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The Evolution of Estimating Systems at Kodak

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In late 1986, the project management division of the Eastman Kodak Company serving the Kodak Park site in Rochester, New York, formed the capital estimating department to provide accurate conceptual and semidetailed estimates for capital projects. The capital estimating department serves an extremely diverse customer base that includes the preparation of project estimates for machine and chemical processes, as well as for general construction and infrastructure projects. In 1989, we presented a paper describing the development of various estimating systems that are used to support the department's needs [1]. This paper is intended to describe the evolution of the capital estimating department to its current status as a key component of project management at Eastman Kodak, and to provide our vision of the future evolution of the department's estimating practices and tools.

BACKGROUND

Kodak Park, in Rochester, New York, is the largest of Eastman Kodak Company's many worldwide manufacturing facilities. Kodak Park contains over 200 buildings and extends over 2,000 acres in a vast manufacturing complex. At Kodak Park, Eastman Kodak manufactures over 1,000 different types of film, 300 kinds of photographic paper, and 900 types of chemicals. In addition, Kodak manufactures copier products and a variety of digital imaging products, including CCD semiconductor chips. Kodak Park is essentially a city-within-a-city, housing support facilities such as power plants, steam and other utility generation facilities, waste disposal, railroads, and fire and security departments. Of course, the most important and unique function of the manufacturing complex is the design and construction of specialized machines for the manufacture of film and paper base, photographic emulsions, and finished photographic film and paper products.

The capital estimating department provides estimating support for the project needs of this wide variety of production and manufacturing facilities, as well as the infrastructure needs of Kodak Park. Capital projects can involve both new manufacturing facilities or processes, as well as the upgrade of existing facilities. In terms of the number of projects, Kodak Park is characterized by many small upgrade projects—approximately 80% of the projects are under US$1 million and under 1 year in duration. The remaining 20% of the projects range in size from US$1 million to $200 million (or occasionally more) with project durations of up to 4 years, but these account for 85% of the total capital budget dollars.

The estimating department has primarily focused on providing estimates ranging from strategic/conceptual estimates (used for strategic analysis, feasibility studies, and alternate schemes evaluation) through semidetailed estimates (used for project funding requests). For an owner organization, such as Kodak, it's the conceptual stage of a project where accurate estimating can have the most impact, by ensuring that the correct projects (those with the best business case) are funded.

IN THE BEGINNING

Prior to the formation of the capital estimating department in 1986, most capital cost estimates were prepared by the design engineers assigned to a project or construction department trade planners or job owners. Early strategic estimates were usually nothing more than a "guestimate" based more upon the desired cost of a project than any firm estimating data or design information. As preliminary engineering progressed on a project, the various engineers on a project would estimate their discipline's portion of the project, and combine them together in order to form a total estimated cost for funding approval of the project. Obviously, some engineers were more capable estimators than others, but project estimates were highly inaccurate and inconsistent. Recognizing the need for improved budgetary and preliminary estimates, the capital estimating department was formed in late 1986 to provide a source for professional estimating services, and to develop and maintain relevant estimating data, software, and techniques.

Although the department was formed to improve estimating capabilities, initially use of the department's services was not mandated by the capital management organization. The department was thus forced to market its services to the project teams and client departments. Project managers and/or engineers could choose to use the capital estimating department, contract with outside estimating resources, or prepare estimates themselves. Tthe department was analogous to a start-up business in a large and competitive market.

The department had limited time and resources to gain acceptance, and had few value-adding products or services to offer. Much of the department's early efforts were devoted to obtaining quality personnel to staff the department. The department chose to augment its base Kodak staff by contracting with Fluor Daniel to provide experienced professional estimators. Contracting with Fluor Daniel provided a wealth of experience in project controls and estimating to augment the site specific process knowledge of the Kodak personnel.

After assembling a dedicated staff of professional estimators, the department focused on identifying customer needs and on targeting its estimating products and services to meet those needs. The key need was to provide accurate conceptual estimates to a wide variety of customers.

Accurate estimates depend on many factors: estimators experienced with conceptual estimating techniques, effective tools and methodologies for creating conceptual estimates, and relevant estimating and cost data. Kodak uses some unique equipment and processes to support photographic film and paper manufacturing,

and has many unusual manufacturing environments (such as "clean room" and "in-the-dark" environments). This creates the need for custom conceptual cost databases applicable to Kodak projects.

