ABSTRACT Effective planning of dozer operations plays a very important role in determining their productivity.- Improvements in equipment use and maintenance based on real "Case Histories" can be postulated promoting better understanding of business goals and using more precise method of performance assessment.Using the interaction between the DPC and other commercial mine design software, the process of scheduling earthmoving operations can be combined with calculations of the dozer productivity, calculating operating costs and forecasting budgets.As indicated earlier, the dozer production calculations can be combined with other commercial mine design software, where the process of scheduling earthmoving operations can be merged with calculations of the dozer productivity, calculating operating costs and forecasting budgets.- Estimation and comparison of dozer's ownership costs including: residual value at replacement, value to be recovered through the work, cost per hour through the work, interest, insurance and taxes costs; and operating costs (fuel, lubricants, undercarriage, repair reserve, special wear items, labor).Requirements for the efficient equipment use can be fulfilled better if the factors contributing to the operating cost are accessible easily and listed in an orderly fashion and calculations can be performed instantly.A research project was undertaken at The Pennsylvania State University to develop a software package to assist a wide range of professionals in quick and consistent evaluation of either new equipment purchasing options or the production and costs related to operating the owned equipment.The technical and cost data summarized in the project bids or other submittals contain generally the aggregate numbers, within which the results of various calculations are embedded.SOFTWARE CAPABILITIES The DPC is a Windows-based software package that is used for determining the productivity and economics of dozer units, using the logic that models simulate real mine situations.To facilitate addressing these issues, a research project was undertaken to develop a tool that can be used for a quick and accurate estimation in planning of equipment purchase and evaluations of costs and performance of the equipment currently in operation.The execution of program function occurs at Level II. Level III is included to facilitate technical and economic evaluations.Calculation of the dozer production is performed by selecting a dozer from the existing database and specifying the cycle elements.In this context, the dozer productivity can be integrated easily into any design providing a valuable source of information needed for accurate estimation of time, which is needed to complete specific earthmoving tasks.The ownership cost per hour is calculated based on input of the following parameters: (1) machine V.J. KECOJEVIC AND M.J. MRUGALA delivered price, (2) ownership time period, (3) operating hours per year, (4) percent of value at trade-in time, (5) interest rate, (6) insurance rate, and (7) respective taxes.The DPC software was designed to fulfill this very need by providing the theoretically-based procedure, which can be applied consistently and in a correct manner any time it is employed by a wide range of potential users.Secondly, they permit the user to concentrate on improving performance in these areas that have the largest weight in the overall cost, thus making their efforts more effective.Its main characteristics can be summarized as follows: - Availability of small, specialized programs can make them available at all levels of business involved in dozer applications.Evaluations of the performance of the dozer in use and planning new activities often rely on past experience, best estimate or other factors whose objectiveness is difficult to assess.The DPC program includes the following features: - Calculation of dozer drawbar

pull, haul, return and cycle time.– Compilation of results from calculations to examine the relationship between variables in the calculation, e.g., dozer type versus costs, operating hours versus costs.Upon completion of technical and economic evaluations, Level IV provides a number of options, where the results of analyses can be displayed.This operating cost section is also supplemented by a series of charts designed to display in a combined fashion all components contributing to the overall operating cost.It should also help the user and the salesperson as both can negotiate more productively, keeping in focus a number of interrelated factors including not only technical performance data but all the other costs and equipment productivity as well.As an example, the term "cost," which by definition includes a number of components, can have many applications that make its use ranging from potentially imprecise to misleading.Since these units have a wide application in surface mining and civil engineering operations, there is a need for the tool for obtaining precise estimates of dozer production and costs.INTRODUCTION Calculating dozer production rates and costs associated with dozer operation seems to represent a relatively simple task.The unique equipment features provided by each manufacturer are usually targeted to emphasize usefulness and technical performance of their equipment under particular field conditions.DPC can be applied to analyze and optimize the performance of the existing dozers or to plan