COOPERATION BETWEEN STAKEHOLDERS MAXIMIZES THE BENEFITS FROM SPATIAL DATA

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Abstract

Spatial data can serve many purposes. Data is often collected and captured with one specific aim in mind. This is particularly the case in developing countries, where institutions frequently work under time constraints. Such constraints arise from the relevant institutions’ urgent need to collect and use data in order to meet development targets eg the establishing of a road network. Thus many broader issues related to a country’s future development may be overlooked and the utility that any collected geodata may have for other interested parties eg the agricultural sector may be neglected. This paper recommends a method to counteract this. It suggests that one central agency should be entrusted with the responsibility for informing all potential stakeholders of any geodata collection projects scheduled at a regional or national level. Such an agency / methodology could help avoid redundant geo-surveys and thereby any necessary concomitant post-survey processing. In this paper we describe the value of taking this broader approach to data collection and how this maximizes the benefits of spatial data collection.

Key Words:
Digital terrain model, GPS, geodata, photogrammetry, remote sensing, spatial data infrastructure
Introduction

Spatial data can serve many purposes. Data is often collected and captured with one specific aim in mind. This is particularly the case in developing countries, where institutions frequently work under time constraints. Such constraints arise from the relevant institutions’ urgent need to collect and use data in order to meet development targets eg the establishing of a road network. Thus many broader issues related to a country’s future development may be overlooked and the utility that any collected data may have for other interested parties eg the agricultural sector could be ignored.

The benefits of any spatial data collection project could be maximized if initial planning were to get on board all potentially interested parties, stakeholders and institutions. Co-operation at both the planning and execution stages would ensure the collection of all relevant data. In addition any data that has already been collected may contain information valuable to, and relevant for, parties other than the major stakeholder. If such data were to be made accessible to all interested parties, duplicate and / or redundant geo-surveys could be avoided, and thereby the concomitant post-survey processing. In this paper we wish to describe two cases which highlight the value of taking a broader approach to data collection. The two cases examine spatial data collection and data availability in the city of Bonn, the previous capital of the Federal Republic of Germany and in Addis Ababa, the capital of the Federal Democratic Republic of Ethiopia. The two cities have been chosen as examples, because during a recent update of its cadastre Addis Ababa modelled its update processes on those used by Bonn.

In order to describe how the benefits of data collection can be maximized this paper will first outline and background the wealth of information available through data collection and geodata extracted from high resolution aerial imagery, and high resolution satellite or medium resolution aerial imagery.

The paper will then present the two case studies and make recommendations concerning an approach to defining and organizing spatial data in respect of the needs of stakeholders at the initiation of spatial data collection / generation projects.

Wealth of Information during Data Collection

Public administrative bodies often work with data that references a specific geographic location. Current practice is to represent geographic locations via spatial data which constitute a component of a geodatabase. Geodatabases include fundamental information about exiting infrastructure, properties, land parcels, and base topographic data.
Geodatabase spatial data is gathered through surveying. Surveying offers a range of methodologies from which the project owner may choose. This choice will be governed by cost and accuracy requirements. Table 1 shows typical accuracy requirements for specific needs.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Horizontal accuracy (rmse)</th>
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<tbody>
<tr>
<td>Rural area</td>
<td>0.5m</td>
</tr>
<tr>
<td>Built up and urban areas</td>
<td>0.1 – 0.2m</td>
</tr>
<tr>
<td>Precise cadastre</td>
<td>0.01 – 0.02m</td>
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Table 1: Horizontal accuracy requirements (Source: Hansa Luftbild, 2013)

Once the accuracy has been specified the appropriate method should be applied for spatial data capture. Methods may be differentiated between direct surveying approaches, such as field surveying, and indirect approaches, such as airborne or satellite remote sensing.

Direct survey methods such as GPS measurement have accuracy advantages and cost disadvantages. GPS measurement ensures correct object identification and is highly accurate. However, it is time consuming and costly and therefore uneconomical for large project areas. Should this method be selected it is essential that many stakeholders be on board with the project owner.

In many cases indirect methods such as airborne or satellite remote sensing can meet identification and accuracy requirements. Both airborne and satellite imagery can deliver a wealth of detail, to the advantage of many stakeholders. An advantage of the less expensive indirect methodologies is the increased scope for frequent updates since costs of such updates are not prohibitive. Table 2 shows the geometric resolution achieved using different indirect remote sensing systems and platforms.
Table 2: Geometric resolution of airborne / remote sensing systems (Source: Dr. Karsten Jacobsen and Hansa Luftbild, 2013)

Overall end results requirements will determine the necessary geometric resolution and consequently define the remote sensing platform utilized, ie aircraft or satellite.