At the time that the estimating department was formed, project management operated from a weak matrix position. Most projects were either led by a lead engineer or operated under heavy influence from the engineering functional groups. While some engineers are reasonably skilled in estimating techniques (at least within a single discipline), almost none have the time to prepare complete and clearly documented project estimates. So, although the engineering community had, up to this time, been the source looked at to provide cost estimates for capital projects, they were ill-equipped to do so. Engineering managers, as well as individual engineers, thus formed the largest source of customers for estimating services. Besides the engineering community, other customers included project managers, project controls engineers, construction managers, as well customer representatives in the actual operating departments (the eventual "owners" of the production asset resulting from the project).

With customers and customer needs identified, the estimating department concentrated on developing tools to make the department immediately productive. There was no question about the obvious advantages that computerized estimating software would provide. The important issues we faced were that of specific hardware and software choices. By early 1987, it was clear that PC-based systems would be most effective for use at Kodak. Mainframes would be more costly to implement, would not be conducive to timely development, and would not offer any other advantages in terms of the application (ease of use, memory requirements, etc.).

The department weighed heavily the decision on whether to use commercially available estimating software or to develop a custom estimating system. Software needs were analyzed and the following key requirements were identified:

- incorporate a custom code-of-account structure since existing standards (such as CSI Masterformat) are not always applicable to conceptual estimating techniques, or to the process-related nature of many of the Kodak projects;
- incorporate varied estimating techniques, including line item or unit cost estimating as well as parametric methodologies such as factored estimating and cost modeling;
- provide the estimators with consistent, easy-to-use software; and
- provide flexibility to add future enhancements and specialty estimating modules.

Based on the above criteria, the decision was made to develop custom software to meet the department's needs. A general estimating system was developed that provides the estimators the capability to prepare estimates quickly, that can access our conceptual estimating database, and that can access specialized semi-independent modules. The software was developed in a phased approach. Our 1989 paper, *Development of Conceptual Estimating Support Systems at Kodak*, provides additional detail on the strategies used in developing these systems [1].

GROWTH AND SUCCESS OF THE DEPARTMENT

From its inception, the capital estimating department has experienced extremely high growth. The department began in 1986 with eight estimators (five Kodak employees and three Fluor Daniel contractors), and has grown to a team of 20 estimators (19 Kodak employees and one Fluor Daniel contractor). In its first full year of operation in 1987, the department completed 367 estimates for US$190,000,000 in total estimated dollars. Most of these estimates were for less than $200,000, and were not for the entire project scope. In 1995, the department completed 881 estimates worth US$1,744,000,000. Estimates now tend to be larger in size covering the entire scope of the project, rather than isolated trades or disciplines. This equates to roughly a three-fold increase in the number of estimates, and a nine-fold increase in the estimated value.

As mentioned previously, the estimating department was initially considered an optional provider for estimating services. By 1993, Kodak Park capital management recommended using the estimating department for all project funding estimates. In addition, all project funding requests over $200,000 must include a cost risk analysis study prepared by the estimating department. The department is also becoming a corporate resource for providing project estimates for other worldwide sites. This reflects the increasing confidence that management has in the services the estimating department provides.

The estimating department has also been instrumental in recent reengineering developments undertaken by the capital community. The reengineering was focused on achieving better project definition earlier in the project schedule so that funding decisions are based on more reliable information. These efforts have placed project management in a stronger matrix position, and has increased the awareness of the need for accurate conceptual estimating. The department is now preparing many more strategic estimates (those with less than 5% engineering complete), which are used to make early decisions regarding the business case of individual projects. Only those projects that can demonstrate a clear and positive investment opportunity at a strategic engineering phase are given the funding to pursue preliminary engineering. At the end of preliminary engineering, projects are reestimated in order to pursue full project funding. The increased importance of strategic estimates has placed added reliance on the capital estimating department to provide systems to support such estimates. One of the primary systems to support such efforts is the project historical retrieval and analysis system (PHRAS), discussed in more detail later in this paper.

CURRENT ESTIMATING SYSTEMS

The estimating systems used by the capital estimating department are organized around a central estimating system known as EST1. This system provides a generic line item estimating system, and forms a central "hub" from which many of the other specialized estimating modules can be accessed. Figure 1 presents an overview of the various estimating systems currently used by the department.

