A COMPARISON OF THE EFFECTIVENESS OF FOUR DATA CAPTURE PRODUCTION LINES

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S.P. Goel
Survey of India (SOI)

J.E. Drummond
International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands

A.M. Tuladhar
International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands

PURPOSE:

The Survey of India (SOI) is considering building a National Topographic Database model of the Indian landscape to the standards and level of detail associated with India's 1:250,000 map series. The project reported here proposes that data will be captured regionally, and to this end it is necessary to find the most cost effective data input means for implementation at regional centres. This paper summarises a joint SOI/ITC investigation carried out on four potential data production lines (manual digitizing, low cost and high cost scanning and vectorizing, and 'heads up' or 'on-screen' digitizing) and compares these in terms of the effort required to achieve a certain quality of end product.

KEYWORDS: Map data capture. Comparison of methods. Time trials. Manual Digitizing. Scan Digitizing. 'On-Screen' Digitizing.

1. INTRODUCTION

This paper reports on an investigation to identify an appropriate spatial data capture method for contributing to building a National Digital Database for India. This spatial component can be referred to as a National Topographic Database. As in any similar endeavour, it is necessary to identify the users of the database and their needs before designing the data-model, identifying the sources, and selecting the sources and methods of data capture. However once the sources have been identified, it is possible to design objective tests to choose the most appropriate method(s) of data capture. In India it has been planned that the spatial component of the National Digital Database will be subdivided into databases representing real world entities at the levels of detail found on maps at the scales 1:4,000,000; 1:1,000,000; 1:250,000; 1:50,000; and 1:25,000 (Agrawal,1989). The following table summarises the 1991 situation regarding some of these Indian series, when considering conventional maps.

Series	% Complete	Number of sheets complete (approx)
1:25,000	30%	7000
1:50,000	100%	5000
1:250,000	100%	300

Table 1 - Status of Indian map series

In this investigation it was proposed to start building the spatial component of a National Digital Database using the 1:250,000 series. The reasons for this were: 1) it was a potentially manageable task from which experience could be gained in capturing and handling large data sets; 2) although of low resolution it would enable the rapid future production of updated 1:250,000 scale maps, which are currently only produced by the manual generalisation of 1:50,000 maps; 3) with only approximately 300 sheets a national database could be built quite quickly; and 4) three users (Forest Survey, Soil Survey, and The Survey of India (SOI)) have expressed an interest in this scale (Stefanovic, 1990a).

In the 1980's digital Cartography was introduced to the SOI. By 1991 in the SOI's Modern Cartographic Centre there was a SysScan Integrated Digital Map Production System, in its Automated Cartography Cell there was another Computer Assisted Mapping installation, in its Digital Mapping Centres were Integraph Map Production Systems, and in its Survey Training Institute several Integraph MicroStation-PCs were used. A core of personnel were already experienced in these systems, and so it was decided that any future production lines (in terms of database building) should not deviate far from these existing systems. However during this investigation it was realised that database building and maintenance could be decentralised to the regional offices of the Survey of India; such decentralisation leads to a requirement for low investment cost systems.

The situation outlined in the preceding paragraph influenced the four production lines tested in this work. The production lines involved: 1) manual digitizing and interactive editing in the Intergraph PC-MicroStation environment; 2) scanning, vectorizing, and interactive editing in the SysScan environment; 3) low-cost scanning (AGFA), vectorizing (SysScan environment), and interactive editing (SysScan environment); and 4) scanning, 'on-screen' digitizing and interactive editing in the Digisys environment. (Digisys is a low-cost MS-DOS based integrated raster/vector cartographic editing system developed by the Dutch company Reprocart bv. It takes input from Scitex and other scanners and produces colour separated plotting files for Scitex laser film printer/plotters (Korver, 1991).) These four production lines will be further discussed in section 3 of this paper.