the selection and acquisition of the new equipment.As any modern software package, DPC includes a dropdown hierarchical menu system that permits access to all software features.Level I includes the following five input elements: (1) equipment database, (2) equipment cycle elements, (3) material properties, (4) roster data, and (5) cost–related data.A typical display of a dozer database, derived from the data published by various manufacturers [1–3], is shown in Figure 2.A distinction has been made between the various components of the overall ownership cost to account for the following: (1) cost per hour through work, (2) cost of insurance, (3) cost of interest, and (4) applicable taxes.Operating Costs Operating costs include the following seven components: (1) fuel cost, (2) lubricants, (3) undercarriage, (4) repair reserve, (5) special wear items, and (6) labor.The planning of any successful technical activity requires that the algorithm used in calculations is correct and the access to and the availability of the accurate information are assured.Availability of the database including data on equipment produced by a number of manufacturers allows the potential customer to perform his own analyses before seeking information from the specific producer.The DPC software contains the help sections, where in clear terms each calculated quantity is defined.First, the graphs in a combined fashion allow the operator to see the relative contribution of each cost element to the overall cost.The DPC software provides the small–scale operators with a tool in precise and standardized form, that can be used for the short– and long–term evaluations of equipment performance.It should be recognized that each leading manufacturer makes their recommendations of a particular piece of equipment using not only numbers calculated according to the standard practice but often applying procedures or coefficients, which are part of the intellectual property of the given company.The program developers recognize this aspect of software ownership and any software user can choose to display or to protect portions or types of information that are made available to others.The time required to learn software is becoming an important issue as software packages grow in functionality and sophistication and the need to follow changes made in subsequent updates becomes a full–time occupation.These

calculations remain a part of the operation accessible to those responsible for the daily task of keeping the company running financially, however, somewhat distant for those responsible for the day-to-day operations.At the core of the DPC software development was an assumption that both dozer operators and manufacturers' sales personnel will benefit from the product that addresses a specific type of equipment.This situation represents a common V.J. KECOJEVIC AND M.J. MRUGALA practice and is understandable, as each sale contributes to the equipment manufacturing company's bottom line.It is also likely that these comparisons may be incomplete or inconsistent as the data provided by each manufacturer vary.A toolbar is provided to pursue specific applications, which are activated by clicking the specific function button.This option is supplemented by a series of charts illustrating the distribution of ownership costs expressed in percent over the period of a designated number of years.Figure 6 shows an example of the display used for calculating the operating costs, while Figure 7 shows a typical chart displaying the distribution of ownership costs.BENEFITS OF USING DPC SOFTWARE One of the benefits of computer technology is the availability of large amounts of information, which can be accessed easily.Its use is envisioned as a facilitator during discussions, negotiations and as an educational aide.The set of graphs included in the DPC software allows for conveying two important messages.The DPC program can be applied to evaluate the predicted versus real equipment performance more readily.The purchase of equipment is based on manufacturersupplied technical parameters and projected performance both in the area of work accomplished as well as costs associated with operation.While larger operations can afford sophisticated equipment performance tracking systems, smaller operations must rely on less precise measurements of such performance.Such a tracking effort is perceived to offer benefits not only to the field operators but also to accounting personnel, who can, with limited training, maintain an accurate history of equipment performance.Obtaining answers even to simple questions requires involvement of experts, who are both expensive and seldom readily available.CONCLUSIONS Trends observed in mining and construction industries favor the use of complex software packages.The Dozer Productivity and Cost software was developed by faculty in the Mining Program at Penn State.- Tangible benefits in terms of cost-based evaluations/decisions provide rational basis for decision makers at all levels.- Communication among business managers, operations and equipment sales can be improved due to standardization of language and terminology used in exchange of information.This paper presents an overview of the structure and code capabilities of the software for dozer production and costs estimation.While each sales representative handles his own company's equipment data, it is not common to have sales people providing information comparing the performance of their own equipment in contrast to other manufacturers.While several civil engineering and mine design software packages are available and are being used, a smaller program designed to perform specialized tasks does not exist.In addition, these comparisons may contain terminology, which is either imprecise or ambiguous.V.J. KECOJEVIC AND M.J. MRUGALA The DPC program was designed utilizing the current version 6.0 of MS Visual Basic.The DPC database was developed using MS Access and applies the Open Database Connectivity (ODBC) standard.It is organized using the relational database model, which produces the database structure with minimum data redundancy, while maintaining relationships between all data.Rimpull

