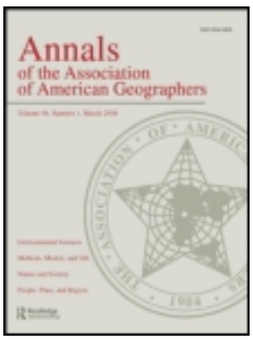

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Toward Open Source Kenya: Creating and Sharing a GIS Database of Nairobi

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To make good decisions about the future direction of cities we need data to contextualize and make recommendations that are based on past results and potential models for the future. Yet access to information including geographic information systems (GIS) is challenging, particularly as data are often seen as a commodity or source of power by those who control it, a dynamic more severe in contexts like Kenya. By generating GIS data for our own transportation model and then sharing them with those interested in doing research on Nairobi, we experienced firsthand some of the power dynamics associated with accessing and generating information in the developing country context. The project had several important lessons: (1) Simply developing data does not make them open; how "open access" is provided to the data is just as important as making them freely available. (2) Developing data can show commitment to a particular place or project that can help generate support for stronger partnerships and project goals. (3) Openly sharing data about place might help push those with access to information to share information as well. Overall this research project illustrated that sharing data can help support a more open access ecosystem locally by establishing a culture of data sharing but only if those interested in using it have the technical ability to both access and use data sets provided. *Key Words: community and GIS, data sharing, developing countries, empowerment, GIS, Kenya, Nairobi, power dynamics, PPGIS, spatial data.*

为了为城市的未来方向做出好的决策, 我们需要根据过去的结果和未来可能模型的数据, 进行脉络化并提出建议。但信息的获取, 包含地理信息系统 (GIS), 是具有挑战性的, 特别是因为对掌控者而言, 信息经常被视为商品或是权力的来源, 而此般情势在肯亚的脉络中更为严重。我们透过为自身的交通模型生产地理信息系统数据, 并将之与有兴趣研究奈洛比的研究者分享, 我们亲身经验了在发展中国家的脉络中, 关乎获取和生产信息的一些权力动态。该计画有下列几项重要的教训: (1) 建构数据本身并不代表开放数据; 如何提供数据的 "开放管道", 与让它能够免费被使用同等重要。 (2) 建构数据能够展现对特定地方或计画的承诺, 进而有助于产生对更高的参与度及计画目标的支持。 (3) 公开分享一地的数据, 可能有助于促使原本拥有信息管道者分享其信息。总的来说, 本研究计画证实, 透过建立数据分享的文化, 有助于支持更为开放的在地生态系统, 但只有当有意使用数据者拥有获得并使用所提供的数据组的技术能力之时才成立。 *关键词: 社群与地理信息系统, 数据分享, 发展中国家, 培力, 地理信息系统, 肯亚, 奈洛比, 权力动态, 公众参与地理信息系统, 空间数据。*

Para tomar buenas decisiones sobre la futura administración de ciudades es necesario disponer de datos para contextualizar y formular recomendaciones apoyadas en resultados pasados y modelos potenciales para el futuro. Sin embargo, lograr acceso a información que incluya sistemas de información geográfica (SIG) es todo un reto, en particular porque los datos a menudo son vistos como una mercancía o una fuente de poder por quienes los controlan, dinámica que es aún más severa en contextos como Kenia. Generando datos SIG para nuestro propio modelo de transporte para luego compartirlos con los interesados en adelantar investigaciones sobre Nairobi, tuvimos la oportunidad de experimentar de primera mano algunas de las dinámicas de poder asociadas con la circunstancia de tener acceso y generar información, en el contexto de un país en desarrollo. El proyecto dejó varias lecciones importantes: (1) El simple hecho de desarrollar datos no los convierte en abiertos; cómo darle "acceso abierto" a los datos es igual de importante a presentarlos como libremente disponibles. (2) El desarrollar datos puede mostrar compromiso hacia un lugar o proyecto particular, lo cual puede ayudar a generar apoyo para asociaciones más fuertes y para los objetivos del proyecto. (3) Compartir abiertamente datos sobre el lugar podría ayudar a decidir a quienes tienen acceso a la información a que también compartan información. En general, este proyecto de investigación sirvió para ilustrar cómo compartir datos puede ayudar a apoyar localmente un ecosistema de acceso abierto más fuerte, estableciendo una cultura de compartir datos siempre que quienes estén interesados en beneficiarse de esta práctica tengan la habilidad técnica para acceder a los conjuntos de datos provistos y sepan usarlos. *Palabras clave: la comunidad y los SIG, compartir datos, países en desarrollo, empoderamiento, SIG, Kenia, Nairobi, dinámica de poder, PPSIG, datos espaciales.*

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In this article, we share our experience of the challenges involved in trying to acquire a geographic information system (GIS) database in Nairobi, Kenya, and how key actors who possess data create barriers to information access. Our response to these challenges was ultimately to generate our own data set and disseminate it to anyone interested in using it. This case study thus illustrates the critical value of sharing data as a way of cultivating and encouraging a broader ethos of sharing (Craig 2005) and also building better local partnerships. This case study also clearly reveals how "locally, contingent and complex social forces" are involved in the creation of GIS (Harvey and Chrisman 1998, 1683) and reveals some of these particular forces and dynamics in an African city. Finally, this case study demonstrates how the production and dissemination of data sets creates what Harvey and Chrisman (1998) called "boundary objects" or new forms of power relations between those who control and use the data set versus those who have limited access to the possibilities it offers.

The process of both trying to acquire a GIS data set and then building a new one vividly illustrates the power dynamics associated with access to information for urban planning and development work. To achieve our goals we worked with outside researchers (academia), local researchers and think tanks, consultants and international development agencies interested in governmental contracts, technology firms, civil society, and the Kenyan governmental itself. Each group had its own agenda for control and dissemination of information about Nairobi. Our project started with the development of a GIS database for our own transportation modeling and planning analysis because we were unable to obtain a data set from the government or private sources. We realized, however, that the data we created could be useful and powerful to share with others working in Nairobi and we hoped that it would encourage an ethics of sharing among some of the actors (Craig 2005). Our own internal shift in understanding the power of the data reflects the arguments associated with production of this type of knowledge by Harvey and Chrisman (1998), among others (Elwood 2002a, 2002b, 2008; Sieber 2007). Ultimately, we hoped that by providing free and open access to data for Nairobi, we had an opportunity to contribute to a small but growing movement around opening access to data, including GIS data, in Kenya.

Our narrative of data creation and dissemination shows our own shift in understanding of the potential power of the GIS database. Initially, we saw it as a tool for modeling and research, but as we deepened our action research agenda in Nairobi, we realized that the construction of the spatial data and our willingness to share it widely showed our commitment to an action research agenda with our partners in Nairobi. Once we viewed the GIS data in this way, the logical next question was how to disseminate it in a manner that would provide more actors trying to improve urban planning in Nairobi with the tools they needed to do so. Here, too, we experienced obstacles to the data's effective use, including the fact that simply making data available does not necessarily mean that stakeholders have the capacity to use it. The work ultimately had many positive results, however, including a more open relationship with our partners and the beginning of an increased community of data sharing among the actors we were able to reach.

Geographic Information Is Political

It is no surprise that geographic data are highly political. There is a great deal of literature that explains why maps are powerful tools that can serve specific interests and represent different ways of conceiving, articulating, and structuring the human world (Harley 1988; Wood 1992; Harvey and Chrisman 1998; Elwood 2002a, 2002b). Because they represent "privileged and formalized knowledge," maps are both the products and creators of power (Kitchin, Perkins, and Dodge 2009, 9), and the mapmaker has a great deal of power in depicting data and information. Varying representations of the same data in maps can reveal and convey very different information (Monmonier 1996; Wood 2010). Ultimately the ability to effectively use this information can be both empowering and disempowering for communities (Elwood 2002b).

