Cost Estimates of Photogrammetric Related Services Using Electronic Spreadsheets

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ABSTRACT: The utilization of spreadsheet computer programs for photogrammetric cost estimation is discussed in detail. A typical design layout is introduced. Also, special features of spreadsheet programming to assist project/marketing managers are highlighted. It is demonstrated in this paper that spreadsheet programs for cost estimation are an excellent choice because users need little programming experience. Spreadsheet programs allow debugging, formatting, and formulating both mathematical and logical statements with ease. Complicated formats can be designed and changed quickly. A manager may interactively enter or change variables and analyze the results simultaneously to test the impact of changes.

INTRODUCTION

Most individuals in photogrammetric related services seldom have the time and experience to write computer programs that compute their cost estimates and that evaluate design variables. Ideally, project and marketing managers need flexible and user-friendly computer programs to save time and provide quick and accurate estimates for services. There is a computer program that allows easy formatting and debugging, is easy to write, saves time, and provides almost instantaneous results. Almost every business office has this software that was originally designed for managing the accounts of offices. It is called a "spreadsheet" program (a spreadsheet program is itself a program, but often the user of the spreadsheet program has to "program" it to perform specific computations).

Spreadsheet programs are essentially electronic spreadsheets, an electronic replacement for the traditional financial modeling tools—the accountant's columnar pad, pencil, and calculator. This electronic pad exists in the dynamic world of the computer's memory and is much larger than the paper pad. Electronic spreadsheets have sizes ranging from 254 rows and 64 columns to 8192 rows 256 columns.

Each row is assigned a number and each column a letter. The intersections of the rows and columns are called cells (referred to as work space in this article). Work spaces are identified by their row-column coordinates. These work spaces can be filled with three kinds of information: numbers; mathematical formulas, including special spreadsheet functions; and text (or labels). A cursor allows the user to write information into each work space much as a pencil lets one write on a piece of paper. Because the grid of spreadsheets is large, the entire sheet cannot be viewed on the screen at one time; that is, one would have to view the sheet a part at a time. However, this feature does not shorten the list of microcomputers that can run these programs. In fact, a variety of microcomputers is suitable for this purpose. Included in the list are the IBM PC, IBM PC compatibles; Zenith Data Systems Z-100, DEC Rainbow, the AT&T 6300, the Wang Professional, and so on. A number of spreadsheet programs are available on the market. Although the format and some features may vary slightly, they are superior programs for cost estimates. Also, they can be used to evaluate design variables in surveying, photogrammetry, and other areas of engineering (Wei, 1987).

Popular programming languages such as BASIC and FORTRAN require skill to write a user-friendly and well-formatted program. Usually, it is difficult for a user (non-programmer) to reformat or add formulas to the program. On the other hand, spreadsheets require little programming knowledge or experience. The menu is friendly and easy to follow. There are no lengthy program statements and logical loops. Debugging is simple. In the following chapters, spreadsheet programming and special features of spreadsheet programs are discussed in more detail.

SPREADSHEET PROGRAMMING

To show the approach to spreadsheet programming, a typical example is illustrated (Figure 1 through Figure 7). A spreadsheet may be thought of as a sheet of paper with row and column markers on which one can design a format and write down mathematical and logical statements. Each column is designated a specific width and may range from one to hundreds of character spaces. Any intersection of a row and a column forms a work space (see Figure 1). A work space is referred to by name (e.g., focal length) or by range (e.g., B11, where B is the column and 11 is the row). Hence, a variable in A1 can be used in a mathematical formula in A2 by stating the name "focal length" or simply 'A1' in the formula at A2. A very basic or a very complicated design (see below for definition) may be placed on a spreadsheet. The example given below is developed on a popular spreadsheet program known as LOTUS 1-2-3.