As can be seen, there is no single system that can satisfy all of the department's needs, especially in a department that works with such a wide variety of projects. The department has focused on supplying many small, focused estimating systems to meet specific needs, and have linked these into the core estimating system where it makes sense to do so. All of the systems support Kodak's standard code of accounts, and reports are standardized as much as possible across the systems.

EST1—General Estimating System

EST1 is a general purpose, line-item, unit-cost estimating system that provides access to Kodak's conceptual item-cost database. The system allows the user to prepare an estimate by easily selecting the appropriate cost data item from the item-cost database. The estimator can select a specific item for inclusion in the estimate by either typing in the appropriate item number or by choosing to scroll

through the cost database selecting items on the fly.

Once an item is selected for inclusion in the estimate, the estimator is presented with a screen showing the default material and labor costs, as well as the default costs adjustments (which can be preset based on the cost division of the data item). The estimator then inputs the required quantity, and makes any other adjustments, as necessary. The estimator can override the standard costs by entering in a new value or by using the cost adjustment fields. The estimator also enters in the project codes required, and any other required documentation for the item.

The estimator can also create unique line items in the estimate, which do not come from the item-cost database. However, the estimator can optionally add these items to the item-cost database for use on other estimates. Items added to the item-cost database in this way are called "user items," and are easily distinguishable from the standard item-cost entries in the cost database. Only the estimator that created a user item (or the system administrator) is allowed to update that user item in the cost database; however any estimator can choose to use that item in an estimate. Standard cost items in the item-cost database can only be updated by the database administrator. On a periodic basis, user items that have been added to the item-cost database are evaluated to determine whether they should become standard items (and, therefore, maintained by the database administrator).

