A Review of Existing Cost Effective Surveying Technologies and Techniques for Developing Countries

Dan SCHNURR, United Kingdom

Key words: Survey measurement, mapping, developing nations, cost effective.

SUMMARY

Since the turn of the new millennium, the focus on survey measurement and map production in the developing world has been mainly on sustainable and spatial data infrastructure (SDI) issues. This has been supported by the World Summit on Sustainable Development in Johannesburg, August 2002 and the two FIG Regional Conferences in Nairobi and Marrakech. Coupled with, and integral to, any sustainable and SDI approach is the appropriate use of surveying technology and techniques for map production.

This paper reviews and outlines the future work of the FIG joint working group WG 5.4 from 2003 to 2006. It forms a working document that underpins part of the group's work in 2004. The objective of this joint working group between FIG commissions 3, 5 and 7 is to produce a FIG Publication in 2006, entitled "Guidelines for Cost Effective Survey Measurement in the Developing World." In this paper some of the most recently published cost effective technology and techniques available for map production at scales between 1:1000 and 1:25,000, is reviewed. Some of the applications and areas where this mapping is required are then summarised. This is illustrated by focusing on both successful and wasteful projects, where a variety of techniques have been used, referring to published case studies. Finally, by combining the lessons learned from these published works and using a planned approach from the actual needs of the developing world, some ideas on best practice guidance for future projects are put forward.

A Review of Existing Cost Effective Surveying Technologies and Techniques for Developing Countries

Dan SCHNURR, United Kingdom

1. INTRODUCTION

In general, when preparing a review paper two possible models can be followed. In the first method, the existing published works, information and projects carried out to date are assessed, conclusions are drawn and formal recommendations and ideas are put forward. In the second model the information review is similarly carried out, however, the paper then allows for further debate and activity in those specific discussion areas. This paper is written along the lines of the second model as it forms a working document as part of the FIG Joint Working Group 5.4 (WG 5.4) year 2004 activity.

In the sections which follow, WG 5.4 is first outlined for those unfamiliar to the group, the mission statement and the work planned for year 2004 to 2006 is summarised. The exact remit is then discussed, as in attempting to addressing all the issues, focus on the core difficulties can be lost. This can also cause the duplication of effort across other FIG and international groups who are working in similar areas.

A review of some previously published works, highlighting current cost effective surveying technologies and techniques is also presented. Finally, some of the survey and mapping applications and the actual needs of the developing world are then discussed.

The task of the group is not a simple one. The shear number of issues involved, the diversity of applications, needs, surveying techniques and technologies all require work. However, the group aims to produce a FIG Publication by the 2006 Congress in Munich, entitled "Guidelines for Cost Effective Survey Measurement in the Developing World." This will not signal the end of the work for the group, as survey technology and techniques are ever changing and the publication must be kept current and up-to-date to ensure the greatest benefit can be obtained from those that use it. With this in mind, one of the areas the working group is assessing is the possibility for a web-based publication, or update service.

The working group is focussing mainly on the use of survey technology and techniques to provide modern accurate geometric mapping and other map products. These then form the basic framework, or structure, upon which other appropriate data sources can be referenced for their numerous applications. It should be noted that this paper is designed to ask some of the many questions which relate to this subject. It is written primarily for those who have little or no technical understanding of the subject. We hope that feedback from those who read it can be channelled into the Working Group's activity for 2005. Please feel free to comment on the paper and its content using the contact details which follow after its conclusions.

2. FIG WORKING GROUP 5.4

FIG Working Group 5.4 was originally conceived during 2000 - 2001 when a joint working group between Commissions 3, 5 and 7 was initially discussed. The original title was to be Low Cost Survey Technologies and Techniques for Developing countries. However, during 2002 - 2004 the working group evolved to clarify the remit, and to focus on the now current WG 5.4 Work Plan. Full details of the Working Group; the current members, work plan, specific projects, workshops, publications and timetable can be found on the FIG web site at:

http://www.fig.net/figtree/commission5/wgroups/wg5 4.htm

The mission statement of the working group has been drawn from the text of the keynote address given by Dr. Anna Tibaijuka to the XXII FIG Congress in Washington DC, 2002.