The power relations involved with GIS are complex because GIS, like many other technologies, appear to have the ability to both marginalize and empower different populations depending on who uses GIS and for what purposes within existing sociopolitical and economic dynamics (Lupton and Mather 1997; Harris & Weiner 1998; Elwood 2002b). GIS that empower communities have been labeled public participation GIS (PPGIS; Sieber 2006). PPGIS was originally defined as "a variety of approaches to make GIS and other spatial decision-making tools available and accessible to all those with a stake in official decisions" (Schroeder 1996, 28). Recent PPGIS literature addresses how "geospatial collaboration" can empower or mobilize communities

around specific policy issues, emphasizing justice for marginalized populations (Craig, Harris, and Wiener 2002; Elwood 2002a, 2002b; Elwood and Ghose 2003, 2004; Bailey and Grossardt 2010).

In PPGIS projects, GIS is often used by community groups to gain legitimacy in decision-making processes because most information used in policymaking, including crime, land use planning, conservation, and service provision, contains a geographical or spatial component (Sieber 2006). It can be argued that when these groups effectively engage spatial data and analysis in their efforts, they have more power in political and civic decision-making processes (Elwood and Leitner 2003; Bailey and Grossardt 2010). Nongovernmental organizations (NGOs) and community groups are increasingly using PPGIS to improve local decisions and enable local-level analyses to be shared and thus influence national-level policies (Alcorn 2000; Rambaldi 2004).[1] Community-based organizations are using GIS to increase their effectiveness in neighborhood-level organizing, planning, and problem solving (Sawicki and Craig 1996; Kellogg 1999; Elwood 2002b; Ghose 2007).

Empowerment derived from PPGIS is dependent on the process but also on the geographic decision-making tools or GIS systems developed to allow for that collaborative process. Whether the tools give access to information and data or provide the ability to analyze geographic knowledge, many would argue that the systems developed for participatory GIS have their own science (Jankowski and Nyerges 2001; Elwood 2008; Bailey and Grossardt 2010). Research looking at these tools is referred to as participatory geographic information science (P-GIS). P-GIS focuses on the methodologies used to incorporate stakeholder values (Jankowski and Nyerges 2001). P-GIS literature looks at how GIS might improve knowledge transmission from participants to experts (e.g., Hopfer and MacEachran 2007). It also looks at how the use of GIS might affect organizational culture through its adoption and systemic use (Cai et al. 2006). Other P-GIS research looks at how groups can experiment with new uses of GIS that allow for collaboration (Nyerges, Jankowski, and Drew 2002; Voss et al. 2004; Jankowski et al. 2006). P-GIS illustrates how GIS themselves affect participatory results and community empowerment. Our work creating and sharing a GIS database for Nairobi falls into both areas of research because we created both a tool and process for decision making using that tool.

How GIS data are accessed and produced influences their role in policy and planning processes. Often, when community groups have GIS data, they derive or obtain it from a variety of sources, including government offices, intermediary institutions, and other community groups, depending on the context (Elwood and Leitner 2003a; Sieber 2007). As we experienced and explain later, many organizations face difficulty in obtaining GIS data (Elwood and Leitner 2003a). Further, when data are obtained, they are often originally produced for another purpose and thus might not be appropriate for a community group's specific needs, or data might require significant modification (Ghose and Huxhold 2002; Elwood and Leitner 2003a; Warren 2004; Elwood 2008). How data are organized (e.g., classification or aggregation) might also be project specific, which can present problems when sharing data among organizations. Finally, data format might also influence an organization's ability to share and obtain appropriate spatial data (Sieber 2007). Sieber (2007) found that the ability of community groups to access appropriate and usable data heavily influences community groups' activities and occasionally "shifts or precludes activism."

Whether data were created through a participatory process or not, access to GIS data remains a key issue when working on urban planning and development projects. *Access* is defined by context, connectivity, capabilities, and content (Laituri 2003), and when one of these components is missing, potential users do not have access. Harvey and Chrisman (1998) usefully drew attention to "boundary objects" or new forms of power relations between those who control and use the data set versus those who have limited access to the possibilities it offers. Indeed, the tools to maximize the power and potential of GIS are expensive, limiting those who can ultimately benefit from them. Harris et al. (1995) noted that the establishment of a GIS database and all its requirements including hardware, software, and trained personnel, can be an impediment to its widespread proliferation. Consequently, as we would discover in our case, GIS technology is often limited to state agencies or large private corporations, and these agencies and corporations have discretion over the access to that data (Harris 1995). This creates a problem for downward accountability to citizens, particularly in peripheral areas, where technology remains inaccessible and limits communities' abilities to use it for planning and development (Obermeyer 1998; Rambaldi et al. 2006).

The dissemination and creation of GIS databases has been contentious because of the role it plays in empowering some and disenfranchising others (Schuurman 2000). Given these power dynamics, there have been efforts throughout the world to increase the availability

of spatial data for more community-based initiatives and more inclusive and transparent planning through collaborative GIS and geographic data sharing agreements (see, e.g., Onsrud and Rushton 1995; Balram 2006). These collaborative data-sharing entities or spatial data infrastructures (SDIs) allow for sharing and access of data across different organizational and governmental entities (Groot and McLaughlin 2000; Elwood 2008). SDIs are typically developed through governmental mandates to encourage collaboration or data sharing between governmental entities (Harvey and Tulloch 2006). There are bottom-up SDIs, however, that have been developed to help those holding data about a particular place share their information. The prevalence of bottom-up or privately developed SDIs has increased in the last few years as many private organizations realize the benefits of creating a shared resource where the government has not been able to create that resource (Rajabifard et al. 2006).

Access to GIS data helps grassroots organizations be involved in the planning process, but research has shown that having data access alone does not necessarily guarantee a role in the policy process (Craglia and Masser 2003; Onsrud and Craglia 2003; Tulloch and Shapiro 2003). Social and cultural institutions also influence the level of access to and participation in PPGIS (Aitken and Michel 1995; de Man 2003), and social networks and cultural practices and expectations shape these institutions (Kyem 2004). Institutional conditions and factors shape how effective any PPGIS exercise will be at influencing societal outcomes and public processes (Kyem 2004). Local political context, which includes various actors and institutions, shapes the process of participation and PPGIS production (Ghose and Elwood 2003). Some research shows that even with the development of SDIs, communities still rely on their social and political networks for accessing and updating information (Harvey and Tulloch 2006).

Even with these efforts, significant challenges to making free and reliable spatial data available and useful in urban planning and development and policymaking processes exist. This is particularly true in developing countries, where the development of SDIs has been difficult because of technological barriers, funding issues, and governmental and political capacity to build these structures (Nkambwe 2001). In addition, accessing official GIS data in these countries can be difficult, if not impossible, as governments often tightly guard data, if they exist at all (Bishop et al. 2000). This is not surprising because geographic data, especially as they relate to land and claims over property, are often highly political.

