14th Congress of the International Society of Photogrammetry
Hamburg 1980

No. of commission : II

No. of working group : 1

Type of paper : Invited Paper

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Title of paper : ECONOMIE COMPAREE ET EXPANSION ANALYTIQUE
(Comparative Economics and Analytical Expansion)

Abstract :

Economic analysis of the various phases of production, respectively : conventional graphic analog photogrammetry, analog photogrammetry equipped with computer-aided peripherals and table, and analytical photogrammetry.

Comparative synthesis of studies of productivity, accuracy and economics in the various fields.

Conclusions concerning stimulating the development of analytical means for certain economic requirements.

COMPARATIVE ECONOMICS AND ANALYTICAL EXPANSION

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PREFACE

Descriptive and quantitative metrology is at the origin of all decisions ; there is nothing new in this statement, for "master surveyors" have always been with us.

Today, however, the scope of requirements has become much vaster, in both space and macroscopic and microscopic realms : mapmaking and cadasters are as much concerned as biological and industrial metrology.

This new situation reveals the anachronic precariousness of means of measurement considered until now as "conventional".

New technological developments emerged, however, in topography and land surveying, both in electro-magnetic distance measuring and in means derived from computers, used for other activities. This evolution was so pronounced that it was believed at one time that the growing control exercised by photogrammetry over means of measuring on the ground would recede. At this moment began the development of analytical photogrammetry with its universal vocation, the only one capable of satisfying needs in the most important fields where modularity, productivity and accuracy are increasingly demanded of means of metrology and are determining factors ; an example : scientific and technical developments linked with space, civil engineering and industry.

In general, and throughout almost the entire world, photogrammetric needs are satisfied by instruments called "analog", but their operating principle leads to all sorts of limitations which render them inadequate for the fulfillment of numerous presentday requirements, such as the development of measuring automation in all realms which has now become an obvious necessity.

On the other hand, there appears to be no limitation to the use of analytical plotters (AP's) as studied herein with particular attention to the Traster System.

Here all simulations, transformations and spatial measurements are mathematical ; adaptations to specific production requirements are assured by specific software which may be integrated into the system's overall software in order to solve a given problem.

The use of AP's does not really require professional qualifications in photogrammetry and they may be quite readily used by the practitioner himself to make his own measurements : the engineer-builder, architect or doctor, for example.

Accuracy has been tripled (in the particular case of Traster), while production is improved at a ratio which the present report will define, with correlative influence on production savings.

Today, everyone admits that the most productive and accurate form of photogrammetry for delicate work and with universal applications can only be analytical, but other factors are quite evident :

. Most photogrammetric work still involves mapmaking and cadasters ;

. Practically all photogrammetric instruments in use are analog. They are often completed by electronic digital acquisition means in the model, a function for which they have not always been initially designed. They then perform what we shall call - in this study - "conventional" analog photogrammetry.

. The most recently designed analog instruments facilitate the use of certain automated functions permitting reducing the importance of labor. However, they remain limited as to fields of use and accuracy because of their very principle : in the present study, we shall call their function "advanced" analog photogrammetry.

Industrialized countries are obliged to gradually renovate that part of their range of instruments which has become technically outdated. Third World countries must be equipped with new cartographic means in order to acquire cadastral and mapmaking autonomy, the natural complement of territorial appropriation.

. The bitterness of competition resulting from the economic situation requires the use of fast, flexible, accurate and economical metrological means, in both cartography and industry.

The pragmatism of public officials, however, cannot be contented with assertions, however evident they may be. They demand that costs and profits anticipated in such development be calculated so as to make the best adaptation of investments to the case under consideration.

The diversity of possible metrological operations does not simplify this sort of economic study, all the less so as analytical plotting instruments alone are capable of performing functions previously performed by several different, complementary items of equipment ; as an example, one might mention the fields of aerotriangulation, graphical and digital plotting, automated draughting, calculations, etc.

As such an economic survey cannot reasonably cover all such work, we have decided to make it in a field of photogrammetry in common use and where rates are common practice : large-scale drawings for development of the French territory. These involve results from photogrammetric surveys made by a group of agencies over scores of years and gradually brought to their most efficient level of productivity via analog photogrammetry equipped with instruments in current use up to 1975.

In order to be exhaustive, however, this study had to be carried out using the most recent analog instruments, which, adapted through their electronics, improve production savings.

Analytical photogrammetry will thus be compared successively with :
. "conventional" analog photogrammetry,
. and "advanced" analog photogrammetry (1)

(1) We shall include in this category the use of instruments from the preceding generation which have been equipped by their users with accessories or peripherals allowing the same general uses and performances as more recent analog instruments.

From these two financial and productivity comparisons one will draw conclusions in which the advantages of the analytical process will be reduced, by principle, to a minimum, for, in fact, the tripling of analytical accuracy will lead to an evolution of the use methodology which will accentuate its productivity, but which has not been taken into consideration in this study.

