Digital Topographic Maps: Production Problems and their Impact on Quality and Cost

J. Raul Ramirez
Center for Mapping, The Ohio State University, Columbus, OH 43212

ABSTRACT: Today, many mapping companies have adopted digital methods for producing topographic maps. Most of these companies were not fully prepared for the change from conventional manual methods to computer-controlled methods. As a result, few companies have realized the economic success they expected. This paper analyzes some common problems found in the production of digital topographic maps and their impact on quality and costs, and presents some suggestions for solutions to these problems.

INTRODUCTION

DIGITAL METHODS OF MAP PRODUCTION have been adopted by many in the mapping community. This is the result of a trend which started in 1976 at the XIII International Congress of Photogrammetry with the introduction of several commercial analytical plotters (Helava, 1977). This trend included the development of commercial Digital Mapping Systems (DMS), and an enormous improvement in performance and cost of computer hardware.

The initial enthusiasm generated by the use of this technology has been replaced by a more cautious attitude based on the experience of the past years. Experience has shown digital production of topographic maps is not a simple process, as previously claimed by most DMS developers, and that the levels of skill required by individuals in various production stages is higher than what was initially anticipated.

In the next section, some problems related to the adoption and use of digital mapping methods are discussed. This is followed by a discussion of their impact on map quality and cost.

PROBLEMS RELATED TO DIGITAL TOPOGRAPHIC MAPS

There are two different set of problems: (1) problems in adopting the new technology (Ramirez, 1988) and (2) problems in the production of digital topographic maps. These problems are discussed in the following paragraphs.

PROBLEMS IN ADOPTING THE NEW TECHNOLOGY

The first difficult change that most commercial mapping companies have faced in the adoption of digital topographic methods is the use of computers. In the past, computers have been used in the mapping environment in a limited fashion; usually to perform batch computations such as phototriangulation or volume computations. These tasks required very little knowledge of computer hardware, operating systems, and the management of computer resources from the perspective of the mapper. Frequently, one or two individuals within a mapping company were involved in the use of computers and they provided assistance to other company personnel.

The use of analytical plotters and especially DMS has completely changed this situation. Today, most of the mapping company's staff (photogrammetric compilers, drafting personnel, supervisors, sales persons, and managers) are involved in the use and applications of computers. These people have progressed from the use of conventional analog methods to computer-aided methods, without any formal computer training. Most of them have been trained "on the job," usually by trial and error methods.

The first complication emerges with the initial decision of adopting computer-aided technology. Questions such as: What kind of computer? What size of hard-disk?, How much memory?, What kind of plotter?, What kind of back-up device?, and What operating system? need to be answered in order to build a system appropriate for the actual and future needs of the company.

In general, there is no one in a given mapping company qualified to answer all these questions and, therefore, it is necessary to rely on outside help. This outside help generally comes from sales individuals who help the mapper as much as possible, but who are constrained by their limited knowledge of the specific needs of the company, by the difficulty in communication due to the lack of a common technical language, and by the product they represent.

The limited knowledge is due to their unfamiliarity with the everyday needs of a particular company. No two mapping companies have the same needs because each have different clients' requirements, equipment, personnel, and capabilities. The lack of a common technical language occurs because there is not yet a standard set of terms used in digital mapping. Therefore, it is very difficult to discuss DMS capabilities and performances in terms that are understood by everyone. In many cases, even long-time established computers terms such as operating system, peripheral devices, etc., are unfamiliar to the mapper. The product represented is a limitation because it is what a sales person can offer.

Finally, the mapper chooses a particular system and generally it is fortunate if this DMS satisfies *all the needs of his/her company*.

The second major problem arrives with the installation of the new system and the training. Installation and training are major problems, especially when no photogrammetric instrument is included as part of the DMS purchased. This problem occurs because production needs to be suspended or decreased to allow installation and training, which usually causes many inconveniences for the mapping company. Most DMS manufacturers usually install their systems in less than one day, unless unexpected problems are found. After installation, the photogrammetric instruments need to be used for training which could take from three to five days.

When the installation includes photogrammetric instruments, additional installation time is needed to set, test, and calibrate the plotters but, in general, this does not disturb production. Also, the new instruments can be used for training and, therefore, production is not affected as much.

