THE COST AND BENEFITS OF SOFTCOPY PHOTOGRAMMETRIC PRODUCTION

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ABSTRACT

A fundamental question in the conversion of film-based mapping operations into end-to-end digital production is its economic viability in terms the initial capital and projected returns from investing in such conversion. This requires a clear understanding of several issues, such as cost, workload, and profitability. This paper evaluates a methodology for cost and benefit analysis of introducing end-to-end softcopy production. The methodology is applied with a specific set of variables, assumptions, and a forecasting risk that is within acceptable limits. The continued developments in geospatial technologies, and the increasing value (declining cost and rocketing performance) of hardware and software, are key to sustained shift toward softcopy operations. The growing margin of the benefits resulting from this shift over its cost is bound to make the conversion more favorable.

1 INTRODUCTION

The primary question in the conversion from film-based operation into end-to-end digital production is no longer whether softcopy technology is superior or not. Rather, the primary question is whether softcopy technology is economically viable in terms of the cost and benefit for photogrammetric mapping. This is demonstrated by the fact that a large segment of the private sector in the photogrammetric service industry is moving cautiously in investing in softcopy systems. This caution is justified for several reasons. Unlike the case with analytical plotters (Chamard, 1980; Lafferty, 1973), there is still a need for solid evidence to support the cost effectiveness of softcopy production over conventional operations. On the contrary, there is a general perception that if based on purely financial terms, it is unclear how to weigh the cost and benefits of softcopy conversion. In addition, photogrammetric production firms have already invested considerable resources in stereoplotting equipment, photographic laboratories, and operator training. Furthermore, introducing a new production system and the conversion of procedures will certainly pose several difficulties that may disrupt cash inflow. Continuous software upgrades and version releases exasperate this problem.

The economic potential of softcopy photogrammetric production needs to be assessed in an objective manner to demonstrate that this technology is a viable alternative worthy of investment (Corey et. al., 1999). This paper presents a methodology for cost and benefit analysis of softcopy systems, compared with conventional analytical plotters. This is a revised version of same approach in Saleh and Worden (1999). The revision includes improvement in the estimates of future cash inflow; dropping the 3 year depreciation option; and modifying systems prices. These revisions are opted to address the market in other developed as well as developing countries. It remains critical, however, to recognize the sensitivity of the analysis to first, the cost of systems, and second, the estimates of future cash inflow.

2 TECHNOLOGY FACTORS AND SYSTEM SELECTION

With most photogrammetric firms, like any other profit-driven business, the decision-makers often face the task of identifying investment opportunities that are worth more to the firm than their cost. Investments must be clearly justified, either in overall valuation of business, or in cash inflow increase, thereby realizing net profits. The first goal is influenced by factors such as public offerings, corporate strategic planning, marketing, and financing. These factors deal with the acquisition in the context of solidification of business assets. This is indirectly connected to the specific technology at hand, which in this case is softcopy photogrammetric system. Decision-making on capital investments for business valuation is rather beyond the scope of this paper. The latter goal is dependent on the system selected, amortization, workload and cash inflow, as well as other factors. This section addresses cost-related issues and the economics of systems under consideration.

The commercial market is saturated with softcopy systems that vary in functionality, performance, efficiency, as well as cost. This wide spectrum of softcopy technology compels businesses to focus only on systems that address the stated goals of expansion or conversion. These may include map revisions, digital elevation models, digital ortho production, etc. Two categories are suggested to represent opposing extremes in commercial softcopy systems. These two categories are coined, for the sole purpose of this discussion, as base-line systems and high-end systems.

A base-line system is one that consists of the bare-essential required tasks for end-to-end digital photogrammetric production. These include interior orientation, point transfer, mensuration, measurements, aerotriangulation, and collection of surface data and linear features. Moreover, the functionality must include other tasks that are specifically required as a result of the digital environment, such as image importing and epipolar resampling. The general task requirement for end-to-end digital production is listed in Table 1, first column under the Function heading. A base-line system can provide a balance between price range and performance, hence an overall value. Such a system may mitigate the impact on skilled photogrammetric operators during the conversion from conventional environment into softcopy production. This is due to the fact that the mode of operation, i.e., the manual photogrammetric tasks, remained virtually the same as in conventional environment. The price for a complete system in this category is assumed to be about $50,000.

High-end systems, on the other hand, offer automation in labor-intensive tasks, such as aerotriangulation and surface generation. Inexpensive, powerful computing hardware has enabled tremendous possibilities for efficiency and speed through automation. The price for a complete high-end system is assumed to be about $100,000. In addition, the cost of new analytical plotters is included in this analysis with a price range of $100,000 to $120,000. It should be noted that refurbished used plotters are also available and popular in the commercial market, with a price range of $35,000 to $50,000. Used analytical plotters are not included in this analysis.