1. STUDY PRINCIPLES AND CONVENTIONAL BASIC ELEMENTS

1.1. General principles of the comparative study.

The basis of the study is productivity and costs of "conventional" analog photogrammetry of which the various phases are priced at rates which are very well known, and which is carried out for public agencies by established firms.

Economies achieved with respect to these rates by "advanced" analog photogrammetry and by analytical photogrammetry result from technological advantages and less labor required for the type of instrument usually used for a well-defined function.

Furthermore, it seemed opportune in the present study to distinguish what concerns the public sector (public cartography and cadaster services, etc.) from what concerns the private sector (industrial or engineering agencies), for the former invest periodically but do not deduct the annual amortization of their equipment in their public accounting (in general), whereas the private sector, obviously, is obliged to do so. In the latter case, linearly proportional amortization in time has been taken into account, but without including money lending rates.

Finally, estimates have been made on the basis of an annual (conventional) labor period of 1,880 working hours covering, on the one hand, one shift per day and, on the other, two shifts per day.

Where cost estimates are required, they have been drawn up in U.S. dollars, without presuming that they apply strictly to the U.S.A.

Employees' benefits contributions linked with labor costs, as well as overhead and profits and maintenance, have been estimated in an identical manner for each type of photogrammetry under consideration.

These comparisons have also involved amounts devoted to investments (and their amortizations) ; these latter vary obviously from one country to another because of the diversity of taxes and customs duties, as well as monetary fluctuations (comparisons in the present study refer to March, 1979).

Since conclusions, however, will concern only the relationship between costs and productivity of analog plotters and those of analytical (Traster) plotters, results - as a basis of comparison - will remain coherent for the various countries, although each elementary value expressed may be contested for a given place or a given circumstance.

Because of the multiple nature of necessary parameters involved, this economic study is quite complex ; it thus seemed useful to indicate at the beginning the references for tables of results : (2.2.2.), (2.2.3.), and (2.2.4.). We should also mention that, as an item in the final result, the analytical method represents an economy of 21 % over the analog method with tripled accuracy in the large-scale plans studied.

These figures, however, will be bettered by using an overall methodology adapted to the analytical method.

1.2. Basic price elements for various types of photogrammetry

1.2.1. Hourly labor expenditures for plan producing agencies (weighted hypothetical values)

Stereoplotter operator : 20.1 US dollars
Draughtsman-assistant : 12.8 US dollars

giving the total labor cost calculated in various cases (see tables 2.1.2., I, II and III) :

"1 technician" = 1 plotter only .... 20.10 US $
"1.1 technician"= 1 plotter + 1/10th time for 1 assistant .... 21.38 US $
"1.5 technician"= 1 plotter + 1/2 time for 1 assistant .... 26.50 US $
"2 technicians" = 1 plotter + 1 assistant .... 32.90 US $

1.2.2. Hourly amortization and maintenance costs

Equipment			a Amortization		b Maintenance	
Type No.	Stereoplotter specification ("advanced" analog)	Presumed purchase price US$	1 shift	2 shifts	1 shift	2 shifts
		Over 8	years ;	cost :	5% per	year
1	Analog, 2nd order, usable for small scale with digitization & recording	80,000	5.32	2.66	2.13	1.07
2	Analog, 2nd order, usable for small scale with digitization, graphic console of central computer for eventual automatic mapmaking.	110,000	7.31	3.66	2.93	1.47
3	Analog, 1st order with co-ordinate recording, tape, semi-automatic table	150,000	9.97	4.99	3.99	2.00
4	Other analog, 1st order with calculation model co-ordinates and tape recording and semi-automatic table, T.V.	202,000	13.43	6.72	5.37	2.69

1.2.2. (Cont'd)

5	1st order as No.4 in"digital system",in geographic co-ordinates coded for automatic map-making	215,000	14.30	7.15	5.72	2.86
Equipment			a Amortization		b Maintenance	
Type No.	Specification for <u>analytical</u> stereoplotter	Presumed purchase price US$	1 shift	2 shifts	1 shift	2 shifts
		Over 5 years ; cost 8 % per year				
6	AP's: Traster example with table and 64K disc, digital and graphical process in geographic co-ordinates of points.	210,000	22.34	11.17	8.94	4.47

1.2.3. Operating Costs

Overall costs, unforeseeables, margins or profits estimated for both public and private sectors

at 80 % of overall personnel expenditures.

1.2.4. Nature of expenditures in both private and public sector accounts

We assume that the cost of an operation will be estimated by accounts for the following items :

. for public sector : labor (1.2.1.)
maintenance (1.2.2.b)
operating costs (1.2.3.)

. for private sector : labor (1.2.1.)
amortization (1.2.2.a)
maintenance (1.2.2.b)
operating costs (1.2.3.)

For each type of production, and whatever the type of photogrammetry involved, estimates will be made for one shift per day, then two.

In all cases, productivities for analog photogrammetry will be applied (2.1.1.11.a, b and c).

The study will then be resumed for analytical photogrammetry in the same cases and the same working procedure, but with its own productivity.

