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Turkish street addressing system and geocoding challenges

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A street address system is one of the most basic techniques used by government and others for service delivery. It enables emergency services, security, taxation, health services, delivery and mail services and it also monitors the spatial whereabouts of individuals within a population. The effective management of urban areas can only be achieved if an accurate street address infrastructure is formed. The present study investigated the problems related to street addressing in Turkey and was conducted in three stages. First, the effectiveness of the existing street addressing system was examined. The problems caused by organisations and individuals that use non-standard formats were addressed in the second stage. In the third and final stage, statistical analyses of various geocoding methods, including dual-range, one-range, single field and the zoning improvement plan, were carried out and the most appropriate geocoding method was found.

Notation

n	number of samples
N	sample number in the groundmass
p, q	homogeneity level in the groundmass
S_i	deviation distance of address point
t	value obtained from table according to the expressiveness level chosen in the study
α	acceptable margin of error

1. Introduction

The street address is the most fundamental unit among all the variations of location data. The street address is the main definition of a piece of land regardless of its urban, health, commercial, industrial, entertainment or traditional purposes, and it is the positional information of a geographical detail on the map (Kellison, 2012). At the same time, it is also the most significant unit used to relate individuals and locations. The street address is more useful than other descriptive numbers such as a personal identification number (PIN), serial number, or telephone number. However, because spatial data is extremely important for data processes and in international descriptions, the street address is very significant in terms of establishing national and international information infrastructures and determining geographical location features (Boqiu *et al.*, 2010; Coetzee and Bishop, 2009; Coetzee and Cooper, 2007; Coetzee *et al.*, 2008; Geymen *et al.*, 2008; Henry and Boscoe, 2008; Lind, 2008; Zandbergen, 2008; Zandbergen, 2010).

The street address is defined as a code or description for the fixed location of a home, building, parcel of land or other entity, and a spatial address is defined as an address together with coordinates for the geo-referenced location of that address. This definition of an address does not include any information about the person or business residing at the address. A spatial reference system is used to identify locations on the surface of the Earth, and the addresses in an addressing system can be described as locations in a spatial reference system (Coetzee *et al.*, 2008; Farvacque-Vitkovic *et al.*, 2005).

The street address is required for three basic functions. In numerous legislative and modern information technology systems, street address information is recorded to unambiguously identify the real property, customer, citizen, business or utility entity in question. In addition, the street address is used as one of the most important mechanisms to merge or link information from different sources, for example, when a bank uses the customer's address to look up information on real property or insurance. Last but not least, addresses are used daily by citizens, businesses and government as an understandable description of the location of a specific piece of information (Coetzee and Bishop, 2009; Coetzee *et al.*, 2008; Yomralioglu, 2009).

The determination of a geographic position from a descriptive address is called geocoding and geocoding tools are important components of the urban geographical information system (GIS) and health-based applications (Tiwari and Rushton, 2010). These tools usually comprise two interdependent parts: a set of geocoding methods and the addressing database, sometimes called the reference database (Davis and Fonseca, 2007; Vieira *et al.*, 2010; Wey *et al.*, 2009). Generically, geocoding works in three stages (Davis and Fonseca, 2007).

Address geocoding is a powerful GIS tool, allowing for the placement of incidents and resources on a digital map based solely on addresses. Even with all the inherent problems of trying to coordinate address data across a municipal government, address geocoding provides an economical, although not entirely accurate, way to apply GIS technology to municipal operations (Hart and Zandbergen, 2012). With address geocoding, addresses can be downloaded from a variety of computer systems and placed on digital maps as diverse as police pin maps, social service client maps, emergency shelter maps, school district maps, and fire station service area maps. Of course, the placement of incidents and resources on digital maps is only as accurate as the GIS-based street network (Ferreira and Duarte, 2006). The address reference file (ARF) is arguably the most important aspect of a well-defined street network. In GIS, street networks are decomposed into thousands of street segments that connect to form a unified street network. Each street segment contains a starting and ending address range for the left and right sides of a street block (Bichler and Balchak, 2007; Picado-Santos *et al.*, 2004; Wey *et al.*, 2009; Zandbergen, 2008, 2009).