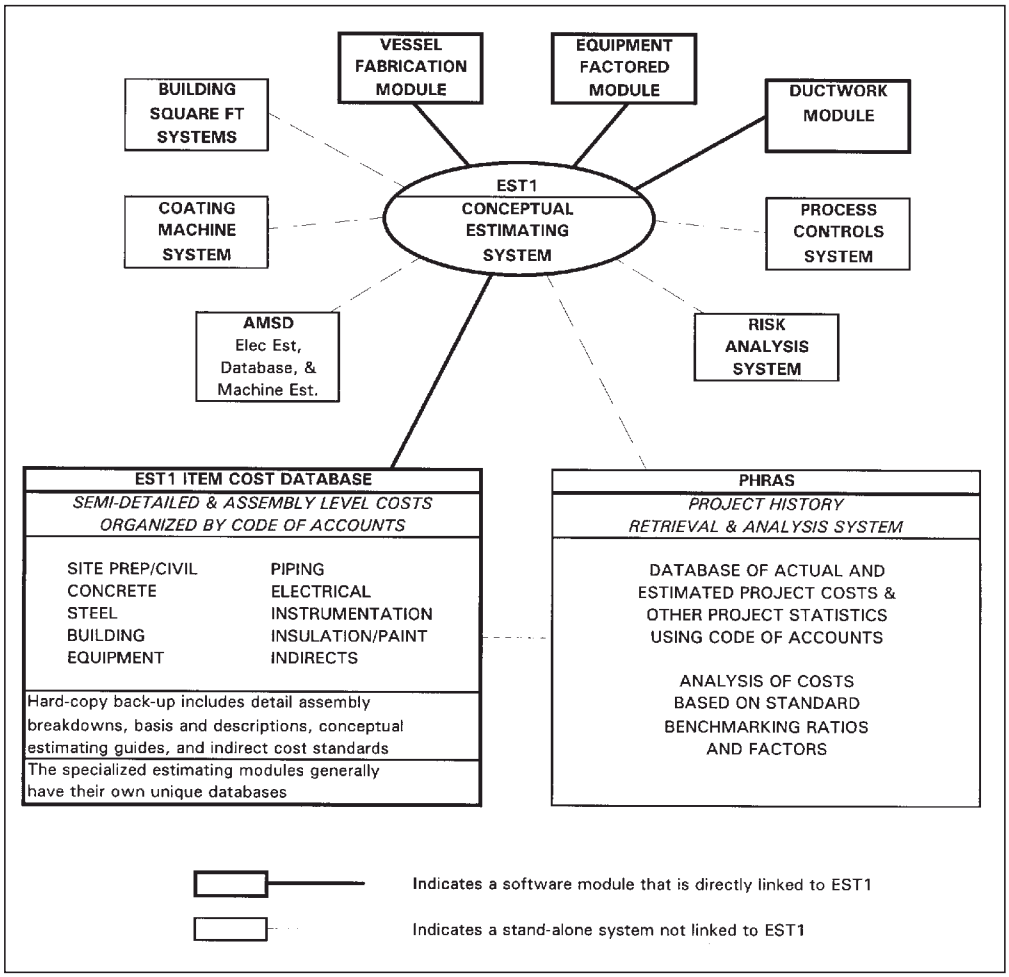

Figure 1—Estimating Systems Used at Kodak

The EST1 system is menu-driven, user-friendly, fully "mousable," and consistent in operation throughout its various modules. Originally developed as a stand-alone system, it is now completely multiuser and operates in a LAN environment. Multiple users can access and work on the same estimate at the same time, but only one estimator can update a given line item at a time. Estimates can also be merged, allowing estimators to work on separate estimates independently, and then merge them together for final roll-up or reporting. The system offers security via a log-in process, and the provision of specific access rights at a very granular level.

One of the most important features of the EST1 system is that it links directly with several specialty conceptual estimating modules. These modules are directly accessible through EST1 menu options and generate standard EST1 line items.

EST1 Equipment Factored Estimating Module

This module provides battery-limit equipment-factored estimating capabilities from within EST1. The equipment factored estimating module contains a unique database containing equipment factor ratios for many types of process equipment (pumps, vessels, reactors, exchangers, etc.). Each type of equipment is separated into four size ranges. This module allows the user to quickly estimate the all-in battery limits cost (including piping, electrical, instrumentation, and all other associated disciplines) for a given piece of process equipment.

The estimator inputs the process equipment type and size range, the purchase costs for the piece of equipment, and various parameters such as metallurgy and duty factors. The estimator has the capability to adjust the factors and generate costs based upon his knowledge of the installation. The module will generate an EST1 line item for each discipline, or optionally a single line item for all-in costs.

The equipment factored estimating module has been used successfully on many projects, and is a key conceptual estimating tool. Historical project costs are monitored in order to validate the equipment factors, and to develop new equipment types for inclusion in the equipment factors database. The original database and methodology are based upon AACE-published information [4].

EST1 Ductwork Estimating Module

The ductwork module is used to estimate the fabrication and installation costs for both building and process ductwork based on key parameters. The input to the module consists of the type of duct (rectangular, plain round, or spiral round), the dimensions, the duct duty (pressure), the length of run, number of fittings by type, and other parameters such as seam type, connection type, metallurgy, insulation type, etc. Based on this input, the system calculates the

weight of ductwork, and square footage of insulation (and lining, if required). The module also generates the material, fabrication, and installation costs. The estimator inputs the information for each duct run, and is summarized by duct system. The module generates a separate EST1 line item for both ductwork and insulation.

The estimator has several adjustment factors (height of the ductwork, congestion factors, etc.) available to fine-tune the generated costs. This module can quickly generate duct costs based on key design parameters, and is another effective conceptual estimating tool.

EST1 Vessel Fabrication Estimating Module

This module can generate fabrication costs for various vessel types based on design parameters. The estimator inputs the vessel type (storage tank, pressure vessel, kettle, etc.) and such parameters as metallurgy, diameter, length, wall thickness, end type (flat, hemispherical, cone, etc.), number of nozzles and instrument connections. This module can handle double wall and jacketed vessels, in addition to standard single wall vessels.

The module generates an EST1 line item for the fabrication costs (material and labor) of the vessel. Installation costs are not generated but can be looked up as a line item in the standard EST1 item-cost database. The generated costs are the bare fabrication costs for the vessel and can be adjusted based on whether internal Kodak shops will be used for fabrication or an outside vendor. If an outside vendor is used, the estimator can adjust for the expected overhead (profit margin) and freight costs.

OTHER SPECIALTY ESTIMATING SYSTEMS

The previous specialty estimating modules are accessible directly from EST1. The department also uses several other standalone estimating systems that are not a part of the EST1 system. Most of these systems are based on elaborate, custom-developed Excel spreadsheets.

Building Square Foot Estimating Systems

The building square foot estimating systems are used to generate conceptual estimates for building construction based on design parameters [3]. There are two different systems: one is for very strategic estimates where minimal information is available (where engineering complete is less than 5%), and the other is a semidetailed system based on the 12-division CSI Uniformat account structure (for projects where engineering complete is up to 25% or so).