2. THE 1:250,000 MAP SERIES AS A DATA SOURCE FOR A NATIONAL TOPOGRAPHIC DATABASE

The SOI 1:250,000 maps are printed in five colours from the following stable transparent film separates:

1. black colour separate, containing point symbols (trig. points etc.) and line symbols (power lines, boundaries of water bodies, centrelines of small permanent and intermittent streams, graticule, etc.);

2. black name colour separate, containing alphabetic and numeric character strings;

3. blue colour separate, containing point symbols (wells etc.) and line symbols (centrelines of canals etc.);

4. blue colour tint separate, providing the infill for water bodies (lakes, reservoirs, major rivers, seas, etc.);

5. brown colour separate, containing contour lines;

6. green colour separate, containing point symbols for different classes of trees;

7. green colour tint separate, providing infill for vegetated areas;

8. red colour separate, containing point symbols for major buildings, temples, shrines, etc. and line symbols for major road casements, centrelines of minor roads and outlines of settlements, etc.; and,

9. red colour tint separate, providing infill for settlements.

The separates and the relevant printed maps were considered to be the most likely sources from which data could be captured to build a National Topographic Database. Projection grid coordinates were also available for the plotted trig. points, and these have potential as control points in data capture as an alternative to printed projection grid intersection points.

2.1 <u>The Quality of the SOI 1:250,000 Topographic Series and its associated National Topographic Database</u>

The SPATIAL quality of real world entities which are well defined on the printed SOI 1:250,000 map series is represented by a 'Standard Error' (equivalent to Root Mean Square Error or RMSE) of 0.25mm, at map scale (Goel, 1992). Although the map printing process contributes to this RMSE and it can be estimated that the RMSE associated with the individual production separates is less than 0.25mm, in this investigation it was nevertheless assumed that the RMSE of the production separates was 0.25mm.

Tests carried out by the OEEPE (Thompson,1984) indicate that various digitizing procedures have Standard Deviations (SDs) of 0.08mm to 0.13mm associated with them.

If it is assumed: 1) that RMSE provides an acceptable estimation of the magnitude of the SD of a procedure; and, 2) that an acceptable estimation of the SD of an overall procedure to which two separate procedures contribute is the squareroot of the sum of the squares of the SDs of the two contributing procedures, then, the overall procedure (digitizing a production separate) which combines two procedures (producing a production separate and digitizing) will produce data having an SD of 0.28mm, at map scale (SQRT((0.25**2)+(0.13**2))). In the SOI an estimate of maximum error is typically 3*SD, or in this example 0.84mm. This value compares unfavourably with the value of 0.50mm accepted in certain professional environments (Drummond et al.,1990) - but its determination through an approximate process of 'pre-analysis' served as a warning that the tested data capture procedures might not produce data of adequate spatial quality. Another aspect of quality which is important to the general GIS user is attribute accuracy. This was not considered in this project, because information was not available on user requirements regarding the nature and quality of attributes, nor was time available to determine these or to test even hypothetical requirements.

Logical Consistency requirements of a database depend on the applications in which a database will be used. At this stage the only definite application of a National Topographic Database is the production of (updated) 1:250,000 maps. As automated cartography experiences have shown 'junction cleaning' to be a most time consuming interactive task, it was decided that in this investigation only the topology of network features would be checked in determining Logical Consistency.

Another important aspect of the quality of a database concerns its completeness. At the scale 1:250,000 many real-world features are unrepresented. The SOI requirement on permitted omissions at the 1:250,000 map scale is (Goel,1992):

"unimportant villages, hamlets, tanks and hills; markets, dispensaries, footbridges, unimportant fords and ferries; benchmarks except primary protected benchmarks; relative heights; embankments and cuttings under three meters; shallow depressions (especially when dry); minor streams and distribution canals; unimportant springs and wells; unimportant temples, mosques, pagodas etc.; unimportant footpaths and tracks, camping grounds and deserted sites; and, reserved forests of 10 sq.kilometeres or less in area"

As the specific definition of what is 'unimportant' or 'minor' in these instances would have been a major additional task, in this project we merely accepted that every feature appearing on the test document (with the exception of text) must be captured for the database. This is of course unsatisfactory for the future, when any National Topographic Database will have to undergo maintenance.

A final database characteristic often dealt with at the same time as the various aspects of quality is 'lineage'. At the moment a generally accepted description of this does not appear to exist. Many mapping organisations (including SOI) have produced 'history sheets', or similar, of their traditional products showing how, when and by whom a map was made. A database has the potential for storing this 'how, when and by whom' information for every attribute of its every object. It is not known whether any existing spatial database actually does this, or even how such information might be used. In this investigation we did not consider the lineage aspect of the SOI 1:250,000, beyond reporting the contents of its 'history sheets' in the relevant report (Goel, 1992).