The interrelated problems of accessing GIS technology and establishing sophisticated SDIs are often more prominent in low-income countries for a variety of reasons (Burke 1995; Bishop et al. 2000; Makanga and Smit 2010). For example, developing countries tend to lack standard guidelines and laws for land registration, planning, and land management, making it difficult for them to establish standardized SDIs (Bishop et al. 2000). Land records are sometimes deliberately left in disarray (Klopp 2000). This stems from the colonial inheritance of multiple legal systems and flawed and exclusive planning systems that continue to serve the more powerful and hence are difficult to reform (Myers 2003; Njoh 2008).[2] In addition, typically, those who possess GIS skills, data, and technology (a smaller pool of people in the developing world context) are often those who work for more powerful entities; the less skilled are disadvantaged and are thus often easier to control (Sieber 2006; Klopp and Sang 2011).

Another barrier to spreading GIS and developing open SDIs worldwide is the commoditization of spatial data. Raw electronic spatial data appropriate for GIS are often legally restricted with copyrights and licenses. Copyrights grant exclusive rights to publish, and licenses govern access, cost, and use of data (Sieber 2007). When protected by copyrights or licenses, data access is often restricted, often to data sellers (Day 2004, cited in Sieber 2007). Thus, through mass production and marketing, spatial data become subject to market forces and hence available only to those who can afford them. This can often lead to global as well as local inequities in access. Although the data might be promoted as something that is "general purpose," because they are a commodity that can be bought and sold, they are often produced to serve a particular constituency (McHaffie 1995; Sieber 2007). Often this constituency has the resources to pay for GIS services, excluding many who do not have access, and the interests and agendas of the buyer influence the product. The marketing of GIS data in this manner also assumes that GIS data produced for one purpose might be appropriate for an often entirely different purpose (Sieber 2007).

The commodification of data is also problematic in developing countries, where the cost of developing the data is often high or prohibitive. Once developed, the data become a commodity for the government or entity who created them and maintains control over its storage and dissemination (Goddard and Openshaw 1987; Thakur and Sharma 2009). This relates to GIS and society arguments, as access to spatial data can be limited by those in power simply because they have the money

to purchase or pay for the development of GIS systems. To deal with this, PPGIS advocates posit that the development of data by local communities can help alter the relative power that the traditional producers of GIS data hold, at the same time challenging state priorities and creating new space for local groups to influence neighborhood change (Elwood and Leitner 2003b). Finally, the movement toward free and open source software for GIS and toward open access GIS data is helping to counter the complete commoditization of this valuable data (Makanga and Smit 2010, 25).

Despite the many barriers, there has been a push to promote the development of GIS and SDIs in Africa. Although this is changing, GIS data development has typically been performed by NGOs, academics, or outside contractors. After these organizations leave their project site, local institutions often struggle to use and maintain the files generated by the external entity (Dunn et al. 1999, 328; Crampton 2009). According to Weiner and Harris (1999), this lack of capacity after an NGO or other external body stops work is widespread. In fact, in most developing countries the "establishment of a spatial technology infrastructure is dependent on external funding or temporary support received through aid projects often introduced with a view to demonstrate the use and need of technology" (Thakur and Sharma 2009, 133). Thus, when the financial support ends, so ends the licensing of software, and the motivation to maintain the initial efforts also disappears. Thus, sustainability of these efforts around GIS and SDIs is a key issue, although it is interesting to note that regardless of the barriers, over the last two decades Africa is moving toward "the rapid adoption and proliferation of GIS with potential to influence and shape the way in which society views, values and uses spatial information" (Koti and Weiner 2006, 2).

Geographic Information in Kenya

Even though Kenya, one of East Africa's largest countries, is recognized for having a thriving information communication and technology (ICT) sector, it faces the typical problems and dynamics around GIS and SDI more generally. A shortage of spatial data and information, especially openly accessible data, exists, and although the government has an official e-government strategy (Republic of Kenya 2003), it does not have an official policy or strategy on spatial information and infrastructures. Where spatial information required for urban and development planning (physical and climactic features; population and demographic characteristics; economic activities; transport and communication; infrastructural utilities; social services; land ownership, tenure, lease, size; etc.) does exist in Kenya, it is often outdated or suffers from limited scale and inconsistent jurisdiction and spatial area unit and is often stored under poor conditions with limited access for those who might need it (Omwenga 2001). This lack of freely available and up-to-date spatial information in Kenya has severely limited the ability of jurisdictions (cities, municipalities, towns, and urban councils) to prepare development plans (Omwenga 2001).

Reinforcing observations made by Harris et al. (1995) about access to GIS and geospatial databases in Kenya, "the central government, large municipalities, local and international research institutions, and donor funded and individual projects" primarily have access to GIS data (Koti and Weiner 2006, 1). The Kenyan government claims that it would like to increase the use and development of spatial data, but it does not always make GIS data easily available for its own planning professionals at lower levels of government. The Survey of Kenya is taking a lead role in this initiative and the latest Kenyan census used GIS. It was also able to insert the Kenyan SDI into the National Development Plan for 2002–2008, thereby mandating resources at the Ministry of Lands and Settlement toward the development of a national GIS system.

Overall, despite the active technology community, growing numbers of local GIS experts, and new teaching programs,[3] Kenya's development of GIS and national spatial data infrastructure is still heavily dependent on donor projects and funding. For example, the Kenya National Spatial Data Infrastructure (KNSDI) was launched to "facilitate the capture, storage, conveyance, and display of geographical information" (Murage, Gitimu, and Sato 2008, 117).[4] KNSDI held five workshops between 2001 and 2006 aimed at creating awareness about spatial data and its importance and also to create a central spatial data clearinghouse (Murage, Gitimu, and Sato 2008), which has in fact happened, making Kenya one of the few African countries to have one in operation (Makanga and Smit 2010, 24). Beginning in October 2006, the Japan International Cooperation Agency (JICA) provided further technical assistance to the KNSDI program. The aim of JICA's involvement was to (1) formulate standards for KNSDI, (2) enhance the Government of Kenya's competence in map digitization, and (3) develop resources for GIS dissemination in Kenya (Murage, Gitimu, and Sato 2008). KNSDI standards, digitization manuals,

and guidelines for facilitating data sharing were successfully completed. The broader objective of promoting the use of GIS in Kenya remains to be achieved, however.[5] It should be noted that the development of this SDI was largely contracted to JICA, which left Kenya with many of the problems associated with the development of SDIs in a developing country context: limited capacity once the agency that develops the infrastructure leaves or is no longer involved (Massar 2005).

More recently in July 2011, the Kenyan Government launched the Kenya Open Data Initiative. The initiative makes government development, demographic, statistical, and expenditure data available in digital format on a Web site.[6] Those data are intended to provide a "platform for innovation" that will produce more efficient outcomes in terms of service delivery, job creation, and citizen feedback systems; enable data-driven and better informed decision-making processes; and improve transparency and accountability in all government operations (see opendata.go.ke). The site features more than 160 data sets, including the 2009 census. Although the data are not specifically "spatial," raw data are available for download and much of it can be depicted spatially.