2. ECONOMIC ANALYSES OF PRODUCTION

2.1. Economic study of analog photogrammetry

Will be studied successively :

- basic statistical productivity in "traditional" analog photogrammetry which will then be transposed into "advanced analog" ;
- significant examples from the point of view of productivity and unit prices of cartographic production.

These two points will be studied successively in the different versions with respect to :

- aerotriangulation,
- model shaping and setting up,
- detail plotting, small and large scale.

2.1.1. Basic statistical productivity in "conventional" and "advanced" photogrammetry

I. Aerotriangulation :

All operations included : 2 hours 50 minutes per pair, i.e., 2.8 pairs per 8-hour day.

II. Plotting, graphical and digital.

a) Time required for shaping and setting up model :

Establishing protocol	Setting up using existing protocol	Setting up using existing documents
1 h 20 mn	40 mn	2 h 5 mn

Average duration 1 hour 22 minutes

b) Exploitation time for details in graphical plotting

	Planimetry of density of residential urban suburb			Altimetry : mountain, average slopes 15 %		
Unit Scale	dm2	Pair	Rate for 1 point	Linear dm of contour	dm2	Pair
Plan 1:2000 Expos. 1:8000	1 hour 23 min	27 hours 40 min	11.33 s	10.8 min	2 h 40 mn	54 h
Map at 1:25,000	3 hours 5 min	7 hours 35 min	11.5 s	10.8 min	18 hours	44 hours

c) Time required for digital plotting performed for automated draughting and creating data storage files.

(Tab.b Cont'd)	Planimetry			Altimetry	
Unit Scale	dm2	Pair	Rate for 1 point (2)	dm2 (1)	Pair (1)
Plan 1:2000 Exp. 1:8000	1 hour 45 min	34 hours 10 min	13.97 sec	5.08 min	6 hours 46 min

(1) Altimetry defined by dimensioned points or by DTM profiles.
(2) including conventional point coding time.

These productivity values are not scores achieved over short periods of time, but are taken from statistical results of bid proposals filed by highly-qualified agencies in response to calls for bids for large projects. Obviously, they include normal coverage for risks involved in technological production with its monitoring and corrections.

These estimates result from 15 years of production ; average job size was 25 pairs of views for each job, with 300 jobs per year.

Modifications achieved via "advanced" stereoplotters have not been counted in productivity but only in unit prices for certain production operations ; these costs are sometimes reduced because of the decrease in the number of technicians assigned - statistically - to each instrument. This factor will appear in the study of "significant examples".

2.1.2. Significant examples of productivity and costs for a pair of views in analog photogrammetry

Operation		Equipment type No. (see 1.2.2.	Duration of operation	"Con." "Adv." Publ. Priv. (1)	Nmbr of useful technicians	Costs per hour		Costs of production	
No.	Nature					1 shift	2 shifts	1 shift	2 shifts
Table 2.1.2. I									
A	Aerotriangulation	3	2h50'	C.Pub. C.Pri. A.Pub. A.Pri.	1	40.17 50.14 40.17 50.14	38.18 43.17 38.18 43.17	113.81 142.06 112.81 142.06	108.18 122.31 108.18 122.31

(1) Abbreviations in this table and following signify :

C. = "conventional" analog photogrammetry
A. = "advanced" analog photogrammetry
Pub. = public sector   Pri. = private sector

Table 2.1.2. II Model shaping and setting up

	Small scale survey 1:25,000	.							
B	Establish. protocol	1	1h20'	C.Pub.	1.5	49.83	48.77	66.44	65.03
				C.Pri.	1.5	55.15	51.43	73.53	68.57
				A.Pub.	1.5	49.83	48.77	66.44	65.03
				A.Pri.	1.5	55.15	51.43	73.53	68.57
C	Use of existing protocol	1	40 mn	C.Pub.	1.5	49.83	48.77	33.22	32.51
				C.Pri.	1.5	55.15	51.43	36.77	34.29
				A.Pub.	1.5	49.83	48.77	33.22	32.51
				A.Pri.	1.5	55.15	51.43	36.77	34.29
D	Use of existing data	1	2h05'	C.Pub.	1.5	49.83	48.77	103.81	101.60
				C.Pri.	1.5	55.15	51.43	114.90	107.15
				A.Pub.	1.5	49.83	48.77	103.81	101.60
				A.Pri.	1.5	55.15	51.43	114.90	107.15
	Small scale, avg.costs: "convent."photo.,public							67.82	66.38
	"advanced" photo., public							67.82	66.38
	"convent." photo., private							75.07	70.00
	"advanced" photo., private							75.07	70.00
	Large scale survey 1:2000								
E	Establishing protocol	3	1h20'	C.Pub.	1.5	51.69	49.70	68.92	66.27
				C.Pri.	1.5	61.66	54.69	82.21	72.92
				A.Pub.	1.5	51.69	49.70	68.92	66.27
				A.Pri.	1.5	61.66	54.69	82.21	72.92
F	Use of existing protocol	3	40 mn	C.Pub.	1.5	51.69	49.70	34.46	33.13
				C.Pri.	1.5	61.66	54.69	41.11	36.46
				A.Pub.	1.5	51.69	49.70	34.46	33.13
				A.Pri.	1.5	61.66	54.69	41.11	36.46
G	Use of existing data	3	2h05'	C.Pub.	1.5	51.69	49.70	107.69	103.54
				C.Pri.	1.5	61.66	54.69	128.46	113.94
				A.Pub.	1.5	51.69	49.70	107.69	103.54
				A.Pri.	1.5	61.66	54.69	128.46	113.94
	Large scale, avg. costs : "convent."phgrmtry,public							70.36	67.65
	"advanced"phgrmtry,public							70.36	67.65
	"convent."phgrmtry,private							83.93	74.44
	"advanced"phgrmtry,private							83.93	74.44