Airborne and satellite imagery, both high or low resolution, capture many types of information and detail and can deliver results in a very short period of time.

High resolution aerial imagery is usually chosen to cover urban areas because details can be mapped in a short amount of time and accordingly save on cost without compromising on quality and accuracy. Figure 1 shows an aerial image of an urban area in Tripoli, Libya. This aerial image has a ground resolution of 10cm. The buildings and the parcel boundaries are clearly visible. The land use is also easily classified. The details such as sumps, manholes, street lighting, kerb lines etc. are identifiable and can be mapped and feature coded. The application of photogrammetry to the stereo imagery will also allow the capture of information in 3D. Figure 2 shows a coloured digital map of building heights generated with a GIS using the terrain height and elevation of buildings above mean seal level. The information which can be extracted from the coloured data gives the number of storeys of each building. Such data could be used by local councils or utility companies to plan water supply and sewage networks by calculating fresh water requirements and sewerage outputs for each dwelling.
Figure 1. Multitude of information in high resolution aerial image (Source: Biruni Remote Sensing Centre, 2006)

Figure 2. Building heights derived from terrain and heights above mean sea level (Source: Hansa Luftbild 2006)
High resolution satellite imagery or medium resolution aerial imagery is often used for surveys of rural areas. High resolution satellite imagery is also used when the airspace access in urban areas is not possible or is difficult for security reasons. In addition small and remote areas are often covered with high resolution satellite imagery because of the high cost of mobilising an aircraft to these areas. In listing the advantages and disadvantages of satellite imagery as in Table 3 and Table 4 it appears that aerial imagery could be a better option for urban and rural survey.

<table>
<thead>
<tr>
<th><strong>Advantages of high resolution satellite imagery</strong></th>
</tr>
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<tbody>
<tr>
<td>Satellite platform is operational 365 days of the year</td>
</tr>
<tr>
<td>Frequent re-visit times (e.g. every 4 days or even more)</td>
</tr>
<tr>
<td>Satellite can easily access remote or restricted areas</td>
</tr>
<tr>
<td>No Air Traffic Control restrictions</td>
</tr>
<tr>
<td>Large area footprints decrease the need for block adjustment and creation of image mosaics</td>
</tr>
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</table>

Table 3. Advantages of high resolution satellite imagery (Source: GEO Informatics, 2012)

<table>
<thead>
<tr>
<th><strong>Disadvantages of high resolution satellite imagery</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Image acquisition geometry is not very flexible</td>
</tr>
<tr>
<td>Imaging time is fixed; cannot be optimized with respect to weather conditions and cloud coverage</td>
</tr>
<tr>
<td>Image resolution is fixed for a particular sensor; aerial images can be collected with the same resolution (in high altitude mode), if necessary</td>
</tr>
<tr>
<td>Radiometric resolution is often too low (problems in shadows and saturation areas)</td>
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<tr>
<td>Image quality is often impaired by different factors and artifacts</td>
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<tr>
<td>Typical off-nadir viewing angle of up to 25° is problematic in image matching</td>
</tr>
<tr>
<td>Reliability of capture and delivery of imagery can be poor at times</td>
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<tr>
<td>Strong possibilities of cloud cover and thus occlusions</td>
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<tr>
<td>Cost of the imagery may be too high (when compared to aerials). Especially multi-image (&gt;2 images covering the objects) concepts are financially hard to realize.</td>
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</table>

Table 4. Disadvantages of high resolution satellite imagery (Source: GEO Informatics Magazine, 2012)
The choice between satellite imagery and aerial imagery is often determined by the size of the area to be surveyed, the data acquisition costs and the accuracy requirements. Figure 3 shows an aerial image with a medium ground resolution of 60cm of a rural area in Eastern Europe. The land plots and consequently the land use are clearly visible. In addition to land use, the road networks, and man-made structures can be identified.

![Aerial image of a rural area](image)

Figure 3. Medium resolution aerial image of a rural area (Source: Hansa Luftbild, 2012)

The two previously shown examples of aerial imagery underline the wealth of information which can be interpreted, extracted, and made available to spatial data users.

**Bonn Case Study**

In Germany, the local authorities, city councils and government ministries consult with interested parties when collecting geo-data in order to maximize the use of that spatial data. The city administration of Bonn, for example, uses its spatial data to manage and plan the duties of its various authorities and
agencies within the city administration. The data is made available through geodata portals and a spatial data infrastructure.