Despite this initiative, major hurdles exist in terms of accessing GIS and other forms of data for Kenya. Government agencies do not wish to release existing data for sharing (Wahitu 2012) and sometimes, in any case, they do not have good data to share (L. Omoto, personal interview, 22 August 2012) or do not have them in a very user-friendly format. More recently, attention has been drawn to the need for a legislative framework to facilitate greater openness, give life to the right to information that is part of Kenya's young 2010 constitution, and formalize the relationship between "government agencies and those in charge of the information" (Kenei 2012, 9). Furthermore, a growing recognition exists that a broader network of actors or ecosystem is needed that includes civil society (Kenei 2012, 10). Indeed, this might help create an environment that enables more "white knights" or "people with the vision and motivation to convince an entire organization to adopt GIS technology and share it" (Craig 2005, 5). Currently, given the reluctance of the government to share data and also the actual lack of critical data including GIS data, more technology firms, researchers, and civil society groups are taking up the challenge. In July 2011, for example, the technology firm Upande Ltd., Wildlife Clubs of Kenya, Jacaranda Designs Ltd., and the International Livestock Research Institute (ILRI), in alliance with a global NGO, the World Resources Institute, launched Virtual Kenya, a platform for aggregating spatial data on Kenya. The aim is to increase data sharing and spatial analysis for decision making and development planning.[7]

Although conditions are clearly improving, finding usable spatial data for the Nairobi area remains difficult. This might in part be due to the fact that there is no longer an allocation for the KNSDI in Kenya's National Development plan, thereby making it hard to continue to dedicate resources that would allow for the dissemination of this information; efforts instead fall on groups like Virtual Kenya. Although low-quality, downloadable maps and other information are available on the KNSDI Web site, raw data are not available. Although the data available on Kenya's Open Data Initiative Web site hold great potential in providing open access to information, the Web site has just been established and much of the data are not inherently geographic or are provided at a regional scale, which makes them hard to use for local planning projects. At the same time, KNSDI does not have the online infrastructure to purchase or download data. It is possible to obtain spatial data through the Survey of Kenya, but this is still limiting because of the cost and the strict licensing agreements involved with obtaining this information.

From a Transport Model to a GIS Map for Nairobi

In Fall 2006, with funding from the Volvo Research and Educational Foundations,[8] we engaged partners at the University of California Berkeley (UCB) Center for Future Urban Transport and the Kenya Institute of Public Policy and Research Analysis (KIPPRA) to help us examine Nairobi's transport system. We started with a preliminary transportation and land-use model of the metropolis and used it to develop a macroscopic traffic simulation model. The traffic simulation model would then be used for scenario analysis and to help identify a course of action to improve the efficiency of Nairobi's notoriously problematic transport system, which suffers from high levels of oil dependency, poor mass transit, high levels of traffic crashes, poor air quality, and severe congestion (Aligula et al. 2005; Republic of Kenya 2010; Klopp 2012). Specifically, teams from our center and UCB aimed to use the traffic simulation model to assess current traffic conditions in the Nairobi metropolitan area, including average vehicular densities and travel times.

The UCB team wanted to be able to provide an assessment of future traffic conditions under different scenarios: if nothing is done versus undertaking certain congestion mitigation strategies such as restricting motor vehicle access to the central business district or bus-only lanes. This assessment would then be shared with KIPPRA, which would incorporate existing data on buses and other shared-use vehicles, such as *matatus* (small fourteen-seaters), at different times of the day. Our research team would be responsible for finding the best fit between possible transportation system strategies and implementation issues as well as engaging a network of policymakers in discussions around the different scenarios. This involves recognition of the need for a multilevel approach and discussions at all levels on policy, institutional and governance reforms, and management and oversight of the transportation system. Ultimately, this work was meant to provide leverage for much of our policy work that focuses on encouraging sustainable policy and planning approaches in the Nairobi metropolitan area.

Acquiring GIS data for Nairobi for the purpose of the transportation study proved to be a delicate matter. Our research team had identified an existing set of GIS data that was developed by JICA and owned and controlled by the government. When we approached the Survey of Kenya for JICA's GIS files developed in 2006, however, we were told the cost would be US$50,000, and the files came with strict restrictions on sharing these data with our partnering institutions, including those in Kenya. These terms meant that it would be impossible to use these data for our purposes. Specifically, we needed to be able to share the data with at least three to four partners, which meant that we would be required to pay the full costs of the data set three or four times, putting the cost of the data set at $200,000. Even with that cost, if we included another partner or shared the data again, it would continue to cost $50,000 each time. Therefore, we needed an alternative solution; the cost of accessing the data was simply too high. Overall, we found that obtaining information and maps from government offices, both local and central, was a disorganized process in Kenya even after the development of the KNSDI.

JICA was contacted about the possibility of obtaining data for the project but was not interested in sharing the data for our research purposes. Although it is hard to speculate on whether JICA was interested in the work we were doing or not, ultimately they cited contractual issues with the government as precluding them from sharing the data set. It should be noted that JICA is in competition with other development agencies and promotes its own transportation and consulting firms within Nairobi and across the developing world.[9] In many ways, this would account for why they would align themselves with governmental practices of control over the data set: This position also provides control to JICA, which then has the capacity to realize the full potential of the analytics provided by the data.

Although JICA retained control of the GIS data set, the Survey of Kenya allowed us to use a scanned georegistered version of their official maps, also produced by JICA, to create digital maps for our transportation model. These maps represented on-the-ground conditions in 2003 and were published in 2005. A team of trained graduate and undergraduate students at our center's university used these maps to trace and digitize land features into GIS files. These Columbia University students were funded directly by our center through a grant from the Volvo Research and Educational Foundations.

Our research partners worked closely to identify the attributes that would be needed for the land use and road network GIS data files.[10] The scope of work originally only included the development of the road network file, but once the team realized that there was some ability to glean density and land use information from the base maps, the development of these attributes was included in the GIS database development. As we created the land use file we realized that the number of buildings on a site might help to measure the building density of an area, and density information could then help us approximate the number of trips generated by a particular place. We determined density figures by counting the number of buildings per acre on each land parcel (see Figure 1). We also developed general land use categories, because the detailing on the JICA maps helped to provide some clues into land uses.

The creation of the land use shapefile (see Figure 2) involved the digitization of the original Survey of Kenya base maps. Polygons representing the various land uses denoted on the original Survey of Kenya maps were drawn and assigned a land use category. Land use categories included commercial, industrial, institutional, mixed commercial–institutional, mixed commercial–residential, no structures, recreational, residential, residential "slum," open space, transportation, water, and unknown. The definitions for these categories were created for the digitization process and were obtained from reading the land uses marked on the Survey of Kenya maps. For example, "residential slum"

