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USING GPS DATA LOGGERS TO MEASURE RURAL ACCESSIBILITY IN SOUTH AFRICA

WYKORZYSTANIE REJESTRATORÓW TRASY GPS DO POMIARU DOSTĘPNOŚCI ROLNICZEJ W POŁUDNIOWEJ AFRYCE

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Keywords: GPS data logger, accessibility, rural South-Africa, space-time analysis
Słowa kluczowe: rejestratory trasy GPS, dostępność, rolnictwo Południowej Afryki, analiza czaso-przestrzenna

Introduction

Human activity involves a range of activities such as working, traveling, eating, shopping, sleeping and spending time with family, hobbies etc. Activities differ from person to person and the time spent per activity is unique to the individual. Time available to the individual is however not unlimited: a budget of time (source) exists that is managed by the individual to satisfy all the activities. Resources available to the individual affect their ability to engage in activities and by implication the time spent. For instance, in deep rural areas it might take a person much longer to travel to town to purchase goods than a person living in town. Some people have a motor vehicle at their disposal and some are dependent on public transport and others are only able to walk. A fair amount of research is being conducted to search for ways to improve people's access to services, information, markets etc. This paper describes the use of GPS data loggers and how this was used to capture individual travel data, which in turn can be used to understand individual accessibility. As the concept of individual accessibility is not well known and applied in SA, this paper will briefly describe it and indicate the role this can play towards overall accessibility analysis.

Accessibility and related concepts

Accessibility has traditionally been conceptualized as the proximity of one location (whether zone or point) to other specified locations. Conventional concepts and measures of accessibility are useful for studying a variety of phenomena, especially the aggregate analysis of social groups within an area-based spatial framework (Kwan & Weber, 2003).

As mentioned above, the importance of accessibility is not disputed: it is essential to the individual, the family and the economy (to name a few). Defining accessibility often depends on the context. Here a more general and widely used definition is sought. In this report there is a general bias towards the "rural accessibility issue" therefore more emphasis is placed on access to the basics: work, essential services, and markets. The definition provided by Moseley (1978) is favoured as it has a strong rural flavor and relates to "people's ability to reach the things which are important to them".

Individual accessibility

When reviewing accessibility related literature, it is clear that accessibility is viewed in different ways. This often forces the researcher to define accessibility related to the context. In many western countries accessibility is viewed largely as an urban measure, and here it relates to measuring transport systems. Miller (2004) even states that the objective of transport systems is to improve accessibility. There are also different ways in which accessibility is measured but often these measures suffer from a lack of rigor (Miller). People's activities take place in space and time. Time geography therefore focuses on the interrelationships between activities in time and space, and the constraints imposed by these interrelationships. Time geography does not explain or predict an individual's allocation of time among potential activities in space, instead time geography highlights the factors that restrict an individual's choice (Hägerstand, 1970).

In the South African context **cumulative** accessibility measures have predominantly been used. Part of the reason has been the nature of planning that considers guidelines (indices) when planning (example: number of people served by a facility). These cumulative measures however make assumptions about the abilities of the individual to undertake activities in space and time. The result is generalized impression of accessibility. It is also crucial to remember the context especially when looking at South Africa's rural areas. Populations are often dispersed and do not always have the means to access transport. The dispersed nature of settlements also makes providing transport services difficult and expensive. The level of detail of accessibility measures was often poor and because results were generalized, this further contributed to a lack of realism. Individual accessibility measures attempt to look at and understand the accessibility of the individual – not all residents have the same travel needs or behavior. The following section explores the use of individual accessibility measures (with an emphasis on space-time measures) as well as alternatives ways in which data is collected to measure accessibility.

Concepts related to space-time measures

The fundamental principle underlying time geography is that all activities have both spatial and temporal dimensions that cannot be meaningfully separated. The sequence of events that comprise a person's existence at any temporal scale (daily, monthly, lifetime) consists of activities that have both a temporal duration and a spatial extent. Desired activities such as home, work, shopping, recreation and socializing occur only at a few locations in space and for limited durations. A person must trade time for space through movement or communication to participate in these activities (Pred, 1977).

According to Miller (2004), activities differ with respect to how changeable they are in space and time. **Fixed activities** refer to events that are relatively difficult to reschedule or relocate. For example, people are often required to work at a specific location for a designated duration. A person's home is usually fixed in place and maintenance or familial obligations (as well as basic biological needs such as sleep) require presence for regular intervals. **Flexible activities** are relatively easy to reschedule and relocate. A person can shop, recreate or socialize at otherwise idle times between work and home hours; he or she also has a choice over where and when this occurs. There are limits on flexible activities as well (e.g., shops that have limited hours and few locations, one cannot socialise if friends are not available), but the activity is flexible if there are some degrees of freedom to the individual(s) involved.