The strategic system requires only the building type (manufacturing, warehouse, office, etc.), gross square footage, and number of floors to be entered. It generates a total installed all-in cost, and indicates the costs per square foot. The system is based upon regression analysis of building cost information from many worldwide Kodak sites, and uses a single exponential algorithm to calculate costs. It is regularly calibrated against new project data.

The semidetailed system is based upon square foot costs for individual components of the building (foundations, wall systems, flooring, etc.). The estimator inputs the horizontal square footage and key parameters for all of the various components of the building. Each component is usually associated with one or more upgrade options which can be selected based on the client's preferences. The system generates and summarizes costs by the Uniformat building system structure. The system is based on approximately 100 algorithms developed from analysis of detailed line item estimates. The system is both quick and easy to use, and provides an excellent means for alternative analysis during the conceptual stages of a project.

Process Control Estimating System

This system estimates the cost for complete process control system costs based on the system I/O quantity and process controller type parameters. It generates the costs for field instrumentation and process control software and can optionally generate the cost of the primary process controllers and other hardware if an estimate or quote is unavailable.

The system is based on regression analysis of historical cost data of Kodak process control projects. Data from recent projects are collected by the engineering group and regularly added to the database in order to calibrate the system's factors and algorithms.

Coating Machine Estimating System

The coating machine estimating system is actually a data handbook and estimating methodology used to generate conceptual cost estimates for film and paper sensitizing projects. Sensitizing is the application of a variety of light-sensitive coating materials to media such as film and paper, and therefore, is one of Kodak's key and proprietary technologies. Coating machines are extremely complex and expensive, and projects for building new machines can take up to several years to complete. However, most projects involving coating machines involve upgrades to existing machines. It is extremely important to be able to generate quick and accurate conceptual estimates for both new and upgrade projects.

The data handbook contains graphical displays of factors and algorithms for every almost every component of a coating machine. Each algorithm is based on key design parameters (such as web width, web speed, etc.), and allows the estimator to rapidly look up the cost for each component based on the values of those parameters. An historical database of past project costs is used in regression analysis to determine the factors and algorithms which form the basis of the system. By keying off of design parameters, the system provides an easy means to conduct sensitivity analysis to identify how costs change in response to the machine design. For example, the trade-off between web width and web speed in order to meet capacity requirements can have a significant effect on project costs. The system allows such studies to be prepared quickly and accurately.

OTHER SOFTWARE SYSTEMS

In addition to estimating systems, the department has also developed software systems for risk analysis and benchmarking. These systems supplement the services that the estimating department provides, and are another critical element to the department's success.

Risk Analysis System

The estimating department previously used a commercial spreadsheet add-on simulation package to perform risk analysis studies for contingency evaluation for funding estimates. After performing studies on the results of the commercial systems simulations and the project parameters input into that system, the department determined that developing a custom risk-modeling spreadsheet would meet the needs for determining contingency funding for project estimates at a lower overall cost.

The resulting spreadsheet is a "risk modeling" system that does not use simulation. It is based on the department's experience that the probability distributions of project cost outcomes are predictable without using simulations (i.e., no Monte Carlo analysis). The predictability was driven by the fact that for most cost simulations, two initial simplifying assumptions were made: 1) cost outcomes on individual estimate line items were assumed to have a triangular

distribution, and 2) the cost outcome distributions are skewed to the right (high side).

The new modeling system contains a table of defined distribution curve "shapes" that are automatically modified to fit the high/low cost estimate ranges entered for the appropriate summary level of a specific estimate. These curves are designed to model the outcomes that the department has become familiar with from years of simulations. The models also incorporate a project complexity adjustment factor that modifies the distribution curve shape in a way that mimics the effects of manipulating dependencies in a distribution (heightens or flattens the frequency histogram in a shark's-fin-type shape).

The resulting system makes risk analysis simple, repeatable, and reliable. It produces reports that are very similar to those of the commercial software. It still requires that project teams review and assess the high/low ranges for the estimate breakdown as always, but provides a simpler mechanism to achieve similar results.

A second risk model for strategic estimate evaluation has also been developed. This model uses the same distribution curves as above, but the only user input required is the total estimated costs and answers to a number of simple questions regarding the project definition status and technology complexity. This strategic model is based on findings published by the Rand Corporation [5].