"To identify more cost effective ways to improve the availability and accessibility of tools of land information. To suggest these methods to aid more effective planning, development and management of the environment. Also to develop innovation, adaptation and resourcefulness in simplifying these tools to fit the local situation."

The key members of the group are currently located in Greece, Turkey, Canada, Argentina, Austria, Trinidad and Tobago and the United Kingdom. Following this review paper and the next paper TS13.2 (which reviews the current difficulties and challenges of providing spatial data to developing countries), the key areas of work for the remainder of 2004 and early 2005 are:

- Development of initial guidelines for cost effective mapping methods, using a review of the separate various techniques published to date.
- Assess whether any existing research or further research into development of methods is required.
- Assess and review the actual mapping products required by developing countries.

Further challenges in actually undertaking and successfully achieving the above work items are caused due to the fact that the working group is a virtual collection of people across the globe. They may only occasionally come together to actually meet face-to-face once every four years. Therefore, any other motivated FIG delegates from commissions 3, 5 or 7 are welcome to become part of the working group.

Those delegates that do wish to join the group will have to commit to actually undertaking tasks, in line with the work plan, by certain deadlines! This is a dynamic working group with a clear target and considerable energy. It fully aims to complete the tasks planned and to publish the guidelines document in 2006, to the highest possible standards.

3. CURRENT ISSUES CONCERNING COST EFFECTIVE MAPPING

3.1 Mapping Specifications

The current mapping that is available in the developing world ranges from none in some countries, to a large amount of older, detailed paper mapping in others. This is especially evident in those countries which were aligned to others in the past. For example, in some parts of Africa (e.g. Niger, Sudan, Ethiopia, Uganda, Zaire, Chad and Tanzania) the old United Kingdom Directorate of Overseas Surveys (DOS) mapping may be available. An example of the type of mapping that was produced in the 1960s is shown in figure 3.1 below.