Function	Low-End	High-End
Interior Orientation	*Operator-Driven*	*Automated*
Point Selection	*Operator-Driven*	*Automated*
Point Transfer	*Operator-Driven*	*Automated*
Point Measurement	*Operator-Driven*	*Automated*
Aerotriangulation	*Operator-Driven*	*Automated*
Exterior Orientation	*Operator-Driven*	*Semi-Automated*
Surface Generation	*Operator-Driven*	*Automated*
Surface Editing	*Operator-Driven*	*Semi-Automated*
Vector Extraction	*Operator-Driven*	*Semi-Automated*

Table 1, Functions and Modes of Operations for Softcopy Photogrammetric Systems.

The initial cost of these systems is summarized in Table 2. The total initial capital consists of the cost of equipment and the net working capital for the first year. This is estimated at $20,000. The actual implication of initial cost is influenced by the depreciation period. Relevant depreciation rules and taxations on the specific country must be applied. Defining the lifetime of the system and depreciation is essential for calculating the total initial capital, working capital, operating cash flow, etc. For the purpose of this analysis, the U.S. tax law is used only as an example. U.S tax laws dealing with depreciation of computer hardware and software dictate 5 and 3 years basis, respectively. This is critical because of the many commercial softcopy systems ranging between hardware and software. In this paper, only 5 year period is used, and the annual depreciation is calculated using a straight-line method. This applies to both softcopy systems and new analytical plotters. The resulting cost effectiveness is expressed using the equivalent annual cost (EAC) for each capital investment, as shown in Table 2.

Investment	Initial Cost	5 Year EAC
Base Line Softcopy	**50**	**23.4**
High-End Softcopy	**100**	**40.1**
Analytical Plotter, I	**80**	**33.4**
Analytical Plotter, II	**120**	**46.8**

Table 2: Initial Cost and Equivalent Annual Cost, EAC, in $1000

The EAC determines present value of initial cost calculated on annual basis throughout the system's lifetime, using a 20 percent annual rate of return. This rate is used in view of the alternative options available in the investment market. The challenge facing photogrammetric firms for any new investment is maintaining continuous cash inflow, high enough to recover the EAC. To factor this cost into billing rate structure, the EAC is expressed in terms of the corresponding hourly basis. Table 3 lists the cost per hour for each alternative with one shift per day for low workload, and two shifts per day for high workload.

Investment	One Shift	Two Shift
Base Line Softcopy	**12.2**	**6.1**
High-End Softcopy	**20.9**	**10.4**
Analytical Plotter, I	**17.4**	**8.7**
Analytical Plotter, II	**24.4**	**12.2**

Table 3: System Usage Cost Per Hour ($) Based On 5 year EAC with 1 and 2 Shift Workload

The cost per hour of equipment usage is then considered in the context of the billing rate the firm charges. For example, a high-end softcopy system costs about $20.9 in one-shift workload and $10.4 in two-shift workload, based on 5 year lifetime of service. If the billing rate is $75.0 per hour, then the system will cost about 28 % and 14 % of each billable hour, respectively. The corresponding cost ratios for a baseline system are 16 % and 8 %, respectively. These cost ratios should be weighed in the context of potential workload. If workload is expected to require only one shift, then the cost of the system will constitute a higher portion of the billing rate. When comparing among softcopy options, this may expedite a decision in favor of a base-line system. However, because high-end systems offer automation capabilities, there is the potential to save, rather substantially, on expensive production labor time.

3 COST/BENEFIT ANALYSIS OF SOFTCOPY PHOTOGRAMMETRIC SYSTEMS

The task of defining profitability is rather problematic, because of the many variables that depend on future estimates. Although they could be realistic at the time, workload may or may not be realized. The validity of the analysis is as good as the estimate. Market research is usually one source for future projections. If projections are erroneous however, it does not matter how sophisticated the analysis tools are, or how the numbers are arranged. The results will be grossly misleading. The possibility that a bad decision is made because of erroneous projections is called *forecasting risk*. There are tools to assess the reliability of cash flow forecasts, such as sensitivity analysis, what-if scenarios, etc., which are beyond the scope of this paper. In addition, when the forecasting risk is within acceptable limits, multiple profitability techniques are employed in examining returns and cost effectiveness of proposed investment alternatives.

Another difficulty is that profitability of acquiring a new softcopy system is weighed against an operational analytical plotter. The decision hinges, in this case, on whether the savings with the new system outweigh the cost of investment. This problem can be mitigated if the salvage value of decommissioned plotter is factored as a deduction from the initial capital. This problem is further mitigated when there is a definite need for expansion or replacement of aging existing equipment. The task then becomes deciding between two mutually exclusive choices.

