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16. Abstract The cost of operating and maintaining equipment frequently exceeds the purchase cost of the equipment itself and varies widely between functionally equivalent candidates. Yet for most public organizations, policy states that a bid award be made to the company submitting the lowest initial cost bid. Life cycle cost (LCC) bidding was established in the 60s. Though the LCC bidding system enjoyed wide popularity in the 70s and 80s, it has been a controversial method ever since. Its implementation complexity and potential legal problems have impeded many public agencies from using this system. This research evaluated the feasibility of awarding equipment bids by life cycle cost rather than by the existing low bid purchase cost within the Alaska Department of Transportation and Facilities (AKDOT&PF). Research results show that the LCC bidding system can be implemented legitimately within AKDOT&PF for equipment procurement. The methodologies and the supporting computer program proposed in this research project can significantly improve the LCC bid process with respect to ease of implementation, efficiency, and user transparency.			
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**EQUIPMENT BID AWARDS:
INITIAL COST VERSUS LIFE CYCLE COST**

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ABSTRACT

The cost of operating and maintaining equipment frequently exceeds the purchase cost of the equipment itself and varies widely between functionally equivalent candidates. Yet for most public organizations, policy states that a bid award be made to the company submitting the lowest initial cost bid. Life cycle cost (LCC) bidding was established in the 60s. Though the LCC bidding system enjoyed wide popularity in the 70s and 80s, it has been a controversial method ever since. Its implementation complexity and potential legal problems have impeded many public agencies from using this system. This research evaluated the feasibility of awarding equipment bids by life cycle cost rather than by the existing low bid purchase cost within the Alaska Department of Transportation and Facilities (AKDOT&PF). Research results show that the LCC bidding system can be implemented legitimately within AKDOT&PF for equipment procurement. The methodologies and the supporting computer program proposed in this research project can significantly improve the LCC bid process with respect to ease of implementation, efficiency, and user transparency.

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I. INTRODUCTION

1.1 PROBLEM

The cost of operating and maintaining equipment frequently exceeds the purchase cost of the equipment itself, and these costs vary widely between functionally equivalent candidates. Yet, for most public organizations, policy states that a bid award be made to the company submitting the lowest initial cost bid. The purpose of this research was to evaluate the feasibility of awarding equipment bids by life cycle cost rather than the existing low bid purchase cost within the Alaska Department of Transportation and Public Facilities (AKDOT&PF).

1.2 BACKGROUND

Life cycle cost, a term used almost exclusively by the government before 1980, is a concept used for deciding between alternative purchases. The determination of life cycle cost includes the first cost of the equipment and such other costs as transportation, installation, direct cost of operation, indirect cost of operation, maintenance inventory for parts and materials, periodic overhauls, supervision cost, service reliability, training cost, benefits and penalties for quality, salvage value, general and administrative expense, conformity with trends, safety and ecological considerations, governmental rules and regulations, uncertainty and risk, and so on. Systems engineering suggests that the system with the lowest life cycle cost is the optimal choice. The calculation of life cycle cost includes the time value of money.

1.3 CURRENT PRACTICE

At the federal level, the Department of Defense (DOD) and its many agencies began to include life cycle cost in their evaluation of new and proposed systems in the late 1960's. By the early 1980's, DOD required support analysis and life cycle cost analysis of every weapon system acquisition. The lowest bidder was no longer assured of award.

In the private sector, many organizations have begun to include life cycle cost considerations in capital equipment decisions. Literature on the subject has recently shown an

increase in the number of organizations applying life cycle costing and a decrease in the lower limit dollar amount of the acquisition to which life cycle costing is applied (Deierlein, 1991).

With respect to AKDOT&PF, the literature indicates that similar government organizations are applying life cycle cost analysis to projects ranging from vehicle fleet management to building, road design, and construction. As budgets become more uncertain, life cycle cost analysis provides a method for insuring that we do not make investment decisions that will overburden our budgets in the future.

1.4 RESEARCH OBJECTIVE

The objective of this project was to a) determine whether or not life cycle cost as the principal criteria for bid awards would be of economic benefit to the state and legally permissible, b) to outline a methodology for calculating life cycle cost that could be used by bidders and AKDOT&PF, and c) to develop a supporting computer software for LCC analysis and bid evaluation. In response to conversations with AKDOT&PF personnel, we also examined the history and legality of life cycle cost bidding in Alaska. It was not the objective of this research to develop specific methodologies for implementation of life cycle cost bidding.