3. THE PRODUCTION LINES TO BE TESTED

As was indicated in the introduction, this investigation involved testing four production lines. The choice of test production lines was constrained by systems and system training already in place at the various institutes of SOI, and by the need for low investment costs should any expansion of database building facility into regional offices of SOI, be advocated.

3.1 Production Line 1 - Manual Digitizing and Interactive Editing

This production line reflected facilities available at the SOI's Survey Training Institute and Digital Mapping Centres. An Intergraph MicroStation PC (80386) with VGA adapter and Calcomp Drawing Board digitizer was used. Stream Delta, Stream Tolerance, and Stream Angle (which between them control the number of points actually stored during stream digitizing) were set at 0.20mm, 0.40mm, and 15 degrees respectively. Subsequent interactive editing was also performed using MicroStation PC software.

This is a low investment cost production line, and could be introduced to regional offices.

3.2 Production Line 2 - Scanning, Vectorizing and Interactive Editing

This production line reflected facilities found at the SOI's Modern Cartographic Centre and Automated Cartography Cell. Scanning was performed on a SysScan Kartoscan Scanner at 0.050mm resolution. Vectorization was performed using SysScan's ABS and GSWREORG programs. Subsequent interactive editing was carried out using SysScan's GINIS software.

This is a high investment cost production line, and although centrally available could not (probably) be introduced to regional offices.

3.3 Production Line 3 - Low Cost Scanning, Vectorizing and Interactive Editing

At SOI the proposed third production line would require some new investment, in the form of a low cost scanner. The scanner used in the test was an AGFA FOCUS II S800GS, which happened to be Macintosh hosted, however it could have been PC hosted. Vectorization and interactive editing was performed as in Production Line 2, above, with the addition of a specially developed program to convert from the output raster format of the AGFA scanner, i.e. Encapsulated Post Script Format (EPSF), to SysScan's run-length encoded raster format (LSC).

Because of the inclusion of the SysScan vectorization and interactive editing software, this production line was not trully low-cost. Low-cost vectorizing software (e.g. ScanPro of American Small Business Computers) could have been used, to produce a trully low investment cost production line. As there is experience amongst the authors of such low cost vectorization software some information will be included in the paper regarding this (see section 4.3.3). A low-cost approach has the potential of being suitable for the SOI's regional offices.

3.4 Production Line 4 - 'On-Screen' Digitizing and Interactive Editing

The fourth production line does not reflect any systems currently implemented in SOI institutions. It was included to determine whether 'on-screen' (or 'heads up') digitizing really was faster than manual digitizing. There has for some years been a 'feeling' that 'on-screen' digitizing is faster than manual digitizing because it may be more comfortable for the operator and may improve the completeness and precision of the digitizing (e.g. Grieco, 1992) but results of (e.g.) time-trials do not appear to have been published, and we felt it necessary to get clear figures on this. 'On-screen' digitizing is now supported by several systems - especially those found in 'multi-media' environments. The system we chose was a PC based cartographic editing package developed by the company Reprocart bv, for use with Scitex scanned data. As well as the 'on-screen' digitizing, elegant prioritizing, text generation, point symbolisation, line symbolisation, and area symbolisation software was available. The software also produced separated plotting files for output to Scitex Laser printer/plotters. Although at the moment limited to the Scitex environment in terms of input and output, the software is low cost and (according to its creators) easily modifiable. It was thought by the authors to have considerable potential in the SOI context where the main application of the National Topographic Database currently appears to be the production of 1:250,000 maps.

4. THE TESTS

On the separates we received, for reasons of security, the projection grid was not available. There was an insufficient number of trig. points in the selected test area to use these for control points, so a projection grid was introduced from a precise grid generated on a Kongsberg 1612 photo-optical plotter. (It is worth noting that in several countries projection grid coordinates are not published on the maps available to the general public or non-military public servants - and this has consequences when planning to build national or regional spatial databases.)

The four production lines to be tested represented methods of data capture which could gather the spatial attributes of the database objects to be stored in a National Topographic Database. The data model is reflected in the database objects. Before describing the investigation in more detail, a brief review of the data model is provided.