2. Turkish street addressing system and standardisation issues

In Turkey, two laws were launched in 2006: the 'Population Service Law', law number 5490, dated 25 April 2006, and the 'Address and Numerating Regulation', law number 26245, dated 31 July 2006. Thus, a new period was started to determine address components and create the Turkish Street Addressing System (Tusas). During this period, local governments were responsible for the addressing studies. However, quite a few problems were encountered during the numerating processes conducted according to local government regulations. According to questionnaire studies, local governments were determined not to use such maps. Therefore, numerating and naming processes could not be performed correctly, and there were problems with procedural steps, such as updating, due to insufficient data. Furthermore, establishing a new numerating process involved problems such as address confusion, data exchange among institutions, frequent change of road names by local governments and multiple streets having the same name. These problems reduced the efficiency of Tusas and resulted in the failure of the address-based applications (Aydinoglu, 2010).

It has been suggested that the legal regulations governing numerating studies do not detail the urbanisation dimension and the importance of the municipality, property ownership laws or development opportunities for information technology. The insufficiency of the numerating regulations has been recognised throughout the application and updating of numerating studies. Currently, as numerating studies cannot be performed efficiently, a great many addressing problems have appeared (Yildirim and Yomralioglu, 2006).

Allocation maps play a key role in creating ARFs, and their dearth represents one of the most important problems of the Tusas numerating system. It is necessary to create zoning plan-based allocation maps in order to correctly perform and update the numerating studies. These maps are created by means of parcelling on a minimum scale in accordance with structuring criteria and by considering the approximated parcel frontage length in free-zoning plan locations. In Turkey, the lack of address allocation maps prevents the ARF from being sufficiently qualified; therefore, an address-based spatial analysis cannot be conducted correctly (Yildirim, 2003). Moreover, a land or land-use survey in numerating studies is important because, in Turkey, numerating maps are prepared using this survey. These maps need to be constantly updated, land-use activities need to be followed, especially in urban areas, and changes need to be saved to numerating databases.

It has been calculated that the maintenance of repetitive addresses in Turkey cost US$52 million in 2010. This calculation accounted for the time cost to the state for data entry and the cost for the data entry operators. The most common assumption is that the address information of a citizen in Turkey is logged in at least 10 public institutions. In addition, millions of dollars are wasted due to incorrect address records, false address declarations or frequent changes in the address components. Taxes in Turkey constitute 33% of the gross national product, and when declarations sent for allocation are delivered late or cannot be delivered due to address problems, a loss of a large amount of money is the result (Yildirim, 2003). However, according to a questionnaire study related to the use of standard addresses in Turkey, each institution or establishment uses a different address format, and the address formats are not standard in the correspondence for the same individuals (Table 1).

Because many datasets are referenced by using an address, describing and utilising a standard address format will allow these data to be used in e-management systems. As address data are used extremely widely within and among institutions, creating a standard format will increase the functional ability of these institutions. Moreover, utilising a standard address format will reduce the waste of money and time that occurs at posting (Barr, 2007; Cete *et al.*, 2009; Coetzee *et al.*, 2008;

Name - Surname	Mail messages	Address
H. YILDIRIM	Electric bill	Anavatan Ave. Near of Zirve Hotel, Pelitli/Trabzon
H. YILDIRIM	Water bill	Devlet Karayolu Ave. Yildirim Apt. Pelitli/Trabzon
H. YILDIRIM	Phone bill	Adnan Kahveci District Rize Ave. Near of Zirve Hotel 61010 Pelitli/Trabzon
H. YILDIRIM	Retirement fund	Adnan Kahveci District Rize Ave. No:160 Pelitli/Trabzon
K. YILDIRIM	Mail message	Hukumet Ave Near of Zirve Hotel Floor:2 Pelitli/Trabzon
K. YILDIRIM	Student selection centre	Hukumet Ave. Adnan Kahveci District No:160 Pelitli/Trabzon

Table 1. Different address formats on mail messages that were sent to the same apartment

Lind, 2008; Nicholson, 2007; Yildirim, 2003). Upon examining the address format in Turkey, it is obvious that there is no standard system. Abundant address components, improper and incorrect implementation of numerating studies, the failure of institutions to use the same address format even for their own documents, and institutions' unawareness of new address components bring about confusion related to addresses in Turkey (GDGIS, 2012).

