THE ANALYTICAL STEREOPLOTTER FOR THE CREATION AND THE UPDATING OF A NUMERICAL CADASTRAL SURVEY CARTOGRAPHY

Carlo Cannafoglia, Luigi Catalani
Direzione Generale del Catasto e
Ottico Meccanica Italiana OMI S.p.A.
Roma - Italia
Commission IV

1. INTRODUCTION

The cartographic production of the Italian Administration of Cadastre, that is also appointed as a National Government Cartographic Agency, is fundamentally ruled by Law No. 3682 of March 3rd, 1886, that prescribes "to survey the shape and the size of individual properties and parcels, and to document them with planimetric maps linked to trigonometric points".

This production task is implemented by the compilation and revision of 1:1,000 scale maps for heavily built-up areas, 1:2,000 maps for moderatly built-up areas (e.g. suburban areas), and of 1:4,000 maps for rural areas.

Parcel maps are produced within the frame of the national geodetic reference system, that is the National Triangulation Net, and they have therefore followed the evolution of the projection system chosen for our national cartography.

The survey operations required for creating our cadastral cartography have been of the classic-traditional type: a basic frame was defined consisting of a triangulation net (primary net, derived net and detail trigonometric points) into which a thick network of traverses, essential support for the following activity of detail survey, was inserted.

Field survey was then the means used to obtain all the topometric information needed for the planimetric representation, at the proper scale, of each cadastral parcel after the demarcation of its boundaries.

More ground features were also surveyed and mapped:

1. public roads (national, province, municipal and by-way roads) obviously including squares, bridges and other state-owned constructions or areas;
2. turrent and river beds; public-property areas interested by lakes, marsh, reservoirs and similar features;
3. main canals conveying water for public or consortium use.

The cartography so obtained, besides being a technical map as a consequence of the direct field survey, is also a true thematic map of "ownerships".

The availability of such an extensive and detailed cartography proved to be fundamental not only as a basic reference for the other official acts of the Italian Cadastre, that is at a merely official level, but also for all those cases of land-use projects for which large-scale cartography is a must.

After having realized the usefulness of cadastral cartography for civil projects and the opportunity of making it more and more suitable for these purposes, the Administration of Cadastre has taken initiatives, supported by proper legislation, having the following goals:

- to integrate cadastral maps with height information;
- to recover the metric precision of the geometric information representing the sections of territory subject to constant and dinamic evolution.

As to the second point, we should keep in mind that due to the long laps of time required by the set-up of the cadastral mapping project, between 1896 and 1956, caused the various sections of territory to have been mapped with different intrinsic metric precision as a consequence of the different surveying methods and instruments used throughout the years.

Only on a local basis the original cadastral maps have been replaced by a more advanced cartography in the attempt to improve the situation, by means of significant remakes.

It is furthermore important to consider the fact that the fundamental requirement for a parcel map is being kept updated: the problems encountered here are not the same as for a common technical map, already heavy on time and resources, but they are the more demanding problems caused by the need of closely following the changes of a large scale thematic map, the theme of which is the graphis representation of some 65 millions individual parcels.

It was impossible for the Administration of Cadastre to directly and continuously survey and record the parcel subdivision: it was therefore necessary to subcontract independent professional specialists. As a consequence of this, the geometric quality of the cartographic documentation suffered a degradation. A number of initiatives, the most important of which are hereafter described, were taken with the aim of improving the situation:

- rules were set concerning the permanent reference points: the technical operational criteria were set for the definition of points of analytically known coordinates, associated to well defined and stable manufacts, sufficiently dense so as to properly cover each sheet of the parcel map. This requirement had the purpose to ensure a positive

link and control for any later local geometric revision;