Bonn’s geographic data management system has its origins in an environmental information system which was developed by the city in 1992. This system was developed to assess environmental problems such as flooding, abandoned hazardous sites and noise pollution. The system consisted mainly of alphanumeric data. Spatial data was handled in CAD systems. In 1995 / 1996 the Bonn street map was digitized in order to establish a desktop GIS for 100 users. This step, in which data was centrally organized, helped in the formation of the first widespread GIS for the various authorities and agencies of Bonn.

With the emergence of the web mapping and web GIS technology the city embarked on developing its current geodata management system, ie a spatial data infrastructure. In 1997, and in cooperation with the Geography Department of the University of Bonn, the city commenced the implementation of its web mapping technology. The city’s web GIS was one of the first to be developed in Germany. Figure 4 shows the current system infrastructure technology of the Bonn geodata management system and the open source software used to develop it, which was based on international standards.

Figure 4. Bonn geodata management system: system infrastructure (Source: Bonn City Administration, 2014)
The system consists of a three-level structure: a content management system, cartographic functionality, and database interface / functionality.

The initial spatial data, input into the system, was aerial imagery, the digital city map and various environmental spatial data which pinpoint information such as areas at risk of flooding by the Rhine. Today the data infrastructure and geodata portals provide more than 1,600 defined data and information layers referencing everything from land development to car parking for people with disabilities. These layers cover more than 200 use-case-systems and serve more than 1,200 registered users.

More than two-thirds of the 30 administrative authorities in the city input and maintain data on a daily basis; thus the entire system is essentially up-to-date. In addition the high resolution digital orthophotos are updated every three years. City administration authority workflows are increasingly being integrated into the system. For example Figure 5 shows the area coverage and location of the Bonn fire brigade services and Figure 6 shows the management of public works and construction sites of the city’s street network.

Figure 5. Bonn geodata management system: management of fire brigade coverage services (Source: Bonn City Administration, 2014)
A further example of the system’s utilization can be seen in the planning and management of events as shown in Figure 7.
In addition to the local authorities / agencies, other parties and service providers make use of the system eg the Bonn/Rhein-Sieg/Ahrweiler regional planning and development group and the Bonn utilities company. The Bonn utilities company uses the system to manage its public transport infrastructure including tram signals, bus stops etc., and parts of its water, gas and power supply facilities.

The general public also has access to multiple layers of spatial data via the Internet. Figure 8 shows a web map of a geological hiking trail in the Bonn suburb of Bad Godesberg. The total annual website logs for all users exceed 7,000,000 hits.

The Bonn geodata management system falls under the Surveying and Spatial Data Unit of the city Communal Office for Cadastre and Surveying Department. This unit employs 31 professionals of whom 4 are assigned the task of running and maintaining the system.

![Figure 8. Bonn city web map: public use - hiking trails (Source: Bonn City Administration, 2012)](image)

**Addis Ababa Case Study**

In Ethiopia the collection and use of digital spatial data commenced almost at the same time as that of the city of Bonn. A multi-purpose cadastre was developed using digital aerial maps (line maps) produced in 1996. The purpose of the multi-purpose cadastre was to support land valuation / taxation, to serve as a basis for city planning, and to facilitate the issuance of title deeds and building permits. Inadequate ongoing maintenance of the cadastre led to its qualitative deterioration and rendered it unusable.
In addition to the multi-purpose cadastre, the results of a 1996 aerial mapping were used by the Addis Ababa Construction and Roads Authority to produce the first fully operational GIS-database based on ArcView 3.3 and Mapinfo 6.5. This GIS-database was handed over to the Addis Ababa City Government in 2005. The GIS-database was used by the Addis Ababa Urban Information and Documentation Department.

By 2005 the existing line maps of 1996 were outdated making modern land and land related property management almost impossible to achieve. In 2005, to alleviate this, the Addis Ababa municipality contracted a mapping firm to update its line maps. The outcome of this update was, as of 2006, new digital orthophotos and line maps. The digital line maps, however, were not used to update the existing cadastre data.

In 2009 a tender was put out by the city of Addis Ababa for the development of a real property register and cadastre system. The tender envisaged, amongst other services, the updating of the cadastral map data.