Table 2.1.2. III. Plotting Details in Analog Photogrammetry

No.	Operation Nature	Equipment type nmbr	Duration of operation per dm2 & survey point	C.Pub. C.Pri. A.Pub. A.Pri.	Nmbr of useful technicians	Costs per hour: Nmbr of shifts/day 1	Costs per hour: Nmbr of shifts/day 2	Production costs: unit costs counted per: dm2 on map 1 shift	dm2 on map 2 shifts	point surveyed 1 shift	point surveyed 2 shifts
Graphical plotting (see Table (2.1.1., II b)											
Small scale survey (1:25,000)											
H	Planimetry (peri-urban)	1	3h05'/dm2; 11.5 sec/point	C.Pub.	2	61.35	53.29	189.16	164.31	0.196	0.17
				C.pri.	2	66.77	62.95	205.57	194.10	0.213	0.201
				A.Pub.	1.1	40.61	39.55	125.21	121.95	0.13	0.126
				A.Pri.	1.1	45.93	42.21	141.62	130.15	0.147	0.135
	Altimetry (mountain)	1	18h/dm2	C.Pub.	1.5	49.83	48.77	896.94	877.86	/	/
				C.Pri.	1.5	55.15	51.43	992.70	925.74	/	/
				A.Pub.	1.1	40.61	39.55	730.98	711.90	/	/
				A.Pri.	1.1	45.93	42.21	826.74	759.78	/	/
Large scale survey (1:2,000)											
J	Planimetry (peri-urban)	3	1h23'/dm2; 11.33 sec/point	C.Pub.	2	63.27	61.22	87.52	84.69	0.199	0.193
				C.pri.	2	73.38	66.21	101.23	91.59	0.24	0.208
				A.Pub.	1.1	42.47	40.48	58.75	56.00	0.136	0.127
				A.Pri.	1.1	52.44	45.47	72.54	62.90	0.165	0.143
K	Altimetry (mountain)	3	2h40'/dm2	C.Pub.	1.5	51.69	49.70	137.84	132.53	/	/
				C.Pri.	1.5	61.56	54.69	164.43	145.84	/	/
				A.Pub.	1.1	42.47	40.48	113.25	107.95	/	/
				A.Pri.	1.1	52.44	45.47	139.84	121.25	/	/

Table 2.1.2., III (cont'd)

Digital plotting (for automatic cartography) (see Table 2.1.1., II c)

Large scale survey (1:2,000)

L	Planimetry (peri-urban)	5	1h45' /dm2; 13.97 sec/ point	C.Pub.	1.5	53.42	50.56	93.48	88.48	0.207	0.196
				C.Pri.	1.5	67.72	57.77	118.51	101.10	0.263	0.224
				A.Pub.	1.5	53.42	50.56	93.55	88.48	0.207	0.196
				A.Pri.	1.5	67.72	57.77	118.51	100.99	0.263	0.224
	Altimetry (mountain) DTM; supplementary points	5	5'18" /dm2; 13.97 sec/ point	C.Pub.	1.5	53.42	50.56	4.52	4.28	0.207	0.196
				C.Pri.	1.5	67.72	57.77	5.73	4.89	0.263	0.224
				A.Pub.	1.5	53.42	50.56	4.52	4.28	0.207	0.196
				A.Pri.	1.5	67.72	57.77	5.73	4.89	0.263	0.224

2.2. Economic Study of Analytical Photogrammetry

2.2.1. Conventional Bases for Estimates

Although the study of yield of analog plotters could be based on long-established practices, this is evidently not the case with analytical plotters ; Traster, in particular, on which this analysis is based, has not yet been in use for a long time and regularly in intensive mapmaking production statistically equivalent to that of analog instruments.

In an initial phase, and on the basis of acquired experience, one must therefore be content with evaluating the logical increase in productivity obtained in the various operating phases of analytical practice. Special attention will be given to aerotriangulation aspects as well as model shaping and setting up, which can be most readily estimated. Most of all, however, attention will be focussed on general conditions for measuring surveys of details on the instrument.

Economies achieved will thus be analyzed successively in :
. aerotriangulation,
. model shaping and setting up,
. operations involving plotting of small and large scale details for both 1 and 2 shifts per day.