At this stage, to determine an address format for Turkey, address formats belonging to 40 developed countries and EU member nations were thoroughly examined, and some criteria were determined according to the component rows in the formats. After a questionnaire, an evaluation was performed and a standard address format was determined that will prevent Turkey from encountering future economic waste in this area.

3. Study area and street address dataset

The study area was located in Trabzon, a harbour city in the north-east of Turkey, roughly between longitudes 39° 34′–39° 52′ E and latitudes 40° 57′–41° 03′ N (Figure 1). This area occupies approximately 3470 hectares centred on Trabzon. According to the 2010 census, the population is 239 704. The city is composed of 39 neighbourhoods with 20 995 buildings. The total road length is 375 km, and there are seven boulevards, 143 avenues and 1414 streets in the city (TUIK, 2011).

The reasons the city of Trabzon was chosen as the application area are summarised in the following list.

- Since 2005, the city has been making the required structural and organisational changes to be managed in accordance with an e-municipality.
- The addressing activities were renewed in 2007.
- Numerating studies have been performed systematically and in accordance with a data-based system.
- The city is one of 12 among the 81 cities in Turkey that use a digital-based addressing system.
- The address data have been used effectively by many institutions including emergency services and automatic school registration.
- The Trabzon municipality was the only municipality asked to contribute to the address law and numerating regulations enacted in 2005.
- Within the address studies, 134 street names were changed, and institutions were informed about the changes through necessary regulations.
- Trabzon is the only city to create ARFs for city road data.

The street address datasets for the study were obtained from three different institutions. The first were collected from address stock prepared by the Turkish Petroleum Pipeline Corporation; this company runs national and international petroleum and natural gas projects. The company is in charge of distributing the natural gas network and aims to create a base for the distribution studies in Trabzon. The collected address data were divided into components and standardised. A total of 22 394 address data points were prepared using the format of the district name, street number, street name, street type and postal (ZIP) code (Table 2).

The second dataset was compiled from a list of the buildings with addresses in the city of Trabzon provided by the General Directorate of Civil Registration and Nationality in accordance with the address-based population registration system. A total of 24 614 address data composed of the district name, street name and street type were standardised.

In the third set, 1514 addresses were gathered by emergency services and courier companies in Trabzon. At this point, it was determined that the format of the collected address data was far from the standard address format and that most addresses did not include the main component, the door number.

4. Materials and methods

This study was conducted in three stages. First, 48 522 street address data were obtained from different institutions and establishments in the city of Trabzon, and the efficiency of the

