Data Collection Techniques for Informal Settlement Upgrades in Cape Town, South Africa

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Abstract: *Informal settlements pose a major challenge for managers and planners of developing world cities. Failure to intervene in a manner that improves residents' quality of life may lead to social and political unrest. Due to continually changing internal social and political environments in these settlements and to frequent changes in the arrangements of shacks, spatial and social data need to be collected more frequently than for conventional development tasks. What are needed are simple, low-cost techniques that preferably involve community members in collecting the data. Palmtop computers, group workshops, and voice recordings incorporated into digital records, digital still and video imagery, and semi-automated feature extraction techniques are methods that have been developed and tested in a number of settlements in Cape Town, South Africa, along with one in Dar-es-Salaam, Tanzania, and that can be used to address these needs.*

Introduction

The burgeoning informal settlements that accompany rapid urbanisation in Africa, Latin America, and Asia constitute a major challenge for land managers, because informal settlements may house 30 to 80 percent of a developing world city's population (UNCHS 1996). Improving the conditions of the urban poor is critical to social and political stability, and there is the potential for urban violence and social unrest as social disparities become more acute (Farvacque-Vitovic' and Godwin 1998).

Managing informal settlements involves, amongst other things, planning and controlling where they are located and how and where they grow; improving the social, economic, and basic health conditions in them; and ensuring that residents in these settlements and neighbouring communities enjoy social justice. Addressing all these objectives requires current, accurate, social, and spatial information, and informal settlements hold certain unique challenges in this respect due to their complexity and frequently changing social conditions. Land tenure security is important in many improvement strategies because it provides the much needed stability for these strategies to succeed. Thus, much of the data collection and information management effort should be directed toward security and equity in the land tenure system.

In this paper we describe a number of techniques to collect social and spatial information. These techniques were developed during projects to upgrade informal settlements in a number of ongoing case studies in Cape Town that started in 1995.

The techniques were developed primarily in studies of the Marconi Beam and Imizamo Yethu ("*through collective struggle*" –Xhosa) settlements in Cape Town. Some of the ideas and techniques were also developed and applied in several other informal settlement upgrade cases in and around Cape Town (e.g., Brown's Farm, Wallacedene, parts of Khayelitsha), and the Manzene informal settlement in Dar-es-Salaam, Tanzania. Two of the techniques were first tested in a rural land reform case in the village of Algeria, some 230 kilmoeters northwest of Cape Town, which is not an informal settlement, because the social and local political environment in the village was far more stable than in the informal settlements. The Algeria village proved to be ideal for first testing ideas in a situation where some of the factors that may exist in informal settlements (e.g. high levels of conflict, continual change) and that may have impeded the experimental processes, were absent.

We begin by describing the historical context of the large number of informal settlements in Cape Town, followed by brief histories of the Marconi Beam and Imizamo Yethu settlements. We then describe a number of general social and political characteristics of informal settlements in southern Africa. These sections demonstrate why social and spatial data need to be collected frequently, especially when major change is occurring in the wider society. Finally, we describe in broad overview various social and spatial data collection techniques that may be useful in situations where informal settlements are to be upgraded.

To distinguish between squatting and informal settlement, as a working definition we have defined *squatters* as illegal occupiers of land and *informal settlers* as people who have some legal recognition of their occupation. In the latter case, for example, an informal settler may be permitted to occupy land until alternative shelter is found for them.

Informal Settlements In Cape Town

Since the early 1970s, Cape Town has been experiencing a significant influx of black Africans, predominantly people whose mother tongue is a Bantu language, from rural areas. Most of these new arrivals are Xhosa speakers who are migrating from the former independent homelands of Transkei and Ciskei in the Eastern Cape, some 1000 kilometers from the city. Nowadays, an estimated 48,000 people move into the city every year (Weaver 2004), and this influx has contributed to the large number of informal settlements in the city, which current estimates put at 164 settlements (Dreyer 2004).

South Africa's informal settlements are unique in some ways, in part due to the country's history of racial segregation, influx control in the cities, and the conflicts that resulted from resistance to these policies. The apartheid government tolerated an influx of black Africans into the cities during an economic boom in the early 1970s, and so squatter settlements started to spring up in periurban areas. However, it harshly repressed influx and the development of squatter settlements during a recession in the latter half of the decade (de Tolley and Nash 1984; Cole 1986). In the 1980s, the government realised that segregationist policies and influx control in the cities were unworkable. Initially, political reforms eased the rigidity of the apartheid system. Permanent land rights for blacks in urban areas were introduced and the pass laws were rescinded in the early 1980s. These reforms became a catalyst for large numbers of people to move from the rural areas into the cities (Lourens et al. 1992; Barry 1999).