BASIC DESIGN

A basic design consists of an output format and a mathematical and logical statement format. A format is an individual layout on a part or a whole area of a spreadsheet and it serves a specific

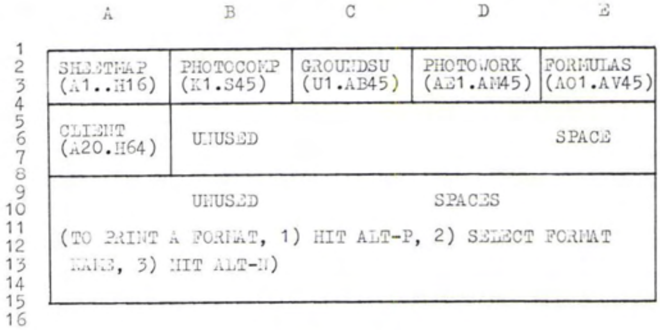

FIG. 1. Sheetmap.

0099-1112/88/5401–47$02.25/0

```
****************************************
*           JOB COST ESTIMATE          *
*                 ON                   *
*   PHOTOGRAMMETRIC RELATED SERVICES   *
****************************************
Mission Aerial Photo,Inc.        Name of Client:
5620 Frairs Rd                   Address:
San Diego, CA 92110
Tel. 619-291-0707                Tel.
Contact:                         Contact:


Date of delivery

Site Information:
Cover(open,wood,resi,indust; %)?      5      0      85          10
Relief( nearest 50 ft, eg 250 )?    200   Ave Terrain HT?       500
Terrain Texture(SMooth or FAir or Sly rough or ROugh)?    fa
Maximum length(break irregular figure into blocks;in ft)?    30,000
Maximum width ( use the short side of a block;in ft)?        17,000
Map beyond stated limit(in ft or 0)?       100
Name of City?  San Diego      State?  CA
Distance of site from office (in mile )?     50

Product Information:
Contour intval( in ft )?     2.0 Final map scale( ft or 0 )?      100
Final map(MAnu,SCRibe ,SCreen,CLient format or NO compil)?  scr

Special Application:
DTM (% of total area )?        0 X sectn (distance in feet)?        0
Profile(dist in feet )?        0 Grid spots elev ( Y or N )?y
Vol (% of total area )?        0 Area comp(% of total area)?        0

Other Information:
Aerial Photography (Yes or No)?  y
Type(B&W or color or both)?      both
B&W spotshot( enter # )?       0        Color spotshot( # )?         0
Field Control Work (Yes or No)?  y
Boundary invol(Y or N)? n

Cost Summary:
Estimated Cost on Field Control                     $      43,148
Estimated Cost on Aerial Photography                $       2,063
Estimated Cost on Photogrammetric work              $     205,873
Total Estimated Project Cost                        $     251,084
```

FIG. 2. Client format.

```
PHOTOGRAPHY COMPUTATION:
Focal length of aerial camera?            6.00 inch
Direction of flight line along the(length or width)?  length
First flight line from maplimit(inside) in % of camera format?      30
First exposure from maplimit in % of format?        0 in/out ? out
Endlap(in %)?            60 Sidelap (in % )?       33
Fly height, if yes C-Factor is N (Y or N)?  y       Value?        3000
C-Factor, if yes fly height is N (Y or N)?  n       value?           0
Note: check contour interval if C-Factor is used
Area/model, if yes C-Factor & fly height is N(y or N)?n
If area/model is YES, length ie forward(ft)?        0 Side(ft)?      0

Cost of aerial photography:
Select method ( TRaditional, IMproved or LUmp sum )?  im
--for traditional,answer questions below(zero if none or not require)
    aircraft ground speed?        250 miles
    time for climb and descent (in minutes) ?       60
    flying time to site(both ways,  minutes)?       30
    turning time per loop (minutes)?        10
    cost of flying per hr =                                  $   200.0
    direct cost(materials & exposure cost) =                 $    20.0
    miscell. cost (                                )=        $    50.0

--for improved method, answer questions below(zero if none)
 a) black and white photo
    basic mobilization per project =                         $   185.0
    Convenience mobilization in normal flying areas  =       $   100.0
    per mile between sites & outsides 50 miles  =            $     1.0
    per 1000' to 10000' when above 5000'  =                  $    10.0
    per 1000' to 12000' when above 10000'  =                 $    15.0
    per 1000' above 12000'  =                                $    20.0
    additional charge in airport control area  =             $    50.0
    per flight line  =                                       $    12.0
    per exposure, mapping job  =                             $    12.0
    per spotshot  =                                          $    25.0

 b) color photography
    basic mobilization  =                                    $   235.0
    convenience mobilization  =                              $   125.0
    minimum charge  =                                        $    90.0
    per spotshot  =                                          $    25.0

--for lump sum cost answer question below(zero if none)
    amount of lump sum chargs =                              $   400.0
```