A person has a restricted **time budget** or available time to allocate among activities. The spatial distribution and limited durations of activities implies that the individual must be at different locations at different time periods to participate. This requires the individual to allocate some of their time budget to movement (transport) or communication. This involves the trading of time for space by the individual. Transportation and communication technologies improve the efficiency of this trade-off by allowing more space to be overcome per unit time. This, however, is not necessarily the case in South Africa's deep rural areas, where people do not have access to the technologies, or often the basic means of transport, to access an activity/facility.

Principles of space-time analysis and representation

Although the concepts relating to space-time (individual) analysis has often been described, it is also important to illustrate this and eventually present this in geo-spatial format. Figure 1 illustrates two main dimensions namely; **geographical space** or mapped environ- ment wherein the individual moves to satisfy certain activities. The second dimension is **time** and is illustrated as the vertical axis. Combining both dimensions provides space-time output. The **space-time path** traces the individual's physical movement in space with respect to time. Where the individual stays in a single location there is a upwards line indicating the time at the location. When movement occurs both space and time is reflected.

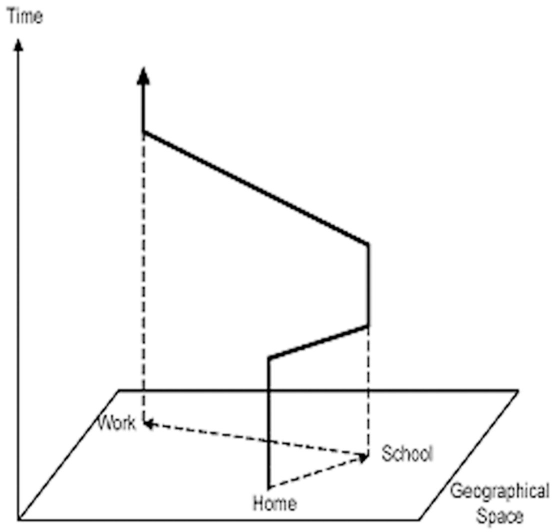

Figure 1. Simplistic illustration of time-space dimensions (Miller, 2004)

Activities play an important role in understanding the reality of the individual, as a result important activities are often referred to as anchors. Anchors can be activities such as home, work, school, etc. These are the main points to be accessed by the individual. They play an important role in the context of the spatial behaviour of the individual. Figure 2 provides a schematic example of the activities mapped on the space-time path.

Time geography is a very powerful way to visualize people's movement in space. Although Hägerstrand (1970) originally developed it primarily to describe individuals' movements over

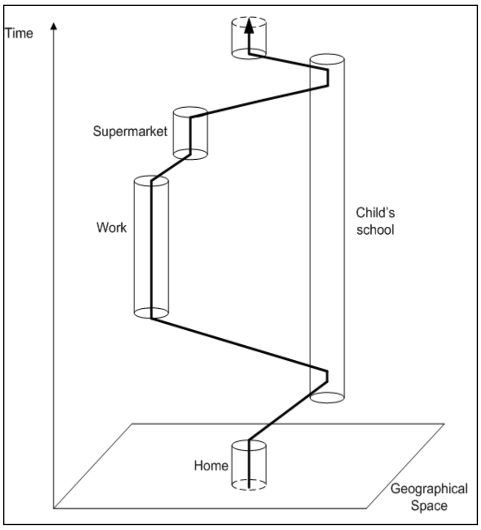

Figure 2. Space-time path with key anchor activities

a long period of time, it came back into focus with the rise of precise tracking technology such as Global Positioning Systems (GPS). It is this potential to use new technology to map difficult environments, such as deep rural settlement, that previously would require more resources. The intention is not only to map the spatial patterns (behaviour) of the residents but also eventually to have an easily understandable 3D impression including the time dimension.

Geo-spatial technologies

One of the crucial issues in individual accessibility measures is capturing detailed travel information at sufficient spatial- and temporal scale (as indicated above). In the past this has meant that participants had to keep a detailed log of their travel over the survey period. This travel log was, in fact, a detailed diary that had to be meticulously completed. This process, therefore, placed great responsibility on the participants to accurately and diligently keep track of their travel behavior. In South Africa's deep rural areas, using a travel diary is extremely difficult due to low literacy levels. Better, more efficient ways are often sought to overcome this constraint. Global positioning systems has resulted in a myriad of GPS based applications becoming available. Mobile phones themselves are devices that has been used to track/record the movement of individuals. A recent study by Krygsman, De Jong and Schmitz (2007) used mobile phones to record the daily rhythms of individuals in a proof-of-concept study which tracked a sample of individuals over a two day period – making use of their personal cell phones to obtain a dynamic motion picture of collective behaviour.

