

CHAPTER 17

Project Planning and Cost Estimating

17.1 INTRODUCTION

Previous chapters have outlined and detailed technical aspects of photogrammetry. The basic tasks and equipment required to create various mapping products have been clearly noted. These tasks generally include aerial imagery collection, ground survey control collection, feature collection and attribution, and formatting the final spatial data. Further, the details regarding necessary equipment and product accuracy have been highlighted. Successful project planning and management must include a thorough understanding of these details. This chapter will provide guidance for the development of a set of specifications and a methodology to develop budgetary estimates of effort and cost to produce typical photogrammetric mapping data sets.

17.2 SPECIFICATIONS

Detailed project planning is the essence of an accurate effort and cost estimate. A quality specification need not be overly prescriptive, but it must include certain details: a description of what the spatial data collection is to be used for, a basic understanding of the required tasks and final products, and what will be required to define and collect them. [Figure 17.1](#) shows a flow chart providing an overview of these items. See Appendix A for a sample specification text along with an estimate for time and cost.

17.2.1 Project Description and Boundary

The project manager should briefly describe the intended uses for the spatial data to be collected. Engineering and design mapping may require some different collection methods than a product that is to be used for GIS environmental analysis.

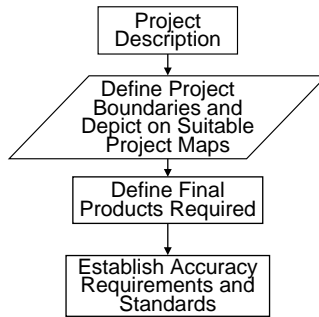


Figure 17.1 Flow chart providing an overview of quality specification for the required tasks and final products and what will be required to define a project design.

Table 17.1 Suggested Spatial Data Purposes vs. Map Scales

Intended Use of Spatial Data	Suggested Horizontal Map Scale	Suggested Contour Interval
Regional and general planning	1 in. = 1,000 ft to 1 in. = 2,000 ft (1:12,000 to 1:24,000)	10–20 ft
Environmental and real estate studies	1 in. = 400 ft to 1 in. = 800 ft (1:4,800 to 1:9,600)	4–8 ft (1.5–2.5 m)
Citywide and facility management studies	1 in. = 100 ft to 1 in. = 200 ft (1:1,200 to 1:2,400)	2–4 ft (0.75–1.5 m)
Detailed engineering design and layout	1 in. = 30 ft to 1 in. = 50 ft (1:300 to 1:600)	1–0.5 ft (0.5–0.2 m)

EXAMPLES

This photogrammetric mapping project is intended to be used for the facilities management and GIS analysis of the Oakville Industrial Complex. The project will include an area-wide planimetric and topographic mapping database along with digital orthophotography.

Large-scale mapping (1 in. = 100 ft to 1 in. = 30 ft) will require different photography scales and survey efforts in addition to a different feature collection criteria than small-scale mapping (1 in. = 1200 ft to 1 in. = 2000 ft). [Table 17.1](#) will assist in making a decision regarding an appropriate map scale.

The project boundary (limits) should be clearly defined. It is best to define the boundary as a line on a suitable published map with a measurable scale.

The project boundary is annotated by the polygon drawn on the copy of the USGS 7.5 ft Warrenton County, MO quadrangle. This project boundary map is considered part of the specifications for this project.

A USGS 7.5-ft quadrangle sheet is a common base map for a project boundary map. These map sheets are published at a scale of 1:24,000 (1 in. = 2000 ft) and are easily obtained at minimum cost from the USGS or other public sources. Projects involving large areas (i.e., projects that may cover portions of several USGS 7.5-ft quadrangle maps) may be depicted on other USGS map products such as 1:250,000 or 1:1,000,000 scale sheets.

The boundary map should provide a polygon indicating the maximum mapping limits. Stipulation of a buffer zone beyond the mapping limits should be avoided. Photogrammetric mapping firms generally provide a minimal buffer beyond the mapping polygon to account for any discrepancies due to inaccuracies in the base map and/or in defining the boundary polygon. However, the project manager should not count upon this buffer. A vague boundary leads to difficulty in estimating project requirements and costs. Some projects may call for a photography boundary that is larger than the mapping boundary. Additional boundaries such as this should also be clearly marked on the project map. [Figure 17.2](#) shows a typical boundary map.