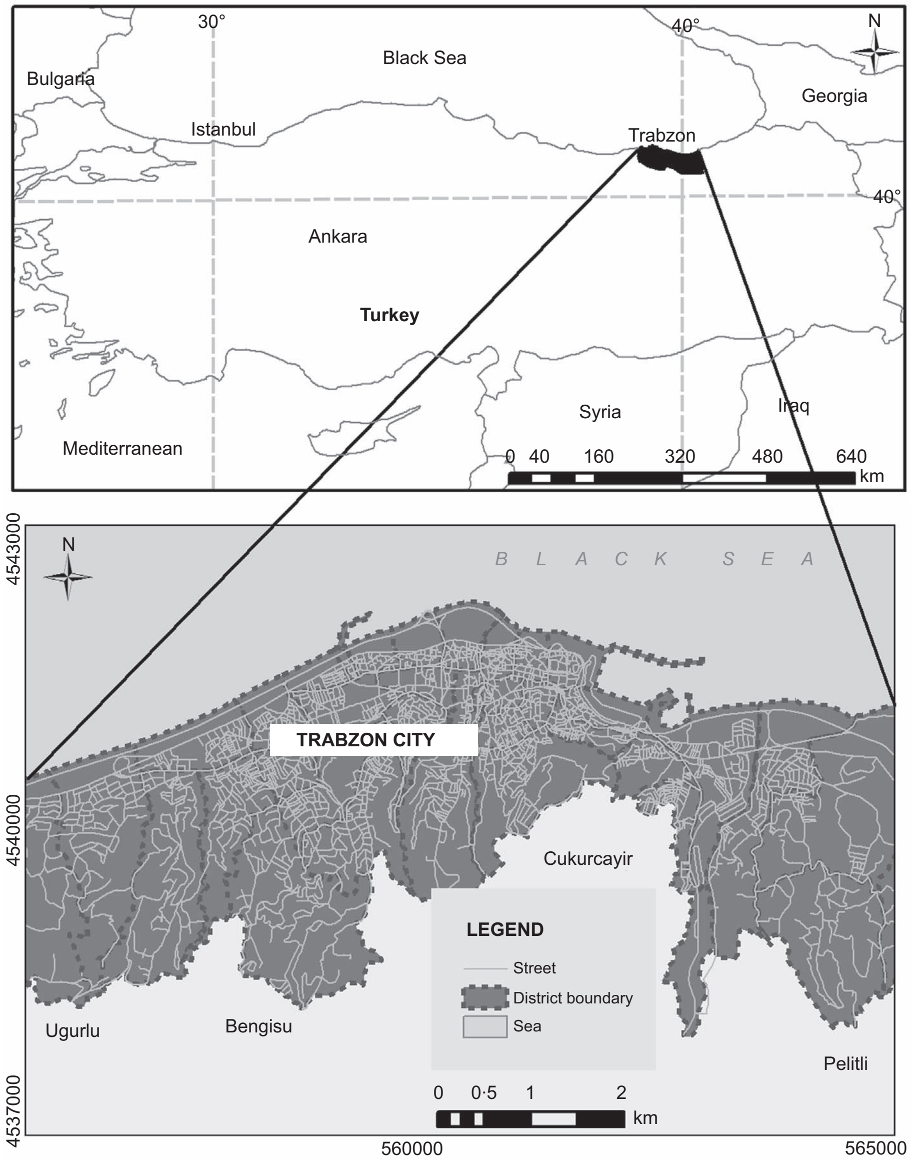

Figure 1. Study area

numerating studies performed by the Trabzon municipality was examined. In the second stage, the address data that did not match with the outcomes of the address geocoding were analysed statistically, and the reasons for the Tusas geocoding errors were also analysed. In the third stage, the geocoding method most appropriate for Tusas was determined. In this stage, the address dataset was coded with road, building and postal (ZIP) code reference files by using worldwide geocoding methods (Rushton *et al.*, 2006) such as the dual-range (DR), one-range (OR), single field (SF) and the zoning improvement plan (ZIP-5) code street address. The data were gathered in accordance with the appropriate data collection methods by considering the data quality, and the data were also organised within the geodata base. The road network was digitised, the road data base and ARF were created, the building data base was prepared, the numerating data belonging to buildings were digitised and the address record was reorganised according to a standard format. The Directorate of Cartography in the Trabzon Municipality provided the road centre axis, the ARF that is composed of the beginning and ending of the streets, the direction and return information, the street names and the changes of street names (Figure 2). Information on the building layer, building address information, building access, parcel number, block number, storey height and the number of apartments was also provided. These data were