One might admit, arbitrarily and for the needs of global evaluation of some estimates, that a single analytical stereoplotter performs all photogrammetric operations for 60 pairs of exposures during the 1,880 annual working hours of one work shift.

In the case of Traster, all operations are performed by a single technician : the plotter. It is therefore interesting to recall the estimates made in § 1.2.1. to 1.2.4. above dealing with various costs constituting overall production expenditures.

For an AP such as Traster, we have, in US dollars :

Table 2.2.1. : Global Value of Hourly Production :

	Public Sector	Private Sector
One-shift operation	45.12	67.46
Two-shift operation	40.65	51.82

2.2.2. Aerotriangulation

Judiciously adapted to the various operational phases of aerotriangulation, analytical plotting permits considerable simplification of previous routines imposed by conventional methods.

This is not an opportune moment to give details of this procedure, although we may mention several of its aspects :

. Following a computer-slaved order to shift the exposures, possibility of automatic plotting on the image of a transfer point already used on the pair of views or on contiguous strips, thanks to exposure co-ordinates, or possibility of shifting to a model space point already defined temporarily on neighboring pairs.

. Definitive shaping of models during the acquisition phase.

. Thanks to automatic servo-travel, checking coherence and accuracy of trans fer points used on a model before any insertion into aerotriangulation calculations.

. Possibility of real-time sequential calculation of aerotriangulation for each strip as acquisitions progress.

. Finally, the possibility of ensuring definitive correction in a few minutes of the block of strips on computer (Traster computer) in deferred time.

Finally, memory storage of definitive results : transfer point numbers, exposure co-ordinates, corrected space co-ordinates, and memory storage of parameters of the various orientations (internal, relative, absolute) for each pair of views.

All these means eliminate the long, delicate organizing work preceding measurements, with the familiar accessories for pin-pointing and transferring points.

Work consisting in placing results in archives has also become useless.

The reliability of such results is at its optimum, for each operation covering a detail is checked in real time, thus permitting, if necessary, immediate touching-up.

It is thus quite evident that productivity is considerably increased since time gained is estimated at 80 % with respect to previous methods.

In the various cases considered, it is advisable to calculate anticipated savings in aerotriangulation on analytical plotter (Traster, for example) ; it should be done for one pair, 60 pairs (which, hypothetically, are completely processed annually by a single instrument) and, finally, for a period of five years (within the same hypothesis).

Table 2.2.2.

Savings (in US dollars)	Case of a public service		case of a private agency	
	1 shift per day	2 shifts per day	1 shift per day	2 shifts per day
Savings achieved with one pair	91.05	86.54	113.65	97.85
Savings achieved with 60 pairs	5,463.60	5,192.40	6,819.00	5,871.00
Savings achieved over 5 years	27,315.00	25,962.00	34,095.00	29,355.00

2.2.3. Shaping and Setting Up Models

A trained operator takes 10 minutes to carry out a complete orientation protocol operation for a pair ; this value must be compared with the average time spent in analog procedure, i.e. 82 minutes (Table 2.1.1., II).

In addition, when orientation has been set previously during aerotriangulation, it is indispensable to set one of the pairs anew on AP's

(Traster, for example) in order to exploit details of plotting ; this "partial orientation" requires only 4 minutes per pair, whereas 40 minutes are required in analog photogrammetry for a similar case of setting using an "existing protocol". In fact, all aerotriangulation parameters are stored in memory and it suffices to extract them.

To obtain a simple overall comparison permitting expressing sums economized on analytical orientations, we shall use the hypothesis of equal distribution of the various types of work previously considered under the heading "small scale surveys", on the one hand, and, on the other, "large scale surveys". (See Table 2.1.2., II, operations B, C and D for small scales, and operations E, F and G for large scales).

In the table below, we shall therefore express the average cost of orientation of a pair in analog procedure, that in analytical procedure and savings achieved thanks to the latter for the eight usual cases for such estimates : public sector, private sector, one-shift and two-shift daily work, and finally, small and large scale.

Table 2.2.3. Average Savings Achieved in Orientations (in US dollars)

(see following page)

2.2.4. Plotting Details

AP's have been designed to be used by a single technician, the plotter. He may intervene manually on the co-ordinatograph-draughting table but, in general, two features render such intervention unnecessary :

. a computer program controls automatic draughting of certain graphical expressions and point interpolation ;

. the draughting table is observed via a TV monitor placed on the control desk.

One factor to be considered in comfort and productivity is the possibility of observing the stereoscopic model to be plotted on an optical screen placed on the control desk (Traster) ; this image has finite distance (which the operator adjusts by adjusting the position of his chair), that is, the same distance as all other controls, and therefore affords the same ocular accommodation.

Another favorable element lies in the grouping of all controls, thus sparing the operator the need to move about : these are keys on the control desk, the tube for dialogue with the computer, the TV tube and means for auscultating the model.