The political reforms of the 1980s were paralleled by an escalation in revolutionary activity against the government and by internecine violence between and within revolutionary organisations that lasted to the end of the decade. Revolutionary activity included large-scale stay-a-ways from work, along with rent, service, and consumer boycotts. It also included the murder of black councillors, policemen, and generally any blacks who supposedly cooperated with the government (Liebenberg 1993). The effects of these conflicts influenced the local-level political climate within informal settlements, and housing projects to upgrade these settlements, throughout the 1990s, especially in settlements where many of the residents had been on opposing sides in the conflicts (Barry 1999).

In 1990, major reforms took place as banning orders on revolutionary movements such as the African National Congress (ANC) and the Pan Africanist Congress (PAC) were lifted, and political negotiations commenced. These culminated in the first fully democratic elections in 1994, when the ANC came to power. However, between 1990 and 1994, the country continued to experience internal conflict as a result of tensions between different political factions. There were also violent attempts to undermine the negotiation process.

In 1994, at the time of South Africa's first non-racial democratic elections, the newly elected government was forced to address a major housing crisis to ensure social and political stability prevailed during the country's post-apartheid transformation. The *Housing White Paper* of 1994 revealed that an estimated 1.06 million households, comprising 7.7 million people, lived in informal settlements. Coupled to this, an estimated 720,000 site-and-service dwellings required upgrading, and 450,000 people lived in various, often inappropriate, forms of hostel accommodation (Republic of South Africa 1994).

More than a million houses have been built since then, and more than a million are still needed to address the housing shortage. However, what is important during such far-reaching change is that deserving individuals receive houses, that the land tenure system to support these housing developments is appropriate, and that the administrative systems to support the tenure system, such as cadastral surveying and land registration, are appropriate and actually used by those who they are supposed to benefit.

Amidst this tense, but optimistic, atmosphere, the authors initiated a series of studies into land tenure, cadastral systems, and the upgrading of informal settlements. The Marconi Beam and Imizamo Yethu settlements, which have been accessible to researchers, have been studied comprehensively as case studies since the mid-1990s. Other settlements could not be studied comprehensively. For example, in the Brown's Farm settlement, a political group prevented the first author from conducting research that involved interviewing residents.

Marconi Beam

Marconi Beam was an informal settlement that developed on land that was owned by the telecommunications corporation in a middle-class suburb of Cape Town. Squatting in Marconi Beam dates back to the 1970s, but the number of shacks and residents mushroomed during the early 1990s.

In addition to the macro-level factors described earlier that contributed to the increasing number of informal settlers in Cape Town, settlement of Marconi Beam was also linked to a strike at the adjacent Milnerton Race Course in 1990, which employed a number of Xhosa speakers as grooms. During the strike, some 200 grooms moved into shacks on the Marconi Beam site. The local authority, the Milnerton municipality, attempted to evict the squatters, and succeeded in demolishing some 20 to 30 shacks before the squatters obtained a court order preventing the demolition. The delicate political negotiations in the early 1990s rendered it unwise for the authorities to pursue further action. Saff (1996) argues that further intervention would have had political and racial ramifications, so the settlement's rapid growth was allowed to continue unchecked. Additional squatters in Marconi Beam arrived directly from the Eastern Cape, and a number also moved there to escape violence in squatter settlements in other areas of Cape Town.

Negotiations between the squatters, the municipality, and the landowner followed, and the informal settlement was limited to an 8.02-hectare fenced in area of the parcel. In November 1990, this area was declared a transit area in terms of the *Prevention of Illegal Squatting Act* 52 of 1951 S6(1), which allowed the residents to stay on the site while accommodation was found elsewhere (Marconi Beam Civic Association et al. 1993). This also provided the existing residents with a modicum of tenure security (Barry 1999).

Following the negotiations between external agents and the informal settlement leadership, the transit site was intended to hold between 400 and 480 shacks (Saff 1996). However, by June 1993, there were 834 households and 2,835 people living in Marconi (Urban Foundation et al. 1993). By December 1996, there were 1345 shacks on site (Barry 1999).

By the end of 2000, after protracted negotiations, Marconi Beam residents were housed in formal housing developments in Joe Slovo Park and another nearby settlement, du Noon. The process was supported by a government housing subsidy that provides

a one-time-only support to acquire ownership of a permanent dwelling. Beneficiaries received a subsidy to pay for the land and infrastructure and to build a basic brick-and-mortar home.