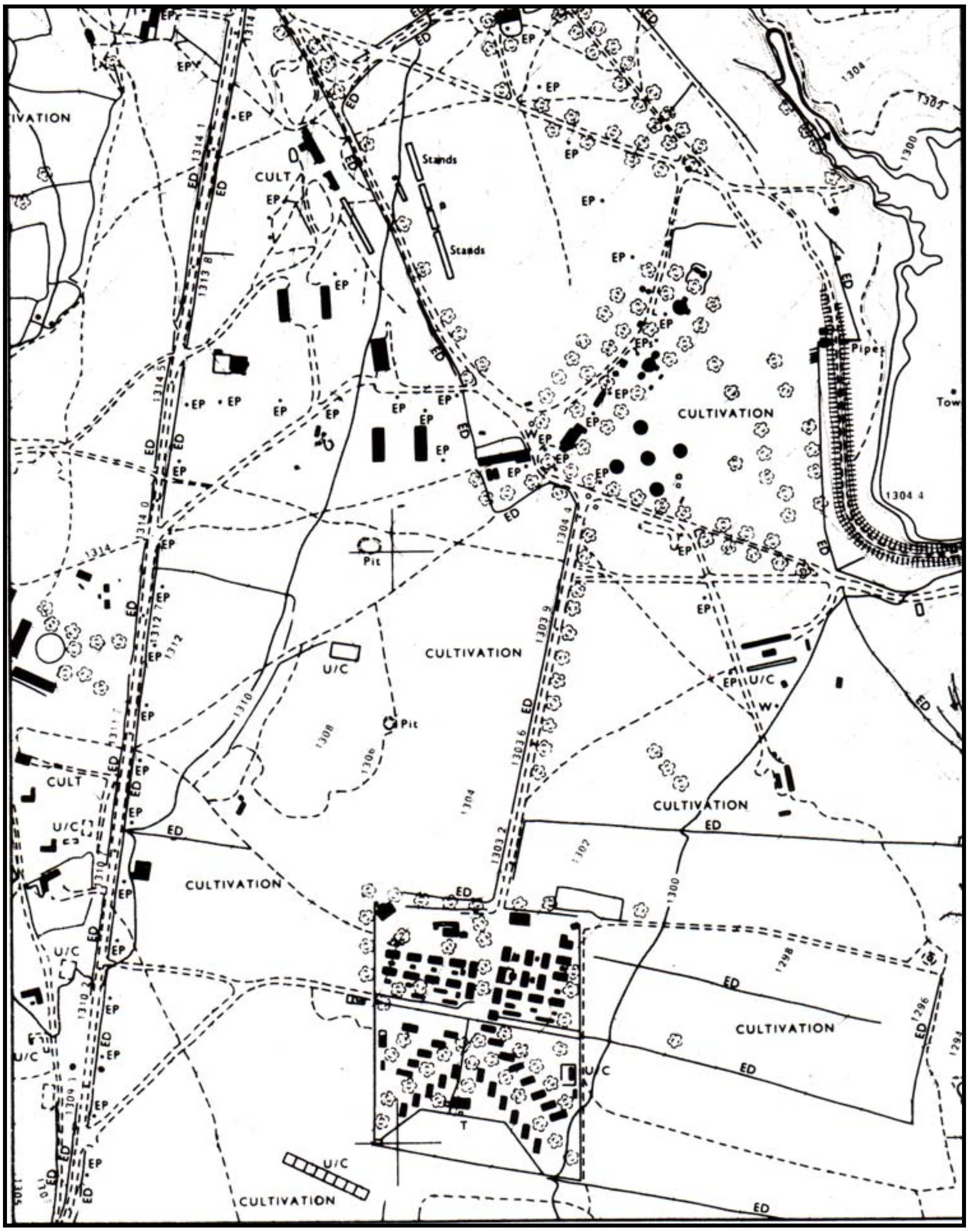


Figure 3.1: Example of older 1:5,000 photogrammetric mapping from Africa, circa. 1967

Conversely, in the developed world, general large scale up-to-date mapping is widely available, typically provided by the countries' national mapping agencies. The circumstances of each country have, however, caused the mapping products to develop into specific products required for the needs of that country. This in turn has caused each country to develop its own mapping specification for the production of large scale mapping. For example in Denmark, the TOP10DK specification is used, and in the UK the TOPO96 specification is required for new mapping [1,2]. In many cases the specifications are also biased by the use of the digital systems and software employed in the different countries offices.

Despite starting with almost a "clean sheet" of paper in some areas of the world, the development of a generic mapping specification for scales between 1:1000 scale and 1:25,000 scale is almost impossible. One of the major difficulties is simply due to the differing terrain types between countries. Some fifty years ago when the deliverable and map product was a simple sheet of paper, even the DOS surveyors had great difficulty in getting agreement of a common specification. An example can be drawn from three territories in East Africa which tried to adopt a common specification in the early 1950s. They failed to agree and a second attempt was made in 1958. However, the difficulties in deciding on a common vegetation classification suitable for all three caused further problems. Finally, agreement was made in October 1962, ten years after it was first initially discussed [3].

Therefore, today where the deliverables can include paper copy mapping as well as numerous digital files, orthophotos and other imagery, development of a common specification is a difficult, if not impossible task. A far better approach is to provide detailed guidelines to help ensure the most cost effective surveying technology and techniques are considered.

The base concept of generating a specification to which the mapping must be made is still however, vital. Whether the mapping is to be funded and generated using a sustainable approach within a certain region, or the economies of scale from the developed world are to be utilised, the specification is key. It ensures the actual final spatial data products are understood by all parties but can also outline the method of data capture to ensure the most cost effective use of technology. For example, a paper from the FIG regional conference, in Nairobi, Kenya in October 2001, outlines the creation of a manual GIS using archive aerial photography spanning 30 years, from 1948 to 1978. The result was a successful and cost effective spatial data product which fully met the original needs defined by the end users [4].

3.2 Current Cost Effective Survey Technologies

Within the band of mapping scales between 1:1,000 and 1:25,000 there are both numerous applications and numerous techniques available to make the map product. These techniques can include; satellite imagery, multispectral, thermal and hyperspectral scanning, microwave sensing using radar and laser and finally, traditional air photography and photogrammetry.