For the project new aerial photography was acquired at a ground resolution averaging 17cm. This resolution was suitable for mapping at scale 1:2000 as well as for producing digital orthophotos at a ground sampling distance (GSD) of 20cm which is also equivalent to a map scale of 1:2000. While the project focussed exclusively on the need for a real property registration system at the suggestion of the contractor, the new high resolution aerial photography was also used to produce a digital terrain model (DTM), containing hydrography data, and orthophotos. The update resulted in accurate parcel and building data covering the entire city area of 520 square kilometers. The street and road network was also mapped in 3D and used to set up a street addressing system. Figure 9, Figure 10 and Figure 11 show some of the spatial data produced and generated for the Addis Ababa project.
Figure 9. Street and road network data of Addis Ababa (Source: Hansa Luftbild, 2011)

Figure 10. Hydrography data of Addis Ababa (Source: Hansa Luftbild, 2011)
In addition to the development of the real property registration system (named AA-CADIS) a land information system (named AA-LIS) was implemented. This land information system was developed in accordance with international standards and will be made accessible to city agencies, private companies and the general public.

Real property data, the core non-spatial data of AA-LIS, is maintained within the real property registration system. Figure 12 shows the structure of Addis Ababa cadastre information and land information systems.

The AA-LIS was implemented on the basis of Open Geospatial Consortium (OGC) web services standards, for example Web Map Service (WMS) and Web Feature Service (WFS). Other agencies or authorities in Addis Ababa can create their own web services or applications to extract or access AA-LIS data to support their processes or add their own specialised data on top of the AA-LIS data. AA-LIS also includes a Web Map Client which can be run in a web browser. Figure 13 shows the environment of the AA-LIS while Figure 14 shows an overview of the AA-LIS infrastructure based on the OGC standards.
Figure 12. Structure of Addis Ababa cadastre information and land information systems (Source: Hansa Luftbild, 2010)

Figure 13. Environment of AA-LIS (Source: Hansa Luftbild, 2011)
Both systems, AA-CADIS and AA-LIS, have the potential to form a pivotal spatial data infrastructure which could be used by the city to make full use of all its spatial data. At present both systems are used exclusively by the city’s Immovable Property and Registration Agency. Clearly all recently acquired spatial data has the potential to be used more extensively by the different authorities and agencies within the Addis Ababa City Administration. Table 5 lists some of these authorities and agencies, and suggests the purposes and uses to which the spatial data produced for the real property registration development project could be put.

<table>
<thead>
<tr>
<th>Authority / Agency</th>
<th>Spatial data and purpose of usage</th>
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</thead>
<tbody>
<tr>
<td>Addis Ababa Environmental Protection Authority</td>
<td>Digital orthophotos, parcels and terrain model for mapping the environmentally vulnerable areas</td>
</tr>
<tr>
<td>Addis Ababa City Sanitation Administration Agency</td>
<td>Digital orthophotos, parcels and terrain model for mapping hazardous areas</td>
</tr>
<tr>
<td>Land Development and Urban Renewal Agency</td>
<td>Digital orthophotos, parcels, and street and road network for mapping development and renewal</td>
</tr>
<tr>
<td>Authority / Agency</td>
<td>Spatial data and purpose of usage</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Construction Permit and Control Authority</td>
<td>Digital orthophotos, parcels, buildings, streets and roads network for verifying permit applications according to regulations</td>
</tr>
<tr>
<td>Land Parks and Cemetery Development and Administration Agency</td>
<td>Digital orthophotos, parcels and terrain model for mapping the parks and cemeteries as well selecting potential new sites for parks or cemeteries</td>
</tr>
<tr>
<td>Addis Ababa Fire and Emergency Prevention and Rescue Agency</td>
<td>Digital orthophotos, parcels, buildings, and street and road network for planning rescue operations</td>
</tr>
<tr>
<td>Land Banking and Transfer Office</td>
<td>Digital orthophotos, parcels and buildings for checking and verifying the legality of property ownership</td>
</tr>
<tr>
<td>City Government of Addis Ababa Water and Sewerage Authority</td>
<td>Digital orthophotos, parcels, buildings, street and road network, hydrography data and terrain model for planning and developing water supply and sewerage networks</td>
</tr>
<tr>
<td>Addis Ababa Construction and Roads Authority</td>
<td>Digital orthophotos, parcels, buildings, street and road network, hydrography data and terrain model for maintaining, planning and developing the road network and for traffic planning</td>
</tr>
</tbody>
</table>

Table 5. Potential usage of recently collected spatial data by Addis Ababa city authorities / agencies (Source: Addis Ababa City Government and Hansa Luftbild, 2013)

The city is aware of this and is taking the necessary measures to make the spatial data available to its own authorities and agencies.