Mobile phone tracking requires a dense network of mobile phone base stations in order to effectively triangulate a person's movement. This presents problems in rural areas, where mobile phone cells are too large to accurately determine this. An alternative method to collect detailed spatio-temporal data is through the use of GPS data loggers. As mentioned previously, GPS technology is not new. Devices that use GPS information is constantly developing and becoming more affordable. The following will outline the approach followed to test the applicability and practicality of using such devices to capture individual travel data, which is also the research question being addressed.

Introducing TrackStick

Tracksticks are small GPS location recorders capable of continuously logging their own location histories for extended periods of time. These detailed recordings include time, date, location, speed, heading and altitude. Built-in flash memory and good battery life allows for the storage of travel information. With this information, the Trackstick can precisely calculate its own position anywhere on the planet to within 2.5 meters (Telespatial Systems, 2007). Figure 3 indicates the GPS data logger used.

Methodology

The methodology applied consisted of three activities as indicated in Figure 4. Firstly it is important to select participants that are willing and able to participate. For the purposes of this test, home-based care workers[1] from the Moholoholo Community based organisation, located in Leroro, Mpumalanga Province (South Africa), were asked to participate. Although the use of GPS loggers here was only a test application, the selection was still important. In a larger (future) test the selection of participants will have to be done in a more rigorous fashion. The preparatory phase also involved informing participants of their confidentiality rights and obtaining their permission for the using the information.

The second activity was to issue, and activate the GPS loggers. These devices would then record the movement of the participant until the devices were returned. As the nature of activities the participants were involved in was unknown, it was essential to have an interview with the participant subsequent to the test to identify the anchor activities for the test period. Often such activities can be deduced from good aerial /satellite or land-use information – however such spatial data is not always available or is of too poor a resolution to be useful. The interview data would therefore supplement the spatial data mapping and analysis. The last step in the process is to download the data from the loggers and to process and map it accordingly. Issues related to the various steps are discussed in more detail.

Preparatory work – Ethical issues

When embarking on research projects involving human subjects, the researcher should carefully scrutinise all ethical issues (Anon, 2004). The principles of ethical propriety, upon which most of these guidelines are based, encapsulate simple considerations of, for example, fairness, honesty and openness of intent. No person should be asked to cooperate in any research that may result in a sense of self-denigration, embarrassment, or a violation of ethical or moral standards or principles (Leedy, 1997). It is also important that no research should ever be conducted under circumstances in which disclosure of the aims and purposes of the research cannot be set forth – preferably in writing. No participant should be lured into cooperating in any research endeavour without knowing fully what participation in the project will involve and what demands may be made on that subject.

When collecting information from individuals it is important to ensure that the rights of the individual are protected. This includes privacy and confidentiality of the individual. Participants are informed of their rights, and the obligations of the researcher to protect their confidentiality. This is done in a written form discussed with each participant. Only after obtaining the written consent of the participant were the devices issued to them.

Interviews with participants

Whilst GPS loggers capture the spatial movement of an individual, it cannot record the necessary attribute information that can explain activities. It is therefore necessary to interview the participants to record the activities (land uses) that can later be related to the logged data. In the rural context, activities are not as plentiful or complicated and less activities occur than is possible in an urban context. For the test purposes, a simple form was drafted in which

[1] Volunteers that takes care of the sick residing in their community.

time, mode of transport and type of activity was recorded. This would later be added to the spatial information to create a complete profile of the person's travel behaviour.

Issues affecting the use of GPS data loggers

The Trackstick device contains the latest GPS technology and is capable of recording locations accurately to within a few meters. To ensure proper operation the Trackstick always requires an unobstructed view of the sky to receive satellite signals. The device will not record information whilst inside a metal object. Clothing, handbags, backpacks, most automobile windshields, fiberglass and other non-metallic objects will not normally interfere with the Trackstick's operation (Telespatial systems, 2007). It is important to inform the "carrier" of the device not to place it in containers during the test period. To make carrying easy each Trackstick was provided with a neck strap to allow the participant to wear it (no instruction was given regarding wearing it). The Trackstick did have advantages and disadvantages and it is important to take note of these for future application.

Advantages of using GPS data loggers:

- The devices are small and can easily be carried by the participants.
- The devices do not require the participant to perform any inputs and they can simply carry the device.

Disadvantages of using GPS data loggers:

- Although there are several devices on the market the device used in Leroro could only be used for a period of 2–3 days due to limited battery life.
- In order to use the devices for a period of 2–3 days, they were set to a lower recording frequency, therefore recording less frequently.
- As the devices are not tamper proof, there is always a risk of the carrier changing the settings of the device and therefore affecting the results.

