Information for Urban Risk Management: the Role of Remote and Close Sensing

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Abstract: The multi-disciplinary research project Strengthening Local Authorities in Risk Management (SLARIM), initiated by ITC, includes three case study cities in Asia. An important question is: what are the essential data for risk management and how to access such data. The role of common sources (e.g. census data), data derived from remote sensing (high-resolution satellite imagery, aerial photos), and data from close sensing (field observation, including mobile GIS) to acquire essential risk management data will be discussed. Special attention is given to the question of the minimum area and to disaggregating population data. A few examples are given of Kathmandu / Lalitpur, Nepal.

Keywords: Urban Risk Management, Remote Sensing, Field Observation, Mobile GIS, Disaggregating Population Data.

1. Introduction

Most of the information required for risk management has a spatial component and, particularly in urban areas in developing countries, is changing continuously. Access to timely and trustworthy spatial data *at the appropriate scale* is an essential element in urban risk management. The tools Remote Sensing and (mobile) Geographic Information Systems are most appropriate to play an important role in the data collection and information management to assess, reduce and prevent risks and vulnerability.

2. Essential Data for Risk Management

A very large number of elements at risk and vulnerability aspects can be defined. In a practical situation a selection has to be made to arrive at a set of **essential** data. These are the data that are collectable and provide crucial information. At the foreground are data on elements at risk: *population, buildings, lifelines and essential buildings and facilities* [2, 3].

Population: number of inhabitants, age composition
Buildings: building type, # of floors, structural type, land use per floor, % built-up area, [age of construction]
Lifelines:
  transportation: main roads, bridges, railway, airport, port
  utility: water, electricity, telephone and data networks
Essential facilities:
  primary: hospitals, clinics, ambulance / fire brigade / police stations, government (town hall, etc)
  secondary: schools, community and religious centers, sports fields, public green spaces, vacant land, non-built-up spaces.

Such a list should be adapted to local circumstances.

In all cases the aspect *location* should be recorded, both for the registration in a geo-database, as well as for analytical purposes.

3. Data Sources

1) Common (Administrative) Sources

Population data are normally acquired from the local census office. In most cases the census tract or ward is the geographic collection unit. Boundaries are fairly stable in time. Where originally the delineation was intended to enclose a *homogeneous* area, in time it may well have developed into a heterogeneous area under the influence of spontaneous, unplanned, developments. There can be a high variation in area and number of population. The census tract system has to be critically assessed in a particular situation to decide whether it is suitable as the data collection unit.

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) Remote Sensing

A reliable inventory of building footprints (that is: the ground area of buildings) can be derived from aerial photographs, negative scale 1: 50000 or larger, or from a high-resolution, 1 meter or better, satellite images. [Such imagery ideally should have an *orthophoto* format to ensure geometric compatibility with GIS and map data.] Additionally, the general land use can be interpreted from such imagery. Main road networks and vacant land can be easily recognized and mapped.

The location of many *essential facilities / buildings*, however, has to be derived from specific maps or common administrative sources.

The *number of floors* or the building heights cannot be derived reliably from most satellite or aerial imagery. Building shadows or stereo images can give useful indications, but usually not the exact number of floors.

Information on *building types* is visible and classifiable, but not the *construction quality* of each building. The building type may have a strong link to a structural quality typology and as such be a basis for sampling.

Remote sensing images are an ideal source of information on building densities, provided the image resolution allows a clear separation of buildings. Image interpretation then will allow a separation between residential and non-residential land uses, and make measurements of *gross and net residential densities* possible [1].

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.

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 when limited to data capture of elements that require a good measure of professional judgment and estimation (e.g. land use, structural quality of buildings).

Quantative measurements of the built-up area from images, on the other hand, are much more accurate and trustworthy than field estimates.

Montoya [2] has proposed a combination of remote sensing imagery and ground video images from a moving vehicle. The geographic location reference of each video image was provided by a GPS. Building attributes were extracted afterwards from the analysis of the video images. A much larger area could be covered in a few days than would have been possible with a ‘rapid sidewalk screening of buildings’ [3] approach.

Mobile GIS is using a computer in the field to capture or edit vector and raster data that is georeferenced. The handheld computer, usually of palmtop size, receives location information from a connected GPS.

Experiences with mobile GIS indicate it is in principle a jump ahead compared to the analogue approach. There is now a field tablet PC with a reflective display that works very well in the bright sun.

For applications in high-density urban environments a GPS that yields sub-meter results with differential correction seems to be the most appropriate choice (e.g. to make sure that plots on different sides of a street do not have overlapping boundaries).

A mature stage of development of computers, software, and GPS is now in sight. Device ergonomics is still a big area for improvement [5].

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 [4].

4. Minimum Areas and 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).

When defining the spatial unit that should be the basis for capturing data sets for risk management, the selection of a *minimum area* and a *maximum area* will lead to more consistent results and a better efficiency of the field survey. The choice of the size of the minimum area should be rather *pragmatical*: at the same time limit the number of areas *and* avoid too much heterogeneity of all the aspects to be captured. In a grid pattern situation (as in Latin America) the city block would be an obvious choice.

In the case study municipality Lalitpur (Kathmandu Metropolitan Area, Nepal) the minimum area in the fully developed urban area was fixed (after a pilot survey) at 1 ha and the maximum area as 2 ha. In the partially developed fringe area the minimum was 1 ha and the maximum 6 ha. Data were collected in the field on the building type, the number of floors, the land use, the construction quality, and the percentage built-up.

5. 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 *population data in a census tract can be disaggregated when a number of conditions is fulfilled*:

- the census tract area and the built-up area inside is known or can be measured from recent high-resolution imagery (or from a recent, complete footprint map)
- residential development between the census and the image /ground survey dates is known or can be well estimated, census tract boundaries are not changed
- all residential use of floor areas in a census tract is detected and quantified
- the number of residential and non-residential floors of buildings in building type classes is known (from building type data, land use survey, field data collection)
- limited variation in use of residential floor area between socio-economic groups. This can be assumed to be the case in socio-economically homogeneous areas. If there are substantial differences in use of residential floor area per inhabitant (m²/person), then the area has to be sub-divided on the basis of the 'consumption' of residential floor area per person. A good indicator would be the type of dwelling (e.g. detached with garden, apartment, etc). For each socio-economic group (or dwelling type) the typical residential floor area use then has to be computed
- limited mixed commercial-residential use in buildings that are predominantly used by commercial activities (and therefore are classified as commercial)

The procedure would essentially be an exercise in 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 typical m²/person floor use could be made after which a best fit could be calculated.

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.

6. Conclusion

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.

Fig. 1 Ikonos image Lalitpur, Nepal, 30 Sept 2001 (top of image is South)

In the top right hand a temple area, surrounded by high-density mixed land use: mostly buildings with 6 floors, of which the upper 4 floors are residential and the lower 2 floors are commercial.

In the lower part a mix of apartment blocks, detached houses, and some old agricultural plots, not yet urbanized.

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