Project Historical Retrieval and Analysis System

One of the most important tools for an estimator is experience. The project historical and analysis system (PHRAS) is designed to collect summary level project cost, schedule, and scope information in order to provide a structured format for the collection of project experience [5]. PHRAS is used to capture and analyze data for all Kodak projects over $50,000, as well as for selected estimates and non-Kodak projects. This relational database system is designed to provide rapid data retrieval based on a flexible query engine.

The information collected by PHRAS serves many purposes. It provides benchmarking data to monitor project cost and schedule performance, provides meaningful ratios and statistics to aid estimate reviews, provides estimating database feedback and calibration information, and serves as a strategic resource planning and forecasting tool. The system can also serve as a strategic cost estimating system to generate estimates based on benchmark measures. PHRAS analysis provides the raw material for developing the many parametric estimating tools used at Kodak.

SUMMARY OF CURRENT STATUS

As with the mechanic at the local automotive repair shop, tools are a key contributor to an estimator's productivity. The various software systems described in this paper constitute the tool set of the capital estimating department at Kodak Park. Each of the systems was developed in-house by members of the estimating department experienced with software development techniques. These systems have contributed to the rapid success of the department, and more importantly to the effective evaluation of capital projects.

Built around a central core system, many of the systems are narrowly focused to meet specific needs of the diverse and highly specialized project mix at Kodak. All of the systems have been designed for use as strategic and conceptual estimating tools, and play an important part in the project process at Kodak, which has been reengineered to concentrate on front-end planning.

ESTIMATING AT KODAK IN THE 21ST CENTURY

Systems Changes

PC-based, commercial estimating software packages have greatly improved in quality and capability in the last 10 years. In addition, with the rapid evolution of PC operating and networking systems and application languages, in-house developed software is difficult to keep up to date. For that reason, the department is currently studying the replacement of the EST1 general estimating system with a Windows-based commercially available estimating system. An important requirement of such a system will be that it offers an open architecture in order to provide connectivity (such as OLE) to other systems, and that it will provide support for the conceptual estimating database which is maintained by the department. In addition, commercial systems now have parametric capabilities that can replace some of our custom applications.

Future directions are to continue with the development and maintenance of specialized conceptual estimating systems, particularly for processes unique to Kodak or which are not commercially available, and to be able to link these systems to the core system via OLE or other connectivity protocols. Future systems developed in-house will be Windows-based in order to facilitate the desired connectivity to a core system.

The Kodak project management division is also migrating to a PC-based planning and scheduling package that will be able to share data with the planned commercial estimating package. It is anticipated that all systems would tie to a common Oracle or similar database in a true client/server environment. Transfer of estimate information from the estimating system into another system for a project cost control budget should be a seamless operation. In addition, Kodak's engineering group is making increased use of 3-D CADD applications that could provide take-off information through the same client/server environment to the estimating system. However, since much of the estimating department's work is conceptual in nature, the value of this link is relatively low.

Process Changes

Kodak's capital organization is undergoing a number of shifts in how they operate. These changes will facilitate the use of Total Cost Management. Increasingly, engineering, procurement, and construction services are being outsourced using partnering concepts. This includes outsourcing of estimating services for control estimates on the largest projects. In addition, the engineering and project management group has been reengineered into fixed asset management teams (FAMTs). These teams eliminate the functional "silos" that formerly got in the way of putting the manufacturing customer's needs first. Estimators are aligned with these FAMTs and are expected to develop expert knowledge in how the customer's processes work.

There is a focus on improving project definition for funding earlier in the project schedule. Estimating must be prepared to provide estimates of optimum accuracy for the level of definition given. This calls for increased use of advanced parametric methodologies using cost databases based on proven historical data. Much of the future "development" work planned for the estimating department involves analysis of historical data to create focused estimating data and tools for each Kodak client area.

Finally, electronic communication is increasing using a corporate intranet as well as the Internet for external communications. Rapid transfer of information with our partners is vital for quicker project cycle time.

Summary of Estimating Trends

In summary, the trends for the Kodak Estimating Department since 1986 have been

- increased professionalism in the practice of cost estimating;
- increased use of parametric estimating methodologies and risk analysis;
- increased need for business and technical understanding of the customer's manufacturing processes in order to support customer and asset focused teams and to develop and use parametric methodologies (key elements of total cost management);
- increased outsourcing and integration with selected partners for detailed estimating;
- increased use of commercial PC software packages using open architecture;
- increased integration of estimating systems with scheduling and engineering systems;
- increased use of electronic communication; and
- increased global standardization in project practices and estimating methodologies.

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