4.1 The Data Model

Current policy is that the data model reflects SysScan's GINIS data structure which consists of a hierarchical system of 'logic blocks'. For example a 'MAP' may consist of several files representing Level-I 'logic blocks' (e.g. the 'classes':

communications, hydrology, vegetation, structures). It was decided to store data on the basis of individual 1:250,000 sheet 'MAPS'. Level-II 'logic blocks' are represented by the 'categories', such as (in the case of the class 'communications'), 'private' or 'official'. Level-III is represented by the 'sub-categories', such as 'Highway Class A', 'Highway Class B', etc.

Individual database objects consist of road, rail, river, canal, powerline, etc. segments; symbolised point features (e.g. trees, wells, important buildings); symbolised area features (e.g. builtup areas); and, alphanumeric character strings as represented on the 1:250,000 series.

Individual database objects are identified at the 'sub-category' level, and the spatial attributes of each object are described in its 'geometric block'. A particular 'geometric block' may be linked to several (usually) Level-III (i.e. 'sub-category') 'logic blocks'.

The 'geometric block' contains a definition of the database object as a graphic element (e.g. line, arc, text, symbol, point, area), sufficient coordinates (eventually, for India's National Topographic Database these will be Latitude and Longitude and not Cartesian coordinates) and other parameters (e.g. linetype, pen number, display colour, display text font, plot text font, angle) to cartographically display the database object. It can be seen that the data model is strongly influenced by the main perceived user of the National Topographic Database, namely the SOI.

4.2 The Test Documents

From a consideration of the database objects described above it was concluded that five (namely 1,3,5,6, and 8) of the nine production separates given in Section 2 and the trig. point coordinate lists could be the sources from which the National Topographic Database could be built.

A common procedure in performing 'benchmarks' or 'time trials' of conversion (or map data capture) systems is to use test documents which are representative of all the task(s) to be performed. For example sheets showing low, medium and high planimetric and contour detail may be used. Furthermore digitizing/scanning and any necessary subsequent processing should be performed by experienced operators. A problem we encountered was that the team was not actually experienced in all four production lines! For reasons of the predicted professional future of one of the team members, it was decided that this single team member should become experienced in all four production lines and perform the 'time trials'. Because of the time needed for this familiarisation, it was not possible for the test to be very extensive. Nevertheless a testing methodology was developed which could be repeated with low, medium, and high detail density map fragments. A single test document (represented by its 5 separates) was used. This document was a 400 sq km. fragment of the SOI 1:250,000 sheet No. 56A, containing medium detail density, with the exception of the contours. In the chosen area the contour density was low, so an identically sized medium contour density separate fragment was selected instead.

Map conversion procedures generally use a set of grid intersection points as the control points whose Cartesian coordinates are known, to obtain transformation constants. As The SOI 1:250,000 series had no projection grid, but only the graticule on it, trig. points (whose Cartesian coordinates are known) could be used instead. But, in the test area there were insufficient trig. points for obtaining transformation constants, so it was decided to register a photo-optically plotted 4 cm grid with the separates, and photographically produce a new set of separates. The resulting nine grid intersection points (in the test area) were given appropriate fictional Cartesian coordinates in the range 0mE,0mN to 20000mE,20000mN.

The FIGURE 1 shows these test fragments.

4.3 The Time Trials

In the following four sub-sections the procedure followed for the investigation of each production line is outlined. The results are given in section 5.

4.3.1 Manual Digitizing Production Line

Set-up involved creating the empty file, setting the mapping units, partitioning the digitizer, selecting the design options, and establishing the control points. This took about 5 minutes per separate. All features in each separate were digitized and the contours were assigned attributes (by assigning them to appropriate layers); times were recorded.

On completion of the digitizing, check plots were made. Missing details were identified, counted, and interactively corrected. There were four missing entities (1 black, 1 red, 2 brown). Time spent on interactive correction was recorded.

Logical consistency was checked on the black and red separates only. No inconsistencies were found.

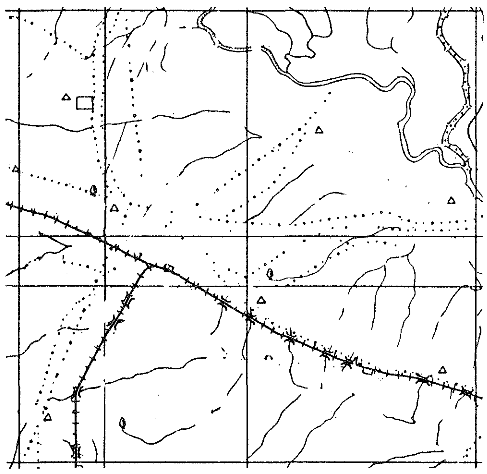
The TABLE 2 below summarises the times for manual digitizing.