1.5 RESEARCH APPROACHES AND RESULTS

The research effort was divided into three phases.

Phase I included an extensive literature search concentrating on the application of life cycle costing within the Department of Transportation and Public Facilities and within construction oriented organizations who might reasonably be expected to use equipment similar to that of AKDOT&PF. Researchers contacted a cross section of these organizations for additional and more detailed information. Concurrent to the literature search, researchers reviewed procurement laws and regulation. The question of interest was how specifications must be written as part of a Request for Bids (RFB) in order to insure that the decision made is based on the lowest annual cost of ownership (life cycle cost based) rather than lowest initial purchase price.

In Phase II, researchers evaluated some typical equipment purchased by AKDOT&PF to ascertain the feasibility of determining life cycle cost before purchase. They attempted to quantify the risk and uncertainty associated with estimates of the various components of life cycle cost. Researchers contacted typical vendors and surveyed industry literature to determine the level and quality of data available to support life cycle costing of this type of equipment. Possible data sources within AKDOT&PF were identified and reviewed.

In Phase III, researchers outlined a methodology for determining life cycle cost. In addition, a supporting computer software (LCCbid Version 1.0) was developed. The methodology and supporting computer program were designed for general equipment LCC analysis and bidding evaluation, rather than for AKDOT&PF's sole usage.

Final research products are assembled by three parts in this project report. Section II is an investigative report on the legal aspects of implementing the LCC bidding system within AKDOT&PF. Section III presents a methodology for LCC bid administration and evaluation. Section IV is a user's guide for the LCC evaluation software LCCbid Version 1.0.

II. LEGAL ASPECTS OF AWARDING EQUIPMENT BID BY LIFE CYCLE COST WITHIN ALASKA DEPARTMENT OF TRANSPORTATION FACILITIES: AN INVESTIGATIVE REPORT

2.1 INTRODUCTION

At least a century ago, American central and local governments introduced the competitive bid concept to curb corruption, inefficiency, and mismanagement by government officials. The principles of competitive bidding generally require the following: preparation of plan specifications for the work; public advertisement to bidders inviting submission of proposals; formal submission of proposals to the contracting agency; submission of financial security by the low bidder, guaranteeing his acceptance of the award; and evaluation of proposals by uniform criteria and award of funds to successful bidders (Harp 1990).

Because the cost of operating and maintaining equipment frequently exceeds the purchase cost of the equipment itself, and because these costs can vary widely between functionally equivalent candidates, lowest initial price bidding sometimes proved not to yield the best value. Through social and economic pressures, additional qualifications of lowest "responsible" bidder and a "public interest" determination were added over the years to statutes that controlled the authority to let and award public works contracts. Life cycle cost is one of the criteria developed to meet public interest.

The LCC bid, from the purchasing official's point of view, has been developed to "help minimize financial and political risk and maximize return on capital invested in equipment." This is accomplished by requiring each bidder to furnish information beyond the initial purchase price required under conventional competitive bidding procedures. Each bidder is required to guarantee that the maintenance cost of his product will not exceed a certain amount during the period of time stated in the published specifications. Each bidder is also required to insure a minimum salvage or resale value by guaranteeing that he will repurchase the equipment at the end of this specified period of time at a stated minimum price. Net present value analysis is used to weigh immediate capital costs against future operating expenses. From a financial

perspective, the option with the most favorable net present value is most preferable, but this choice sometimes does not present the lowest initial price.

In practice, however, "value" is too often limited to purchase price only, especially when the purchasers are government agencies. This is because a substantial risk of legal action exists if a bid is awarded to someone other than the lowest bidder. Public purchasing is a legal process; its resulting contractual obligation for a jurisdiction has legal consequences far beyond many other governmental decisions. This section of the report investigates the legal aspects of using LCC as the principal criteria for bid award rather than using the existing low bid purchase cost currently practiced by AKDOT&PF. The investigation covers the current public procurement laws of Alaska and other states, possible legal challenges to the LCC bid process, the current practice in public procurement in and out of Alaska state, LCC bid concept and methodology development, and legal trends in LCC bid issues. Finally, the recommendations offered are based upon funding in the above aspects.