The key to the use of the appropriate technology is the concept of final map scale. The link between the final scale of the mapping and the ground resolution of any survey technology is even more important today than in the past.

Previously, when a mapping product was a simple sheet of paper, or other hard copy format, the line thickness at the given scale defined the resolution and accuracy of the detail on the map. For example, a 0.2mm line (the limit of plot resolution) on a 1:1000 scale map defines a item of detail 0.2m wide on the ground. Thus, any stone walls of a thickness less than 0.2m, which might mark out a boundary, would have to be shown by a single line on a 1:1000 scale map. Because of this issue, detail at a size of less than 0.2m will “disappear” from a 1:1000 scale map. If it is decided there are critical items smaller than this which must be shown, a symbol will then have to be used on the mapping.

This usage of symbols becomes more common at smaller scales of mapping. For example, at 1:25,000 scale a 0.2mm pen thickness defines the plot resolution as 5m. An access track which is only 3m wide on the ground may be shown as two lines on the mapping say, 1mm apart (one for each side of the track). At 1:25,000 scale this would relate to a feature 25m wide. Cleary as the track is only 3m wide in reality, the two lines on the map sheet are actually a symbol of the feature. This effect also causes feature displacement and ould lead to the incorrect location of property boundaries if incorrect imagery is used.

The reason this factor is more important today are twofold. Firstly, there is the difficulty of constantly zooming in with a digital map product. In digital format, a 1:5,000 scale map could be plotted at 1:1,000 scale and used for a 1:1,000 scale purpose. However, if the surveyor or cartographer produced the mapping at a ground resolution of 1m (0.2mm pen thickness at 1:5000 scale) any items of a dimension less than 1m might not be shown. More importantly, the accuracy of the measurements used at 1:1000 scale may be thought to be ±0.2m, or better. However, in reality as it was originally a 1:5,000 scale map, it will have been produced to an accuracy of ±1m.

The second reason, is that the appropriate use of current survey technology and techniques is closely linked with ground resolution. Most methods utilise imagery sources for map production and all images have a pixel size within the digital environment.

Some typical mapping scales, their plot or “ground resolution” (based on a 0.2mm pen thickness) and possible applications are outlined in the table below:

Mapping Scale	“Ground resolution”	Typical Application
1:1000	0.2m	Urban cadastre, detailed engineering design and construction
1:2000	0.4m	Rural cadastral and other boundary demarcations
1:5000	1m	Town planning
1:10,000	2m	City planning
1:25,000	5m	Large area developments and Country wide medium scale maps

Table 3.1: Map scales, ground resolution and possible uses

Since the launch of the first satellite, this technology has revolutionised modern mapping methods. The simplest and most cost effective method of map making, in line with the scales and ground resolutions outlined above, is to utilise a suitable imagery source, coupled with appropriate GPS control measurements.

This is no different to the methods utilised in the past. It is just that for the smaller scales of 1:10,000 and 1:25,000 satellite imagery can now be used rather than commissioning bespoke aerial photography. As in the past, by using appropriate stereo image coverage, a three dimensional topographic mapping product can be derived. GPS control is also now used rather than a traditional triangulation scheme.

There have been several papers published where single frequency hand-held GPS receivers have been used for surveys with carrier phase GPS measurements. These tests have demonstrated the possibility of centimetre accuracy which, if used appropriately in a control scheme, could drastically reduce the cost of high precision GPS [5,6,7]. Figure 3.2 below demonstrates an excellent example of appropriate, cost effective use of modern survey technology

Figure 3.2: Single frequency L1 carrier phase GPS system with choke ring antenna!