3.1 Estimating Cash Flow

There are many variables that determine the estimated annual cash flow, most of which are subjective. In this paper, assumptions are made to fit a typical decision making scenario. This is based on 240 single shift production days per year, and a billing rate of $75.0 per hour. There is also fixed and variable cost associated with production operations. The fixed cost is required for the mapping services to exist, regardless of production. This means that fixed cost will still accrue even if there is no production. Variable cost on the other hand varies depending on production volume. Annual cash outflow is assumed in this analysis, however, to be consistent throughout years of service. This is justified since the mapping firm succeeds in maintaining the target sales volume. The total cash outflow is estimated at $20,000 per year. Based on these variables, particularly the single shift assumption, the resulting net annual cash inflow is about $124,000 as shown in Table 4.

The cash inflow from larger billable workload is determined by multiplying this amount by the number of daily shifts. For example, the net cash inflow is $248,000 per year if the firm maintains two daily shifts of billable work. Although estimated future net cash inflow is independent of technology selected, higher end systems can sustain higher workload, thanks to automation. Same cash inflow will be used however in both options.

Working days per year	**240**
Production shifts per day	**1**
Billable hours per shift	**8**
Billing rate, $ per hour	**75**
Cash inflow in $K per year	**144**
Cash outflow (fixed + variable) in $K per year	**20**
Net cash inflow in $K per year	**124**

Table 4. Estimating Annual Net Cash Inflow

3.2 Measuring Profitability

The task is to evaluate the investment in softcopy system by comparing it with that in an analytical plotter. Thus, each of the two investments must be weighed against its projected future returns. The critical variable is the discounted cash flow, which is the present value of future returns based on a target rate the investment must achieve. The discounted cash flow, in other words, is the present value of future net profit that is generated as a direct result of the capital invested in softcopy production capability. As mentioned earlier, this analysis adopts a 20 percent annual rate of return. The discounted present value of net profits from future sales of services is hence weighed against the initial capital. The difference between discounted cash flow and the total initial capital is called the net present value (NPV). The total initial capital consists of the cost of equipment and the net working capital. The cost of equipment is the average value for each option from the earlier section; an average cost of $110,000 for a new analytical plotter, and an average of $75,000 for PC-based softcopy system. To calculate the net future return option for each investment, needed variables are quantified for this analysis. They are summarized in Table 5.

Variables	Analytical Plotter	Softcopy System
Investment Rate of Return	**20%**	**20%**
Average Equipment Cost, $K	**100**	**75**
Depreciation Period, years	**5**	**5**
Straight Line Depreciation, $K/year	**20**	**15**
Tax Rate	**34%**	**34%**
Net Income, $K/year	**53**	**56**
Net Working Capital, $K	**20**	**20**

Table 5. Variables for Evaluating Investment Options.

The task at hand is to estimate the annual net cash flow for each of the three options based on the above assumptions as well as on the corresponding annual net working capital. The annual net cash flow values, listed in Table 6, are calculated using commonly known finance procedures. Table 6 shows starting year's net return with a negative value, simply because this is an outflow, not inflow. This outflow consists of the cost of equipment plus net working capital for start-up year, $20,000. These figures are sufficient to determine the investment that yields the highest positive NPV. Negative INPV means that the present value of estimated future return is less than the total initial capital. In general, this indicates the investment is undesirable.

Investment	**Years**						**NPV**
	0	**1**	**2**	**3**	**4**	**5**	
Softcopy System	-95	87	87	87	87	107	**126**
Analytical Plotter	-120	89	89	89	89	109	**106**

Table 6. Estimated Annual Cash Inflow and the Resulting NPV, all in $1000.

This decision, however, is very dependent on the estimated future cash inflow. The validity of the decision is, hence, as good as the reliability of the estimate itself. So far, specific variables have been defined with reasonable accuracy, such as initial capital, depreciation, and net working capital. On the other hand, the estimate of future cash inflow may, or may not, be realized, depending on sales the mapping firm makes. As a result, multiple criteria are presented to discern most profitable among proposed capital investments.

One measure that is closely related to NPV is the internal rate of return (IRR). This measure is defined as the discount rate that generates a present value of future net cash flow that is equal to the initial capital. Consequently, the IRR is a rate of return that results in a zero NPV of an investment. Another measure is the discounted pay back period - the duration at which the total of the discounted cash flows becomes equal to the future value of initial capital. A proposed investment is deemed acceptable only if its discounted payback is realized within predefined time. Positive net cash inflow beyond the payback period is profit. These measures are applied to Table 6 and the results are shown in Table 7. In examining the table, the IRR leads to the same decision made earlier based solely on NPV. The EAC too leads to the softcopy system as the most cost-effective choice.