2.2 CURRENT ALASKA PROCUREMENT LAW

Competitive bidding statutes generally contain provisions requiring officials to award public contracts either to the "lowest bidder," the "lowest and best bidder," or the "lowest responsible bidder." Unlike statutes containing the phrase "lowest bidder," which have usually been interpreted as forbidding the exercise of discretion, those with the phrase "lowest and best bidder" or "lowest responsible bidder" have been interpreted to allow purchasing officials a certain amount of discretion in awarding public contracts. Alaska procurement law is one that contains the language "lowest responsible bidder" and even provides determination other than "low bids." Consider the following excerpts:

As 36.30.150. BID ACCEPTANCE AND BID EVALUATION.

(a) Bids shall be unconditionally accepted without alteration or correction, except as authorized in AS 36.30.160. (AS 36.30.160. LATE BIDS; CORRECTION OR WITHDRAWAL OF BIDS; CANCELLATION OF AWARDS). The procurement officer shall evaluate bids based on the requirements set out in the invitation to bid, which may include criteria to determine acceptability such as

inspection, testing, quality, delivery, and suitability for a particular purpose. The criteria that will affect the bid price and be considered in evaluation for award must be objectively measurable, such as discounts, transportation costs, and total or life cycle costs [emphasis added]. The invitation to bid must set out the evaluation criteria to be used. Criteria may not be used in bid evaluation if they are not set out in the invitation to bid. (b) A contract based on total or life cycle costs may be awarded only when the chief procurement officer or, for construction contracts or procurements for the state equipment fleet, the commissioner of transportation and public facilities, determines in writing at the time of contract solicitation that the contract promotes overall economy for the purposes intended, encourages competition, is not unduly restrictive, and is in the best interests of the state.

AS 36.30.170. contract award after bids.

(a)..., the procurement officer shall award a contract based on the solicited bids with reasonable promptness by written notice to the lowest responsible and responsive bidder whose bid conforms in all material respects [emphasis added] to the requirements and criteria set out in the invitation to bid.

2.3 COMPARISON WITH PROCUREMENT LAW OF OTHER STATES

A comparison of procurement statutes around the country reveals that the majority of states mention factors other than price in their bid award language. Many use language that incorporates quality, delivery, specification compliance, reliability of the bidder, and terms like "most advantageous to the state," or "as will best promote the public interest." Some typical provisions are as follows:

North Carolina:

acceptance made of the lowest and best bid(s) most advantageous to the State as determined upon consideration of the following criteria: prices offered; the quality of the article offered; the general reputation and performance capabilities of the bidders; the substantial conformity with the specifications and other

conditions set forth in the request for bids; the suitability of the articles for the intended use, the personal or related services needed; the transportation charges; the date or dates of delivery and performance; and such other factor(s) deemed pertinent or peculiar to the purchase in question which if controlling shall be made a matter of record. (GS 143-52, pp. 2-3 Public Laws Relating to the North Carolina Pouches and Contract Division)

Virginia:

the contract shall be let to the lowest responsible bidder, taking into consideration the quality of the articles proposed to be supplied, their conformity with specifications, the purposes for which required, and the times of delivery provided however that whenever the Division has reason to believe that the low bid is not the best price, it shall have authority to enter into further negotiations with the apparent low bidder to the end that the price paid shall be the best price obtainable. (Code of Virginia 2.1-442)

New Jersey:

award shall be made...to that responsible bidder whose bid, conforming to the invitation for bids, will be most advantageous to the State, price and other factors considered. (New Jersey Statutes annotated 52.34-12)

Vermont:

shall be awarded to the person whose bid or quotation is in the best interest of the state...in his determination of the best interest of the state shall consider (1) specified quality (2) price (ease of access of supplies (4) incidental administrative costs (5) proven reliability of bidder. (Requisition for supplies and materials, T.29, Sec. 903)

The award language used by North Carolina, North Dakota, Rhode Island, Vermont, Virginia, and Washington are examples of clear intent to take more than just price into account when awarding a bid. Along with Arizona, Alaska is one of only two states that provide language like "material aspects" in procurement code.