A further cost effective surveying technology which is becoming commonplace is LiDAR. For example, a successful $532km^2$ project area in Congo was mapped in 2002 [8]. The table below reviews the current digital imagery and other surveying systems which should be considered for cost effective map production for developing countries:

Platform	Imagery / System	Resolution	Imagery control method	Typical mapping
Satellite	Landsat	10m	“Level 1” GPS	1:50,000
	SPOT	5m	“Level 2” GPS	1:25,000
	IKONOS	1m	“Level 3” GPS	1:10,000
Fixed Wing Aircraft	1:24,000 VAP	0.5m	“Level 3” GPS	1:10,000
	1:12,000 VAP	0.25m	“Level 4” GPS	1:5,000
	1:3,000 VAP	0.06m	“Level 4” GPS	1:1,000
	LiDAR – low res.	0.3m	“Level 4” GPS	1:5,000
Helicopter	1:1000 VAP	0.02m	Land survey	1:500
	1:600 VAP	0.01m	Land survey	1:200
	LiDAR – high res.	0.05m	“Level 4” GPS	1:500

Key to table terms: VAP - Vertical Aerial Photography
Resolution - the ground pixel size (note VAP typical scan at 20μm)
Land survey - traditional levelling and EDM methods (≤ ±0.01m)
LiDAR - low res. (low resolution), high res. (high resolution)

Table 3.2: Types of visible spectrum imagery sources for mapping

The GPS imagery control methods quoted above in Table 3.2 have been simplified unto four levels which correspond to different accuracies. These “levels” are the four different basic methods of using GPS technology for positioning, and are summarised below in Table 3.3.

GPS “Level”	Description of GPS measurement method	Accuracy
Level 1	Standalone pseudorange GPS Positioning	25 – 10m
Level 2	Differential code GPS, or “DGPS”	2 – 5m
Level 3	Carrier smoothed differential code GPS	0.4 – 0.8m
Level 4	Double differenced carrier phase GPS	0.01 – 0.04m

Table 3.3: Basic levels of GPS accuracy

Note that the nominal photograph scales for the mapping scales listed in the table are widely quoted in various literature [9] and are based on standard 9inch x 9inch film, with a 6 inch lens. The table also shows which imagery types have been used for map production in the past, and on recent public and private sector projects. It should be realised that the ground resolutions where shown, from the vertical aerial photography, are approximately those which will be achieved using a typical 20 micron digital scan of the film.

Scan resolution can be increased and new digital aerial cameras can also further improve resolution values for a given flying height and scale of photography. It could be argued that with the forthcoming rise of the digital aerial camera it will soon become the ground resolution of the imagery which is specified, with the scale of the photography simply becoming a secondary factor.

The methods employed from a helicopter platform are typically for use at scales greater than 1:1,000 and thus can be excluded from further discussion as they also generally entail higher cost and complexity. From the table, it can be seen that typically at the mapping resolution required, about 16 pixels of imagery are used to measure the smallest detail that is to be plotted. For example, 1:24,000 vertical aerial photography scanned at 20 microns gives a pixel size of 0.5m on the ground. From Table 3.1, the plot resolution of 1:10,000 scale mapping is 2m, thus, 16 imagery pixels (4 x 4) will be used to produce the minimum size of detail at this scale. This is shown diagrammatically in Figure 3.2 below.