In addition the city could promote its spatial data services offering them to federal and security agencies, as well as to the private sector. The private sector could derive enormous benefits from access to the spatial data, for example, the national mobile telephone operator could make use of DTMs and building data for the planning and optimizing of receiver and transmitter locations in its network.
**Recommendations**

The benefits of spatial data can only be maximized when the data is made available to a large group of potential users and when all government and private organizations / institutes, which deal with, handle or use spatial data, have access to the data.

During the conceptual phase of a spatial data collection and/or generation project owners could inform all potentially interested parties, government and private, of the project. Thus these organizations would have the opportunity to state their spatial data requirements specifying those which have the potential to be captured or processed during the project execution. Project owners could then, on the basis of this feedback, decide whether to incorporate external organization’s needs into their project. Though the group of interested parties might not be directly involved in the relevant project, during its initial phase, they could also become stakeholders. On becoming stakeholders their needs and requirements would be incorporated into the project avoiding repetitious data collection projects. The consequence for a state or region would be a recovery of costs, in the case of bringing private enterprise on board, and a reduction in costs in the case of the participation of other governmental agencies.

An illustration of the potential recovery / reduction in costs is that of the project owner, who in this case a land administration authority, wants to acquire a high resolution digital terrain model (DTM) with digital orthophotos of a city or a town for land administration purposes. The DTM is often collected and generated using mass points (also LiDAR data) and break lines. The break lines can be either natural features such as rivers or streams, or man-made features such as streets, pathways and embankments. Normally it is recommended that natural and man-made features be captured and coded according to their feature type, ie roads as roads, streams as streams etc. and not as feature break lines. The additional work required in coding the features according to their type is minimal, but the benefits large. For example such a DTM could provide an entire road network data to a city / town roads authority. Thus the land administration authority could deliver data to the roads authority. The roads authority would then only need to add its maintenance and development information to the acquired road network data. This would help reduce the costs of data collection to be met at regional and national level. The project owner would retain ownership of the base data, but the stakeholders would have access via Web Mapping Services (WMS) and Web Feature Services (WFS) and therefore be able to manage their own data which sits over the base data.
It is recommended that project owners should not be made responsible for informing potential stakeholders of spatial data collection / generation projects. It would be more advisable if one authority or agency in a country or region were to be responsible for disseminating such information. This would ensure that the information is issued from a single source and reduce any redundancy in bureaucratic processes. The responsible authority / agency should compile a list of all potential users, public and private, for any and all spatial data collection / generation projects, which may take place. The authority’s / agency’s central role would be to receive and disseminate information about such projects. Notice of any planned spatial data collection / generation project, would have to be forwarded by the project owner to the authority / agency. The responsible authority / agency would then inform the spatial data users / potential stakeholders on the compiled list about the upcoming project and invite them to express their needs or interests. The authority / agency, as the facilitator and coordinator between the project owner and potential stakeholders, could then assess the feasibility of the needs before forwarding them to the project owner. The project owner would then have the final say as to whether to incorporate the needs into the project. If the stated needs were incorporated into the project then the cost of the additional work should be borne by the requesting stakeholder(s). Management of the project would remain, however, in its entirety with the project owner.

Almost all countries have national or regional land and survey authorities and agencies. These authorities or agencies are responsible for the geodetic and geographic data for their respective country or region. They are independent in their operation and report either to the head of their government or a government ministry. Hence it would be logical to assign the task of managing the dissemination of information about planned spatial data projects to these organizations. If a country does not have such an organization then it would be advisable if an agency could be established at governmental level to be responsible for centrally managing the dissemination of information about spatial data collection / generation projects. In addition to the central role of disseminating information such an organization could also be the coordinator of a national or regional spatial data infrastructure initiative.

**Conclusion**

This paper has considered how the use of spatial data can be maximized, taking as a descriptive case study the cities of Bonn and Addis Ababa. The paper first described data collection and the wealth of information which can be obtained during the spatial data collection process. The paper then showed that the required technology and the data are available in the case study cities of Bonn and Addis Ababa. In both cities international spatial data standards are applied. Various aspects of both cities geodata
processes were described including historical antecedents, organizational structure, and technologies. The paper then recommended an approach to be followed by countries or regions in order to maximize the benefits derived from spatial data by involving all spatial data users and potential stakeholders during the project initiation phase.

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