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It is very important to select the right time for the installation of any DMS, but this is not an easy task. One reason is the fact that aerial photographs, the basic material for most mapping products, can be obtained only under favorable weather conditions. Any delay in obtaining the photos may disrupt the production schedule for several weeks or even months and thereby ruin any hope for an "ideal time" for installation and training.

The third major problem is the expectation by the mapper of an immediate achievement of high production from the DMS. Several factors contribute to this misleading idea. Two of the most common factors are (1) the lack of understanding about the complexity of digital mapping and (2) the false notion that a DMS can be mastered in a week or so.

The reality is different: *digital mapping is a complex operation and DMS takes time to learn and to master*. The planning and the execution of digital mapping projects are very involved tasks, very different from conventional analog map production. Sometimes the only way to master them is by trial and error, a potentially costly and slow process.

Some of the major differences between conventional and digital mapping originated from the nature of these processes. For example, analog maps are drawn on a tangible, permanent material. Digital maps do not have a permanent tangible representation; only their coordinate values and attributes have a permanent representation in computer files, and this representation cannot be seen, touched, or taken home. These types of differences set digital mapping apart from analog mapping.

Learning to use a DMS is not a simple task. Experience has demonstrated that a period of six to twelve months is a more realistic estimation of the time needed to become proficient with the operation of a DMS.

Problems in the Production of Digital Topographic Maps

Four major problems are encountered: development of a cost-efficient methodology, management of digital files, digital data exchange, and the pricing of digital maps.

Development of a Cost-Efficient Methodology. This is a major problem in the production of digital topographic maps. Without it, the financial future of any mapping company will be unclear. Some of the factors considered in the development of such methodology include data collection techniques, editing during data collection, quality control, editing in general, model connection, and map sheet generation.

Photogrammetric data collection for the production of digital topographic maps is quite different from analog data collection. To understand the difference, it is necessary to realize that in analog map production, planimetric and altimetric features are collected in the same fashion. Linear and area features are outlined by segments traced with the pantograph; symbols are indicated by their position and a label or a free-hand drawing; and labels are placed by free-hand writing. The compiled map is just the BASE MAP which will be redrawn by drafting personnel in order to produce the final map.

On the other hand, planimetric and altimetric features are collected in a different fashion in digital mapping. Generally, planimetric features are collected by the end points of their segments and the lines between them are generated by the DMS as they are displayed on the final map with the proper line weight, line type, and line symbol. Corner intersections can be drawn automatically at ninety degree angles, polygons can be closed, arcs and circles can be generated, symbols are drawn automatically by collecting them at their origin, and text can be placed exactly as it would appear in the final map.

Collection of contours in digital mapping is usually done in "automatic mode" by setting some rejection factors. Examples of these rejection factors are distance and slope differences. Automatic mode means that after the mapper starts the collection mode the system collects a point every time some conditions, defined as a function of the selected factors, are fulfilled. For example, the system collects a point every time the distance between the previously collected point and the actual position of the floating mark is greater than or equal to the defined distance, or the slope difference between the vector defined by the two previously collected points and the last collected point and the actual position of the fiducial mark is greater than or equal to the angle set as a rejection factor.

The major problem with data collection *is the amount of data generated*. Regardless of the DMS employed, the greater the amount of data collected, the slower the system becomes. Generally, the major source of data are contours. This is the factor that makes the treatment of planimetric and altimetric features different in digital mapping. A major priority in digital mapping is the minimizing of the contour data.

Editing during data collection is a major concern in digital mapping. The question that must be answered is: How much editing, if any, should be done by a photogrammetric compiler? Several factors need to be understood in order to answer this question. In the subsequent lines, some of the most important factors to be considered are mentioned.

- A compiler's time is usually more expensive than an editor's time.
- Editing is very distracting for a compiler because his/her attention is removed from the stereo-model.
- Editing by the compiler restricts the photogrammetric instrument (limiting its production).
- There are mistakes that are not easy to locate after the whole model is collected but that can be corrected as soon as they are made, with little effort.
- Some mistakes can be fixed only from the photogrammetric instrument. The editor does not have the means to correct them and, therefore, the model needs to be reset.
- Some editing operations are more efficient with few data and they perform better during data collection than after all the data are collected.

It is not easy to decide how much editing, if any, should be done by the photogrammetric compiler. Usually, this decision should be made for each project. This is the type of decision that could greatly affect the overall cost of map production.