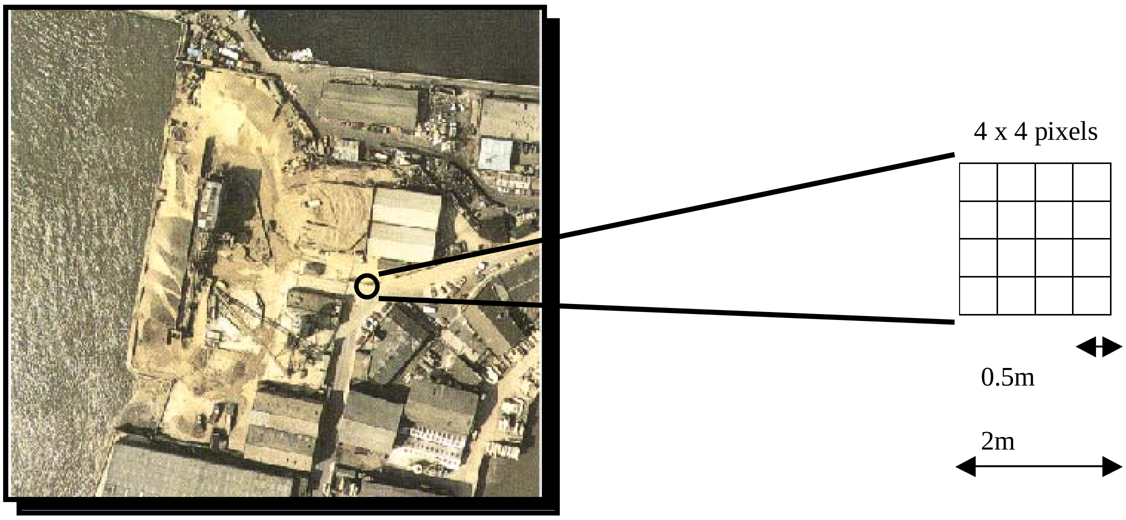


Figure 3.2: 2m x 2m square on ground represented by 4 x 4 image pixels

This then clearly shows the importance of using the correct imagery resolution for the mapping product that is required. For example, in extremis, one would never attempt to produce a geometrically correct and accurate 1:5,000 scale map from Landsat imagery which has a pixel size of 10m.

3.3 Appropriate use of Current Technologies and Techniques

Despite the simplicity of using suitable imagery coupled with GPS ground control, this is not the complete solution for cost effective use of survey technology and techniques for developing countries. As mentioned above in section 3.1, older archive material and classical survey techniques have their place and can be far more effective. These older tools of land information are often already simplified and are well suited to fit the local situation. This ties-in well with the Working Group's mission statement.

An example might be the use of plane tables for hard copy plotting of urban cadastral plans coupled with a simple scanning or digitising system for eventual digital map production [10]. This method might well prove to be more cost effective than a highly priced RTK GPS system. The RTK GPS system also has the drawbacks of sky-view obstructions causing the system to fail, which can be an obvious difficulty in urban environments. In addition to the initial equipment costs, the in-depth training, technical support and associated software costs can multiply the final amount spent. The true value of a high cost RTK GPS system for cadastral surveying in a developing country must be carefully considered.

A further consideration must be that the basic geometrically accurate topographic map is only a part of the solution. The end use for the base mapping must also be assessed. Consideration must be given to the final application which might be; land use classification, geological and soil mapping, agricultural, forestry and water resource assessments, urban and regional planning applications and wildlife, archaeological or environmental assessments. Many of the imagery types which can be used for map production can also be used for interpretation to provide additional datasets in the above areas. This generates added value to the mapping and is an important part of the overall cost benefit.

Finally, as discussed Getting it together – the geography jigsaw [11], the coordinated use of surveying technology and techniques in joint project is vital:
"There is a trend for any individual donor to support joint projects or programmes or at least in the same areas as other donors. This can be very beneficial if the projects are complimentary, though it imposes the burden of co-ordination on one or more of the organisations or the recipient government.... Delivery of computer hardware is relatively easy and off the shelf; delivery of specialised software is fraught with specification, design, performance and implementation problems.... It is very difficult to devise a strategy that can fairly balance the advantages of 'international standards' against the desire to create and nurture local expertise on a sustainable basis."