17.2.2 Define Products

Clear definition of the products required for a project is mandatory and should be clearly understood in the initial stages of project planning and cost development. The costs and overall time required are dependent upon the delivery item requirements. Products may be divided into two groups: intermediate and final.

1. Intermediate products would include items such as:
 - Processed aerial film
 - Paper prints
 - Diapositives and/or scanned images
 - Ground survey control data
 - Project planning reports
 - Aerotriangulation reports
 - Check map sheets
2. Final products would include such items as:
 - Paper prints of aerial film
 - Hardcopy map sheets
 - Digital planimetric and/or topographic map data
 - Digital orthophotograph

EXAMPLE

The final deliverables for this project will include two sets of black and white 9 × 9 in. prints and one set of digital planimetric and topographic maps at 1 in. = 100 ft with 2-ft contours on CDROM.

17.2.3 Standards and Accuracy Requirements

Stating a required horizontal map scale and contour interval for a map is not sufficient alone to establish effort and cost. To truly design and estimate the effort required in collecting and presenting a set of spatial data products, horizontal and



----- Boundary

Figure 17.2 Sample project boundary map.

vertical accuracies must be stated. Several standards have been discussed in previous chapters, namely, FGDC, NMAS, and ASPRS. All three are widely accepted today. However, NMAS and ASPRS have been around for a longer period of time, and for some casual spatial data users they are more familiar. Regardless, it is imperative

in a successful specification to not only state the map scales required, but also to state the accuracy standard to which they will be held.

EXAMPLE

The planimetric and topographic mapping data produced for this project will meet ASPRS Class I accuracy standards for 1 in. = 100 ft with 2-ft contours.

17.3 PROCESSES

As previously stated, the project manager must understand the basic processes required to produce the final products requested. This understanding is necessary to ensure that the specifications and cost estimates include the necessary intermediate products required in the production of the final products and to evaluate and compare proposals. A project manager must be careful not to be too prescriptive in describing these processes so as to exclude new or the most efficient technology. However, some intermediate products may have other uses. For example, control survey points may be used for other projects such as construction of structures. It may then be necessary to request that the ground control be established as a permanent benchmark with several reference points and a concrete post with a descriptive cap on top. These types of requirements need to be spelled out in a set of specifications. However, the type of equipment to be used (brand and model) is not necessary.

EXAMPLE

Ground survey control points shall be collected for photogrammetric mapping. The mapping contractor will develop a ground survey plan that will produce the final mapping at the specified accuracy.

The processes for a typical photogrammetric mapping project generally include:

- Aerial imagery collection
- Ground survey control collection
- Densification of ground control through the use of aerotriangulation procedures
- Elevation data collection
- Planimetric feature data collection
- Final formatting of data sets

These functions should be noted in a set of specifications in order to develop an independent budget estimate of the time and funding required and to allow the project manager to truly compare proposals from several prospective contractors.

17.3.1 Aerial Photography

Aerial photography should indicate the following:

- Type of camera system (analog or digital)
- Type of film or sensor (black and white, natural color, color infrared, etc.)

- Negative scale of the imagery (i.e., 1 in. = 300 ft or 1:3600)
- Focal length and format of the camera (i.e., 6-in. focal length, 9 × 9 in. format aerial camera)
- USGS camera calibration within the time period of the last calibration (i.e., three years)
- Approximate altitude above mean terrain (AMT)
- Number of sets of paper prints and or scans

17.3.2 Ground Survey Control

The ground survey control process should note the following:

- Procedures that will produce survey locations with accuracy suitable to produce the final photogrammetric mapping reliability shall be listed.
- A ground survey plan shall be developed that will indicate control monuments used in the project, the approximate location of the proposed ground control points, data to be used for the project (both vertical and horizontal datums), and the proposed methods that will be used to establish their respective locations.
- Ground control point location information will then be tabulated, recorded, and marked on one set of paper prints (control prints) for future mapping.
- A final ground control report shall be prepared that compiles the results of the survey along with a narrative describing the procedures used, any problems encountered, and how they were resolved.