Extracting data from data loggers

The devices are equipped with USB ports which makes transfer from the device to Personal Computer (PC) easy and fast. The process to extract logged data, therefore, is easy with the data provided in an easy to read spreadsheet format as illustrated in Figure 5. The data can then be exported to several formats for use in other applications (such as GIS software).

Mapping/spatialising data

Given the need to eventually extract space-time information, this activity is a crucial one. Information of this nature is usually viewed in two dimensions within a GIS. It is, however, essential that the move to three dimensions (3D) is made[2] . Given the increasing use and flexibility of Google Earth and Google maps it was decided to explore the mapping of the GPS logged data and mapping it on Google Earth. Various functions and scripts already exist that allow the GIS user to transform/ export GIS data layers to Google format, also known as KMZ format.

[2] Not described in this paper.

Figures 6–8 indicate the outputs when mapping the results within Google Earth. As the data also has a time-dimension it can also be shown over time, and the time component can be controlled with the time slider (Figure 7). Using Google Earth is an extremely useful way to map and display the logged data. It does still present difficulties to differentiate activities (anchors). A possible improvement could be the development of a utility that can display time data vertically.

GIS mapping section

Although the Google mapping helps to visualise the GPS logged data, it is still essential to map the logged data points within a GIS. Anchor activities need to be related to points: the list of activities as obtained from interviews then aids towards classifying the activities. The extent of travel, travel speed, time at locations etc. can then be extracted spatially. In the following example the spatial patterns of two participants are illustrated. Both are involved at the Moholoholo Community centre; Participant A performs a more managereal function, while Participant B is a home-based care worker from Leroro who provides a service at the centre as well as in the community where she resides. Figure 9 and 10 illustrates the routes traveled and key activities engaged over a two-day (test) period.

It is important to note that the extent of activities are limited, given that the test period only extended over two days, however there are common activities in which both participant take part, also referred to as co-location. Traveling is an essential activity for both – here there is clear distinction between A and B. Participant A has a vehicle and this is a major implication, as it reduces the time spent travelling. Participant B, on the other hand, has to walk everywhere, which takes substantially more time (approximately 5-hours over two days is only spent on transport). This is significant as the distances traveled are not large. Participant A does however spend more time at his home location, which also serves as an office. Participant B visits patients along her route to the centre and has a high frequency of stops between home and centre. Retail is not significant in the test cases, as no real opportunities exit in the settlement for this activity. Residents would have to travel to the nearest town for this activity.[3] The geographical space for each participant can be mapped and the overlapping co-locations can be identified. The extent of travel, distance traveled and mode used can be sourced from the logged data. The extent of walking (mode) for instance can be quantified – something that often was estimated before. Combining the GPS data and other spatial data in a GIS allows for profiling and extracting the level of access to services and key activities (Fig. 11 and 12).

Conclusion/Recommendations

Given the need to undertake space-time analysis activities, the ability to source detailed travel diary-like data is important. This is still a challenge within deep rural areas of South Africa. Fortunately, technology has evolved which makes the capturing of such information easier. Using TrackStick GPS data loggers have proven to be effective and cost effective to

[3] As this was only a short test period this activity did not feature in any of the volunteers

collect this type of information. The devices are not overly expensive and new versions might improve the functionality currently available. One key limitation is that of battery life, which limits the time period, the devices can be used. New versions of the TrackStick could overcome this limitation. Should a wide application of GPS logging be required it would be advisable to utilise the newer “Super TrackStick”.

Use of GPS logging also enables micro-scale analysis within South Africa’s rural area – an environment in which it is already difficult to work due to the lack of infrastructure, high poverty and low levels of literacy. It also simplifies the data capturing process and speeds up the process of analysis and reporting. It is therefore appropriate (technology) for the context for which data is collected.

It is essential given the sensitivity of tracking individuals that proper attention be paid to the ethical and related procedural issues. Confidentiality rights of the individual have to be protected according to the South African Spatial Data Information Act. Converting the logged data in a GIS also allows for profiles to be extracted for different participants as well as the spatial implications within a given area. An additional activity to be undertaken is the 3D mapping of the GPS data – mapping it on Google Earth, or using GIS software, would allow for viewing the information in terms of time geography using space-time paths.

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Abstract

Rural accessibility continues to be a challenge in South Africa. This is due largely to past policies that forced residents to locate to homelands. Although political regimes have changed, the effects of past policies remain. In order to better understand the nature of accessibility, particularly individual accessibility, it is important to apply appropriate technologies. Normally aggregate spatial accessibility measures are used; however, here an attempt is made to focus on individuals. This paper explores the use of GPS data loggers and its potential contribution to understanding rural travel behaviour.

