has emerged, with the purpose of developing geographic data production and sharing standards for solutions to data interoperability issues (Budic et al., 2004; Aydinoglu, 2009). Governments and public organisations have developed their own GDIs, which aid in effective data manipulation throughout different thematic applications.

The incredibly rapid growth of cities results in sustainable land management being rather challenging. One of the greatest difficulties faced at present is dealing with the social, economic and ecological problems caused by rapid urbanisation (International Federation of Surveyors (FIG, 2010). This uncontrolled growth of cities should be monitored and governed. Efficient and comprehensive land administration functions supported by GDIs may provide an optimal solution to this problem (International Federation of Surveyors (FIG, 2010), because GDI supports decision-making and encourages increased concrete results for the sustainable management of land and all related components. Access to standardised and public information regarding land also easily increases structural harmonisation and allows for successful policy implementation (Dawidowicz et al., 2014). Thus, if land-related datasets can be obtained from a national GDI, reliable evaluations of land parcels can be performed, which may directly contribute to social and economic development. Certain countries, such as Poland (Dawidowicz et al., 2014; Wysocki, 2015), Croatia (URL. 2), Serbia (Aleksic et al., 2017) and Singapore (URL. 3) have developed real estate information systems as part of their national GDI, with the support of the UN and the World Bank.

GDI supports land planning, real property management and environmental development by providing up-to-date and interoperable data (Osei, 2006; Williamson et al., 2006). Numerous aspects need to be examined in order to obtain objective and adequate information regarding land and real property, and to arrive at appropriate decisions thereon (Kelly, 2007). Integrated and standardised land-related data provided by the GDI would lead to the more successful implementation of various thematic applications. Because many different factors affect land and real property, there is a need for reliable and qualified information to enable effective decision-making and implementation. Legal and thematic information concerning the use, condition, environment, value and tenure of land and real property can be obtained from the GDI (Kelly, 2007; International Federation of Surveyors (FIG, 2010; Molen, 2012; International Federation of Surveyors (FIG, 2014).

The advent of information technologies and geographic information system (GIS) capabilities have enabled users to develop a greater understanding of and efficient management over land (Longley et al., 2005). However, information alone is not sufficient for decision making; it must be analysed and interpreted logically in order to obtain improved results. The analysis capabilities of GISs can help to improve the understanding and efficiency of land and real property valuation processes (McCluskey et al., 1997). Furthermore, GIS technology allows for the performance of advanced statistical analysis, such as fuzzy logic, random trees, support vector machines and weighted regression, which may be an effective tool for analysing land-related data.

In this study, the main topic is proposing a model approach for extracting land and real property-related information for users in different thematic areas, by using a national GDI. It is considered that it is necessary to obtain reliable, coherent and interoperable information about land parcels easily from non-commercial public sources. Furthermore, it is required that improved evaluations regarding the land and its value be made, with the aid of information technologies for dealing with land-related issues. In accordance with these objectives, the remainder of this paper is structured as follows. In the 'Land-related Data Requirements' section, literature research and data requirement analysis are performed to determine the effects of thematic factors on

land parcels. In the 'Data Model Design' section, an extension for obtaining land-related data from the Turkish national GDI (TUCBS) is added to the current data model. In the case study section, a case study is conducted by using a fuzzy logic analysis approach, in order to apply the proposed model in the GIS environment and obtain thematic information regarding land.

## 2. Methodology

### 2.1. Land-related data requirements

Numerous different aspects affect the value and attractiveness of land parcels, such as parcel and zoning details, environmental conditions, distances to public services and cultural facilities. All of these aspects should be examined in order to reach more comprehensive and objective decisions regarding land parcels. Thematic factors vary depending on personal subjective expectations and land-related processes. For example, expropriation application requires information regarding ownership and zoning datasets, while real estate valuation requires information regarding location, public service opportunities and the physical conditions of the building. Because of the application needs and personal subjective expectations, different thematic factors may be required. In this perspective, all of the land and real property-related factors must be determined and examined in order to achieve improved results for valuation processes. For determining land-related information, generally accepted factors that significantly affect the value should be analysed, such as physical, economic, social and legal aspects (Sui, 1992; Yomralioglu and Nisanci, 2004; Nisanci, 2005; Yomralioglu et al., 2007; Droj and Droj, 2015). For this purpose, nationally and internationally accepted standard documents (IVSC, 2011; RICS, 2014; TEGoVA, 2016; TDUB, 2017), regulations (CMB, 2006; TKGM, 2011), books (Aclar and Cagdas, 2008; Appraisal Institute, 2001) and academic research studies (Yomralioglu, 1993; Nisanci, 2005; Candas, 2012; Yalpir and Bunyan Unel, 2016) regarding the valuation of land and real property have been examined in detail.

Following the literature research, the most widely accepted factors were determined and the compiled factors were grouped into four main categories according to their relations: legal/planning factors such as ownership and zoning status, legal restrictions and parcel position defining location information; environmental/utilization factors including ground conditions, slope, aspect and green space; public services such as infrastructure, public transport, healthcare centres and educational facilities; and socio-cultural factors, including educational level, income rate and cultural centres. In order to analyse the possibility of obtaining these land-related factors within the GDI concept, the Turkish National GDI, known as TUCBS, and Infrastructure for Spatial Information in Europe (INSPIRE) were examined as basic examples. TUCBS is an e-government project initiated with the purpose of establishing a national GDI for Turkey under the responsibility of the General Directorate of GIS in the Ministry of Urbanization, as a part of e-Transformation Turkey (TKGM, 2005, 2006; URL. 1, 2016). TUCBS corresponds to national-level user requirements in accordance with INSPIRE specifications with base geographic and thematic data themes (GD-GIS, 2012a; Aydinoglu and Bovkir, 2017). The INSPIRE project aims to provide technical standards, protocols, regulations and policies for producing consistent and interoperable data at the regional and national levels, to be used in application areas such as the environmental, agriculture, transportation and various other sectors (EC, 2007). The main motivation behind both projects is to enable geographic data interoperability and effective data management among different data providers and users (GD-GIS, 2012a; Aydinoglu and Bilgin, 2015).

In Table 1, the availability of the INSPIRE and TUCBS infrastructures for land valuation process is examined, and a data requirement analysis for the determined thematic factors according to both infrastructures is performed. Matching tables were created between each thematic factor and corresponding feature classes in the INSPIRE

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