- a research and development program was undertaken to develop advanced field survey and computation methods: by the use of modern survey instruments such as electro-optical devices fitted with automatic data recording and by the use of computer processing techniques, map revision or remaking for relatively limited areas were considerably improved;
- aerial photogrammetric techniques were studied and used, with special regard to Analytical Stereoplotters and data processing, with the double purpose of verifying the map revision process for large areas and of using the aerial triangulation technique for the definition of control points;
- digital data processing procedures, referred to as "Numerical Cadastre", were defined and applied: their purpose is the establishment and the updating of data banks on magnetic supports containing the geometric information coming either from direct field survey, from the photogrammetric models, or digitized out of existing cadastral maps. Such data can be easily processed by computers, videographic systems and plotters;
- a program was promoted with the aim of making the Administration of Cadastre and its related external bodies aware of the importance, beyond the merely fiscal issue, of a cadastral cartography that complies with the metric precision requirements at the different scales and in a proper revision status.

2. THE NUMERICAL CADASTRAL CARTOGRAPHY

The first step for the creation of cadastral numerical archives was the definition of the possible sources and methods for the collection of information.

They were identified as:

- digitizing existing cadastral cartography;
- field survey and collection of field data with electro-optical recording instruments;
- use of aerial photogrammetry and Analytical Stereoplotters for coding and digitizing cadastral information directly from the stereomodel.

The two latter techniques are furthermore particularly suitable for the updating of previously mapped areas, since the instrumentation used permits to solve this problem via interactive processes through the creation of geometric and census-related data bases.

2.1. THE PHOTOGRAMMETRIC PRODUCTION AND REVISION OF CADASTRAL CARTOGRAPHY

The Administration of Cadastre first experimented the application of the photogrammetric method, back in 1936, for the cadastral mapping of the Terni and Viterbo Province.

The then-followed survey method was organised along the following steps:

- preliminary set-up of the ground control points and demarcation of the non-visible boundaries;
- determination of the densification and control nets, both horizontal and vertical-wise, derived from the national geodetic net, by field survey;
- photographic mission and plotting of stereomodels;
- field survey for the metric completion of hidden details, collection of toponomy information, evaluation of the quality of cultures, collection of census data, etc.;
- compilation on standard size map sheets, calculation of the parcel areas and recording of the data on the administrative and census documents.

This method did not prove to be, at that time, economically sound mainly because of the considerable amount of activity in the field, required both for the demarcation of the individual parcels and for the qualitative integration and survey. These factors did then limit the use of the photogrammetric method.

The technological progress in this field, mainly brought about by the availability of Analytical Plotters, and the research carried-on by the Administration in the field of numerical cadastral cartography have made it practicable the use of photogrammetry for the cartographic revision of large areas, in particular of those areas concerned by urban development.

The Administration, within the frame of a programmed activity for the modernization of the cadastral structure, has undertaken a research and production activity centered on the use of OMI Analytical Stereoplotters Model APC4 and aiming to:

- determining by aerial triangulation stable control points, that is points of known analytical coordinates, with a precision consistent with the requirement of being later used as control points for further surveys;
- starting an activity of cartographic revision for those areas interested by massive urban development or subject to heavy sub-structural mutations;

- starting an activity of geometric and qualitative updating of the recording of current cultures by means of stereoplotting and photo-interpretation;
- utilizing the new instruments for testing the cadastral cartography revision work subcontracted to other organizations.

The OMI Analytical Stereoplotter was selected for the following reasons:

- quality and easy operation of the system;
- control computer, a DIGITAL EQUIPMENT PDP 11/23, that permits a direct interfacing to the computing tools already in use for Numerical Cadastre at the Administration facilities, consisting of DIGITAL EQUIPMENT VAX computers;
- software available and under short-term development, that permits to reach the goals described, particularly in relation to the requirement for the creation of geometric archives through the digitizing and coding of the cadastral elements observed in the stereomodel and transferable to the Data Base SYSCAN structure, presently utilized by the numerical cadastral cartographic centers;
- reliability and availability of the manufacturer for the implementation and the personalization of the hardware and the software supplied.