Streszczenie

Dostępność rolnicza cały czas jest wyzwaniem w Południowej Afryce. W znacznej mierze spowodowane jest to prowadzoną w przeszłości polityką, zmuszającą mieszkańców do osiedlania się w swoich ojczyznach. Mimo, iż reżim polityczny się zmienił, skutki tej polityki rzutują na dzień dzisiejszy. Ażeby lepiej zrozumieć naturę dostępności, zwłaszcza jednostkowej, ważne jest zastosowanie odpowiednich technologii. Zazwyczaj wykorzystywany jest ogół pomiarów dostępności przestrzennej; jednakże, w tym przypadku pokuszono się o skoncentrowanie na jednostkach. Niniejszy artykuł bada wykorzystanie rejestratorów trasy GPS oraz jego potencjalny wkład do zrozumienia zachowań, dotyczących migracji podejmowanych w celach rolniczych.

DIE GEBRUIK VAN GPS DATA LOGGERS OM LANDELIKE TOEGANKLIKHEID IN SUID-AFRIKA TE MEET

Sleutel terme: Ruimtelike toeganklikheid, Landelike Suid-Afrika, Ruimte-tyd analise

Oorsig

Landelike toeganklikheid is steeds 'n problem in Suid Afrika. Dit kan grootliks toegeskryf word aan die beleid van die vorige bestel wat baie nie-blanke inwoners na tuislande verskuif het. Alhoewel die beleid intussen verander is, is die ruimelike gevolg steeds deel van die Suid Afrikaanse landskap. Om toehganklikheid beter te verstaan, veral individuele toeganglikheid is dit belangrik om gepaste tegnologie aan te wend. Kumulatiewe toeganklikheis maatstawe word normaalweg gebruik – hier is daar egter gefokus op die individu. Die dokument beskryf die gebruik van GPS data loggers en hoe dit moontlik kan bydra om landelike reis patrone en gedrag beter te verstaan.

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Figure 3. Example of a GPS data logger – TrackStick (TrackStick, 2008)