Quality control is a very important step in digital map production. Generally, this is done from a hard-copy of the digital map at the deliverable map scale. One of the major problems in performing quality control is to select corrections that can be made in a cost-efficient fashion. From this point of view, it is necessary to understand that evaluating a digital map is different from evaluating an analog map. Of course, any mistake which affects the accuracy of the map (in agreement with the given specifications) must be marked for correction, regardless of its cost.

Editing, in general, is a time consuming and costly operation. Some of the major problems of editing are

- Use of the proper map scale for editing. Digital maps are made to fulfill certain accuracy standards. Editing must be done at that specific map scale in order to minimize the amount of work.
- Segments replacement. This is usually a very computer-intensive operation which includes partial deletion, data collection, and segments connection. It is very important to minimize the execution of this operation.
- Screen updating. This operation changes the display on the graphic screen (to show a larger or smaller area or a different part of the map). It is a time consuming operation that must be eliminated as much as possible.
- Errors location. This operation locates and displays, on the graphic screen, a feature that needs correction. This is time consuming and needs to be organized as efficiently as possible.

Model connection is the operation that allows tracing a digital map as a continuous unit across different photogrammetric models. The major problems of model connection are in deciding when and how to connect adjacent models. There are several options. For example, after a model is collected, it is possible to extract its common area with the next one, to create a new file with the common area, and to use that file to collect the new model. Another option is to display the previous model as a reference or auxiliary file and to collect the new model using the display as a reference for continuation. Another possible option is to collect each model independently and have a batch program available to connect adjacent models.

Map sheet generation is a step which is only needed when hard-copy maps are to be delivered as part of a project. The major problem is similar to the one for model connection–when and how to generate the map sheets. There are two basic options: (1) before model editing and (2) after model editing. This step is different from map sheet plotting.

Managing of Digital Files. The second major problem in the production of digital topographic maps is the managing of the digital files. There are two different aspects to be considered:

- How to safeguard, backup, and retrieve those files; and
- How to maximize digital map production.

The first aspect is related to the problem of protecting valuable data during and after map production, and then to retrieve those data at any moment in an efficient way. Questions such as: How to control access to the data?, How frequent to perform data backup?, etc.?, need to be answered. The second aspect is related to the efficient use of digital data in the process of map production. Several problems need to be solved including: What is the optimum size of digital files?, When should digital files be merged or divided?, What is the most efficient approach to manipulate data?, When should planimetric and elevation data be collected in different files?

Digital Data Exchange. The third major problem in digital mapping is the exchange of digital information (Ramirez, 1988; Ramirez, 1989). A contemporary problem is that digital data cannot be exchanged directly among different DMS or different Computer-Aided Drafting (CAD) systems. This problem has generated the need for translators. These translators are computer programs that take a specific set of digital files generated with a DMS and then generate a second set with the proper format of another DMS. The selection of efficient translators and the development of a cost-efficient methodology for data exchange are the two major items to be solved.

Pricing of Digital Maps. The fourth major problem in digital map production is pricing. There are two aspects to be considered. The first one is inexperience on the part of the mapper. As indicated earlier, mappers were not involved with computers in the past. Also, the mastering of the new technology has been a long process, and digital map production is a complex process. Very few companies have developed a complete cost-estimation methodology for digital map production today, although many are working on it. As a result, digital maps have been priced in a similar manner as conventional analog maps. Companies have learned that this is a mistake. The second aspect is the inexperience of the end user. It is a fact that many people are ordering digital maps without having a real need for them. These people are using only the hard-copies generated from the digital map. For them, the value of a digital map is not greater than the value of an analog map, and they expect an equivalent cost for it.

IMPACT OF THESE PROBLEMS ON MAP QUALITY

Map quality is still the most important consideration in the production of topographic maps regardless of the method used. The problems discussed in the previous section have a major impact on the quality of digital maps. This impact is discussed in the following paragraphs.

The lack of a cost-efficient methodology for production of digital topographic maps may ultimately affects their quality, if the cost of the production of digital maps is higher than the adequately estimated cost. If this is the case, the company may need to minimize its loss by cutting corners. This will affect the overall map quality.

