DISAGGREGATION OF CENSUS DISTRICTS: BETTER POPULATION INFORMATION FOR URBAN RISK MANAGEMENT

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ABSTRACT

The vulnerability of population in urban areas, especially in developing countries, under the effects of natural and man-induced hazards, is a major reason for concern. The potential consequences of such hazards require risk management to reduce vulnerability and mitigate disasters. Information on population, required for risk management, has an essential spatial component and, particularly in urban areas, is changing continuously. Access to timely and trustworthy spatial data is an essential element in urban risk management. The tools Remote Sensing and Geographic Information Systems are most appropriate to play an important role in the risk data collection and information management.

The paper will first discuss briefly the multi-disciplinary research project Strengthening Local Authorities in Risk Management (SLARIM), being implemented by ITC, with three case study cities in Asia.

The paper then will focus on population data. The census district is the common basis for collecting population data. However, in many cases the census district is too large and too heterogeneous to provide a good insight into the spatial distribution of the population at risk. The question then is: how can population data in census districts be disaggregated using remote sensing imagery and (mobile) GIS. Land uses, building types, floor space, densities and household sizes are variables to be studied. Examples from the Asian case study cities will be used, in particular from Lalitpur, Kathmandu Valley, Nepal.

1 INTRODUCTION

1.1 Research project Strengthening Local Authorities in Risk Management (SLARIM)

Urban risk is rapidly increasing, particularly in developing countries, where urbanisation is often occurring in areas susceptible to disasters. Cities are more and more vulnerable to disasters, as proven by disaster statistics.

The International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, the Netherlands, has initiated a research project under the title: “Strengthening Local Authorities in Risk Management” (SLARIM). The objective of this research project is the development of a methodology for the implementation of risk assessment and spatial decision support systems for risk management by local authorities in flood and earthquake threatened urban areas in medium-

size cities in developing countries. The ultimate aim of this project is to improve the safety of communities, and consequently make them more sustainable and prosperous.
The main objective and benefit of this program would be to develop generic methodologies for GIS based risk assessment and decision support that can be beneficial for local authorities in managing disasters. The project will include a sequence of work packages, dealing with analysis of the institutional setting, user needs assessment, evaluation of the spatial data infrastructure, hazard assessment, generation of databases of elements at risk, vulnerability assessment and risk assessment.

Disaster management is typically multi-disciplinary, requiring many types of data with spatial and temporal attributes, that should be made available to local authorities in the right format for decision-making. The main deliverable of this project will be a web-based training manual for the use of geo-information in urban risk assessment and management. The methodology will be developed with a number of case study cities in different developing countries: Lalitpur Sub-Metropolitan City in Nepal and Dehra Dun in India, which are mainly is threatened by earthquakes, and Naga City in the Philippines, which is flood affected.

Figure 1 Non-uniform distribution of population in a census ward
Oblique aerial photo, Lalitpur 13 Sept 2003 (photo Paul Hofstee)

1.2 Localizing the population

For disaster management it is essential to have a good insight into the spatial distribution of the population at risk. In many cases the census district is too large and too heterogeneous to provide a good insight. The question then is: how can population data in census districts be disaggregated to smaller geographical or mapping units, that better satisfy the demands for information for emergency actions and disaster mitigation management.
This is a task for which Remote Sensing and Geographic Information Systems are by nature the appropriate tools. With remote sensing imagery and (mobile) GIS data on land uses, building types, floor space, densities and household sizes can be collected and analyzed.
There is no ideal and universally applicable minimum spatial unit as situations in different cities and in many countries are very diverse. Only a local definition may be appropriate to satisfy the information demands from the local risk managers.

2 DATA SOURCES

2.1 Population data

The census tract, ward or district is usually the geographic collection unit. In most cases the boundaries are fairly stable in time. However, when the census district also is the electoral district, there may be frequent boundary adjustments to keep the electoral districts approximately equal in population numbers (to avoid the infamous *rotten boroughs* from British history). The census tract system has to be critically assessed in a particular situation to decide whether it is suitable as the data collection unit. When the population has to be localized more precisely by disaggregation of census data, it is quite a difficult exercise, only to be undertaken when adequate *indicator*s of the location of dwellers are available (from aerial photos or high-resolution satellite images, together with building footprints, number of floors and land use maps) as there can be a high variation in area and number and characteristics of the population.

Population data are normally acquired from the local census office. In many cases there exists a variety of *land and building data registers,* e.g. cadastre, building permits, zoning, value assessment, taxation data. Such sources may contain a lot of risk and vulnerability related data. Actual use of such data may not be without problems: access could be very time-consuming by the hand-written or printed format, difficult because of the organization of the data (e.g. address-based without geographic coordinates), or restricted because of privacy rules or commercial property.