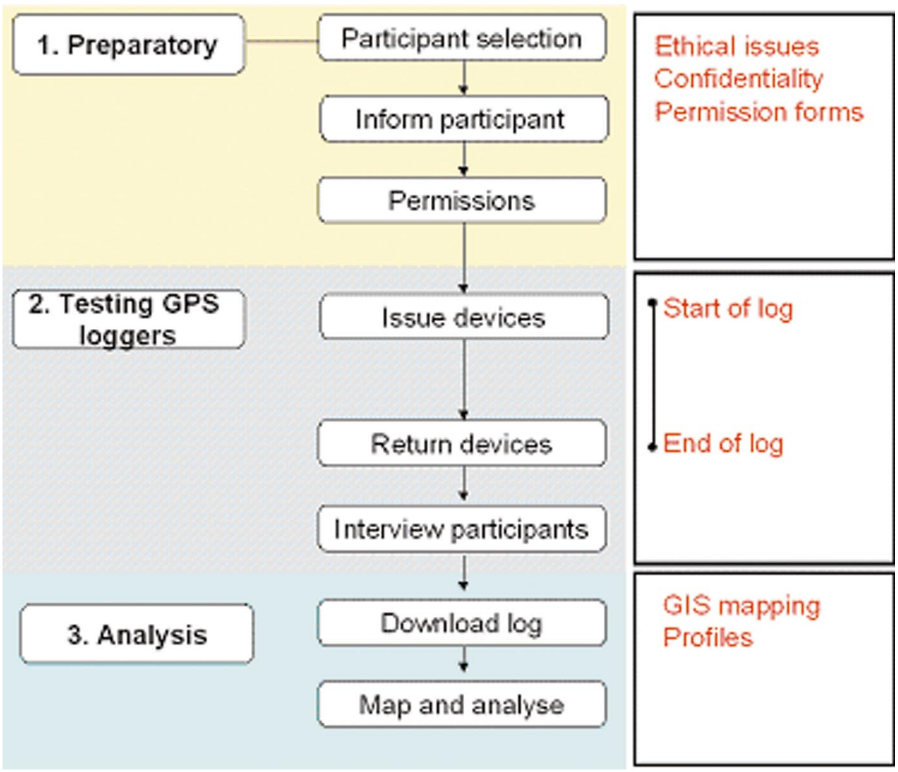
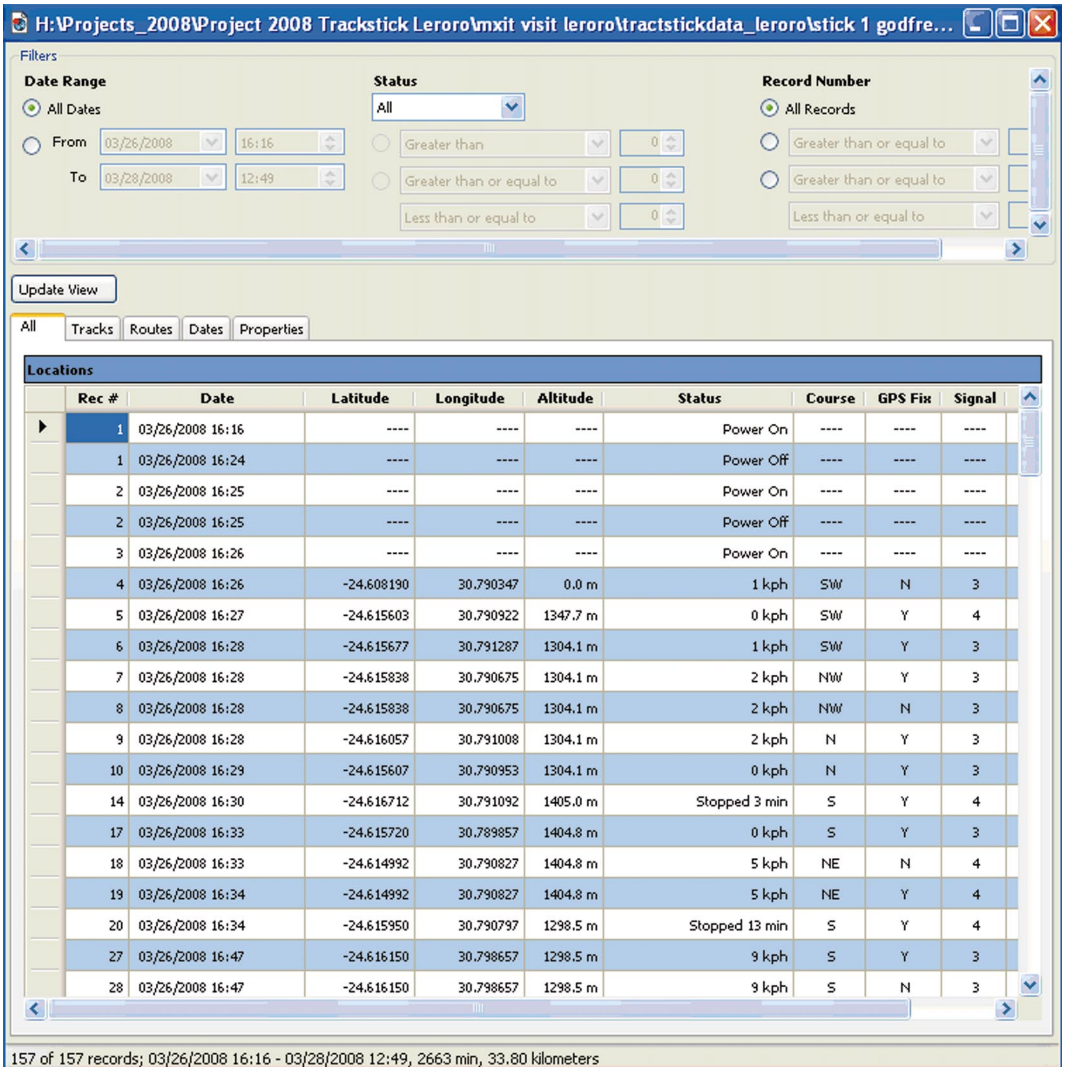


Figure 4. Methodology to capture individual movement data



Rec #	Date	Latitude	Longitude	Altitude	Status	Course	GPS Fix	Signal
1	03/26/2008 16:16	----	----	----	Power On	----	----	----
1	03/26/2008 16:24	----	----	----	Power Off	----	----	----
2	03/26/2008 16:25	----	----	----	Power On	----	----	----
2	03/26/2008 16:25	----	----	----	Power Off	----	----	----
3	03/26/2008 16:26	----	----	----	Power On	----	----	----
4	03/26/2008 16:26	-24.608190	30.790347	0.0 m	1 kph	SW	N	3
5	03/26/2008 16:27	-24.615603	30.790922	1347.7 m	0 kph	SW	Y	4
6	03/26/2008 16:28	-24.615677	30.791287	1304.1 m	1 kph	SW	Y	3
7	03/26/2008 16:28	-24.615838	30.790675	1304.1 m	2 kph	NW	Y	3
8	03/26/2008 16:28	-24.615838	30.790675	1304.1 m	2 kph	NW	N	3
9	03/26/2008 16:28	-24.616057	30.791008	1304.1 m	2 kph	N	Y	3
10	03/26/2008 16:29	-24.615607	30.790953	1304.1 m	0 kph	N	Y	3
14	03/26/2008 16:30	-24.616712	30.791092	1405.0 m	Stopped 3 min	S	Y	4
17	03/26/2008 16:33	-24.615720	30.789857	1404.8 m	0 kph	S	Y	3
18	03/26/2008 16:33	-24.614992	30.790827	1404.8 m	5 kph	NE	N	4
19	03/26/2008 16:34	-24.614992	30.790827	1404.8 m	5 kph	NE	Y	4
20	03/26/2008 16:34	-24.615950	30.790797	1298.5 m	Stopped 13 min	S	Y	4
27	03/26/2008 16:47	-24.616150	30.798657	1298.5 m	9 kph	S	Y	3
28	03/26/2008 16:47	-24.616150	30.798657	1298.5 m	9 kph	S	N	3