Yet another favorable factor is the replacement of the traditional hand cranks for X and Y travel by a ball on air cushion ; after a brief period of adjustment, the operator usually agrees that this latter is better adapted to human physiology. In this case, Z travel is controlled by the operator's other hand, rotating a small cylinder, replacing advantageously the customary circular pedal.

Since statistics have not yet been established for very long operating periods, one must be content with logical evaluation - slightly subjective - in order to estimate productivity gains achieved.

Table 2.2.3. Average Savings Achieved in Orientations (expressed in US dollars)

	Avg cost of orientation for 1 pair				Cost of orientation for 1 pair				Savings achieved for orientation of 1 pair			
	analog				analytical							
	Publ. Sector		Priv. Sector		Publ. Sector		Priv. Sector		Publ. Sector		Priv. Sector	
	1 shift	2 shifts	1 shift	2 shifts	1 shift	2 shifts	1 shift	2 shifts	1 shift	2 shifts	1 shift	2 shifts
Small scale survey	67.82	66.38	75.07	70.00	6.02	5.42	8.99	6.91	61.80	60.96	66.08	63.09
Large scale survey	70.36	67.65	83.93	74.44	6.02	5.42	8.99	6.91	64.34	62.23	74.94	57.53
Averages, all scales combined :				a	for one pair				63.07	61.59	70.51	65.31
				b	for 60 pairs/year				3,784	3,695	4,230	3,919
				c	over 5 years				18,921	18,477	21,153	19,593

Average overall savings on orientations come to 90.5 %

One may thus estimate, under equivalent production conditions, that described features increase productivity in a proportion which might be reckoned very prudently at a minimum of 15 % on the best "advanced" analog plotting instrument.

The following tables deal with survey of details using an AP. Table 2.2.4.,I gives the cost in US dollars for operations previously dealt with in analog photogrammetry (in 2.1.2.,III). Table 2.2.4.,II gives savings achieved with respect to conventional and advanced analog procedure. Tables 2.2.4.,III and 2.2.4., IV are summaries extracted from the preceding, facilitating polling results.

Table 2.2.4., I. Plotting Details in Analytical Photogrammetry

Operation		Nmbr type equipment AP's	Duration of operation for 1 dm2 & 1 point surveyed	Public sector Private sector	Nmbr of useful technicians	Cost per hour		Production costs : unit costs counted for :			
								dm2 on map		point surveyed	
No.	Nature					1 shift	2 shifts	1 shift	2 shifts	1 shift	2 shifts
Graphical plotting (productivity values of table 2.1.2.b increased by 15 %											
Small scale survey (1:25,000)											
H	Planimetry (peri-urban)	6	2h37'/dm2, 9.77 s/point	Pub.	1	45.12	40.65	118.06	106.37	0.122	0.11
				Pri.	1	67.46	51.82	176.52	135.60	0.183	0.141
I	Altimetry (mountain)	6	15h18'/dm2	Pub.	1	45.12	40.65	690.34	621.95	/	/
				Pri.	1	67.46	51.82	1,034.14	792.85	/	/
Large scale survey (1:2,000)											
J	Planimetry (peri-urban)	6	1h10'/dm2; 9.63s/point	Pub.	1	45.12	40.65	52.64	47.42	0.121	0.109
				Pri.	1	67.46	51.82	78.70	60.46	0.18	0.139
K	Altimetry (mountain)	6	2h16'/dm2	Pub.	1	45.12	40.65	102.27	92.14	/	/
				Pri.	1	67.46	51.82	152.91	117.46	/	/

Table 2.2.4., I (cont'd)

Digital plotting coded for automatic cartography (productivity values of Table 2.1.1.,IIc increased by 15 %)

Large scale survey (1:2,000)

L	Planimetry (periurban)	6	1h29'/dm2 11.87 sec / point	Pub.	1	45.12	40.65	66.93	60.30	0.149	0.134
				Pri.	1	67.46	51.82	100.07	78.87	0.222	0.171
	Altimetry (mountain) supplementary points DTM		4'32"/dm2 11.87 sec / point	Pub.	1	45.12	40.65	3.25	2.93	0.149	0.134
				Pri.	1	67.46	51.82	4.86	3.73	0.222	0.171

Table 2.2.4., II. Savings Achieved via Analytical over "Conventional" and "Advanced" Analog (with tripled accuracy and same methodology)

Operation		C.Pub. C.Pri. A.Pub. A.Pri. (1)	Savings in costs (US$) on unit values				Savings in %age on unit expenditures			
			dm2 on map		/point surveyed		dm2 on map		/point surveyed	
No	Nature		1 shift	2 shifts	1 shift	2 shifts	1 shift	2 shifts	1 shift	2 shifts
	Graphical Plotting Small scale survey (1:25,000)									
H	Planimetry (periurban)	C.Pub.	71.10	57.94	0.074	0.06	37.6%	35.3%	37.9%	35.3%
		C.Pri.	29.05	58.50	0.03	0.06	14.1%	30.1%	14.1%	29.9%
		A.Pub.	7.15	15.58	0.008	0.016	5.7%	12.8%	6.2%	12.7%
		A.Pri.	-37.90	- 5.45	-0.036	-0.006	-26.6%	- 4.2%	-24.5%	- 4.4%
I	Altimetry (mountain)	C.Pub.	206.60	255.90	/	/	23.00%	29.20%	/	/
		C.Pri.	-39.44	132.89	/	/	-4.00%	14.40%	/	/
		A.Pub.	40.64	89.95	/	/	5.50%	12.60%	/	/
		A.Pri.	-205.40	-33.07	/	/	-24.80%	-4.40%	/	/