2.2 Remote Sensing

A reliable inventory of building footprints (i.e. the ground area of buildings) can be derived efficiently from aerial photographs, negative scale 1: 50000 or larger, or from a high-resolution, 1 meter or better, satellite image. Additionally, the general land use can be interpreted from such imagery. Main road networks and vacant land can be easily recognized and mapped. Ideally such imagery should have an *orthophoto* format to ensure geometric compatibility with GIS and map data. The location of many *essential facilities / buildings*, however, has to be derived from specific maps, common administrative sources or field observation.

On the basis of the *building height,* nowadays available from airborne LIDAR (Light Detection And Ranging), one can estimate the *number of floors*, which is key information for assessing the potential damage to the structure and the contents, and for estimating the number of inhabitants.
Some building information is best visible and classifiable by field observation through sidewalk screening, an example being the clear view of the *number of floors* and the *land use*. The *building type* (i.e. structural type, construction materials, construction quality) of each building, requires extensive screening techniques [Hofstee & van Genderen, 2003].
High-resolution remote sensing images are a pretty good source of information. However, shadows pose an obstacle for footprint generation as the limits of buildings may be unclear, even in the case of visual image interpretation. Nevertheless, despite the obvious limitations, the *overview of a large area* and the *details* that are visible on high-resolution imagery will allow an efficient selection of areas (or sample areas) for detailed investigations.

2.3 Close Sensing

Close sensing is observations / measurements made from nearby. It includes visual observations, photographs, video imagery and other analogue or digital data capture in the field.

Observation by a trained person, particularly when reinforced by local knowledge, is a powerful data capture tool. It is also efficient for data capture of elements that require a good measure of professional judgment and estimation (e.g. land use, building type, construction quality). *Quantitative measurements of the built-up area* from images, on the other hand, are much more accurate and trustworthy than field estimates.

Mobile GIS is using a computer with a GPS in the field to capture or edit vector and raster data that is georeferenced. Digital data capture leads to saving a substantial amount of time in *data transcription* (compared to analogue data capture) and provides compatibility of digital field maps and final output maps [Njagih, 2003]

4 MINIMUM AREAS AND HOMOGENEOUS AREAS

4.1 Minimum Mapping Areas or Homogeneous Areas

Homogeneity is an ideal condition to delineate an area. In the reality there is often a *lack of homogeneity*, caused by a variety of building types and mixed land uses, particularly in unplanned areas. *Unplanned areas* are a very common feature of residential development in developing countries. Moreover, even when a homogeneous zone can be defined with respect to one aspect (e.g. construction quality), it is not very likely that the same delineation will also apply to another aspect (e.g. number of floors).

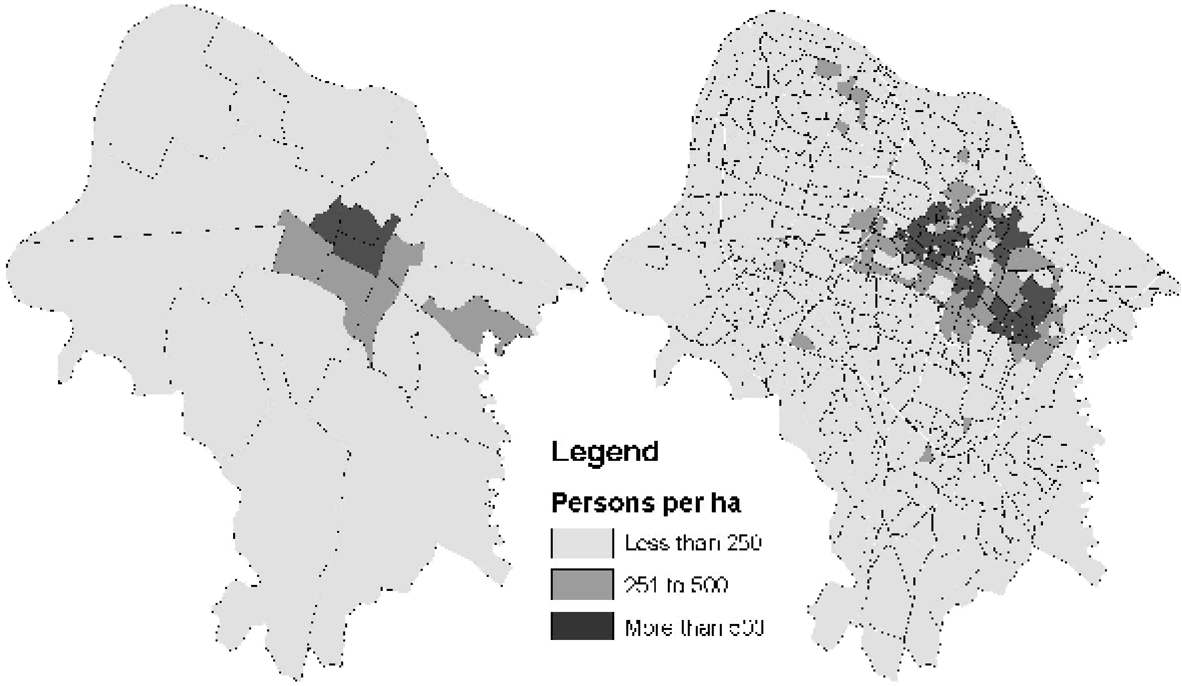

Figure 2 Population density in wards (census districts) and mapping units (blocks) in Lalitpur, Nepal
Left the 22 census wards, right the 498 blocks as developed by Islam [2004].