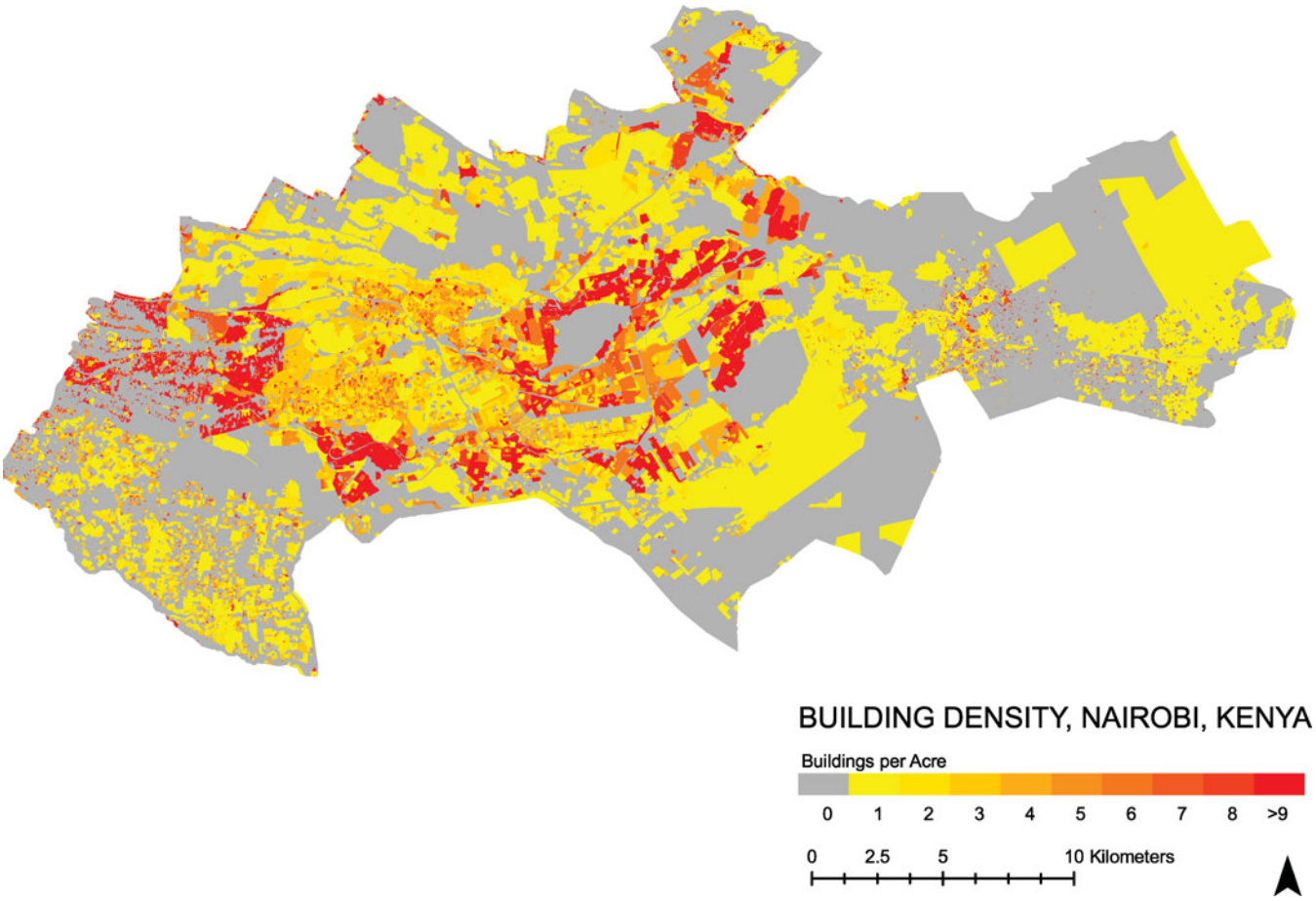

Figure 1. Geographic information system map of the building density (buildings per acre) created through the digitization process described in text. (Color figure available online.)

was delineated and marked on Survey of Kenya maps as a land use type, and where this was written on the map we generated a polygon and categorized that polygon as "residential slum." Where land uses were not marked on the on Survey of Kenya maps, an "unknown" category was given to the land divisions. The maps did not include official parcel boundaries, but JICA did create delineations of land masses using a dotted line and these borders were used to create the polygons for the land use map. Depending on the amount of information provided by the original map, a more specific description, official name, or both were added to the polygon in the attribute table. This further information could easily be translated into points-of-interest data. The number of buildings contained within the land use polygon was then counted, either individually or by determining an average building per acre. Because lot lines and parcel boundaries were not always clearly indicated on the original map, we created polygons using these boundaries as only a loose guide.

The creation of the roads network GIS file (Figure 3) involved much of the same process as the development of the land use files. Street centerlines were digitized by tracing the original Survey of Kenya maps and measuring width to add to the attributes table. Street centerlines are network-based GIS files that are the standard for use with transportation models and can have a number of attribute fields including speed limit, traffic signals, and average traffic flow. The data we developed only had information about width and road category because we had limited information on traffic rates. The road categories were taken directly from the Survey of Kenya JICA map categorization and included main road, bitumen (minor road), earth (dirt road), other tracks, footpaths, and main tracks. Depending on the amount of information provided by the original map, an official name was added to the attribute table. We then measured the width of the road in meters on the original map and also added an attribute table. Finally, we identified several road obstacles and

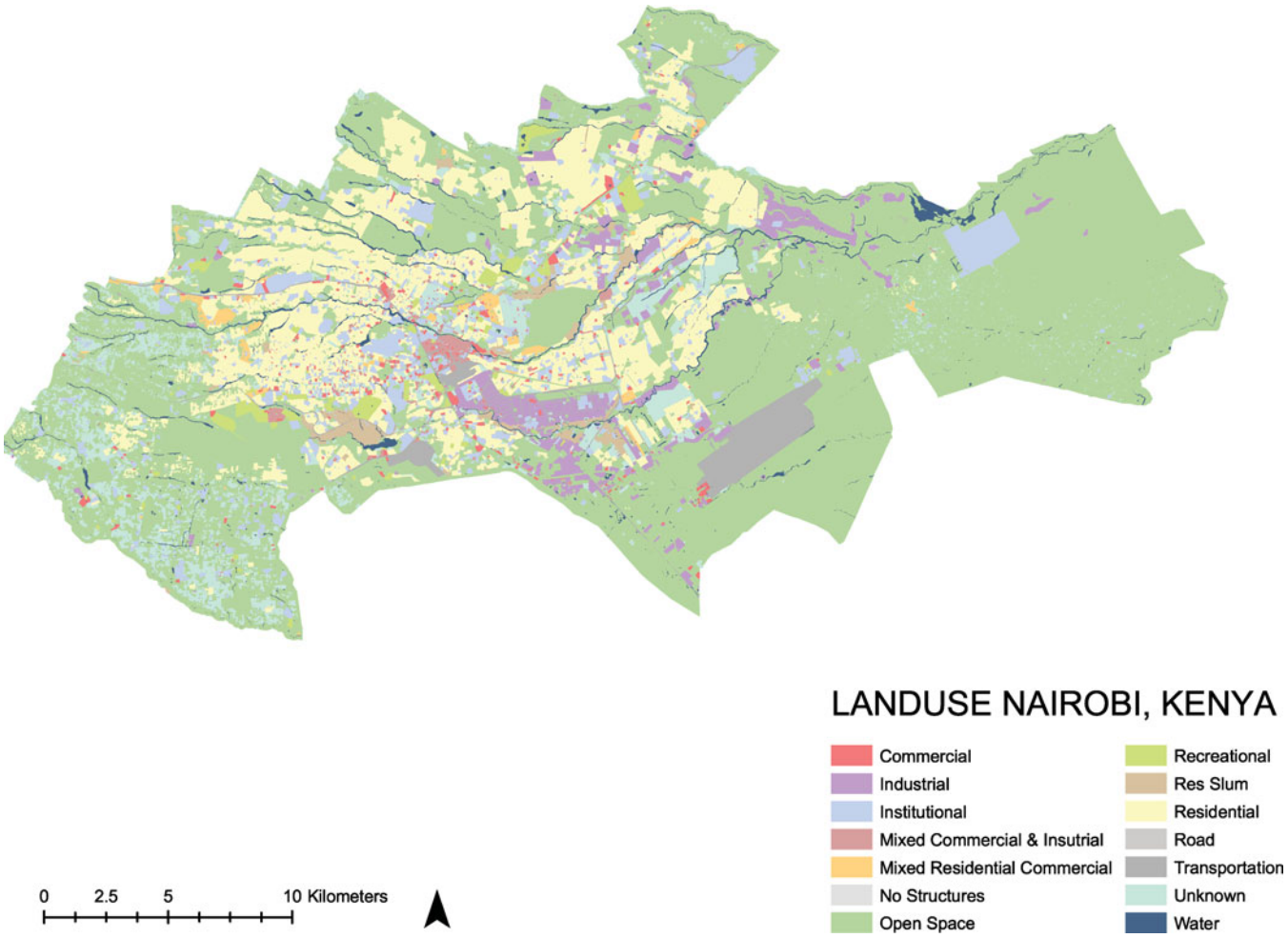

Figure 2. Geographic information system map of the land use file created through the digitization process described in text. (Color figure available online.)