17.3.3 Densification of Ground Control

This process generally is accomplished through the use of aerotriangulation (AT) processes. The specifications should note whether analog or softcopy AT processes will be used. Analog AT will require the production of diapositives, and softcopy AT will require the production of scanned images suitable for softcopy AT. An AT report should be generated that indicates the methods used, expected results, final results, any problems encountered, and how they were resolved.

17.3.4 Elevation Model Collection

Elevation model collection guidance should define the purpose of the elevation model. Elevation models generated for contour production require more detail than those used only for orthophoto rectification. Elevation models for contour generation are generally produced by collecting mass points and breaklines to adequately define the surface. A surface model or TIN may also be required for software to use in the generation of contours. It is also very important to state the expected contour interval and accuracy standard.

17.3.5 Planimetric Data Collection

Planimetric feature data collection guidance may be divided into two categories.

Features are normally collected from aerial photo negative scale for a specific map scale. As a general rule, the larger the photo negative and map scale is, the more detail that can be seen, identified, and plotted. Generally, the specifications state that the photogrammetric technician shall plot all features visible and identifiable in the imagery.

However, some projects may require limited and/or very specific planimetric feature data collection (i.e., only water boundaries and major roads). Cases such as these may require that the specifications list the features to be collected and/or note the features not to be collected.

17.4 ESTIMATING PRODUCTION EFFORT AND COST

Project managers should prepare an independent estimate of the time and costs associated with a photogrammetric mapping project. This independent estimate will help assure that the products requested will be purchased at a fair and reasonable cost and will also allow the project manager the knowledge required to compare proposals and determine differences between them. These independent estimates must account for all significant phases of the project. A process is described in the following sections that will allow a project manager familiar with the basic processes as described in previous chapters in this text to develop a budget estimate of time and associated cost for a typical photogrammetric mapping project. New technology and unique project requirements may make this process not applicable. However, this section will present a generalized protocol that may help to guide cost estimates of most projects that require aerial imagery along with planimetric and topographic mapping that can fit the processes, and if followed closely a reasonable budgetary estimate of time and cost can be developed.

17.4.1 Estimating Factors

Three major considerations must influence the project's cost estimate: labor, equipment, and overhead and profit.

17.4.1.1 Labor

The involvement of qualified scientists and technicians is one of the most significant factors in the project cost. An accurate budget should estimate the time and unit cost for each required function. The amount of work required by various staff members is considered direct labor. For the purposes of this chapter, the staffing effort will be expressed in hours along with a unit cost per hour. Labor rates for most of the disciplines listed in this chapter can be obtained from local labor rate schedules and/or by consulting with other project managers in the area who have had similar work accomplished for them.

17.4.1.2 Equipment

Hardware and ancillary software associated with the various staff operations are also significant cost items to consider. As stated in earlier chapters, equipment such as aircraft, cameras, stereoplotters, and scanners can be very costly. The project manager should consult others who have had similar work completed recently for hourly costs for these items.

17.4.1.3 Overhead and Profit

Although these significant items may tend to be subjective, they must be considered as objectively as possible. Overhead and profit for photogrammetric mapping firms may legitimately be higher than many other engineering firms in the vicinity. As stated above, maintenance and updating of equipment, as well as the necessary staff to operate and maintain it, are expensive. Aerial photography and ground surveys are often affected by weather and access at the project site, so the risk may be greater than for some other design projects. Therefore, profit percentages may be more than those normally associated with other design projects.

17.4.2 Costing Aerial Photography

Many factors, including manpower and equipment rental, must be considered in estimating production hours in the aerial photo mission.