District name	Street name	Street type	Building name	Street number	Postal (ZIP) code
Besirli	Devlet Sahilyolu	Avenue	Canim Apt.	575	61040
Besirli	Güvelioglu Ave	Avenue	Cakir Apt.	14	61040
Besirli	Eyüp Camii	Street		4	61040
Besirli	Harita	Avenue		5	61040
Besirli	Kanallitas Street	Street		36	61040
Besirli	Engin Aevenue	Avenue		38	61040
Bostanci	Zafanoz Ave	Avenue		52	61080
Bostanci	Trt	Street	Kongur Apt.	24	61080
Erdogdu	Soguksu A.	Avenue		89	61030
Erdogdu	Soğuksu	Avenue		63	61030

Table 2. Turkish Petroleum Pipeline Corporation address data

recorded into the databases along with their attribute data to create topological data. A total of 20 995 buildings and 128 335 instances of numerating data belonging to independent departments were also added to the system.

Taking account of the size of the study and the amount of the data, the exemplar design had to be analysed statistically to demonstrate the consequences according to scientific criteria.

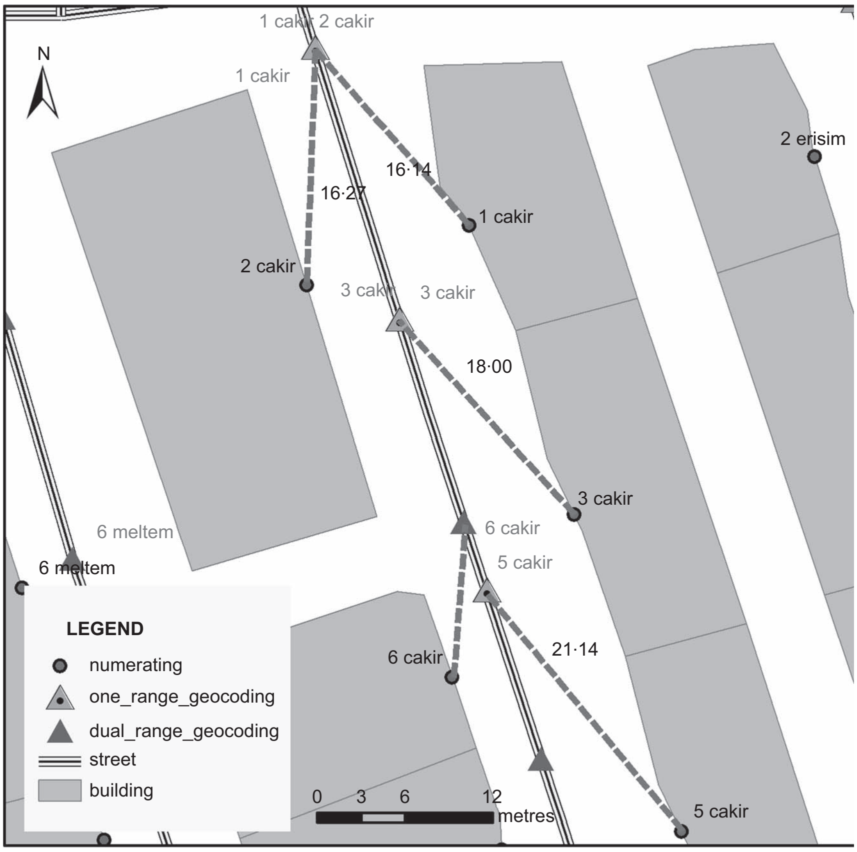

Figure 2. Door number match points that are coded using the dual-range and one-range geocoding methods

In this study, for the sample size in the groundmass, the known formula (Equation 1) was used:

1. $$n = Nt^2pq/\alpha^2(N-1) + t^2pq$$

where n is the number of samples; N is the sample number in the groundmass; p and q are the homogeneity level in the groundmass such that if the groundmass is homogeneous, $p = 0{\cdot}9$, $q = 0{\cdot}1$; if not, $p = 0{\cdot}5$, $q = 0{\cdot}5$; and t is the value obtained from the table according to the expressiveness level chosen in the study.