added them to the attribute table (see Figures 4 and 5). This was needed because several roads were completely impassible, even though they appeared to be through streets. All of the map and attribute information was gleaned from the Survey of Kenya paper maps to provide consistency in the way the data were produced throughout the maps.[11]

Once the data set was complete, the UCB team set out to study traffic conditions in Nairobi by developing a CORSIM module that uses street networks and intersections to observe "the evolution of congestion" based on different demand scenarios (Gonzales et al. 2009, 10). CORSIM simulates behavior of individual vehicles through predicting the impacts on traffic patterns from implementing changes to the road network or through an increase or decrease of traffic volumes. The module makes it possible to identify a relationship between existing road conditions and the impacts of increased travel demand (Gonzales et al. 2009). The study revealed that Nairobi has a predictable macroscopic fundamental diagram (MFD). That is, the relationship between the accumulation of vehicles on a street network and the ability of the network to serve the number of vehicular trips is predictable (Gonzales et al. 2009). Further, this relationship is reproducible, as it is consistent at different levels of demand. More broadly, the UCB study showed, perhaps unsurprisingly, that as population in Nairobi increases, so too does vehicular traffic, which increases the demand on the road network. The goal of the project was to help quantitatively and visually support claims that showed that increased travel demand would create increased gridlock on Nairobi roadways. The model produced evidence to support this claim, which the research team hoped would help influence much-needed changes to Nairobi's transport system.

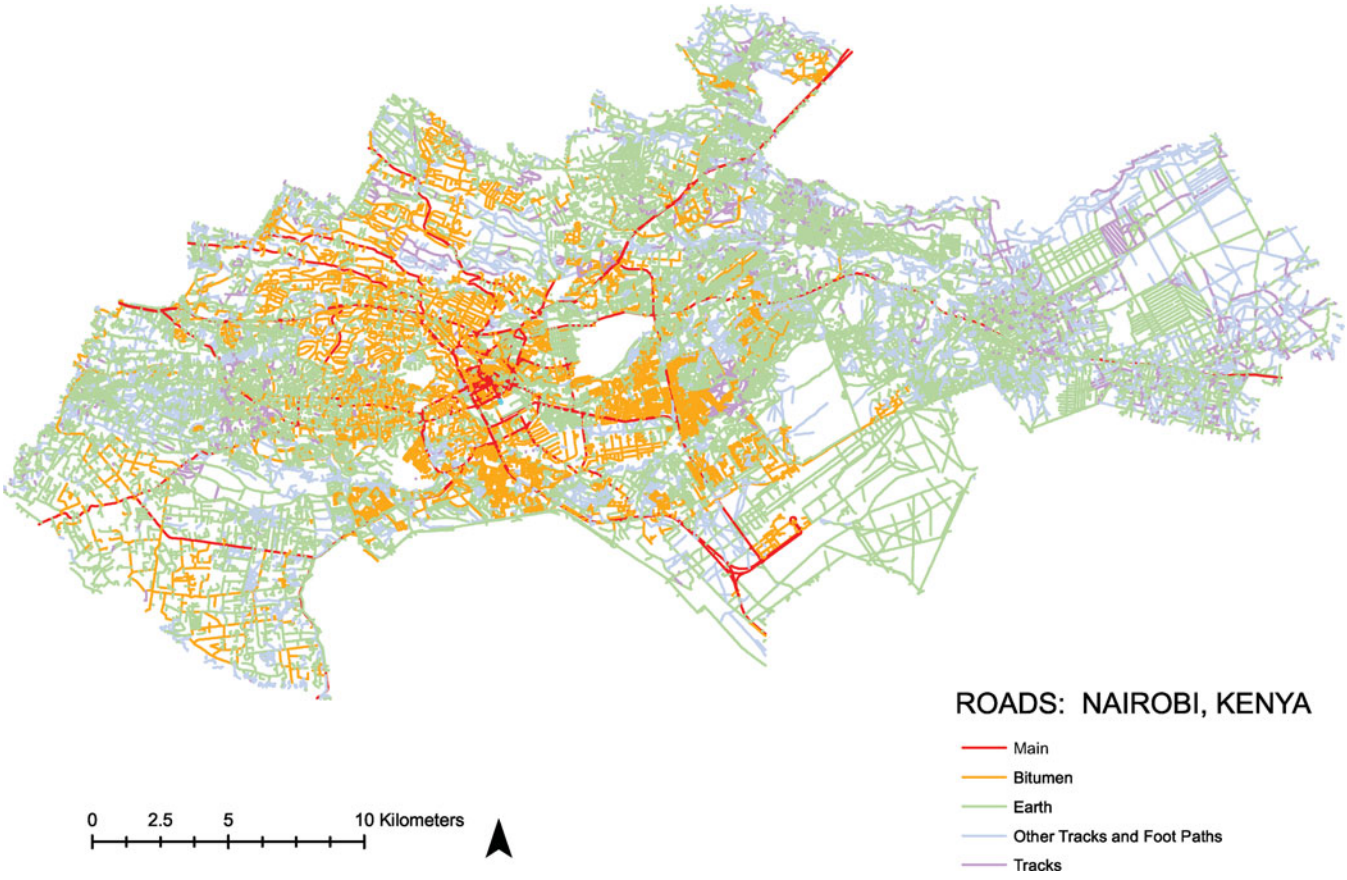

Figure 3. Street centerline map file created through the digitization process described in text. (Color figure available online.)

Sharing the Nairobi GIS Database

After sharing the GIS database with our Kenyan partners, including KIPPRA and the University of Nairobi, we realized that the map not only had value to our work in Nairobi but that it might also have value to others doing work in the area. This realization was heightened when Google asked if we would share the data to enhance their Points of Interest (POI) data for their Google map of Nairobi. For KIPPRA, the data were largely used to understand possible associations between land use patterns and Nairobi traffic survey data that they had collected (Salon and Aligula 2012). According to KIPPRA, the data were also useful in enabling "a better visualization of the land-use patterns on the ground." Toward this end, the maps have been used for drafting policy reports (E. Aligula, KIPPRA, personal communication, 10 March 2011). The data were also useful in a transportation modeling study conducted by a member of the young professionals program of the infrastructure and economic services division at KIPPRA. Interestingly, we did not find out that the data were used for this purpose until a year later, when we discovered that the individual had simply "found" our land use data on a disc in KIPPRA's offices (J. Gachanja, personal communication, 22 July 2011). After we discovered this, we knew that formalizing that data-sharing process had been a valuable endeavor and that the GIS data could have great value if more widely and systematically disseminated.