Imizamo Yethu

The Imizamo Yethu informal settlement is situated in the Hout Bay Valley. Squatting occurred sporadically in the valley, in pockets, for more than 50 years before the Imizamo Yethu settlement was created. By 1990, more than 2000 people lived in five informal settlements in the area. Collective action by squatters to obtain legal property rights, and the reaction to the informal settlements from existing property owners in Hout Bay, forced the authorities to make formal property available for the squatters. Forestry land at Imizamo Yethu was made available in late 1990, and 429 sites were occupied in March and April 1991 (Gawith and Sowman 1992). These were registered informal settlers, as opposed to illegal squatters. The site was regarded as a transit area while the formal layout in the same vicinity was being planned. At the time, in 1991, municipal planners envisaged 700 parcels being created for a total of 2,400 people. However, as with Marconi Beam, the authorities could not control further influx, and by May 1992 there was pressure from the community for more land as squatters and new arrivals were laying claim to the buffer zones around the settlement (Nathan and Spindler 1997). By June 1997, an estimated 5,000 people occupied the settlement and surrounding greenbelt areas (Barry 1999). Currently, there are approximately 7,000 people in the settlement, including shacks in backyards and in the greenbelt buffering the settlement. A number of these early settlers are now housed in 457 formal houses that were planned in the early 1990s.

These ongoing influxes have led to conflict between the Imizamo Yethu residents and surrounding residents, conflict within community groupings in Imizamo Yethu, conflict between the Imizamo Yethu residents and the authorities, and conflict between different authorities (e.g., provincial and municipal) on how to manage the situation. For example, in July 2002, a court order was granted allowing for the Cape Town municipality to evict squatters who had recently arrived in the settlement. However, a significant sector of the community mounted the "We will not be moved" campaign to oppose this. The evictions, along with the demolition of 189 shacks, were planned for June 2003, but the Cape Town city manager cancelled these actions on the basis that this constituted inhumane treatment of the residents (van Zilla and Ajam 2003).

The situation has also led to conflict between two opposing civic organisations in the settlement itself. The Sinethemba Civic Association supported the surrounding middle-class residents' ratepayers association in exerting pressure on the city to evict the newcomers. In March 2004, the Sinethemba leader was physically threatened and his house burned down by a mob. In turn, he accused the leadership of the South African National Civic Organisation (SANCO) in Imizamo Yethu of being behind the incident (Hartley 2004).

Informal Settlement Characteristics

The Marconi Beam and Imizamo Yethu cases illustrate that informal settlements are complex, dynamic social systems that, in many cases, experience continual change. In occupying land informally, residents are often prepared to flout the law in the hope of improving their lives. Accordingly, there are a few general characteristics that an external agent should be aware of prior to intervening in a particular settlement.

In general, in an informal settlement, the internal social and political dynamics tend to be characterised by both solidarity and schism. Conflict is inherent in the relationship between the general community and outside agencies, such as the authorities and surrounding residents, and in the relationships between different groups in the settlement itself. Thus, a community may act in solidarity when negotiating with the authorities or when invading land. However, while solidarity may prevail in dealings with the external agents, schisms occur within community groupings in the implementation of deals made with the authorities and in the day-to-day operation of a settlement (Fourie 1993; Barry and Mayson 2000).

Schism occurs as different groups and individuals in a settlement compete for power, land, and resources. Solidarity may be critical in pulling off a deal with external agents or perhaps pressuring government to do something that will benefit a settlement. However, once a deal is made, entrepreneurially-minded individuals may strive to maximise their own benefits. In so doing, they may attempt to manipulate internal settlement rules and agreements that have been made with outside agencies. The result is that the de facto tenure rules and practices tend to change continually, unless a very powerful faction controls the settlement (Davies and Fourie 1998; Barry and Mayson 2000).

The quality of leadership and the power wielded by community leaders is an important factor in upgrading projects. Leadership coalitions are often comprised of disparate groups. In our observations, a small group outside this clique may wield substantial power and so disrupt and overturn long-standing agreements with the authorities. Such infighting hampers attempts at reform and delays processes that are intended to improve conditions in a settlement (Barry 1999). In addition, leaders may play gatekeeper between the community and outside agents, and filter information (Cross 1999).

The above phenomena were observed in both Marconi Beam and Imizamo Yethu. For example, in spite of agreements with external agents to limit the number of people in both of these settlements, the numbers of people in the settlements continued to grow. This, in turn, caused conflict between factions within the settlements. The burning down of the Sinathemba Civic Association leader's house in Imizamo Yethu in 2004 is an extreme example of internal schism.