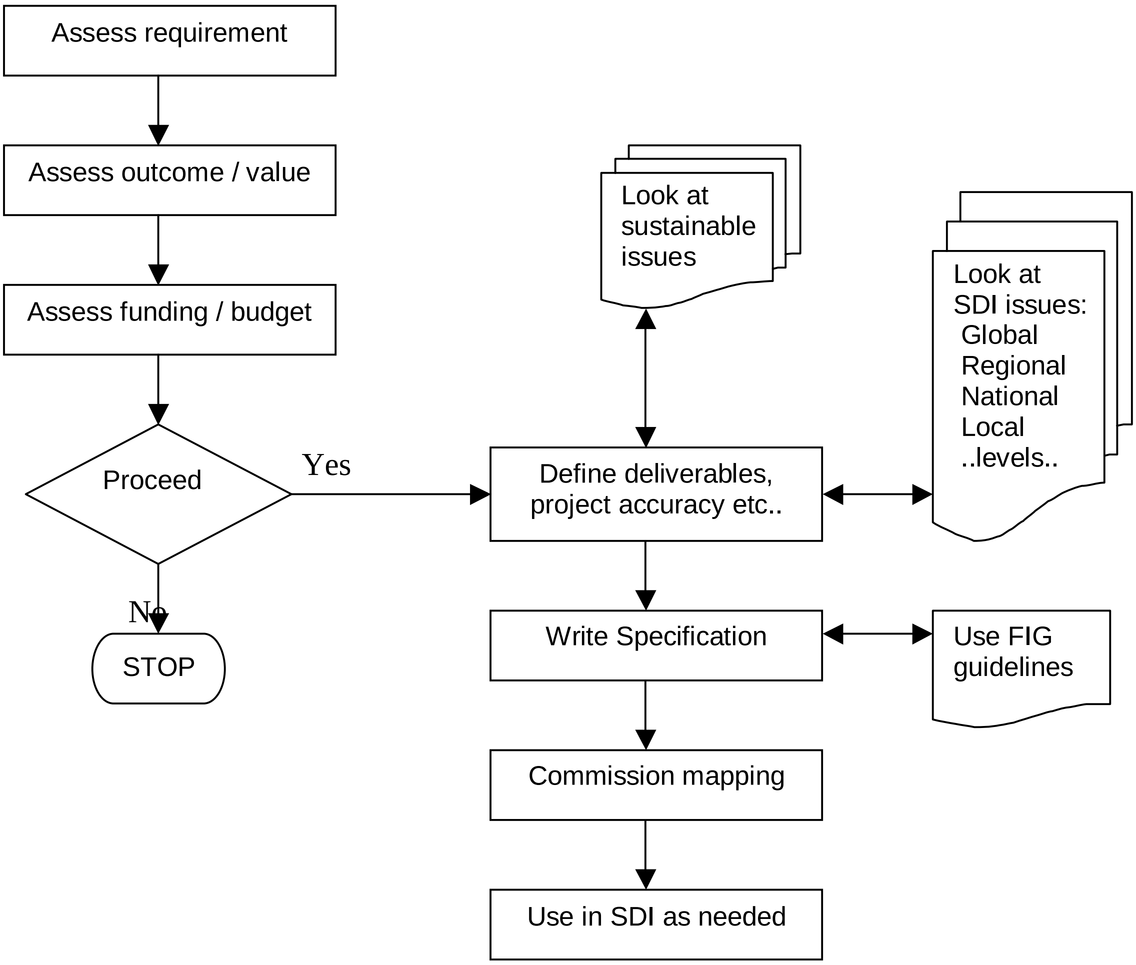
4. APPLICATIONS IN THE DEVELOPING WORLD

As mentioned in the introduction, pulling together the strands of the current cost effective survey technology and techniques, their appropriate use and the applications and needs for them in the developing world is not an easy task. The common factor universally agreed is that appropriate geometrically correct, accurate mapping is the life-blood of sustainable, planned and controlled development. The applications for it may be in areas as diverse as; environment, e-government, e-citizen, public sector, agriculture, transportation, statistics, risk management or land administration.

There have been many case studies published where the final use for mapping is outlined in detail. One international conference which centres mainly on some of the 2D mapping applications (i.e. using a single satellite image) is the annual GIS for Developing Countries (GISDECO) Conference [12].

Other areas where both 2D and more importantly 3D applications are discussed include papers from previous FIG working weeks and FIG regional conferences [13]. Further articles can be found in publications such as GIM International [14] and the national survey press of various FIG member countries.

Whatever the application might be, and whatever the challenges are in providing the spatial data to the developing world, a general process flow line should be followed. We propose this should be standardised to ensure the very best use of survey technology and techniques and cost benefit is maximised during the mapping phase of the project. A general flow line which has been discussed amongst the working group members is shown below:



A real difficulty still however remains. This is the balance between determining the actual needs of the developing world against what the developed world thinks that they need. This difficulty is highlighted when a western corporation with shareholders to satisfy and sales targets to meet, wades into a project and insists on providing inappropriate technology and techniques. Conversely, the complexity and difficulties of a project can rapidly overwhelm local resources if it is allocated purely to a local legislative body. Both scenarios can result in a wasteful use of resources. The next paper in this session discusses and reviews some of these challenges.