Although we cannot say this definitively, we suspect that sharing the GIS data with KIPPRA gave them a reason to more freely share some of their data with us, namely, Nairobi traffic survey data. Data exchanges with KIPPRA went more smoothly after the Nairobi GIS data files were shared with them. Until that point, our research center had largely depended on KIPPRA for much of the data used for transportation and policy analysis. Early on, discussions between the two organizations about access to data were often strained, as motives behind the research and the terms of the partnership were not always well understood. We believe that KIPPRA saw the potential for using the data with their traffic survey data and was perhaps more willing to

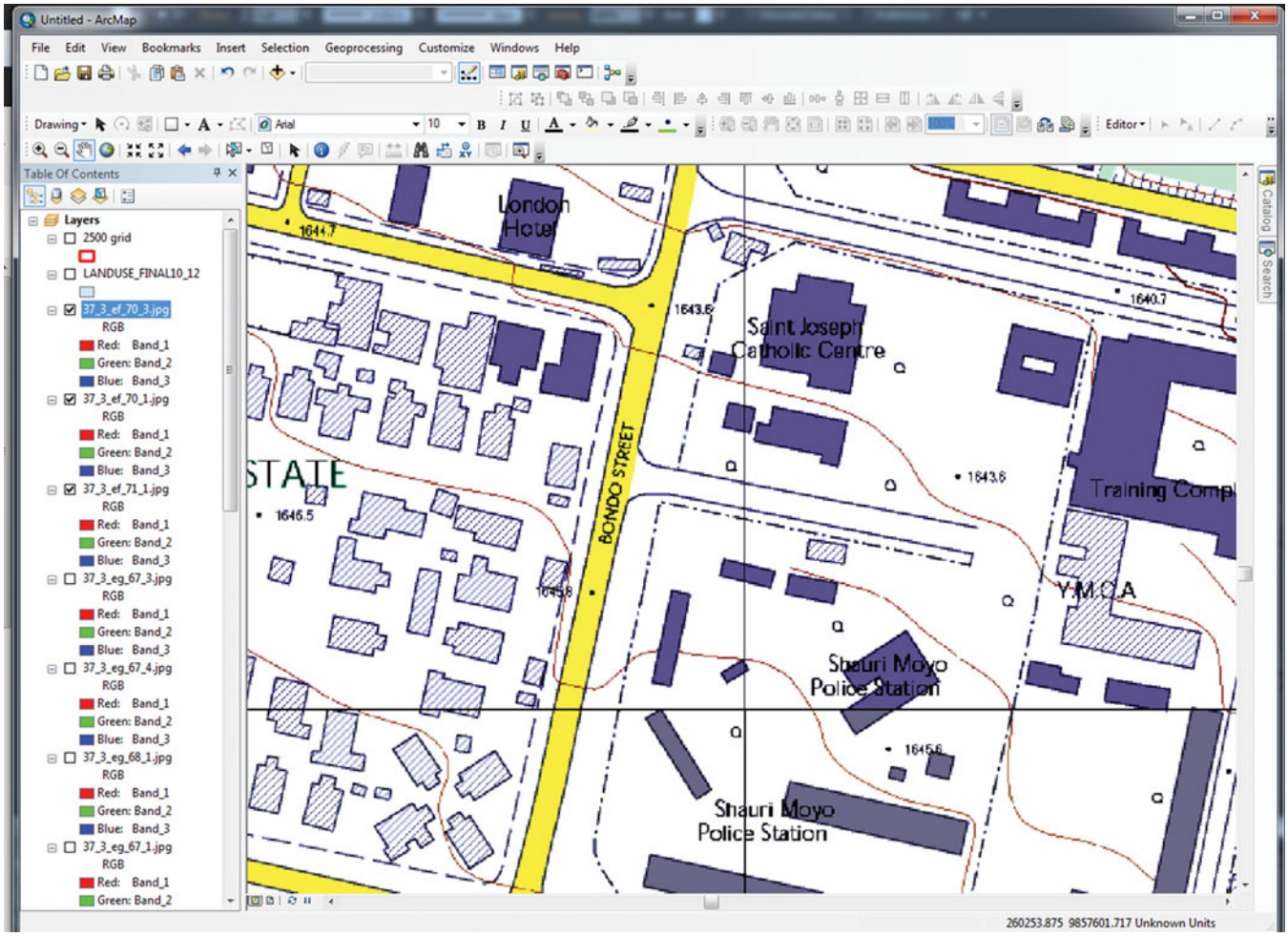

Figure 4. Screen shot of Survey of Kenya map in ArcGIS. The screen shot shows an area where obstructions can be seen on the map. (Color figure available online.)

collaborate on data sharing. The initial sharing of the GIS map was based on the ideal that each organization brings its own data and shares them with others in an effort to collectively solve a common problem (Pinto and Onsrud 1995) and promotes an ethos of sharing (Craig 2005). This helped reinforce the message that we were seeking a more equal basis for collaboration in examining Nairobi's transport problems. Our transportation model for Nairobi did not start as a participatory GIS project, but the boundaries shifted, and the data access we enabled provided for a more collaborative analysis and decision-making process with our partners, akin to a participatory GIS.

To disseminate the data beyond KIPPRA, we realized that a more efficient and formalized system to share the data would be necessary. To facilitate the data-sharing process, our research team created an online wiki space through an existing interface within our center's home university known as "wiki scholars." This wiki space would allow for download of the data files and public discussion on data quality and possible uses for it. Our decision to make the data available in a wiki space stems from the fact that the wiki scholar interface already existed within our university's information technology services. Many of the features we wanted for the dissemination of the data (discussions, commenting, etc.) were already in the system. Thus, it made the most sense to take advantage of it and experiment with it. We have since learned that there is some precedent for making data available through online wiki spaces, although most of the existing and well-established approaches, such as Freebase,[12] are top-down formats, and few efforts exist at the grassroots level (Benson et al. 2010). Although in many ways the wiki space provides an easy way to allow people to download the data, ultimately we believe that because it was not

Figure 5. Google Earth image of area seen in Figure 4. The obstructions in the road are visible. (Color figure available online.)

initially directly linked to other data-sharing initiatives in Kenya, we did not reach many of the people we had hoped to engage. This might not have been directly a result of the wiki format, but it does show that connections with existing data communities are important for the dissemination of this type of data. In some ways we created our own boundaries to data access by working within our own knowledge base and not initially reaching the broader Kenya open data community.[13]

Although anyone who finds the Web site is free to download data, at the beginning when we posted the data we required users to register to the wiki space so that we could track use. At this point, the Nairobi GIS data wiki has been functional for over two years and requests have largely come from other academic institutions, NGOs, or students interested in doing work in Nairobi. As of June 2013, it has sixty-five registered users, a substantial number in Kenya, and we are exploring ways to increase availability and use of the data. People who initially came to the site did so through a reference from our center or one of the partnering institutions, although it appears that more people are finding the data through Internet searches. In October 2011, we also partnered with Virtual Kenya, which posted our data on its platform, no doubt increasing its accessibility to a group with the skills and knowledge to use it. Indeed, James Gachanja, a junior professional officer at KIPPRA, used the map to enter a Virtual Kenya competition that he subsequently won along with two other entrants. In his words, "The GIS land use database for Nairobi is a great initiative. It holds the key to solving many planning issues especially monitoring development control and guiding urban development policy"[14] (J. Gachanja, personal communication, 14 December 2012).

Most of the participants registered to download data from the wiki site have academic affiliations, and a large portion of these academics have been students interested in investigating or exploring issues in Nairobi. We are excited about the number of people who have

already downloaded the data, but it is clear that we are not reaching many of the people we would like, particularly community-based policy and planning groups in Nairobi. Our early perception was that those agencies doing community and urban development work in Nairobi would be eager to use this kind of data. That has not been the case, though, most likely because most fall outside of the "boundary object" for various reasons. In other words, simply building a GIS data set does not necessarily mean that it will be used. There continue to be institutional and technological barriers that make access and use of the data for political processes hard to achieve (Harvey and Chrisman 1998). Had we made a better attempt to work within those structures, perhaps by publicizing its existence to the various stakeholders, the possibilities for it use might have grown. It is not enough to create a delivery tool for participatory data sharing without engaging the community in which it serves. Overall, more publicity and networking for the GIS data are required to continue to spread the use of the data.