FIG. 3. Photography format.

```
GROUND CONTROL ACQUISITION:
Cost of ground control survey
Analytic  required ( if Y check photo work, Y or N)?  y
Select method ( COnventional, ADvanced or LUmp sum)?  co
--for conventional(theodolite,EDM,level) ans questions below
    note: enter zero if not appliable or not required
    input total # of mile(Y or N)?  n          if Y # ?      0.00
    traverse cost per mile  =                        $      110.0
    computing cost per mile  =                       $       67.0
    charge on legal boundary per project =           $        0.0
    panel setup per mile  =                          $       40.0
    Basic mobilization fee per project =             $       50.0
    leveling cost per mile =                         $      160.0
    miscell. cost (                          )=      $        0.0

--for Advanced method answer questions below(zero if none)
    note: Advanced methods are GPS, Inertia System,etc
    basic fee per "day" =                            $       50.0
    mobilization fee per "day" =                     $       50.0
    monumentation fee and panel per point =          $       20.0
    cost of processing per point =                   $       15.0
    cost of field personal per hr =                  $       50.0
    miscel. cost (                           )=      $        0.0

Field labor time estimation for GPS Service
    Site information:
      input total # of control pts?       40
      distance between pts(average in miles)?     0.00

    Time factors:
      observation time per point?          60 (min)
      travel time between points?          15 (min)
      instrument setup time / point?       15 (min)
      travel time to/from site/day?        90 (min)

    Computation factors:
      Redundant observations (select option,one only!)
      option I (Yes or No)?n
      % of total # of points/project?                          33
      option II(Yes or No)?y
       new point(% of total new pt)?      30 # of pt ?         20
       vertical cont pt(% of total)?     100 # of pt ?          4
       horizon cont pt(% of total)?      100 # of pt ?          4
      estimated  #  of points  observable  per  day ?           5
      misc.  survey  & down  time in % of total time?          25

--for lump sum fee answer question below
    amount of lump sum fee =                         $          0
```

FIG. 4. Ground control acquisition format.

purpose, e.g. Figure 2. Information is entered directly onto the format (see Figure 2). Computer information appears on the same format. Formulas and logical statements are not seen by users and the format is protected from alteration. This type of design is good for users who do not want to change constant variables according to input information. An example of a constant variable is the charge on compiling topographic data per model. It is also good for users who do not have the technical knowledge to manipulate the input information. For example, the flight direction of aerial photography can be changed according to the dimensions of the mapping site in order to optimize the coverage of each stereo model. The output format can be printed as hard copies for delivery to clients or for office use.

ADVANCED DESIGN

A more advanced design is presented in Figure 1 through Figure 7. The presented design was completed at a fraction of the time that would be required when using the FORTRAN programming language. To illustrate the workings and programming approach of the design, the following discussion is based on each figure.

Figure 1 is referred to as a sheetmap. The purpose of a sheetmap is to provide the user with the name and location of all the formats available on the spreadsheet. It also provides the programmer with the information on the unused spaces, instructions, and design improvements.