2.4 STATUS OF LCC UNDER CURRENT ALASKA LAW

A first viewing of the Alaska law may lead us to conclude that AKDOT&PF can award bids by life cycle cost rather than low price as long as the commissioner of the department feels such action is appropriate. However, the issue is more complicated than it appears. On the one hand, the law includes provision for "life cycle cost" and some determinations other than initial purchase price; on the other hand, it provides "material respects." A logical conclusion that can be reached from the law is that the Alaska procurement law allows LCC as criteria in bid process, as long as LCC is made of measurable material respect.

Is LCC a material respect of procurement? The answer to this question is critical to the fate of LCC practice within Alaska public procurement. There are controversial opinions on this issue. People arguing from the opposing position hold that LCC involves future factors while the future can not be accurately predicted. Thus LCC is not measurable. Even some government authorities take a cautious position on this issue. According to The Council of State Governments' "State and Local Government Purchasing (3rd Addition)":

true life cycle costing usually requires a series of demonstrable factors and figures to be used as cost elements, sufficient to construct a total cost formula, that rarely available. As a result, many purchases are made under a LCC misnomer, represented as life cycle costing, when, in fact, they are not. While projections, if logically arrived at, are permissible under LCC, the purchasing office should be aware of legal implications of a deficient life cycle costing formula when assumptions or approximations are used instead of reliable data. The overall purpose and intent of LCC applications are to be encouraged, however, even while a more accurate understanding of the term is needed generally.

Since LCC bid has not been a commonly accepted system in public procurement, it is important to be aware of possible legal challenges when using this system. When LCC is issued as principle criteria, it must have measurable monetary value, and so must all the cost factors that are the elements of LCC. For the factors that do not have monetary value, conversion should be quantitatively demonstrable.

2.5 POSSIBLE LEGAL CHALLENGES TO LCC BIDS

The most common challenge to the LCC bid process is made of on the grounds that competitive bidding statutes incorporating the phrase "lowest responsible bidder" require purchasing officials to award the contract to the lowest bidder. Challengers interpret "lowest responsible bidder" as the lowest requisition price bidder.

The challenge, which has received much attention from judicial authorities, is that LCC bidding specifications are so restrictive as to preclude competitive bidding. LCC bidding provisions require greater guarantees and participation on the part of the seller than are required under conventional specification. Because of this, there are many possible arguments to support the contention that LCC bidding specifications unreasonably restrict free and open competition. A similar argument is that LCC bidding discriminates in favor of larger companies with greater financial resources.

The challenge that specifications published by purchasing officials are so vague and indefinite as to stifle competition has been raised in both conventional and LCC bidding cases. The basis of this challenge is that particular specifications fail to provide a precise standard upon which bids may be prepared by bidders or compared by purchasing officials. Such specifications discourage free and open competition and, consequently, violate the spirit of competitive bidding statutes. An example of such a case can be found in *Douthit v. Allen*. Municipality officials in that case advertised to purchase a large tractor on a total cost basis (life cycle costs). This bidding procedure was challenged at once and only one tractor company had responded to the invitation at the time court action commenced. The court discussed several objections to the legality of total cost bidding, leaving the exact basis of the decision somewhat in doubt. The opinion concluded, however, by stating that "inherent uncertainties" in the maximum-cost-of-repair and minimum-repurchase provisions would tend to stifle competitive bidding. Having adopted this position, the court held that the specifications were not in the public interest and were therefore invalid (Vickry 1972).

2.6 CURRENT PRACTICE OF AKDOT&PF

In issues pertaining to the Procurement Code Statewide Equipment Fleet, Langel, Alaska Statewide Fleet Manager, notes the following:

Alaska statutes and regulations require competitive bidding for all purchases exceeding \$10,000 and that certain provisions be adhered to when writing and awarding bids for equipment. Essentially, these requirements are that specifications cannot be written which are "unduly restrictive," and that bids be awarded to "the lowest responsive and responsible bidder whose bid conforms in all material respects to the requirements and criteria set out in the invitation to bid." The statutes and regulations make provision for other procurement "tools" such as life cycle costing (also known as total bid cost), and bid evaluation using criteria other cost. Generally, these have not been used very often because of resistance from the vendor community.

To remedy this situation, the SEF (Statewide Equipment Fleet) initiated Senate bill 245, hoping to enhance SEF's ability to reduce long-term maintenance and replacement costs of heavy equipment to the state, and clarify the intent of the Legislature that procurement of heavy trucks and heavy equipment should consider factors other than price, and could be processed by either competitive sealed bidding or competitive sealed proposals.