Thus, from the perspective of an external agent, intervening in informal settlements may be an extremely difficult task. With community leaders perhaps acting as gatekeepers, violence and intimidation often prevailing in internal conflicts, and relations with the authorities tending to be confrontational, it is difficult for

formal land administration institutions to reach agreements that can be implemented, at least not within a specified time frame.

Owing to the complexity of these situations, many upgrading projects do not achieve the results desired by external agents. Moreover, there are no easy solutions and often informal settlements involve situations that can, at best, only be alleviated or improved incrementally in any single initiative. In many cases, it is naïve to think that a project can be set up that will "solve the problem" on time and within a defined budget. While recognising that such situations can at best be alleviated rather than solved, both social and spatial information are critical in assessing a situation and initiating appropriate strategies for improvement.

In terms of data collection and management, an initial census and a map of the settlement followed by frequent, cheap, rapid data collection is required to ensure that management information is accurate and current. We now describe some of the data collection and processing techniques that we used in Cape Town's informal settlements.

Social Data Collection Techniques

The legal integrity of a system of enforceable agreements requires that official land tenure records be held to be legitimate by all parties concerned. Otherwise, the record, and indeed the system, has little value as a land administration resource. One way of cultivating such legitimacy is to make the processes of data acquisition and information management participatory and transparent. Notwithstanding the tensions that may exist in a community, community members should, ideally, participate in the definition of the information to be collected, in collecting the data, in collating the information, and in disseminating it. This is only likely to happen if the purpose and processes of the data collection exercise are generally accepted as legitimate. To further enhance the legitimacy of the information, it is also important that community members are able to understand it. This may seem an obvious criterion, but it is all the more important in communities where many people (often the most vulnerable segments of the population) are not fluent in the languages commonly used by officials.

Census-type socio-economic data pertaining to the number of dwellings, number of people in a dwelling, income levels, employment levels, and demographics of a settlement are required for an initial assessment. What may also be required is an analysis of the system of tenure that prevails in a settlement, what tenure system is desired if it is upgraded, and if the systems to support the tenure system, such as land registration and cadastral surveying, are likely to be used.

Palmtop Computers

Conventionally, census-type socio-economic data are collected using paper questionnaires. This is time-consuming and expensive. Information surveys often require skilled data collectors and the data has to be transcribed and entered into a database manually. As mentioned earlier, in informal settlements, these data need to be updated frequently to keep pace with continual changes in a settlement.

Cheap, rapid collection methods that employ members of a community are ideal for this purpose. Given the tensions and the various agendas that may exist in an informal settlement, residents might be inclined to give false information to an outsider. Because of community members' intimate knowledge of their own settlement, unless the data collectors themselves choose to provide false information, a high level of accuracy should be ensured (e.g., data incorporating verbal responses and statistics relating to the number of people living in a house). Furthermore, collecting data on a palmtop computer reduces the time required to transfer data to a central repository, and it simplifies the verification of previously collected data in the field. The challenge is whether people with limited education are able to use the technology effectively.

Palmtop computers were tested in two different settings. Techniques were first tested in a stable environment and then were further tested and developed in a more volatile case. The first case, a land reform project, was in the rural village of Algeria. In terms of the discussion above, data does not have to be collected frequently in Algeria—the case was merely used to experiment with a range of data collection techniques. For the second case, Imizamo Yethu, data relating to land occupation had to be collected frequently.

In both cases, a number of residents volunteered to collect the data, and they were provided a palmtop computer equipped with a global positioning system (GPS) module to supply position data. Icons were developed to represent different data types. Three people in Algeria and eight individuals in Imizamo Yethu collected data using the palmtop computer.

The icon-based data collection study was inspired by the *Cybertracker* project, which developed a system whereby game trackers, who may not be able to read or write, used palmtop computers interfaced with a handheld GPS receiver to collect spatially referenced scientific data relating to animal behaviour in South African game parks. In the *Cybertracker* project, game trackers were involved in developing graphic icons that describe a specific type of animal behaviour. When a game tracker observes an animal performing a particular behaviour, the icon is accessed and the time and location of the event recorded in the palmtop computer (Cybertracker 2004).

The settlement studies adapted the *Cybertracker* data collection methods and software and hardware systems to collecting census-type socio-economic data. In contrast to animal behaviour observations, socio-economic data collection does require a certain level of literacy, because much of the data is textual. In Algeria, the three data collectors had two to three years of high school education, while in Imizamo Yethu, the eight data collectors had an average of four years of high school (Barodien and Barry 2004).