Conclusions

Our process of developing and ultimately disseminating a GIS database in Nairobi illustrates the inherent boundary relationships created when these types of systems are developed (Harvey and Chrisman 1998). The power dynamics are complex, because they involve foreign and local researchers, development agencies, technology firms, civil society, consultants interested in governmental contracts, and the Kenyan government itself. As one might expect, each one of these groups has its own agenda for control and dissemination of information and GIS data. As we developed our research we had to negotiate and navigate within this political landscape to develop a data set that would allow us to work with our partners aiming to make informed decisions about Nairobi. The ability to perform the analysis was not the only result of our research, however, as the sharing of the data ultimately showed that we could begin to change our relationships with Nairobi partners (KIPPRA). Sharing the data with our direct partners helped to establish trust and we believed that disseminating to the larger Nairobi community would help further establish our relationships with the Nairobi planning community. We also came to believe that opening the data to anyone interested in using them would help to further even access to knowledge and cultivate a sharing ethos. In doing this, however, we operated within our own institutional boundaries, as we had yet to connect with groups that could access, use, and disseminate the information more broadly. Realizing this, we actively sought to enlarge the community within the boundaries created around the data (Harvey and Chrisman 1998).

GIS data access is a global problem perhaps made more acute in Kenya because of its authoritarian past. Making spatial data freely available threatens the relative power that governments and other entities maintain by keeping data private or available for a high cost. When the government has power over a commodity, especially one that might reveal problems in government services or accountability, it is no surprise that the government would not be willing to share it freely.[15] Until access to spatial data is increased, either through the development of SDIs or by governments and civil society simply making spatial data more freely available, stakeholders will continue to have unequal power relationships because of a lack of access (Elwood 2008).

Our attempts to access GIS data show that the Government of Kenya needs to take better ownership and initiative in developing a functioning SDI; legislative measures are necessary to create an environment for public access to spatial information (Harvey and Tulloch 2006; Sieber 2007; Kenei 2012). Kenya has a strong and growing ICT community within the private sector and academic world that could be leveraged for these efforts. The KNSDI, launched largely through the initiative of external actors (e.g., JICA), has not been wholly successful. This is not surprising, as projects proposed by external entities, including NGOs or private companies, often have mixed results because of a lack of leadership, capacity, and interest at the civil society and government level (Weiner and Harris 1999). The Kenya Open Data Initiative is another promising project on the part of the Kenyan Government, but it needs continued pressures from a wider open data ecosystem, and time will show how well the data sets are maintained and shared. The development of SDIs across Africa has been problematic because of the complexity of funding, political structure, and capacity. The question becomes how Kenya can overcome some of these problems to develop a successful plan for GIS and its society. In a small way, building and sharing data at any level thus becomes part of building a broader environment to enable change.

Grassroots dissemination of data does not break down boundaries if the message about the availability of the data has not reached the community that needs it. We

might have helped to fill a small gap in the distribution of GIS data in Nairobi, but a solution for the provision of these data for those interested in performing research and doing policy work still needs to be developed. Had we used a more participatory method in data collection we might have reached more local actors interested in using and disseminating the data, reinforcing the PPGIS literature that finds that participatory data collection helps expand the potential of many groups using and the data and telling others about it (Bailey and Grossardt 2010). Similar to other developing countries, it is clear that the ability to obtain GIS data in Kenya has a little to do with capacity; however, it is likely it has more to do with power and control, as one can obtain the data for a price. Moving forward, our research will continue to work toward providing open access to data developed in the course of action research. Ultimately and more important, Kenyans themselves need to address the issue of data accessibility at many levels, pushing the government to open up, creating new databases from below, and building a vibrant and inclusive open data ecosystem. Moving toward open access in this way might just help improve policy decisions in and for Nairobi.

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Notes

1. Rambaldi has developed an online PPGIS training course for NGOs and GIS activists at http://pgis-tk-en.cta.int/ (last accessed 20 October 2013).
2. Early attempts to develop a GIS database in Botswana show that record keeping for land tenure in many developing countries can be complex and based on a cross-section between colonial allocation and indigenous systems, thus making it hard to develop databases that correctly convey ownership (Nkambwe 2001).
3. For example, in 2006 the Department of Geospatial and Space Technology within the school of Engineering at the University of Nairobi started a master of science in GIS program.
4. The policy of the KNSDI is to collect, integrate, and distribute geospatial information and services for use and sharing by all public, private, and civil society organizations in Kenya. The overall stated goal of the initiative is to encourage the use of geospatial information in local, regional, and national levels of government to achieve gains in market development, sustainable development, and transparent and participatory governance (Survey of Kenya 2008). KNSDI policy acknowledges the importance of establishing a national repository of spatial data to encourage access, sharing, and dissemination. Further, the policy acknowledges how important spatial information is for legislative and policy development, natural resource allocation, public safety, and regulatory activities.
5. Some of the limiting factors to achieving this goal include high Internet costs, the need for a clear communication strategy to reach more users and increase awareness of the NSDI, passing NSDI policy and related legislation to legalize and institutionalize GIS, a lack of adequate funding for NSDI for both hardware and software, and the wider recognition that spatial data are a resource that should be accessed freely and disseminated (Murage, Gitimu, and Sato 2008).
6. See opendata.go.ke
7. See http://www.virtualkenya.org (last accessed 3 January 2013).
8. The Volvo Research and Educational Foundations (VREF) represents a collaboration of four foundations that fund research and education on transportation, the environment, and energy. The four foundations that contribute funds to VREF include the Volvo Foundation, the Volvo Educational Foundation, the Dr. Pehr G. Gyllenhammar Foundation, and the Hákan Frisinger Foundation for Transport Research. It supports eight research centers funded by VREF, or Centres of Excellence (CoEs), located throughout the world that focus on the future of urban transport. VREF is governed by a board that decides which research will be funded, establishes policy, and is responsible for long-term asset management and the Scientific Council, which evaluates the scientific quality of research funding applications and the ongoing output of each of the CoEs. VREF funded this work as part of its Future Urban Transport Programme (FUT), which aims to "contribute to the development of sustainable transportation systems" through interdisciplinary academic research in collaboration with intended users' research results, such as traffic and city planners, politicians, government agencies, and interest groups (VREF 2013).
9. As an anonymous reviewer for this articles pointed out, "This intra-development coalition competition for geospatial data is not confined to the Kenyan case. It is a fundamental reality for all users of geospatial systems" (see also Goss 1995).

10. It should be noted that transportation models usually need a combination of land use data, population information, and road network data. The road network data in a transportation model clearly form one of the most essential components, as they usually provide information on road capacity and limitations such as street direction or ability to turn. As mentioned, whereas census information for Nairobi was available for population information, land use and building density data could help to estimate the amount of trips generated by certain land uses. For example, a retail location will produce more trips than a residential location.
11. We recognized the importance of verifying data through on-the-ground observations, but the Survey of Kenya maps were made earlier than our maps and we wanted the data we digitized to represent the world as it was surveyed by JICA at the time.
12. See http://www.freebase.com/ (last accessed 20 October 2013).
13. In many ways, our addition of the data to a wiki space acted as an informal or bottom-up SDI for Nairobi where a governmental SDI did not yet exist.
14. See the project "Map of Land Use Change From Residential to Commercial: City of Nairobi: 2008–2010" at http://www.virtualkenya.org/maps/map-images/524-map-of-land-use-change-from-residential-to-commercial-city-of-nairobi-2008–2010 (last accessed 3 January 2013).
15. We also discovered that people within government or with links to government sometimes use spatial data as a commodity to be sold informally. Thus, this group would have little interest in making such information freely available.

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