Investment	**Profitability Measures**			
	NPV ($K)	IRR %	DPB (Yr)	EAC ($K)
Softcopy System	**126**	**0.71**	**1.71**	**32**
Analytical Plotter	**106**	**0.55**	**2.19**	**40**

Table 7: Comparison of Multiple Profitability Measures

With multiple profitability measures, a decision can be reached on the system that would ensure the highest return on investment. It should be emphasized that the validity of the analysis is as good as the estimate. How sophisticated the analysis tools are is rendered irrelevant if projections are erroneous.

Based on the above estimates of future cash inflow, the decision is clearly in favor of softcopy technology. The adoption of softcopy photogrammetric production necessitates a reliable and cost-effective source of digital imagery. There are various data sources available for photogrammetric operations, (Spradley, 1994). Cost-effectiveness of the various imagery sources can be examined in view of the mapping scale and the specific applications of the firm (Foley, 1993; Saleh and Jaafar, 2000).

4 CONCLUSION

There is a sustained shift from conventional film-based production toward softcopy operations. An important question though has not been fully addressed: how to assess the economic viability of this shift in terms of its cost and projected returns; is the substantial cost of investment justified?

This paper has presented a cost and benefit analysis methodology for the cost associated with the conversion into softcopy production. The methodology is applied with a specific set of variables. These variables, some of which are interdependent, include equipment cost, depreciation, overhead, anticipated workload, future cash inflow, and discount rate. The candidate system and the depreciation period affect future cash flow and net profit. These define profitability of the conversion, which is critical for the firm's strategic planning.

The outcome of the analysis is closely dependent on the variables. As a result, the validity of the analysis is as good as the estimated values. Furthermore, the associated forecasting risk for the variables must be within acceptable limits. With this in mind, the analysis has shown that investing in softcopy systems provide higher net present value than investing in new analytical plotters.

In addition, the decline in hardware cost and the utilization of automation capabilities are both compelling factors in making a decision in favor of softcopy systems. Developments in geospatial technologies may result in drastic changes in how the photogrammetric process is executed. These include airborne GPS and automated aerotriangulation (Ackermann, 1999); digital aerial cameras (Rosengarten, 2000); and automated feature extraction (Förstner, 1999). The growing margin of the benefits resulting from this shift over its cost is bound to make the conversion more favorable.

REFERNENCES

Ackermann F., 1999. Geo-Coding of the Baltimore County GIS Project by GPS Supported and Automatic Aerial Triangulation. Third Turkish-German Joint Geodetic Days, June 1-4, Istanbul, Turkey.

Chamard R., 1980. Cost of Aerial Triangulation Using Analytical Plotters, Proceedings of the Analytical Plotter Symposium and Workshop, Reston, Virginia, April 20-25, pp. 225-229.

Corey M., Kirwan R., Walker A., 1999. Ordnance Survey Ireland and its Transition to Digital Photogrammetry. Photogrammetric Engineering & Remote Sensing, Vol. 65, No. 3, pp. 218-226.

Foley B. L., 1993. Past, Present and Pricing of Orthophotos, Proceedings of the International Society for Optical Engineering, State-of-the-Art Mapping, Orlando, Florida, April 13-15, pp. 242-245.

Förstner W., 1999. 3D-City Models: Automatic and Semiautomatic Acquisition Methods. In Photogrammetric Week '99, Eds. D. Fritsch, R. Spiller, Wichmann, Heidelberg.

Lafferty M. E., 1973. Accuracy/Costs with Analytics, Photogrammetric Engineering, Vol. 39, No. 5, May, pp. 507-514.

Rosengarten H., 2000. http://www.ziimaging.com/ZI/Corporate/News/OtherDocs/47thPhoWkFAQ.htm (March, 2000)

Saleh R., Jaafar M., 2000. Economics of Image Acquisition Alternatives for Digital Photogrammetric Production. International Archives of Photogrammetry and Remote Sensing, Amsterdam, Vol. 32 (B2/7).

Saleh R., Worden K., 1999. The Economics And Cost Recovery Of Softcopy Photogrammetric Systems, proceedings of the ASPRS Annual Conference, Portland, Oregon, May 17-21, pp. 814-823.

Spradley L. H., 1994. Cost-Effective Data for Regional GIS Bases, International Archives of Photogrammetry and Remote Sensing, Vol. 30, Part 4, Athens, Georgia, May 31-June 3, pp. 203-208.