The data collectors designed icons to represent particular questions. As a backup they also stored the questions in text form in the palmtop computer. In the field, they were accompanied by a researcher who observed the data collection process, recorded the responses simultaneously on a paper questionnaire,

and compared results with those of the data collectors (Barodien and Barry 2004).

All but one of the eleven data collectors proved to be competent in using the palmtop computer after a brief training period. A comparison with the hard-copy questionnaire showed that responses were accurately recorded. However, the use of icons to represent a question and an associated set of answers was found to be unsuitable for collecting census-type socio-economic data. In Algeria, all three subjects reverted to using the textual expression of the questions, and they recorded the responses in textual format. In Imizamo Yethu, the eight subjects used a mixture of icons and text to pose questions and record the responses (Barodien and Barry 2004).

The study suggests that palmtop computers are, in principle, feasible for socio-economic data acquisition. Data collection in text form can be carried out successfully by members of a community provided they have a level of education that equips them for basic computer tasks. However, the use of icons to represent questions and answers was found to be of limited suitability if employing people from a particular community to collect the data is a major objective. If someone collects data as a full-time occupation, then using icons to represent questions and answers will probably be more efficient in the field. However, this defeats the objective of eliciting local community participation in land information system development.

We found that employing literate members of a community to collect and update socio-economic data, using current technology, makes it possible to maintain the currency of the population register in the settlement.

Photographs and Video Imagery

In the informal settlement studies in Cape Town, disputes arose among community members over who should or should not be assigned land rights. It was found that the people who initially occupied land in a settlement tended to be the first ones in the queue when government-subsidised houses were allocated. However, in many cases, once there were signs that houses might be allocated to people in a settlement, this became a catalyst for a rapid influx of people into the settlement, presumably in the hope of also benefiting from the housing program. In addition, the official records that were intended to reflect transactions in land rights were often inaccurate shortly after the initial adjudication, largely due to unrecorded transactions in land rights, which led to further disputes when the time came to register land. In Marconi Beam, even though the community maintained a record of transactions in a book kept in an administrative office in the settlement, for various reasons, many transactions were not recorded. Moreover, at the time that people were being moved into formal houses in Joe Slovo Park, a faction challenged the legitimacy of this set of records and intimidated the administrative staff to the extent that the administration office had to close, disrupting the formal delivery of houses (Barry 1999).

Subsequently, based on the experiences in a similar settlement to Marconi Beam, the project managers took photographs

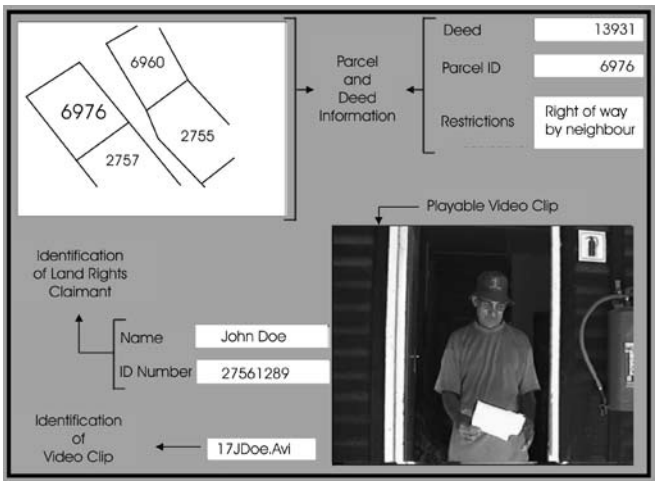

Figure 1. On-screen Title Certificate

of every person in a household who had met the requirements for a grant of ownership of a house in a nearby settlement. The photographs formed part of an adjudication certificate. Lodgers in a shack who were not part of the family unit were excluded. If a transaction in land rights took place prior to ownership being delivered, the updated certificate was displayed for public inspection on a notice board in the settlement. Minutes of meetings and agreements were also posted on the notice board. In this project, manipulation of the agreements between the landowner and the community leadership and the rules pertaining to that agreement were reduced, arguably as a result of the publicity and transparency in managing the tenure system.

In spite of this, a group of people attempted to disrupt the delivery process, arriving in the settlement after the adjudication had been completed. Most of this group lodged with families who were expecting to be granted a house. It was in the interests of the group of lodgers to disrupt, and hopefully manipulate, the land delivery process in order to acquire ownership of a house themselves. However, arguably because the information was updated continually and it was publicly available, in the end this group could not raise a credible claim.