But according to Diane Mayer Pearson, C.P.M.,

Life cycle costing and total cost bidding have been used in the past by the State for heavy equipment, building construction and leasing, appliances, lighting, air charters, vehicle purchases and rentals, light bars, testing equipment, generators, and other goods and services. Both techniques are vital parts of the array of advanced procurement methods currently available to procurement professionals throughout the world. (Source unknown.)

She pointed out that there are two major problems with SB 245. First, it excludes heavy trucks and heavy equipment from the article on competitive sealed bidding, the article that allows total cost bidding and life cycle costing as part of the objectively measurable evaluation criteria to be set out in the invitation to bid. Second, the bill includes heavy trucks and

equipment in the article covering competitive sealed proposals, which is the method typically used for professional services such as consultants and engineers. By setting aside heavy trucks and equipment for special treatment, the bill would be detrimental to all other purchases that could benefit from LCC or total costing bidding. She suggested that a more effective resolution would provide suitable directions to procurement officers instructing them to use LCC and Total Cost bidding to the extent practicable in all procurements, including but not limited to procurements of heavy trucks and heavy equipment.

Langel commented that "the existing statutes are flexible enough to be used in innovated ways to improve the quality of the equipment we buy, but not to standardize the equipment fleet in any planned way." The real intention of the SB 245 may be that the SEF hopes to use RFPs rather than RFBs to gain flexibility in choosing brands of equipment, in order to standardize equipment and maintenance.

2.7 SUMMARY

Having examined state statutes, opinions, and practices of the state of Alaska and of other states, I conclude that the legality of the LCC bid system is well established in Alaska procurement law. There are some provisions in Alaska law that provide even larger grounds on which LCC bid can be implemented. Unlike many other states' laws, which prohibit public officials from obligating themselves to make payments for any purpose in an amount greater than that budgeted for the current year, or to contract to pay for services which may be rendered or paid for at some future date, Alaska law provides that a contract for supplies, services, or professional services may be entered into for any period of time. This provision is considered to be in the best interests of the state, provided that the terms of the contract and conditions of renewal or extension, if any, are included in the solicitation and funds are available for the first fiscal period at the time of contracting. State law further notes that payment and performance obligations for succeeding fiscal periods shall be subject to the availability and appropriation of funds for them (AS 36.30.390 Multi-term Contracts).

Though it meets resistance from the vendor community, LCC bidding has been implemented for some projects, including heavy equipment procurement. The problem is not

implement it well, what cost factors should be considered, and how to make all the factors of measurable value.

Recommendations of how to use a LCC bid system legitimately and effectively will be discussed in the next part of this report, along with LCC evaluation methodologies. In brief, to be valid and protest-proof, a life cycle cost must be capable of identifying demonstratable cost variations in the utility of a purchase over its expected life. It should be noted that when uncertain factors are considered in a LCC bid process, quantification rules to these factors must be provided in the RFB. The quantification of uncertain factors is beyond the scope of this report. Interested readers can view the related references or another research report of the authors.

III. METHODOLOGY FOR LIFE CYCLE COST BID EVALUATION

3.1 INTRODUCTION

Life cycle cost (LCC) bidding is a method for considering bids and offers that uses price/performance evaluations to their fullest extent. An LCC bidding procedure takes into account all major cost factors incurred in the initial purchase, maintenance, and disposal of a piece of equipment. The LCC bid system has been regarded as a complicated procedure throughout its process. Bidding administrators usually are worried about specification preparation, evaluation model establishment, life cycle cost computation, paperwork, and so on. Bidders are also frustrated by government bidding.

A survey has been conducted for DOD to investigate private business's attitudes towards government bidding (David V. Lamm 1988). According to the survey, almost 70% of the respondents identified burdensome paperwork as one of the leading causes of problems in dealing with the government. Almost 57% of the respondents indicated that DOD bidding methods are difficult to understand and require much patience.

This part of the project was directed at simplifying the LCC bid system by accomplishing the following: 1) streamlining LCC bid procedure; 2) establishing a general LCC model structuring platform on which bidding administrators can easily build their own LCC model; 3) proposing a LCC analysis and scoring approach; 4) developing a computer programming approach that can implement all the processes involved in LCC bid procedures. Though this project was conducted for AKDOT&PF, the approaches proposed can apply to any other organization.