Production Hours for Aerial Photography
Direct Labor
Project mission:
Flight preparation = 1.5 h
Takeoff/landing = 0.5 h
Cross-country flight = miles to site \times 2 ways/mph
= _____ \times 2/ _____
= _____ h
Photo flight =
End turns = lines \times 0.08 h = _____ h
Photo lab:
Develop film = _____ photos \times 0.04 = _____ h
Check film = _____ photos \times 0.04 = _____ h
Title film = _____ photos/40 = _____ h
Contact prints = _____ photos/45 = _____ h
Equipment Rental
Aircraft = project mission hours = _____ h
Airborne GPS = project mission hours = _____ h
(if not included in aircraft rental)
Film processor = develop film hours = _____ h
Film titler = title film hours = _____ h
Contact printer = contact prints hours = _____ h

17.4.3 Costing Photo Control Surveying

The specified accuracy requirements will dictate methods and procedures (conventional and/or GPS) to be employed as well as indicate the number and pattern of control points to be established. A pre-project field survey plan should be conceived and thoroughly discussed with a licensed surveyor.

Photo control is often estimated either as an average cost per control point or with a detailed staffing and equipment estimate for the total project. In these cases it is usually fair to estimate these efforts and cost on a per control point method. Detailed estimates should be reserved for unique projects where the ground surveys will compose a large part of the total project cost. The project manager should consult with others who have obtained these products to get a current unit cost that is fair and reasonable.

17.4.4 Costing Aerotriangulation

Many factors, including manpower and equipment rental, must be considered in estimating production hours in the AT procedure.

Production Hours for Aerotriangulation	
Direct Labor	
Photo scan = _____ photos	$\times 0.3 \text{ h} = \text{_____ h}$
Aerotriangulation (workstation):	
Model orientation = _____ models	$\times 0.2 \text{ h}$
	$= \text{_____ h}$
Coordinate readings = _____ photos	$\times 0.3 \text{ h}$
	$= \text{_____ h}$
Computations = _____ models	$\times 0.4 \text{ h} = \text{_____ h}$
Equipment Rental	
Scanner = scanning hours = _____ h	
Workstation = aerotriangulation hours = _____ h	
Computer = computations hours = _____ h	

17.4.5 Costing Photogrammetric Compilation

For site-specific information, the following items are to be calculated, estimated, or measured to assist in the computing costs associated with digital mapping:

1. Number of stereomodels to orient
2. Number of acres to map
3. Complexity of terrain character
4. Complexity of planimetric culture
5. Format translations of digital data

Production Hours for Stereomapping

Model Setup

Model setup includes planning the collection procedures and georeferencing models in the data collection system. Analytical stereoplotters or softcopy workstations may accomplish data collection. Analytical stereoplotters will require diapositives, and softcopy workstations will require high-resolution scans. For additional explanation and detail, review portions of Chapters 5–10.

Model orientation = _____ models \times 0.1 hours = _____ h

Photo scan = _____ photos \times 0.2 hours = _____ h
(if not done previously)

Digital Data Capture

Planimetry (cultural features)

The project planning map used to outline the mapping area should be overlain with a proposed flight line layout. The flight line layout should note the approximate location of each photo stereopair. The planimetric feature detail in each of the models should be assessed based on the amount of planimetric detail to be captured (full or partial stereomodel and the final map scale) and the density of planimetry to be captured in each stereomodel. For example, highly urban area stereomodels require more time to compile than rural area stereomodels. [Table 17.2](#) will aid in estimating the production time required to produce the planimetric features.

Topography

The project planning map used to outline the mapping area should be overlain with a proposed flight line layout, which should note the approximate location of each photo stereopair. The topographic feature detail in each of the models should be assessed based on the amount of topographic detail to be captured (full or partial stereomodel and the final map scale). Topographic detail must consider the character of the land to be depicted. For example, a 1-ft contour development in a relatively flat terrain requires much less time than collection of 1-ft contours in very mountainous terrain. [Table 17.3](#) will aid in estimating the production time required to produce the topographic features.