2.2. THE ANALYTICAL PLOTTER FOR THE REVISION OF CADASTRAL CARTOGRAPHY

One of the most interesting experiences made in this area was the analysis of quality ane costs concerning a cadastral revision project carried out with the aerial photogrammetric method and designed to obtain a numerical cartographic product, by comparison of the method that makes use of analogue stereoplotters plus digitizers with the one that makes use of Analytical Stereoplotters. Part of the work was performed by house personnel, part of it was subcontracted to independent companies.

The object of this research was the revision and remake of the cartography of a 1240-acre heavily urbanized aread, originally mapped on four 1:2,000 scale sheets. The following technical-economic elements were to be verified:

- verification of the geodetic triangulation net, and definition of the photographic control points derived from it both by traditional survey and by aerial triangulation;
- suitability of the aerial photogrammetric method for the revision of existing cadastral cartography;
- verification of the possibility of superimposition and integration of

existing cadastral maps, converted to the 1:1,000 scale of the new plotting, to the corresponding photogrammetrically plotted drafts;

- qualitative and quantitative analysis of the discrepancies observed from the superimposition and analysis, in the light of topographically defined criteria, of the mathematic deformation models;
- qualitative and quantitative investigation on the detection of the property boundaries non materialized on the ground but identifiable through interpretation on the stereomodel.

The project and its implementation phases are described in Table 1, from which it can be seen that preliminary field work was not carried out in that the area was heavily built-up and therefore the property boundaries were well identifiable in the stereomodel.

Tables 2, 3 and 4 show how the time and resource-wise most significant phases were developed for the sake of a compared analysis of the two methods being investigated.

The hourly costs used in these tables are relative to the Administration personnel: those costs relative to activities outside the Administration facilities were incremented accordingly.

TABLE 1

OPERATION PHASE	ANALOGUE PLOTTER		ANALYTICAL PLOTTER	
	IN-HOUSE	SUBCONTRACTED	IN-HOUSE	SUBCONTRACTED
PRELIMINARY FIELD WORK	NONE	NONE	NONE	NONE
MAIN AND PHOTOGRAPHIC CONTROL GEODETIC NET	IN THE FIELD, WITH GEODIMETRIC TRAVERSING		AERIAL TRIANGULATION ONLY	
PHOTOGRAMMETRIC FLIGHT		YES		YES
PHOTOGRAMMETRIC STEREOPLOTTING		YES	YES	
FIELD SURVEY	YES		YES	
CREATION OF NUMERICAL GEOMETRIC ARCHIVES	BY DIGITIZING THE INTEGRATED COMPILATION DRAFT		BY CODING THE GEOMETRIC ELEMENTS FROM THE STEREOMODEL AND FROM THE FIELD SURVEY INTEGRATION	
CREATION OF A CADASTRAL GEOMETRIC DATA BASE	DIRECTLY DURING DIGITIZING		PARTLY DURING DIGITIZING OF MODEL, PARTLY DURING VIDEOGRAPHIC ACTIVITY	
PLOTTING OF MAP SHEET	AUTOMATIC PLOTTING		AUTOMATIC PLOTTING	

TABLE 2

OPERATION PHASE : MAIN AND PHOTOGRAPHIC CONTROL GEODETIC NET									
STEPS	VERTEXES VERIFIED AND PHOTOGRAPHIC CONTROL POINT DEFINED	METHOD	OPERATORS	TIME (HOURS)	COST (*)	METHOD	OPERATORS	TIME (HOURS)	COST (*)
VERIFICATION OF THE GEODETIC NET	5	TRILATERATION TRIANGULATION	3	16	($7.80/HR.) $375.00	AERIAL TRIANGULATION	3	16	($4.40/HR.) $ 70.00
INTEGRATION OF THE GEODETIC NET	3	TRILATERATION TRIANGULATION	3	8	($7.80/HR.) $187.50	AERIAL TRIANGULATION			
DEFINITION OF PHOTOGRAPHIC CONTROL POINTS	35	GEODIMETRIC TRAVERSING	3	50	($7.80/HR.) $1,172.00	AERIAL TRIANGULATION	1	5	($4.40/HR.) $ 22.00

(*) Mean 1983/84 Italian Lira/U.S.Dollar exchange rate.