Operation	Times in minutes/separate				
	Black	Red	Blue	Green	Brown
Digitizing	90.00	105.00	10.00	10.00	110.00
Editing	20.00	20.00	0.00	0.00	30.00
Total	110.00	125.00	10.00	10.00	140.00

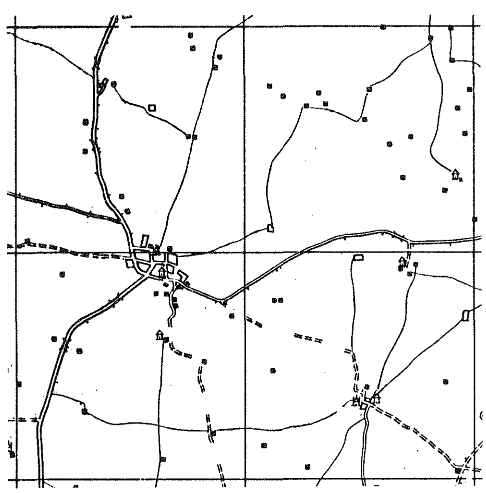
Table 2 - Summary of elapsed times for manual digitizing

As the grid was not digitized an estimate of RMSE values and thence MAXIMUM ERROR was obtained from the error percentages provided at digitizer set up (control pointing). This approach provides an estimate of static rather than dynamic digitizing accuracy. Results are shown in TABLE 3.

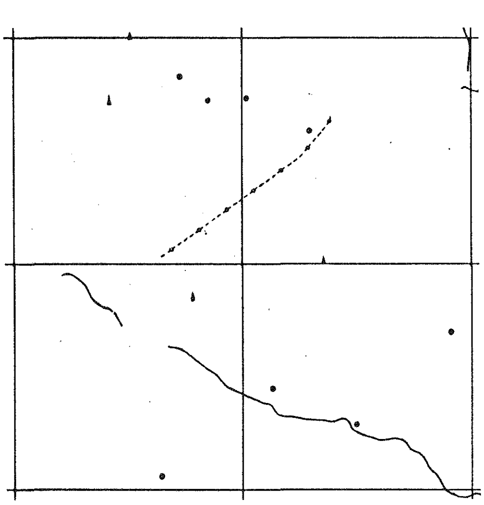
Figure 1 - Five test fragments used in the time trials.



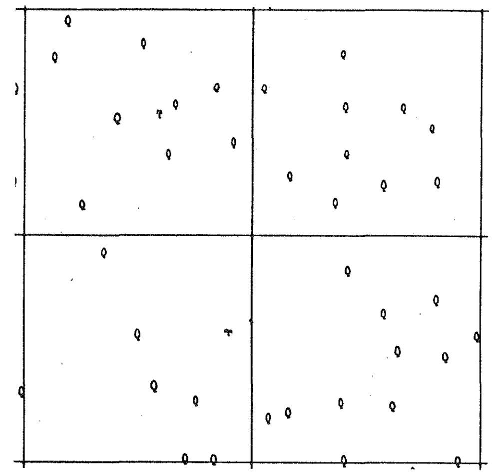
1a Black Colour Separate



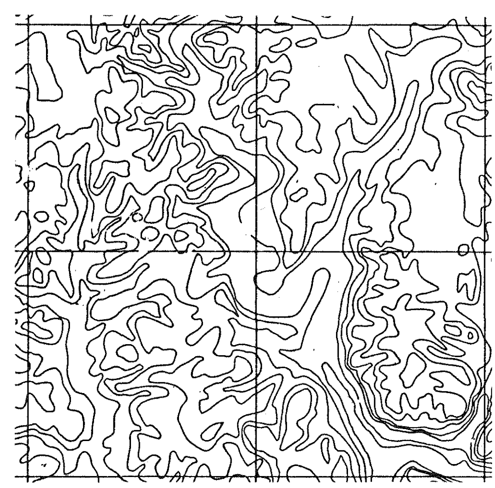
1b Red Colour Separate



1c Blue Colour Separate



1d Green Colour Separate



1e Brown Colour Separate

Separate	RMSE	Maximum error (map scale)
Black	0.048mm	0.088mm
Red	0.032mm	0.056mm
Blue	0.048mm	0.064mm
Green	0.040mm	0.080mm
Brown	0.048mm	0.096mm

Table 3 - Estimated rmse and maximum error for manual digitizing

4.3.2 Automatic Digitizing Production Line - High Cost

Character recognition was not part of the test, so characters had to be removed from the black, red, and brown separates. This took 20, 5, and 5 minutes respectively.