Another option first tested in the village of Algeria and then tested in Imizamo Yethu was the use of video imagery to record information relating to land rights. Video clips were included in a relational database in which an on-screen title certificate was created, enabling the user to view standard titling information. The video could be played back by clicking on the image of the person as shown in Figure 1. The title certificate was linked to a geographic information system (GIS) used to manage the transition to permanent land rights for the community.

In the initial development and testing of the video imagery system in the Algeria case, people claiming rights in land were recorded on video while they read an affidavit in front of their house, which noted the subject of their claim of interest in land. The contents of this affidavit were determined by the people

Figure 2. Group Discussions in an Informal Settlement

themselves. This proved to be unsatisfactory because people were unsure what should be included in such an affidavit. Some affidavits included superfluous information with the result that they were too long and required a large amount of disk storage space. In addition, a number of people had not prepared the affidavit when they were due to be filmed, hence delaying the recording process (Roux and Barry 2001).

This system was later tested in the formal and informal settlement portions of Imizamo Yethu, where a researcher conducted structured interviews with a sample of residents. This proved to be a workable method because interviews could be kept to a reasonable length of time, thus reducing disk storage space requirements (Roux and Barry 2001).

The system is currently being redeveloped for the application of multi-media land record systems in real situations because technology has improved so that storing and retrieving large video files is now feasible. The initial study and prototyping showed that incorporating video evidence in a land record system (or, if appropriate, a land registration system) has potential in situations where conflict exists over land rights, provided that the use of video itself is regarded as legitimate by the members of a community. An adjudication record that incorporates video clips should be more readily accepted by people in informal settlements than a record based solely on written documents and diagrams. The information can be retrieved and played back in an easily understood format in cases of conflict, or in cases where there may be uncertainty over the definition and allocation of certain rights and interests. Moreover, filming in the street tends to attract onlookers and family members, thus creating a large population of witnesses to the transaction (Roux and Barry 2001).

Land Tenure, Boundaries, and Registration

Issues that warrant further exploration include the desired system of tenure, and predictions and factors concerning the actual adoption and use of boundaries and registration by settlement residents. Tenure questions relate to the nature of the land tenure system that prevails in a settlement, and the system of tenure desired if and when a settlement is upgraded. Significant questions relating to land registration include the usefulness and likelihood of the use of the registration system to record transactions in a secondary land market or when dealing with deceased estates. Boundary questions should be explored if a particular boundary type (e.g., fixed, general, or vaguely defined) is likely to be adhered to.

These questions are best addressed through interviews with influential people in the settlement, that is, a representative sample of people who will make decisions about their land rights in households in the settlement, and agents outside of a settlement (e.g., officials). These can be augmented by studies of similar cases where land has been registered based on a particular type of boundary.

In studying the tenure system with the general populace in a settlement, it is important to ascertain the beliefs underlying the land tenure system. However, beliefs on their own are a poor predictor of actual behaviour. Behaviour in this instance refers to how people will use the infrastructure delivered in the upgrade, which includes registration and boundaries. If people have control over their actions, what should be measured is their intention to perform or not to perform a particular action. If it is not possible to measure intentions, it is best to attempt to measure attitudes toward performing a particular action (Ajzen 1991). For example, a sample of residents in Marconi Beam and Imizamo Yethu demonstrated strong negative attitudes to the possibility of a neighbour encroaching over their legal boundary. Moreover, they expressed an intention to evict the encroacher (Barry 2005).

In collecting this type of data, it was found that questionnaire-based interviews with residents were not useful. The situations were far too complex for a simple question-and-answer interview. Each question had to be explained in detail, and often the question itself was framed too narrowly to obtain useful data.

What was found to be useful was a system of group discussions, some of which were held in the streets and public areas (Figure 2) and others in private. In addition, some groups were composed of men only, others of women only, and others included both men and women. To reduce the likelihood of particular opinions being clustered according to particular areas in a settlement, a grid was superimposed on an aerial photograph of a settlement and at least one group discussion was held in each grid cell. In the public group discussions held in the streets, group participants could find themselves challenged as passersby would stop to observe the process and often joined in the discussion.

Models of houses, shacks, and boundary systems were used in posing questions and generating scenarios. Questions were posed to establish beliefs about the tenure system, and scenarios were created to elicit statements of intention to perform or not to perform particular actions. For example, groups were asked what they would do if a stranger claimed that he or she owned the house that each of the group members were expecting to be granted to them. What action did they intend to take in such a

case? In this way, a variety of responses was obtained relating to intentions to use title deeds, attorneys, the courts, or community-based conflict resolution mechanisms.