(1) Legend : C = conventional analog ; A = advanced analog
Pub. = public ; Pri. = private

Large Scale Survey (1:2,000)

J	Planimetry (periurban)	C.Pub.	34.88	37.47	0.078	0.084	39.9%	44.2%	40.4%	43.5%
		C.Pri.	48.59	44.37	0.119	0.099	48 %	48.4%	49.6%	47.6%
		A.Pub.	6.11	8.58	0.015	0.018	10.4%	15.3%	11 %	14.2%
		A.Pri.	-6.16	2.44	-0.015	0.004	-8.5%	3.9%	-9 %	2.8%
K	Altimetry (mountain)	C.Pub.	35.57	40.39	/	/	25.8%	30.5%	/	/
		C.Pri.	11.52	28.38	/	/	7 %	19.5%	/	/
		A.Pub.	10.98	15.81	/	/	9.7%	14.6%	/	/
		A.Pri.	-13.07	3.79	/	/	-9.3%	3.1%	/	/

<u>Digital Plotting</u> (for automatic cartography and data files)

Large Scale Survey (1:2,000)

L	Planimetry (periurban)	C.Pub.	26.55	28.18	0.058	0.062	28.4%	31.8%	28 %	32 %
		C.Pri.	18.44	22.23	0.041	0.053	15.6%	22 %	15.6%	23.7%
		A.Pub.	26.62	28.18	0.058	0.062	28.5%	31.8%	28 %	31.6%
		A.Pri.	18.44	22.12	0.041	0.053	15.6%	21.9%	15.6%	23.7%
M	Altimetry (mountain)	C.Pub.	2.48	1.96	0.114	0.09	43.3%	40 %	43.3%	40.2%
	supplementary points	C.Pri.	0.87	1.16	0.041	0.053	15.2%	23.7%	15.6%	23.7%
	DTM	A.Pub.	1.27	1.35	0.058	0.062	28.1%	31.5%	28 %	31.6%
		A.Pri.	0.87	1.31	0.041	0.053	15.2%	26.8%	15.6%	23.7%

Table 2.2.4.III. Summary of Financial Savings in Analytical

Taken from table 2.2.4.II : results distinguished by types of scales,
by sectors,
by comparisons between types of analog,
but with one and two-shift work combined.

	Savings in analytical over conventional analog		Savings in analytical over advanced analog	
	Public	Private	Public	Private
	Graphical Plotting			
Small scale No. H and J	+ 33.1 %	+ 16.4 %	+ 9.4 %	- 14.8 %
Large scale No. J and K	+ 37.4 %	+ 36.7 %	+ 12.5 %	- 2.8 %
	Digital Plotting			
Large scale No. L and M	+ 35.9 %	+ 19.4 %	+ 29.6 %	+ 19.8 %

Table 2.2.4.IV. Another Aspect of Financial Savings

Averages summed up from Table 2.2.4.II as above but with sole reference to work on two shifts.

	Savings in analytical over conventional analog		Savings in analytical over advanced analog	
	Public	Private	Public	Private
	Graphical Plotting			
Small scale No. H and J	+ 33.4 %	+ 24.8 %	+ 12.7 %	- 4.3 %
Large scale No. J and K	+ 39.4 %	+ 38.5 %	+ 14.7 %	+ 3.3 %
	Digital Plotting			
Large scale No. L and M	+ 36 %	+ 23.3 %	+ 31.6 %	+ 2.4 %

It should be stressed that comparisons herein are made of costs under hypotheses defined above,but in all cases of detail plotting :
.1) speed is greater by 12 % in analytical,
.2) accuracy is tripled,
.3) throughout the world, the normal working day on computer equipment is two shifts (i.e. the final financial result in the above table).

3. SYNTHESES OF COMPARISONS OF COST AND PRODUCTIVITY STUDIES IN CONVENTIONAL AND ADVANCED ANALOG PHOTOGRAMMETRY WITH THOSE IN ANALYTICAL PHOTOGRAMMETRY

3.1. Comparison of Time Required for Identical Production

3.1.1. Reminder of overall results obtained :

. Basic gain of time in analytical :
  . for aerotriangulation : 80 %
  . for orientations : 90.5 %
  . for plotting details : 15 %

3.1.2. First mode of estimating time gained.

Let us choose the hypothesis that a single analog instrument is used for aerotriangulation, orientations and detail plotting.

Average time gained results from weighting the above percentages because of true statistical productivity (indicated in Tables 2.1.1.).

Time gained is thus 22.33 %.