Calibration of the scanner prior to scanning took 30 minutes, and the actual scanning of each separate took 0.48 minutes, at 0.050mm resolution. See TABLE 4 under 'preparation' and 'scanning'.

Times for processing (vectorization, post-processing, and geometrically transforming the files) took between 6 and 29 minutes per separate. See TABLE 4, under 'processing'.

A check plot was produced and revealed no missing detail. Other errors were interactively edited, and at the same time the contours (brown) were tagged. Times for this combined operation are shown in TABLE 4, under 'editing'.

At this point the captured objects were not the required objects as indicated in section 4.1 so some interactive structuring was needed. See TABLE 4, under 'structuring'.

A check for logical consistency on the black and red separates revealed no inconsistencies.

OPERATION	Times in minutes/separate				
	Black	Red	Blue	Green	Brown
Preparation	20.00	5.00	0.00	0.00	5.00
Scanning	0.48	0.48	0.48	0.48	0.48
Processing	19.72	28.88	19.77	8.84	20.04
Editing	20.00	15.00	0.00	0.00	45.00
Structuring	15.00	15.00	5.00	5.00	10.00
Total	75.20	64.36	25.25	14.32	80.52

Table 4 - Summary of elapsed times for automatic digitizing - high cost approach

It should be noted that no reference is given here to CPU time, although this was recorded. In former, predominantly 'main-frame', environments CPU time was a convenient tool for allocating costs. With the increased power of computers and widespread use of 'stand-alone' systems CPU has become, practically, much less important than Elapsed Time. In this investigation Elapsed Time is represented by 'man-minutes' spent on a task.

The nine grid intersection points were used in the geometric transformation of the files. The acquired transformation constants were then applied to the whole data set for each separate. Using the grid intersection points as check points their transformed coordinates were used to give an estimate of RMSE and MAXIMUM ERROR for the whole of each separate (TABLE 5).

Separate	RMSE	Maximum error (map scale)
Black	0.045mm	0.081mm
Red	0.059mm	0.148mm
Blue	0.227mm	0.484mm
Green	0.080mm	0.236mm
Brown	0.209mm	0.600mm

Table 5 - Estimated rmse and maximum error for automatic digitizing (high cost)

4.3.3 Automatic Digitizing Production Line - Low Cost

As already explained in section 3.3, only the scanner was low-cost in this production line. Scanning times increased from the 0.48 minutes of the high-cost scanner to 1.50 minutes. With the low-cost scanner the positional quality statistics shown in TABLE 6 arose.

Separate	RMSE	Maximum error (map scale)
Black	0.042mm	0.078mm
Red	0.060mm	0.091mm
Blue	0.042mm	0.067mm
Green	0.040mm	0.067mm
Brown	0.089mm	0.166mm

Table 6 - Estimated rmse and maximum error for automatic digitizing (low cost)

Although not part of the investigation being reported here, the reader may be interested in some times achieved when using low-cost vectorizing software for processing the low-cost scanned data. A small test in which the red and brown separates were scanned using an HP SCANJET PLUS Scanner at 500dpi (approx. 50 microns), vectorised using SCANPRO vectorizing software from American Small Business Machines, edited as necessary and restructured to achieve logical consistency among entities gave the following times (TABLE 7):

OPERATION	Times in minutes/separate	
	Red separate	Brown separate
Preparation	5.00 mins	5.00 mins
Scanning	03.75 mins	02.50 mins
Vectorizing	04.75 mins	06.50 mins
Editing	110.00 mins	132.00 mins
Restructuring	130.00 mins	0.00 mins
Total	252.00 mins	146.00 mins

Table 7 - Summary of elapsed times for automatic digitizing - low cost scanning and vectorizing

The results shown in the above table and compared with those in TABLE 4 demonstrate the advantage of high-cost software (resulting from its having a greater range of capabilities) when building a database. A program such as SCANPRO would be entirely adequate when the main purpose of scanning and vectorizing is vector redrafting.