Figure 5. Extracted TrackStick data tables (example)

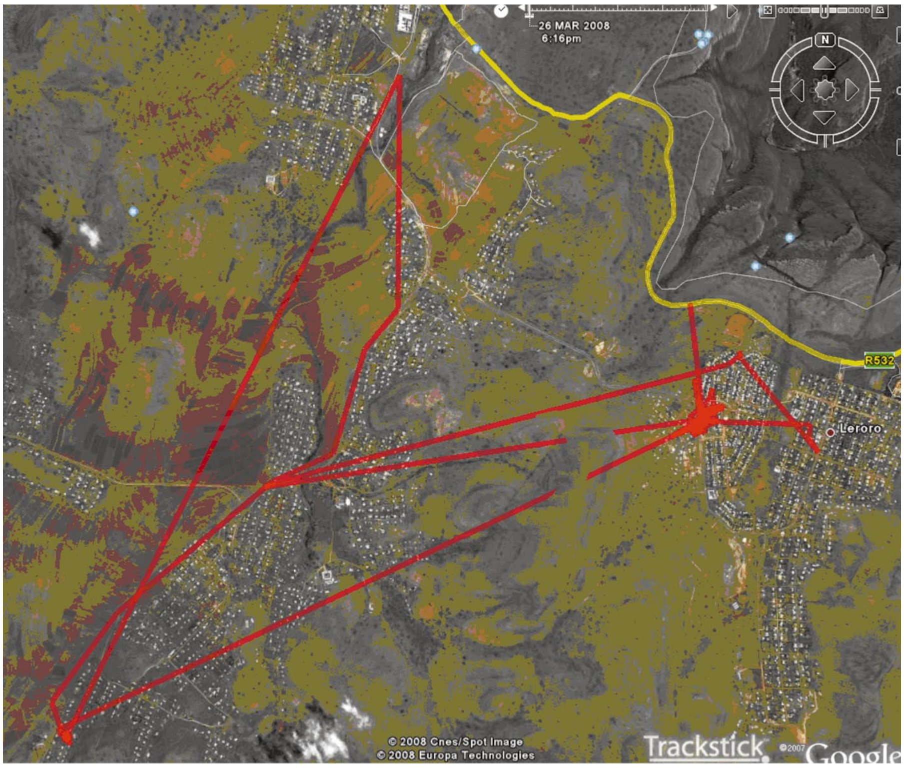


Figure 6. Two-dimensional presentation of participant's (A) travel on Google Earth backdrop

Figure 7. Time slider for logged data

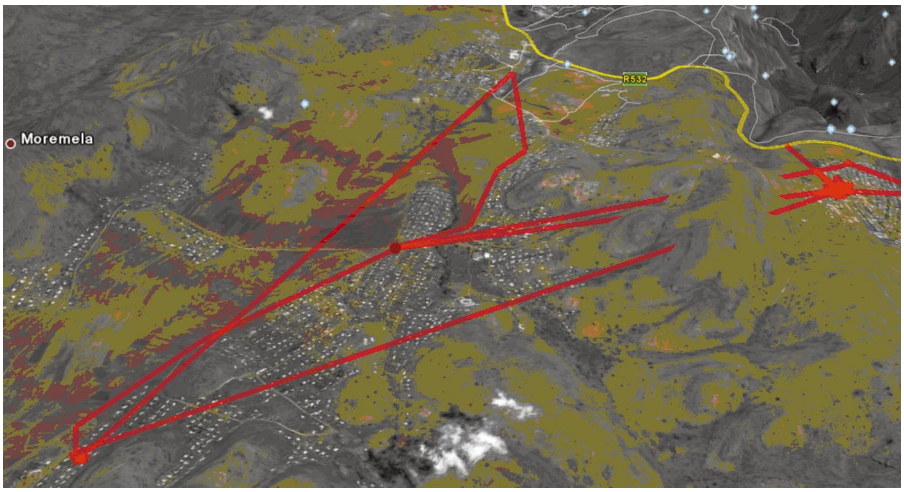


Figure 8. Semi three-dimensional presentation of TrackStick data on a Google Earth backdrop