Samples were matched with the address numbers for all geocoding methods analysed. With the DR geocoding method, 33 965 address data were matched out of 48 522 addresses, and the numerating points showing door access were matched with 24 034 buildings. Using the OR geocoding method, 22 458 addresses were matched out of 48 522 address data, and a total of 18 056 buildings matched with the numerating points showing door access. In the SF geocoding method, 29 698 addresses were matched out of 48 522 address data, and a total of 29 698 buildings matched with the numerating points showing door access. With the ZIP-5 code method, 33 105 addresses were matched out of 34 216 address data, and a total of 16 032 buildings matched with the numerating points showing door access. As the structures on the streets were not homogeneous, p and q values of 0·5 were used. If $N = 24\,034$ and $\alpha = 5\%$, the sample number was 385 according to Equation 1 for all geocoding methods.

5. Results

5.1 Geo-statistical evaluation

When evaluating matching circumstances of coded addresses, mismatched addresses resulted from errors in door number and the incompatibility of street names (35 and 28%, respectively). Mismatched addresses due to errors in door numbers resulted from incorrect beginning and ending street numbers in the ARF comprising the numerating infrastructure. Declared street names were not included in the database due to mismatched street names. Accordingly, it was concluded that the changes to the street and district names were enacted without informing citizens. The addresses gathered by emergency services and courier companies did not match with the database. The shortage of door number data was caused by an incorrect allocation of numbers when determining the beginning and ending of street numbers.

In the geocoding process, other reasons for errors may include incorrect addresses and errors in spelling, abbreviation, typing and formatting (Table 3).

Error	Rate: %
Errors in the ARF	35
Errors in the streets database	28
Incomplete addresses	15
Misspellings	9
Incomplete offset data	5
Typographical errors	4
Improper format	4

Table 3. Geocoding error sources for Turkey

5.2 Determination of an appropriate geocoding method for Turkey

Regarding the sample numbers, the distance to the actual location was calculated with the aid of the coordinate information for building access and using the geographic location corresponding to the address data determined after each geocoding method (Figure 3). By considering the sample numbers calculated above, the distances of the samples to the real building access chosen among the matching addresses for each method were calculated using the coordinate values (Table 4). Using the DR method, 386 samples were chosen randomly among the matching address data, and it was determined that the average location misplacement was 23 m. Using the OR method, 385 samples were chosen randomly among the matching address data, and it was determined that the average location misplacement was 36 m. Using the Zip-5 code method, 385 samples were chosen randomly among the matching address data, and it was determined that the average location misplacement was 980 m. Using the SF method, 385 samples were chosen randomly among the matching address data, and it was determined that the average location misplacement was 7 m.

6. Conclusions

The ARF is the most important component of the geocoding method. The road names, types of roads, abbreviations, bidirectional beginning and ending numbers of the streets, and accuracy of the road centre axis directly influence the reliability of the geocoding process. Due to problems in allocating numbers, unplanned construction, zoning plans and plan modifications, the structures on the roads do not exhibit a homogeneous distribution. The length of the road segments, especially in regions where structuring is very under-developed, decreases the reliability of the geocoding applications.

The following are some of the significant problems facing the implementation of Tusas.

- A standard address format has not been created.
- Street names are changed arbitrarily.