3.2 A PROPOSED LCC BIDDING PROCEDURE

Public bidding is well established in its conventional format. The LCC bidding system is based on the conventional procedure, but adds some new elements. We will only discuss LCC elements in a bidding procedure in the following sections. The proposed LCC equipment procurement bidding procedure is summarized as follows:

3.2.1. Determine Life Cycle Period. Theoretically, equipment can be used for an infinite amount of time, as long as repairs are furnished, but the operating and repair costs will increase tremendously after a certain period (see Figure 3-1). Therefore, it is necessary to determine an equipment's replacement or disposal period so that the total owner's cost is as low as possible. This replacement or disposal period is the optimal equipment economic life cycle, which can be found through engineering economic analysis.

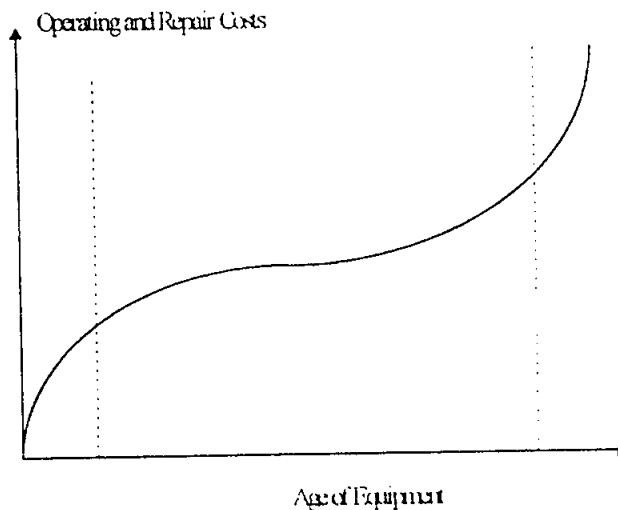


Figure 3-1

3.2.2. Estimate Interest Rate (Rate of return). Deciding on an appropriate interest rate (or rate of return) is a very important part of the LCC bidding process because LCC takes into account all life cycle costs and their time value. When the purchaser is a government agency, the rate of return is decided by the federal government. The interest rate set forth should include anticipated average inflation in the period.

3.2.3. Identify Cost and Revenue Factors. The most important and sensitive process of the LCC bidding system is how to prepare specifications and set them forth in the RFB. The RFB must cover the basic points for conducting a life cycle cost analysis of the equipment. An LCC model should include all important factors with monetary value or factors that could be properly assigned a monetary value. For this reason, it should include all capital purchase expenses and information to determine annual operating expenses throughout the equipment's expected life. Following are some major factors that should be included in an LCC bid:

- Initial equipment purchase price (including all acquisition expenses at initial purchase, such as transportation, operator training, etc.).
- Supply cost for any materials needed to operate the equipment, such as fuels, spare parts, etc. Terms in the bid request should specify maximum annual cost increase for supplies over the expected life of the equipment.
- Service maintenance cost, specifying maximum annual cost schedule over the expected life of the equipment.
- Operator wage cost.
- Cost of other services required, such as operator training and parts inventory.
- Price of similar equipment the agency might buy in the future because an organization often will want to standardize on one manufacturer's equipment.
- Product reliability concerns, such as equipment down time, should be reprinted by monetarily measurable values. For example, down time is multiplied by a reasonable unit time rental cost for the equipment to represent the down time cost factor.
- Revenue factors, if applicable.
- A guaranteed resale value (salvage value).

3.2.4. Specify LCC Bid Evaluation Sensitivity Analysis Methods. Research results show that LCC bids are not always effective. Often this is because uncertainties exist in the future cost factors, such as maintenance cost, and in system parameter, such as rate of return. These uncertainties may greatly affect the LCC evaluation process. Therefore, sensitivity analyses on these uncertain variables should be conducted to determine 1) how sensitive are the evaluation results (ranks) to variations in these uncertain parameters? 2) will these variations tend to justify the decision of making an award based on the life cycle cost? 3) how much variation in a given parameter is required to shift the decision to select one to another?