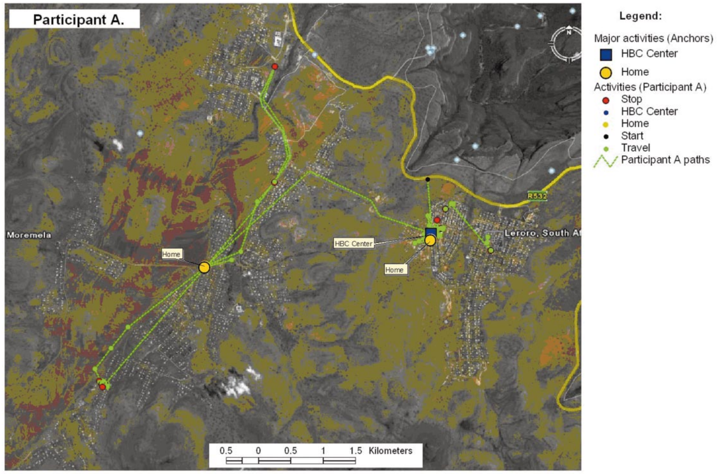


Figure 9. Participant A – routes and key activities (2-day period)

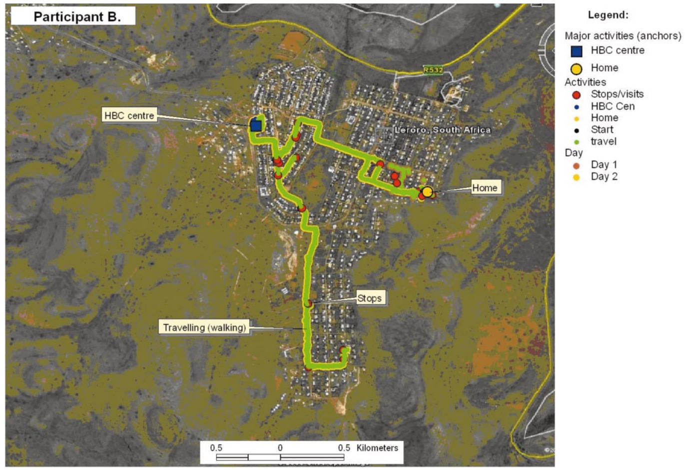


Figure 10. Participant B – routes and key activities (2-day period)

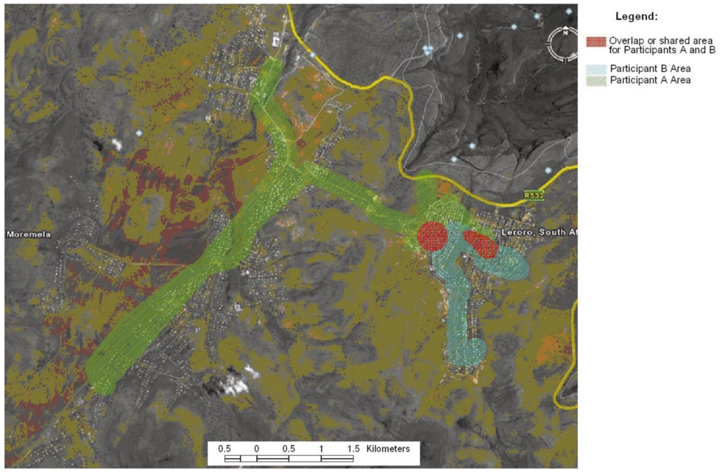


Figure 11. Activity space of both participants including joint space

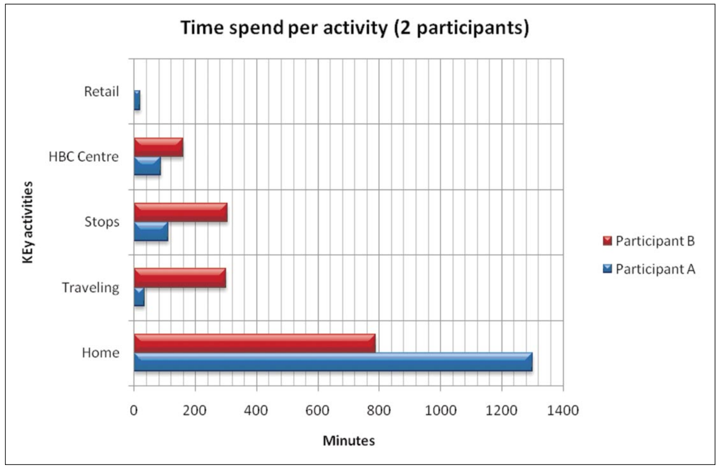


Figure 12. Comparative activity periods for each participant