Figure 2 is referred to as the client format. A hard copy of this format is a price quote for the client. Input data on this format is usually supplied by the clients. A client can provide

```
PHOTOGRAMMETRIC WORK:
Select cost computation method(per MOdel, per ACre, LUmp sum)? mo
Special application only !! (i.e. no compil, Y or N)? n
--for per model, answer questions below (zero if not applicable)
    Note : basic compilation(standard)/model includes manuscript layouts
         compilation and basic labwork(labor and material)
    Charge on basic setup & compil(standard)/model  =          $  500.00
    Analytic cost per model(if bridging is needed) =           $   50.00
    Note: check ground survey for "analytic"
    Special application/model with no compilation involved =  $   10.00
    Charge on DTM/% of total area(/% of basic compilation cost)     2.00
    Charge on Cross section/hundred feet  (same as above)           0.02
    Charge on Profile/hundred feet    (same as above)               0.05
    Charge on Grid spot/% of total area          (same as above)    0.10
    Charge on Volume/% of total area        (same as above)         0.10
    Charge on Area/% of total area        (same as above)           0.10

--for per acre, answer questions below (zero if not applicable)
    Note: Total acreage is computed automatically
    Charge on basic setup & compil(standard)/acre =            $       4
    Analytic cost per "model"(if bridging is needed) =         $      50
    Special application per acre(with no compil) =             $       0
    Charge on DTM/% of total area(% of bsic compilation cost)       0.10
    Charge on Cross section/hundred feet (same as above)            0.02
    Charge on Profile/hundred feet  (same as above)                 0.05
    Charge on Grid spot/% of total area (same as above)             0.10
    Charge on Volume/% of total area (same as above)                0.10
    Charge on area/% of total area  (same as above)                 0.10

--for lump sum fee, answer question below(zero if none)
    amount of lump sum fee =                                   $       0

Data tables:
  Relief     Code Terrain       Code Final map     Code Gnd Cover     Code
   0.00      1.00 sm            1.00 ma            1.00 open          1.00
  50.00      1.01 fa            1.05 scr           1.80 wood          1.05
 100.00      1.05 sl            1.10 sc            1.90 resid         2.00
 250.00      1.10 ro            1.20 no            0.00 indus         2.20
 500.00      1.20                    cl            2.00

Contour      Code          Map scale     Code Color Typ     Code
0            0.50             0.00       0.00 b&w           1.00
.5           1.20            10.00       1.15 color         2.00
1            1.15            20.00       1.10 both          3.00
2            1.10            50.00       1.10
5            1.08            80.00       1.05
10           1.05           100.00       1.02
20           1.00           250.00       1.00
```

FIG. 5. Photogrammetric work format.

```
Formula area:
Basic Photography              Cost of Aerial
a) comp end &side lap          I) Improved method
   0.33                        a)basic charges
   0.60                              1.00
b) check flight direction      b) color selection
   30000                             3.00
   17000                             0.00
c) comp fly height                   0.00
   3000                        c) site comp
   6000                              0.00
d) comp model dimen                  0.00
   1800                        d) altitude comp
   3015                         3500.00
   1800                              0.00
   3015                              0.00
e)comp maplimit                      0.00
   30200                            72.00
   17200                          1296.00
Number of model                e) charge for b&W
   0.00 (1 mod work)                 285
   0.00                        f) charges for color
   0.00                              360
a) # of model per strip        d) total charge per job
   0.00                              0
   16.78                             0
   16.00                             645
   17.00                             695
   17.00                             2063
b) # of strip                  II) Tradit method
   5.26                        a) flying dist
c) total # of model                 34.32
   5.00                            148.24
   6.00                        b) cost of tradi
 102.00                              564
d) total # of exposure         III) Method of test
   0.00                              0
   18.00                             2063
 108.00                              0
                                     2063
                                     2063
```

FIG. 6. Formulas format.

all the required data on the phone in a few minutes. The input consists of site information, product information, special application requirements, and type of services required for a project. A cost summary appears on this format.

Figure 3 is referred to as photography. The first part of the format prompts the user for a number of inputs such as the focal length of the camera. Essential data can then be computed with regard to the design of the photography. The second part of the format involves the entry of inputs to compute the cost of aerial photography.

Figure 4 is referred to as the ground control acquisition format. Necessary data are input to calculate photogrammetric ground control costs. A user selects options such as boundary surveys and/or analytical bridging.