The accuracy of any prediction based on beliefs, attitudes, and intentions regarding cadastral systems, garnered from verbal responses, needs to be checked against measurements of actual usage of registration and boundary systems. This is best done by studying cases of communities that had previously lived in informal settlements and subsequently moved into formal housing.

There are a number of reasons why predictions about cadastral system usage based solely on interview data may prove to be inaccurate. First, people may choose to provide a response to a question that they know does not accord with their actual beliefs, attitudes, or intentions. Direct verbal statements of sampled members of the public may not provide a reasonable guide to their likely future action (Wilkins 1986). Second, the research itself may influence the results. As researchers become part of the groups that they investigate, part of the behaviour observed will be in response to the presence of the researcher (Shipman 1972). Consequently, as people learn about the subject matter of the research, they may be inclined to give the "right" answer in an interview or group discussion. Third, land tenure systems are not static, particularly in volatile situations, such as in the informal settlements that were studied. People's behaviour changes over time as they learn and interact with others, including the researcher (Lévy-Leboyer 1986). Therefore, a response that a person gives to a question at a particular time in the process of land delivery may differ from the response that they might give at a later date. An interview or group session provides a snapshot of a situation. Fourth, what Ajzen (1991) refers to as "control factors" may prevent people from carrying out their intentions.

Control factors fall into two distinct categories. First, a lack of resources may prohibit a person from performing an intended action. For example, people may say that they intend to use the land registration system to transfer land but, when the time comes for the transaction to be effected, they may find that they cannot afford the registration costs. Consequently, they may transfer the land informally and the transaction may not be legally recognised. Second, power factors, such as the actions of a squatter lord or a similarly powerful individual or group, may prevent the performance of an intended action.

Spatial Data

Spatial information and GIS provide the means to measure some of the discrepancies observed between predicted behaviour and actual behaviour. Spatial information is critical for making informed decisions about community growth projections and infrastructure planning. GIS can integrate the different information types for administration and analysis.

The collection and processing of spatial data for informal settlement management can be rudimentary. For example, photographs captured with an inexpensive camera and measurements with handheld GPS receivers can be used to count, record, and locate the number of shacks in a settlement. However, more sophisticated techniques are desirable when monitoring changes, such as the occupation patterns in a settlement.

The rationale for more sophisticated techniques is best illustrated in the case of Marconi Beam. As mentioned above, the authorities and the private landowner reached an agreement with the community leadership to move the residents to a new development. Based on a census survey in 1993, 750 households would be moved to Joe Slovo Park and the shacks demolished. Within a few months of this agreement being struck, there were a total of 1,345 shacks in the settlement. However, the landowner was unaware of this development and project managers in the housing development completed their project based on the original figure of 750 households. Given the political climate of the time, the landowner could not evict the additional householders, and he was forced to find accommodation for the additional 600 households.

In this case, an initial survey had been carried out using stereo aerial photography at a photo scale of 1:10,000. Subsequent surveys were performed using aerial imagery captured with a non-metric digital camera, rectified using polynomial rubber sheeting, and overlaid on the original survey using GIS software. However, the frequent changes in the settlement meant that control points were often destroyed or moved, and the distortions that remained in the polynomial rectified images were unsuitable for meaningful overlay analysis. Increasing the density of control points fixed in the field using recognisable features from previous surveys as control points and tiling the images improved the quality of rectification (Barry and Mason 1997). However, the tasks of identifying shacks by on-screen inspection and manually delineating individual shacks in an on-screen digitising process proved to be laborious and uneconomical. Attempts were thus made to develop algorithms for fully- or semi- automated feature/shack extraction.

Automated Feature Extraction

The automated extraction of man-made structures such as buildings and roads from digital imagery has been a focal point of photogrammetric and image processing research for the past 20 years (Nicolin and Gabler 1987; Huertas and Nevatia 1988; Liow and Pavlidis 1990; Haala and Hahn 1995; Henricsson and Baltsavias 1997; Seresht and Aziz 2000). Approaches to building extraction vary widely and so do the degrees of automation and the detection rates. Most systems that have been developed are based on generic building models comprising simple regular shapes, structured settlement plans, and/or homogeneous roof materials. Typically, however, informal settlements are not built in structured patterns. Shacks are irregular in shape and height, and roof materials vary in structure and colour. Moreover, different materials are often used to waterproof and cover the same roof.