TABLE 3

OPERATION PHASE : PLOTTING OF STEREOMODELS							
STEP	QUANTITY OF MODELS	METHOD	TIME PER MODEL	COST PER MODEL (*)	METHOD	TIME PER MODEL	COST PER MODEL (*)
INTERIOR ORIENTATION	10	ANALOGUE STEREOPLOTTER	0.2 HOURS 12 MIN.	($4.40/HR.) $ 0.90	ANALYTICAL STEREOPLOTTER	0.025 HRS. 4 MIN.	($4.40/HR.) $ 0.11
EXTERNAL ORIENTATION		ID.	1.5 HRS 90 MIN.	($4.40/HR.) $ 6.60	ID.	0.75 HRS. 45 MIN.	($4.40/HR.) $ 3.30
PLOTTING OF STEREO-MODELS		ID.	4 HRS. 240 MIN.	($4.40/HR.) $ 17.60	ID.	7 HRS. 45 MIN.	($4.40/HR.) $ 30.80
COMPILATION OF PLOTTING DRAFT		AUTOMATIC PLOTTER AND MANUAL INTEGRATION	1.33 HRS. 80 MIN.	($4.40/HR.) $ 5.85	ELECTRONIC PLOTTER	--	

(*) Mean 1983/84 Italian Lira/U.S.Dollar exchange rate.

TABLE 4

OPERATION PHASE : CREATION OF GEOMETRICAL ARCHIVES AND OF CADASTRAL DATA BASE							
STEP	QUANTITY OF MODELS	METHOD	TIME PER MODEL	COST PER MODEL (*)	METHOD	TIME PER MODEL	COST PER MODEL (*)
DIGITIZING OF THE COMPILATION DRAFT	10	MANUAL DIGITIZING AND CREATION OF DATA BASE	10 HRS.	($4.40/HR.) $ 44.00	--	--	--
DIGITIZING OF THE STEREO MODEL		--	--	--	DURING PLOTTING OF STEREOMODEL	--	--
EDITING FOR METRIC INTEGRATION		VIDEOGRAPHIC INTEGRATION PROCEDURES	3 HRS.	($4.40/HR.) $ 13.20)	VIDEOGRAPHIC INTEGRATION PROCEDURES	3 HRS.	$ 13.20
CREATION OF CADASTRAL DATA BASE		DURING DIGITIZING AND EDITING	--	--	DURING PLOTTING OF THE STEREOMODEL AND EDITING	--	--

(*) Mean 1983/84 Italian Lira/U.S.Dollar exchange rate.

3. CONCLUSIONS

No significant discrepancies were observed as far as the definition of the integration vertexes and of the photographic control points by ground survey and aerial triangulation are concerned.

The discrepancies are well within the figures currently accepted for cadastral cartography.

The aerial photogrammetric method, vs. the traditional field survey method, proved to be suitable in that the property boundaries were directly identifiable in the stereomodel for more than 85% of cases. The integration activity in the field resulted therefore considerably reduced.

However, the comparison between old and new cadastral cartography, as far as the basic line structure is concerned, has shown the practical difficulty of their geometric superimposition. The disappearance of boundary lines, no longer locatable by field survey due to the dinamics of urban developments, made this problem more evident in the presence of the different intrinsic precision of the new survey methods versus the old ones. This leads to the conclusion that a complete remake of the cadastral map for obtaining a document homogeneous with the precision of the geometric information collected in view of the integration with numerical cartographic systems, especially when mapping scale changes are requested, is highly desirable.

Moreover, the economic advantages and the time savings consequent to the use of the Analytical Plotter are made evident by the analysis of the Tables.