Figure 5 is referred to as the photogrammetric work format. Variables to compute the cost of bridging/stereo compiling or drafting are entered at this point. A user may also supply data for special projects' requirements such as cross sectioning and profiles. Information in character forms (e.g., wooded area, scribe) is provided with numerical codes for mathematical calculation on this format. These codes are usually represented as a relative value and may be changed by the user. For example, an open area is given a 1.0 while a residential area is given a 2.0. A residential area is given a 2.0 because it takes twice as much time to compile a topographic map of a residential area compared to an open area. This code assignment area is called a data table.

Figure 6 is referred to as the formula format. Mathematical and logical statements are placed in this area. These statements are needed to do all the computation to provide a cost summary. To simplify editing and debugging, each group of statements is placed under a specific heading. Accordingly, four groups

```
A01: 'Formula area:
A02: 'Basic Photography
A03: 'a) comp end & side lap
A04: +SIDELAP*0.01 "SIDELAP"
A05: +ENDLAP*0.01 "ENDLAP"
A06: 'b) check flight direction
A07: (FO) @IF(DIRECTION="length",LENGTH,WIDTH) "LENGTH1"
A08: (FO) @IF(DIRECTION="length",WIDTH,LENGTH) "WIDTH1"
A09: 'c) comp fly height
A010: (FO) @IF(C-FACTOR="y",CONTOUR*CFACTOR,FLYHEIGH) "H"
A011: (FO) 12*H/FL "S"
A012: 'd) comp model dimen
A013: (FO) +S*9/12*(1-ENDLAP1) "LMODEL"
A014: (FO) +S*9/12*(1-SIDELAP1) "WMODEL"
A015: (FO) @IF(AREA/MODEL="y",MODELLENGTH,LMODEL) "LMOD"
A016: (FO) @IF(AREA/MODEL="y",MODELWIDTH,WMODEL) "WMOD"
A017: 'e) comp maplimit
A018: (FO) +LENGTH1+2*MAPLIMIT "LAREA"
A019: (FO) +WIDTH1+2*MAPLIMIT "WAREA"
A020: 'Number of model
A021: @IF(LMOD>LENGTH1#AND#WMOD>WIDTH1,1,0) "ONEMODEL"
AP21: '(1 mod work)
A022: @IF(WMOD>LENGTH1#AND#LMOD>WIDTH1,1,0) "ONEMODEL1"
A023: @IF(ONEMODEL=1#OR#ONEMODEL1=1,1,0) "SINGLE"
A024: 'a) # of model per strip
A025: @IF(INOUT="in",EXPBOUND*-0.01*S*9/12
      EXPBOUND*0.01*S*9/12) "EXTRALENG"
A026: @IF(LENGTH1>LMOD,(LAREA+EXTRALENG)/LMOD,0) "MOSTRIP"
A027: @INT(MOSTRIP) "#MOSTRIP"
A028: @IF(MOSTRIP-#MOSTRIP>0,#MOSTRIP+1,MOSTRIP)
      "T#MOSTRIP1"
A029: @IF(SINGLE=1,1,T#MOSTRIP1) "T#MOSTRIP"
A030: 'b) # of strip
A031: @IF(WAREA>WMOD,(WAREA-LINEBOUND*0.01*S*9/12)/WMOD,1)
      "STRIP"
A032: 'c) total # of model
A033: @INT(STRIP) "#STRIP"
A034: @IF(STRIP-#STRIP 0,#STRIP+1,#STRIP) "T#STRIP"
A035: @IF(T#STRIP>1,T#STRIP*T#MOSTRIP1+SINGLE) "T#MOD"
A036: 'd) total # of exposure
A037: +SINGLE*2 "SINGLEEXP"
A038: @IF(SINGLE=0,T#MOSTRIP+1,0) "#EXP"
A039: @IF(T#STRIP>1,#EXP*T#STRIP,#EXP+SINGLEEXP) "T#EXP"

"SIDELAP" is an assigned Range name
```

FIG. 7. Content of work space.

are formed; i.e., basic photography, cost of aerial photography, cost of field work, and cost of photogrammetric work (these last two groups are not shown in Figure 6).