As an example of the quality issue, we will discuss the production of contours by digital means. As indicated earlier, digital contours generate an enormous amount of data. Alternative methods, such as contour interpolations (Digital Terrain Models, Linear Interpolation), and contour digitizing from hardcopies are sometimes used to minimize production costs. Interpolation methods can be used in some areas without affecting the overall map quality. However, it is not possible to use them all the time as an alternative to direct contour generation without jeopardizing the accuracy of the map. Contour digitizing from a hardcopy map is a very inferior alternative to direct contour generation due to the low accuracy of table digitizers, compared to the accuracy of photogrammetric instruments. Its use will greatly affect the quality of a digital map. If any of these methods are used indiscriminately with the purpose of decreasing production costs, the quality of the maps would be affected.

The lack of a proven methodology affects the map quality too. For example, the collection of contours in "automatic" mode requires the selection of parameters, such as distance and angle, appropriate for each map scale. The wrong definition of those parameters would produce contours with the wrong resolution–too little or too many points. This is not only true for contours but for any other cartographic features, such as roads, water lines, etc., collected in the "automatic" mode. Another way the lack of a proven methodology can extensively affect map quality is if operations such as quality control and editing are not coordinated properly, because errors can be left uncorrected.

Poor managing of digital files has a major impact on the quality of maps. As indicated before, digital maps are just temporal representations. The only "permanent data" are the coordinates and attribute definitions of the cartographic features which are stored in computer files. On the other hand, to change these data either by intention or accident is very easy, but to detect these changes could be very difficult.

Any undetected accidental change affects the quality of the map. To further complicate the situation, there are usually several copies of a file and several individuals involved in the production of a map. If, for example, the map is compiled by a person and edited by another, it may be necessary to transfer a copy of the original file to another computer, or copy it to another directory for editing. Then, there are at least two copies of the same file and at least two persons involved in the production of that map. If, after editing is done, those files are misplaced, the unedited file could be used, by mistake, as the final map. Any error in the identification of the current file (where the latest version of the map data is kept) will affect the overall quality of the map.

Another consideration of the implication of the poor management of digital files is the fact that *digital maps are supposed to be used over a prolonged period of time.* One of their major advantages, for example, is that they allow partial updating. If there is the need to update an area of a map, it is sufficient to collect the data for the area to be modified and merge them with the old digital map. For this or similar reasons, a mapping company may need to retrieve digital files generated five or ten years ago. Any error in retrieving the appropriate files will affect the quality of the new map.

Digital data exchange can effect the quality of a map due to different facts such as limitations of the DMS (the one where the map was made, or the one where the map is transferred); translator limitations or errors; and errors in data exchange (in transferring the files from one computer to another). Some of these errors can be prevented by having a consistent and proven methodology for data exchange. Some of these errors cannot be prevented and it is up to the end user to check for consistency in the map.

Poor pricing of digital topographic maps is a major hazard to the quality of a map. The effect of poor map production's methodology on map quality was discussed. It was assumed there that the pricing of the cost of map production was right but the method poor. Here the situation is reversed. The cost of map production is calculated incorrectly. Even if there is a cost-efficient methodology for production of digital maps, the actual cost will be different than the calculated one. In reality, the situation seems to be even worse. In many cases the price is calculated wrong and there is no cost-efficient methodology for map production. This is the worst possible situation.

The effect of poor pricing in map quality is unpredictable. It may not affect it at all if the mapping company is willing to assume the loss generated by the extra cost, or it may affect it enormously if the company wants to minimize or eliminate the loss.

WHAT NEEDS TO BE DONE

In order to protect the quality of digital maps, it is necessary to increase the level of understanding about the complexity and capability of digital maps by the mapper and the end user. It is obvious that digital maps have a tremendous number of advantages over conventional analog maps. Some of them include

- Generation of different types of maps from the same data, such as planimetric maps, road maps, and contour maps.
- Partial map update by allowing the combination of portions of the old map with the new one;
- Generation of maps at different scales by not only allowing the production of hardcopies at any scale but by merging different files into a single one or the dividing of a file into several;
- Statistical information can be compiled without major costs; and
- Many types of computations, such as distances, area, volumes, can be performed from the data with little extra cost.

On the other hand, digital map production is a complex operation which requires qualified personnel in computers, photogrammetry, and cartography, and a tremendous amount of planning and supervision. Digital maps are a different product than analog maps and they are not required to have a similar appearance.

If mappers and end-users agree on these principles, it will be possible to start solving some of the problems that affect the quality of digital mapping. Mappers must be willing to expend more time and effort in developing cost-efficient methods of map production, reliable systems of file managing, improved techniques for data exchange, and realistic methods of pricing because the end-users will be required to pay the fair value of digital maps.

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