3.1.3. Second mode of estimating time gained.

In this mode it will be assumed that the analog plotter instrument is used only for orienting the pairs of views and plotting details, aerotriangulation, made on other equipment (stereocomparator or plotter and computer), not being counted.

Let us imagine that this analog plotter handles 60 pairs per annum during 1,880 working hours (on one shift). This gives 31 h 19 mn per pair, 1 h 22 mn for orientation and 29 h 57 mn for plotting.

In this same case, the single analytical stereoplotter will handle the three operations on each pair, i.e. :
. 0 h 28 mn for aerotriangulation,
. 0 h 08 mn for orientation,
. and 25 h 27 mn for plotting details (85 % of 31 h 19 mn), i.e. a total of 26 h 03 mn per pair. Thus, working 1,880 h/yr on one shift, AP's handle more than 72 pairs, an increase in production of 20 %.

3.1.4. Conclusions Concerning Time Gained

One may accept a gain in time of more than 21 % whatever the means compared in analog photogrammetry and the scales or type of work under consideration.

3.2. Comparison of Costs for the Same Work

Table 2.2.4. shows that the estimate of financial gain cannot be expressed in an overall manner so simply as productivity because of the great number of parameters. In the case under consideration, however, the direct estimate is defined.

Let us simplify several elements in order to facilitate the estimate.

3.2.1. Respective weights of the 3 phases of analytical plotting.

We find :	A. Aerotriangulation (on Traster)	1.7914 %
	B. Orientations	0.5118 %
	C. Plotting details	97.6968 %
of analytical expenditures.		100.0000 %

3.2.2. Test of economies achieved in costs.

Weighting of operational phases reveals quite evidently that the third is determining (Table 2.2.4.I.).

Whatever attitude is taken, however, with respect to this third phase, one must not lose sight of economies already achieved in the first two recalled below and which are valid for the comparison both with "conventional" analog photogrammetry and with "advanced" analog photogrammetry.

In both cases, this comparison is made, on the one hand, for one-shift work and, on the other, for two-shift work.

Table 3.2.2. Sum of economies achieved in aerotriangulation and orientation.

Economies in US dollars	Public Sector		Private Sector	
	1 shift	2 shifts	1 shift	2 shifts
on one pair	154	148	184	163
on 60 pairs	9,247	8,887	11,049	9,790
during 5 years	46,236	44,439	55,248	48,948

Note that even for 60 pairs per year (as we have seen, one may expect to handle 72) during the 5 years of instrument amortization, the gross gain reaches 1/4 of the price of the analytical plotter (in spite of amortization expenditures), whereas this represents only 2.30 % of the instrument's work.

This represents an average saving of 85.25 % over correlative expenditures in analog photogrammetry.

For surveys of details - in the private sector case, we shall consider only two-shift work, for they are computer-aided. The least favorable indication uncovered was the comparison with "advanced" analog in small-scale surveys in the private sector, since expenditures are 4.3 % greater in analytical (Table 2.2.4.IV.).

In the latter case, the average weighted with previous phases (Table 3.2.2.) leads to a total supplementary expenditure of 2.24 %.

We should also point out that - simultaneously - there is still a gain in time of 21 %, with accuracy three times better.
This is the least favorable case.

Let us make the same calculations in the most favorable case : the comparison between "conventional" analog and analytical for large-scale survey, public sector, one-shift work. Here we find an advantage of 34.9% which, considering weighting with the first two phases (Table 3.2.2.), gives overall savings of 40.45 %.

All cases are distributed between these two limits.

CONCLUSION OF FINANCIAL STUDY

One must insist upon two basic points :

1) Amortizations (if applicable : for private sector only) have been counted for :
   . 8 years in analog photogrammetry with electronic accessories,
   . 5 years in analytical photogrammetry.

   Estimates of economies have been minimized in all phases of the study.

2) Systems have been compared within a methodological procedure practiced for analog photogrammetry. This is the case where an analytical instrument is added to other analog instruments in use, but without changing the methodology.
   Since, as it is well known, analytical is from 2 to 3 times more accurate for the same quality of production, the methodology itself must be reconsidered, for example :
   . exposure-taking scale,
   . number of geodetic points determined on the terrain, etc.

   An eclectic adaptation of methods to analytical photogrammetry will give savings quite substantially greater than "minimum" estimates indicated above.

3) Besides speed and accuracy, valid in all cases, the basic advantage of analytical plotters is obviously in its use for large scale surveys and digital photogrammetry.

4) There is no great advantage for the public sector in working two shifts, unless it be to double production. On the other hand, it is advantageous for the private sector, as it is whenever it uses systems derived from computers.

5) There exists no sector in which the use of analytical photogrammetry, in the present state of the art, is ill-advised, but a study of Table 2.2.3.III covering surveys of details is the determining factor from the financial point of view.

Considering remarkable analytical performance in large scales and digital surveys, compared with more modest performance in small scales, the question is posed as to whether or not there should not be a move to develop analytical photogrammetry "at the bottom of the line", in the light of the above study.