4.3.4 'On-Screen' Digitizing Production Line

Scanning for the 'on-screen' digitizing was carried out using Scitex equipment set at a resolution of 0.050 mm, and took 3.6 minutes per separate. The resulting raster files were screen displayed, one by one. During screen display digitizing was carried out, 'digitizer' coordinates actually being selected by a mouse controlled screen cursor. Times spent on digitizing and interactive editing were (TABLE 8):

OPERATION	Times in minutes/separate Black	Red	Blue	Green	Brown
Scanning	3.60	3.60	3.60	3.60	3.60
Digitizing	60.00	75.00	10.00	10.00	90.00
Editing	20.00	20.00	0.00	0.00	20.00
Total	83.60	98.60	13.60	13.60	113.60

Table 8 - Summary of elapsed times for 'on-screen' digitizing

Geometric transformation using 4 grid intersection points for control was possible. Thereafter discrepancies at the nine intersection points were used to determine RMSE and MAXIMUM ERROR, as shown in TABLE 9.

Separate	RMSE	Maximum error (map scale)
Black	0.065mm	0.112mm
Red	0.044mm	0.071mm
Blue	0.033mm	0.071mm
Green	0.052mm	0.071mm
Brown	0.037mm	0.071mm

Table 9 - RMSE and maximum error for 'on-screen' digitizing

'On-screen' digitizing is very similar to manual digitizing as far as the responsibilities of the operator are concerned. Thus, as with manual digitizing, completeness and logical consistency were very much under the control of the operator. After digitizing logical inconsistencies were not present, and the data were complete.

5. RESULTS

The results presented in the foregoing sections can be summarised to give TABLE 10 (quality) and TABLE 11 (elapsed times).

Method	RMSE in mms at map-scale black	red	blue	green	brown
Manual	0.048	0.032	0.048	0.040	0.048
Automatic, high cost	0.045	0.059	0.227	0.080	0.209
Automatic, low cost*	0.042	0.060	0.042	0.040	0.089
On-screen	0.065	0.044	0.033	0.052	0.037
*Agfa scanner + SysScan software					

Table 10 - Quality comparison of the four production lines

The RMSE values for the blue and brown separates in the Automatic Digitizing - High Cost production line were noticeably higher than all other RMSE values. On contacting the organisation which had carried out the scanning it emerged that these two separates had been kept in a different room and scanned at a different time from the other three separates. This adequately accounts for the anomalies, and disregarding them it can be said that all production lines more than adequately meet the spatial quality requirements of mapping professionals (see section 2.1).

Method	Times in minutes black	red	blue	green	brown
Manual	110.00	125.00	10.00	10.00	140.00
Automatic, high cost	75.20	64.36	25.25	14.32	80.52
Automatic, low cost*	nm	252.00	nm	nm	146.00
On-screen	83.60	98.60	13.60	13.60	113.60
(nm = not measured)					
* HP scanner and SCANPRO software					

Table 11 - Time comparison of the four production lines

6. CONCLUSIONS

From the results presented in the previous section it can be seen that the production lines need not be distinguished from each other in terms of the geometric or topological quality of the captured data. The 50 micron resolution used with the scanners was adequate, although the test could have been repeated with a faster but coarser resolution (e.g. 100 microns). The resulting maximum errors were much smaller than predicted in Section 2.1.

The test fragment used was so very small that although it was possible to make an estimate for the time required to capture data off a SOI 1:250,000 sheet (the estimate was 136 man-hours), such an estimate is likely to be unreliable. Nevertheless it is clear that certain production lines suit a particular separate.

Automatic digitizing was fastest with the separates containing continuous lines, such as the brown separate which held the contours. Manual digitizing was faster on the blue and green separates, and these consisted mainly of point features. 'On-screen' digitizing was fastest with those lines which had a patterned linestyle. Otherwise little difference was noted between 'on-screen' and manual digitizing.

To use a mixture of production lines for the different separates of a map series might be cumbersome in a small organisation, but in an organisation the size of SOI (30,000 employees), a division of the labour along the lines manual digitizing for point features, automatic digitizing for continuous line style features, and 'on-screen' digitizing for patterned line features seems feasible.

It is expected that further investigations into the most appropriate method for building India's National Topographic Database will be carried out.

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