Diagram Drawbar pull is the horizontal force that dozer can produce at the track-ground contact.Ownership Costs A write-off straight line based on the number of years and hours the owner expects to use the machine gainfully represents an estimate of ownership costs.The total operating cost represents the final aggregate number component (7) summarizing all .The personnel can also alert the field operators to potential discrepancies encountered between the predicted versus real equipment performance.The DPC software is also designed to fulfill the needs of the equipment manufacturer sales representatives.The expense involved with hiring personnel designated to learn and operate these complex programs can be costly.ESTIMATION OF DOZER PRODUCTION AND COSTS self-contained package is designed to address a specific need, and it can be used quickly and effectively with modest training.These multi-faceted programs are capable of fulfilling a wide range of uses related mainly to mine design and are designed for routine daily use by trained personnel.In most cases, it is based on available literature and manufacturer-published equipment specifications.Left somewhat behind in this setting is the customer, who often has no other means but collect the data from several sources for comparison and optimization purposes.It is clear that under these circumstances a tool serving the both manufacturer sales representatives and the users/operators would be useful.As a result, a Dozer Productivity and Cost (DPC) software package was developed.To assure program usability under any circumstances, the program can be accessed using both a mouse and a combination of the designated keys on the keyboard.By returning to Level I and selecting new input parameters the results can be modified.The record is a single entry in a table, consisting of a number of data fields, where each field is a specific piece of data contained in a record.Dozer performance is characterized by the performance curve of the drawbar pull versus dozer speed.Dozer Cycle Time and Production The dozer cycle time is defined as the time required for the dozer to complete a full pass including the required time components.A typical template summarizing the result of ownership costs calculations is shown in Figure 5.It was designed to provide the definition of all terms used in the program such that ambiguity in terminology can be avoided.As users of this information, we would like to be reassured in our decisions often asking others to verify our findings.This "do-it-yourself" aspect was considered important, as some operators would prefer to perform their own analysis of equipment performance before entering the negotiation stage.At the click of a button an entire line of equipment produced by their employer can be retrieved from the database helping to address needs of different potential clients.The DPC software is designed to fulfill such needs by being applicable in any type of operation, especially those smaller in size.Accounting departments perform operational cost analysis of equipment.As the economy goes through its cycles, companies emphasize the need for every employee to contribute to the company's bottom line.It was designed as a flexible package, of which size and complexity can grow to fit the needs related to individual applications.The verification of background calculations in such submittals is not always either available or possible.Within an operational environment there are no conditions for maintaining catalogues and up-to-date information on equipment at the site.Program functions are associated with specific icons that provide a clue regarding the purpose of the given function.As an enhancement to the program functionality, each function button was supplemented by an appropriate tool tips.These tool tips can be used as a quick learning tool for the new program operator and as a

reminder for those using the program sporadically.These tables and queries consist of data records, each record containing the same type of information.The display used to calculate the drawbar pull is shown in Figure 3.A typical display showing the results of dozer cycle time and production is shown in Figure 4.ESTIMATION OF DOZER PRODUCTION AND COSTS other components.One of the basic tenets of effective communication is the use of proper terminology.Software can be used to develop real history of equipment use and point to areas that need focus.The sales personnel also could take advantage of such a standardized process whenever comparisons are to be made between various new .machines.– Calculation of dozer production.1.2.3.3.2.3.3.3.4.3.5.3.6.3.7.4.5