Figure 7 is an expanded view of column one of Figure 6, i.e., basic photography. It shows the content of each work space. The first character string of each row represents the range of the work space. For example, AO1 means a work space at row 1 and column AO. The first character of the second character string of each row indicate the purpose and function of the content. Some examples of these characters are discussed below.

A "'" indicates the work space contains a character string.

A "+" or "−" or a numerical value indicates a mathematical formula.

A "@ " indicates a mathematical or logical function.

A "(FO)" indicates the presence of a format indicator where O means no decimal, or in another word, an integer.

A "(" indicates a mathematical formula.

For others, one may refer to the manual for the spreadsheet program.

CAUTION

At present, high level mathematical computations, such as the method of least squares, cannot be done on spreadsheets alone. Also, high level logical statements may not work on some spreadsheet programs (first- and second-generation spreadsheet programs).

It is more convenient to refer to a work space in a mathematical or logical statement by name than by range. For example, in Figure 7, work space "AO10" is referred to as H in work space "AO11". "H" is preassigned to work space "AO10". Debugging and editing of formulas can be carried out more efficiently.

SPECIAL FEATURES OF A SPREADSHEET

Special features of a spreadsheet program make it easier, faster, and more friendly to use than ordinary programming languages. Therefore, it is worthwhile to describe these features in this paper. Each feature is discussed briefly below with regard to its capability and advantage over a typical ordinary programming language. Readers are reminded that the described features need not be a complete listing.

- *Formatting:* Each character string need not be squeezed into a single space (i.e., spilling over to the adjoining space is allowed). Thus, one may simply enter any character string onto the spreadsheet. No format statement is needed as in the case of ordinary programming. Unused adjoining spaces are not disturbed in any way.
- *Editing:* Editing is done in a manner similar to word processing. Format, and mathematical and logical statements, can be altered interactively.
- *Debugging:* Only mathematical and logical statements require debugging. Each statement is located in a space. To debug these statements on a spreadsheet, one simply moves the cursor to the work space where the erroneous statement is located. The statement appears on the screen and is debugged, and the "result" is analyzed at the same time. The "result" of any alteration to a statement can be looked at simultaneously (result means the output from the computer after a statement is processed).
- *Move:* One may move a block (e.g., a format name sheetmap) from the top of the spreadsheet to any part of the sheet easily by the Move feature. This feature is particularly important when a user wants to change the appearance of a format from time to time.
- *Hard copy:* One may print a hard copy of any format on the spreadsheet. This feature is useful when a user wants to keep a hard copy of a format each time an input is changed on the format.
- *Protection:* The protection feature allows a user to protect designs or entries on the spreadsheet from being erased accidentally. Protection can be disabled at will so that a user may modify the format.
- *Interactive Communication:* Once a variable is entered, the result is available for analysis. This feature allows one to enter various values of a variable and analyze the change in the result (e.g., enter various C-factor values and look at the changes in the number of models and in the cost related to aerial photography).
- *Macros:* Macros are simply collections of keystrokes that can be called up with a single, two keystroke command. This is an important feature. It allows the user to reduce command entry time. It gives the user added control and flexibility in the use of spreadsheet.

CONCLUDING REMARKS

Spreadsheet programming is a powerful tool for photogrammetric related services. Programming knowledge can be acquired in a few hours. It is easy to work with and requires little programming experience. Worksheets can be debugged fairly quickly. Mathematical and logical statements can be formulated with minimal programming ability. Complicated formats can be designed and changed with ease and confidence. Choices of inputs and their values can be analyzed in a short time because a user can enter/change variables and their values while analyzing the results instantaneously. Furthermore, a spreadsheet program is inexpensive and can be used for other office work (e.g., scheduling or graphic display of data).

The above qualities of a spreadsheet program will certainly improve decision-making abilities of managers. Both company and clients will be benefitted substantially. For example, a marketing manager can advise a client on the cost difference between color and black-and-white aerial photography for a specific project on the telephone immediately.

REFERENCES

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