5. CONCLUSIONS

Despite the obvious difficulty, a specification for the mapping of any given project must be detailed. In the past, the RICS Client Specification Guidelines (based largely on the original DOS mapping specifications) could have been used. In particular, the “Specification for Mapping at Scales Between 1:1000 and 1:10,000” (1981), or Second Edition (1987) were suitable. These are now some 20 years out of date. Therefore, it is proposed that a section relating to specifications is integral to the Working Group 5.4 2006 publication, “Guidelines for Cost Effective Survey Measurement in the Developing World”.

Regardless of the mapping specification it is paramount that any mapping projects and use of survey technology and techniques, is undertaken appropriately. A process flow-line must be standardised and followed. This will then ensure the maximum value and cost benefit is obtained for any mapping project.

Projects must ensure that the precise requirements and needs of the local situation are fully met by the mapping produced. There must also be a careful assessment of the balance between the capacity and ability of the local circumstances, against those of the commercial environment. Then, where possible, use of local resources should be used to improve the overall sustainable solution. The difficulty of assessing the mapping required and the coordinated development of mapping projects, however, remains an anathema. The paper following this, TS13.2 looks at some of these critical issues.

REFERENCES

TOP10DK Geometrisk registrering. Specifikation udgave 3.2.0. May 2001

TOPO96 Survey Specifications, Ordnance Survey, Great Britain.

Macdonald, A., (1996)

Mapping the World, A History of the Directorate of Overseas Surveys 1946 – 1985. HMSO, London.

Rostom, Prof. R. S., (2001)

A Manual GIS System for Machakos District, Kenya. *Proc of FIG International Conference on Spatial Information for Sustainable Development*, Nairobi, 2 – 11 October 2001.

Schwieger, V., (2003)

Using hand held GPS receivers for precise positioning. *Proc. of 2nd FIG Regional Conference*, Marrakech, 2 – 5 December 2003.

Katiyar, S.K., Dikshit, O., Kumar, K (2003)

Benefits of Low-cost Hand-held GPS. GIM. Volume 17, **6**: 29-31

Hobbs, K. F., (2003)

Positioning in the Maldives by low-cost GPS. GW. Volume 11, **4**: 35-37

Tolman, J., Corbley, K. P., (2004)

Applying LiDAR Technology in Congo. GIM. Volume 18, **3**: 40-43

Lillesand, T. M., Kiefer, R. W., (1994)

Remote sensing and Image Interpretation, Third Edition. Wiley, New York.

Lee, M., (2001)

Future Vision on Korean Cadastral Surveying. *Proc. FIG Working Week 2001*, Seoul, 6 – 11 May 2001.
Waters, R., Woodsford, P., Hoskins, R., (2003)
Getting it together – the geography jigsaw. RICS Foundation. RICS, London.

Proceedings can be found at: http://www.geog.uu.nl/gisdeco
Proceedings can be found at: http://www.fig.net/figtree/pub/proceedings
Details on the publication can be found at: http://www.gitc.nl/gim

BIOGRAPHICAL NOTES

Dan Schnurr is a Chartered Land Surveyor and works as Deputy Head of the Survey Department at Atkins Survey and Mapping. He is widely respected in the UK as one of the most expert GPS surveyors in the commercial sector. He is broadly experienced in land surveying throughout the world having worked in Europe, the Middle East, Australia, West Indies and United States. Dan currently helps manage the department of some 40 staff located across Europe working on a wide range of different survey and mapping projects. He is a corresponding member of the RICS Mapping and Positioning Practice Panel and is the UK delegate to FIG Commission 5. Within this role, he is also Chair of FIG Working Group 5.4: Cost Effective Surveying Technology and Techniques for Developing Countries.

CONTACTS

Dan Schnurr BSc (Hons.) MSc MRICS
Atkins Survey and Mapping,
Connect 17, Langley Park,
Chippenham, Wiltshire, SN15 1GG,
Tel. +44 1249 455026
Fax + 44 1249 455045
Email: dan.schnurr@atkinsglobal.com
Web site: www.atkinsglobal.com