Islam [2004] used a high-resolution satellite image (Ikonos) to divide the 22 wards of his study area into homogeneous units (criteria: size of buildings, building density and type, building heights and land cover). Main geographical features such as streets were used to define the boundaries. During his field survey he further subdivided these blocks as he considered that the stratification made on the basis of the image was not satisfactory. In the end, each ward was on average divided into 23 blocks. More than 50% of the final blocks were smaller than 2 ha, 45%

were between 2 and 7 ha. Only 27 blocks were larger than 7 ha (30% of the total 1489 ha and containing only 5% of the total population of 162000 inhabitants), all located in the urban-rural fringe area. In the Lalitpur case study, the minimum area in the fully developed urban area was fixed at 1 ha and the maximum area at 2 ha. In the partially developed fringe area the minimum was 1 ha and the maximum 7 ha. Data were collected in the field on the building type, the building height, the land use, and the percentage built-up.

4.2 Disaggregating Population Data

The census tract (ward, census district) may be *too large* for collecting meaningful data on risk, vulnerability, or loss estimates. When that is the case, and the census tract is the smallest population data collection unit, one has to examine whether the census tract population data can be disaggregated into smaller units.

The procedure would essentially be an exercise of distributing the population on the basis of their residential floor area use (‘consumption’) to the calculated available residential floor area in small homogeneous building type areas, with a maximum size of e.g. 1 or 2 ha. If there are no accurate floor area use figures available, then estimates of the typical m^2/person floor use could be made after which a best fit could be calculated. Horizontal and vertical subdivisions are not always clearly visible. Particular in room rent situations m^2/person or m^2/household may be very small, leading to a very high density, but not easily observable. The method of counting the number of dwelling units is stated by Lo as an excellent basis for an estimate of the population (Lo, 1986). He applied assumptions as the exclusive use of a dwelling unit by one household and very standard household sizes. However, in developing countries this may not be realistic at all, which then requires a more detailed insight in densities and density variations (Pollé, 1984).

A similar procedure, also based on the typical use of floor space, could be applied to calculate the number of working people on non-residential floors during working hours. For large establishments it may be more efficient to collect data on workers and visitors from the organization. Similarly the total number of students attending a school (plus the teaching staff) may be the basis to calculate the number of persons, who will stay there during the school working hours. Separate calculations have to be made to estimate the number of irregular, temporary *visitors* to e.g. shopping centers, offices, etc. When only the location of the schools is known, remotely sensed images can be used to establish the schools’ floor area. By using census data containing population breakdown per age groups, the number of students in each establishment can be estimated.

5 CONCLUSION

Very high resolution remotely sensed data offers great potential for urban applications. However, the shadow issue presents a problem. LIDAR data can be used to assess building heights. Close sensing has not been superseded, as specific building information (as quality of construction) must be collected and this can only be achieved on the ground. Mobile GIS saves a substantial amount of time in data transcription and provides compatibility of digital field maps and final output maps.

Census data is often available at scales, which are unsuitable for specific urban applications. Disaggregation of population data is possible given a number of conditions.
A discussion of the different tools to capture urban risk management information leads to the conclusion that there are several good roads to efficient data collection. An optimum (efficiency, quality) can be achieved by an intelligent combination of tools.

Data source for indicators of population distribution	Derived indicator	Indicator represents	Assumptions	Requirement for detailed information
Aerial photos Satellite image	Building footprint	Household	One household per footprint No horizontal or vertical subdivision No non-residential land use	Low *Applicable in homogeneous middle class residential areas with detached or row housing*
Aerial photos Satellite image Ground survey	Building footprint # of floors	Household Floor space	Standard m² residential space/person No non-residential land use	Medium
Aerial photos Satellite image Ground survey	Building footprint # of floors Land use / floor	Household Floor space per land use Residential space	Standard m² residential space/person Horizontal / vertical subdivision known No mixed use on a floor	High
Aerial photos Satellite image Ground survey	Building footprint # of floors Land use / floor Socio-economic status	Household Floor space per land use Residential space per socio-economic group	Standard m² residential space/person/socio-economic status group Horizontal / vertical subdivision known No mixed use on a floor	Very high *Applicable in heterogeneous areas when appropriate data are available*

Table 1 Data sources and indicators for disaggregation of population data

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