In the context of research on informal settlements, a method for the extraction of shacks based on a sequential hybrid image processing/digital photogrammetry approach was developed by Martine, Rüther and Mtalo (2002). In this method, off-the-shelf software is combined with code developed for the specific application.

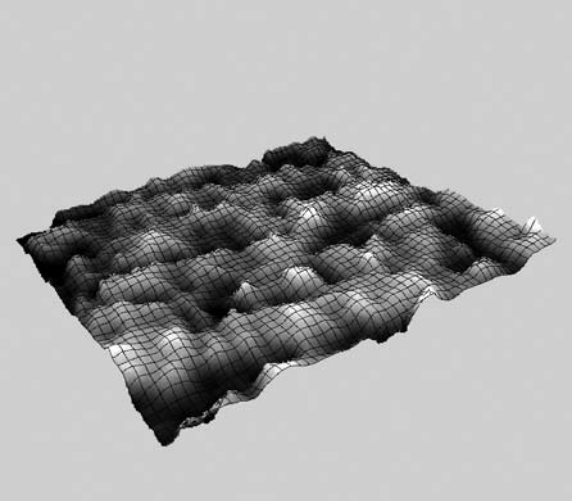

Figure 3. DSM of Marconi Beam with Shack Blobs

Figure 4. Intermediate Processing Stage Showing Detected Blob Edges

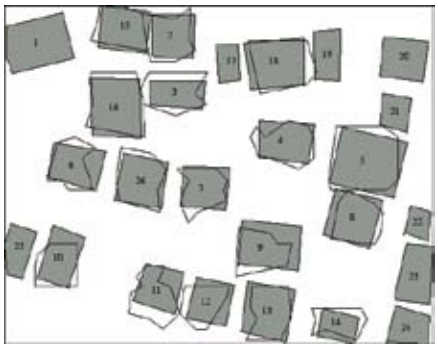

Figure 5. Intermediate and Final Shack Outlines

Two test cases, one in Marconi Beam, Cape Town, and one in Manzene, Dar-es-Salaam, were investigated. The Manzene images were scanned from conventional aerial photographs of relatively low photographic quality and had to be enhanced using the image pre-processing algorithm known as the Wallis filter (ERDAS IMAGINE 8.3.1). The Marconi Beam images were captured with the digital Kodak DCS camera and required no pre-processing.

In the next stage, digital surface models (DSMs) (Figure 3) and orthoimages were generated using the digital photogrammetry station SocetSet from LH-Systems. The DSM, as opposed to a digital terrain model (DTM), represents a combined surface of roofs and terrain, with the shacks appearing as "blobs" raised above the terrain (Figure 4). This stage is followed by the generation of a DTM in which the ground surface is modelled from a grid of ground surface points visible between shacks. A raised structure hypothesis is then implemented that segments the image into shack/ground sections by global height thresholding of the DSM supported by the DTM (Figure 4). Threshold height values are above the ground surface and below the rooftop heights.

Approximate coordinates of building centres are then derived from the segmented DSM image. These serve as focus-of-attention areas for subsequent building feature extraction in the orthoimages. Initial windows for building extraction are provided by projecting the elevation blobs' centre points into the orthoimage. Approximate building contours are subsequently established by using regions growing from the blobs' centre points constrained by edges. Approximate building contours are then formulated into snakes. In this context, a snake is a dynamic, heuristic process for creating a final estimate of the outline of a complex object (Figure 5). In the snakes approach, building contour nodes can change positions, thereby enabling the contours to slither. Ideally, during slithering, the optimal delineation of buildings as defined by contours is attained.

In the Marconi Beam and Manzene studies, this process resulted in detection success rates of between 60 and 70 percent. Although not entirely satisfactory for practical purposes, the method does yield significant time savings and merits further development.

Concluding Remarks

We have presented a number of data collection techniques that were used in the management of informal settlements upgrades, some of which involved participation by members of a particular community. As the general discussion on informal settlements indicates, negotiating this participation is often a major task in itself.

Globally, the management of informal settlements poses one of the most serious development challenges for the next 20 years, and increasing the level of land tenure security is a key factor in improving the residents' quality of life. Collecting relevant, current, and accurate social and spatial data in support of land tenure security and intervention decisions pose unique challenges. Due to the rapidly changing, and at times violent, social dynamics

that often characterise informal settlements, social and spatial data need to be collected frequently, at low cost, and, where possible, in a participatory manner. The above techniques and processes provide a foundation for developing and applying data collection and management methods that may be suitable for a particular situation.

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