17.4.6 Costing Orthophoto Images

Current technology allows for total softcopy generation of orthophotos (see previous chapters for more detailed information). If a contractor has collected the digital terrain mode with an analytical stereoplotter and created diapositives, then a clean set of diapositives will need to be made and scanned for orthophoto generation. However, if the contractor uses softcopy stereocompilation for the elevation model collection, then the same scanned images may be used to generate the orthophotos. The user must assume one method or the other in developing a cost estimate. The difference in cost should be negligible.

[Table 17.4](#) is a chart for estimating the production time required to produce topographic features.

17.4.7 Summary of Production Efforts

[Table 17.5](#) provides a summary of the production hours itemized above. Note that in addition to the total labor hours, an appropriate overhead should be established and applied to the total cost of labor. Also, an appropriate profit should be established and applied to the total of labor and direct costs. Ground survey requirements

Table 17.2 Chart for Estimating Production Time Required to Produce Planimetric Features

Planimetry				Approximate Planimetric Time (Hours/Model)			
Density Type	Models Per Type	Hours Per Type	Total Planimetry Hours	Final Map Horizontal Scale			
				1 in. = 40 ft to 1 in. = 60 ft	1 in. = 100 ft to 1 in. = 150 ft	1 in. = 200 ft to 1 in. = 300 ft	1 in. = 400 ft to 1 in. = 1600 ft
Light planimetry							
1				3.0	2.5	2.5	2.5
2				4.0	3.5	3.5	3.5
Medium planimetry							
3				5.0	4.0	4.0	4.0
4				7.0	6.0	6.0	5.0
Heavy planimetry							
5				10.0	8.0	7.0	6.0
Total planimetry hours							
Edit time: generally 30% of total planimetric compilation hours							

Table 17.3 Chart for Estimating Production Time Required to Produce Topographic Features

Topography (Topo) Collection of Mass Points and Breaklines for Production of Contours				Approximate Topography Time (Hours/Model)			
Terrain Character (Slope)	Models/Type	Hours/Type	Total Topo Hours	Final Map Contour Interval Scale			
				1 ft	2 ft	4 ft	5–8 ft
Flat				2.0	2.5	2.5	2.0
Rolling				4.0	4.0	4.0	3.0
Hilly				6.0	6.0	5.0	4.0
Steep				8.0	8.0	6.0	5.0
Disturbed				10.0	10.0	8.0	7.0
Total topo hours							
Edit time: generally 30% of total topo collection time							

Table 17.4 Chart for Estimating Production Time Required to Produce Orthophotographs

Orthophoto Production Costs (Direct Labor)				
Elevation Model (DEM) Development (Ortho Only) Developed by the Stereocompiler				
# Stereo Models	Hours/Model		Total DEM Time	
	2 h/model		(Stereo Models × Hours/Model)	
Tasks Below Accomplished by Softcopy Technician				
Natural Color and Color IR			Black and White	
	Hours/Image	Total Hours	Hours/Image	Total Hours
Image scanning	0.3			
DEM — scan data merge	0.5			
Radiometric correction	2.5			
Tiling/sheeting	0.25			
Total hours				

Table 17.5 Summary of Total Estimated Production Time and Costs for the Project

Photogrammetric Mapping Project Production			
	Hours	Unit Cost	Total Cost
Production labor			
Aerial photography			
Aerotriangulation			
Model setup			
Planimetry			
Topography			
Orthophotography			
Total			
	Units	Unit Cost	Total Cost
Direct costs			
Film		Foot	
Prints		Each	
Diapositives		Each	
Hardcopy prints		Each	
CDs, disks, or tapes		Each	
Aircraft w/camera		Hours	
Stereoplotter		Hours	
Softcopy workstation		Hours	
Edit workstation		Hours	
Scanner		Hours	
Total direct cost			

established should also be added to the total costs below. [Table 17.5](#) provides a summary of the total estimated production time and costs for the project.

By applying wage rates to labor hours and equipment rental to equipment hours the estimator can arrive at project budgetary costs. To support the process of estimating production hours of various photomapping phases, the estimator of a project is urged to seek current labor and equipment rates more applicable to a project or geographical area, perhaps using regional wage rates and actual negotiated contractor rates from recent or current contracts.