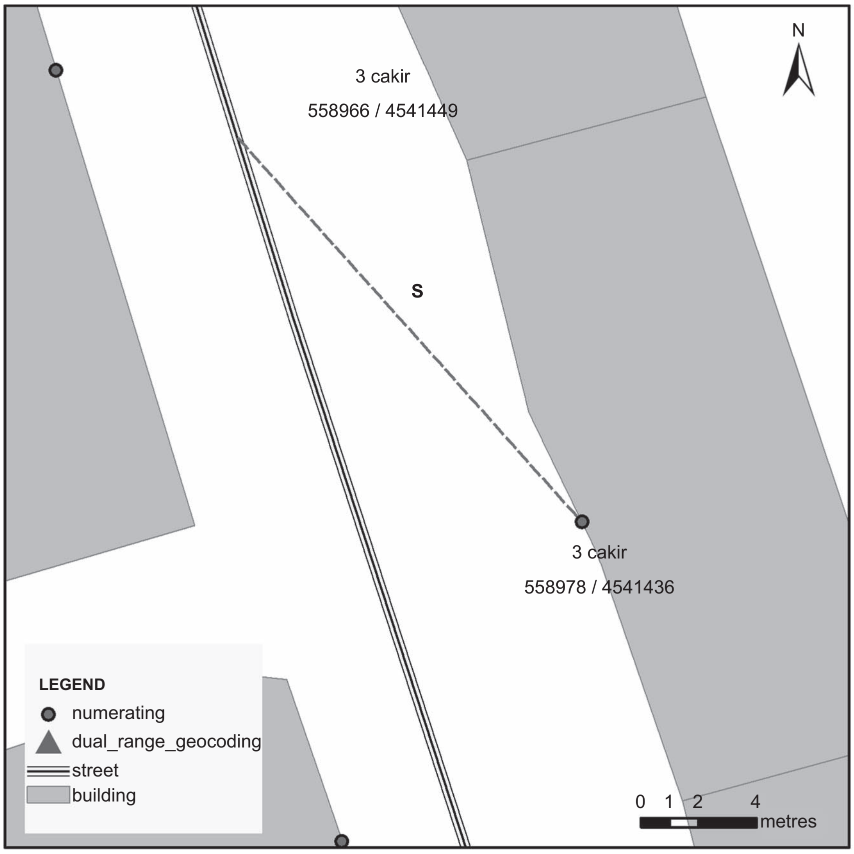

Figure 3. Deviation in distances of address points that were acquired with the dual-range geocoding

- Changes of address are not relayed to the relevant institutions and establishments.
- Citizens cannot participate in the changes of street names or door numbers.
- There are deficiencies in the legal regulations in terms of the spatial information systems.
- Local governments do not update the numerating studies.
- Numerating maps and allocation number maps have not been created.

In Turkey, where the addressing infrastructure is insufficient, the SF geocoding method, in which the address information is coded directly into the reference files, provides the most accurate results. In this method, the distance of address points to the building access is on average 7 m. Because the accuracy of the DR and OR methods depends on the accuracy of the reference files, it is impossible to apply these methods in Turkey.

It is necessary to implement regulations that include spatial and attribute data linking and the latest technology. Until such regulations are put into practice, municipalities will have to name streets, give numbers to buildings as well as create an address information system that includes features of buildings and roads. The implementation of new regulations and address systems in Turkey during the EU accession period provides opportunities not only to escape address repetition but also to avoid future financial expenditure generated by this problem.

In order to remove the address problems in Turkey, address data should be gathered in one centre. This centre should be directly associated with the local governments. Updates of the street address records performed by local governments should be transferred to this database. Moreover, in this system, changes of address should be implemented immediately. Institutions, foundations or firms that require address data should be able to obtain it from this database, on the condition that the necessary permission is first granted. Accordingly, economic and temporal losses will be reduced.

Base maps, orthophoto maps, numerating maps and allocation maps should be reproduced accurately. Zoning plans should be

Address	Y_1	X_1	Y_2	X_2	S_i: m
3 Cakir St	558978	4541436	558966	4541449	18
5 Diyar St	559202	4541475	559193	4541490	18
14 Detay St	558929	4541388	558936	4541373	17
13 Diyar St	559210	4541444	559211	4541427	17

S_i, deviation distance of address point.

Table 4. Deviation distances of address points

applied and plan modifications should be minimised. Thus, problems relating to the allocation of numbers will be reduced, and the numerating system will be sustainable. The responsibilities of citizens and legal arrangements should be redefined as to numerating studies and criminal sanctions determined. Legal arrangements should be made to eliminate street name changing issues. Public participation should be included in the process of changing street names. A street name bank should be established in the numerating departments of local governments, and the names must be accepted by all segments of society. Related institutions should be immediately notified of address changes. In addition, different communication tools should be used to announce these changes to the people living in the region.

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