If the evaluation model parameters will be adjusted according to the results of the sensitivity analyses to reach a final decision, the analysis method must be specified in the RFB. For example, a bidding administrator can specify that an interest rate sensitivity analysis will be conducted to determine if a break-even point exists among the lowest LCC bids when the

interest rate changes in the $\pm 10\%$ range. The analysis results should be reflected in a later evaluation process.

Sensitivity analysis can also be used to test whether the lowest LCC bid is better than the lowest initial cost bid in terms of quantified risk and uncertainty. In this project report, the author only describes sensitivity analyses about interest rate and inflations as examples. Other sensitivity analyses, such as future maintenance cost and uncertainty analysis, are discussed in a separate research paper, "Quantifying Maintenance Cost Uncertainty--A New Approach To Improve Life-Cycle-Cost Bid System" (Lei Chen and E. R. Baker).

3.2.5. Set A Bidding Evaluation Scoring Rule. In a conventional initial purchase bidding system, bidders are finally ranked by initial purchase price. In the LCC bidding system, bidders are ranked according to LCC. A combination scoring method is presented here to demonstrate that using LCC as the only criteria may not be sufficient all the time. The following combination scoring rule is proposed:

$$S_{IP} = N - K_{IP} + 1$$

$$S_{LCC} = N - K_{LCC} + 1$$

$$S_{TT} = W_{LCC}(S_{LCC}) + (1 - W_{LCC})S_{IP}$$

Where	S_{IP}	Initial price bid score
	S_{LCC}	LCC bid score
	S_{TT}	Total combination score
	N	Number of bidders
	K_{IP}	Initial price bid ranking place (The lowest price bid ranks first)
	K_{LCC}	LCC bid ranking place (The lowest LCC bid ranks first)
	W_{LCC}	Weight of LCC score in total combination score

The scoring rules should be set forth in the RFB, i.e., the LCC weight factor W_{LCC} must be set forth in the RFB. The LCC weight factor W_{LCC} can be defined by fixed value, a continuous dependent variable of certain sensitivity analysis results, or a discrete dependent variable of certain sensitivity analysis result. The mathematical function of W_{LCC} with respect to other variables must be clearly defined in the RFB.

3.2.6. Set Forth All LCC Bidding Elements in RFB. Federal law requires that all bidding evaluation criteria and methods be explicitly specified in the RFB text. It is critical to clearly describe the sensitivity analysis methods to be used in the evaluation procedure if the analysis result will be used as additional decision making criteria. When computer software will be used for evaluation, it is recommended that the software be distributed with examples to bidders, if doing so does not violate the software distribution copyright regulation.

3.2.7. Implement LCC Bidding With A Computer Aided Evaluation System. A computer aided LCC bid evaluation system named LCCbid was developed for AKDOT&PF as part of this research project. It is a general bidding evaluation system that can be used for any project LCC analysis and for LCC bid evaluation. Please review Section IV of this report.

3.3 A PROPOSED GENERAL LCC MODEL STRUCTURING PLATFORM

Thousands of models have been developed for life cycle costing analysis of different industry projects and products. In *Life Cycle Costing Techniques, Models and Applications* (1989), Dhillon suggests more than one hundred models for equipment life cycle costing analysis. Except for some equipment with special operating characteristics, life cycle cost is usually the sum cost of all factors, including a consideration of time value. Cost factors differ between equipment and organizations. A general LCC model platform should be established so that purchasers (bid evaluators) can build their own LCC model. The following is a proposed general LCC model that can be expressed by a computer program as an LCC model structuring platform:

$$LCC_{presentvalue} = \sum_{i=0}^n \sum_{j=1}^m \frac{C_j - R_j}{(1+r)^i}$$

Where

$LCC_{presentvalue}$	Life cycle cost in present value
C_j	jth cost factor
R_j	jth revenue factor
r	Interest rate (rate of return)

- m Total number of cost and factors
- n Life cycle period in years
- i Ordinal number of life cycle period
- j Ordinal number of cost or revenue factors

3.4 A COMPUTER PROGRAMMING APPROACH

Researchers on this project developed a computer program to support the proposed LCC bid procedure. The core of the program is a flexible database structuring module expressing the general LCC model proposed. Users can build their own models simply by typing in cost and revenue factors and parameters. Figure 3-2 is the conceptual structure of the computer program.

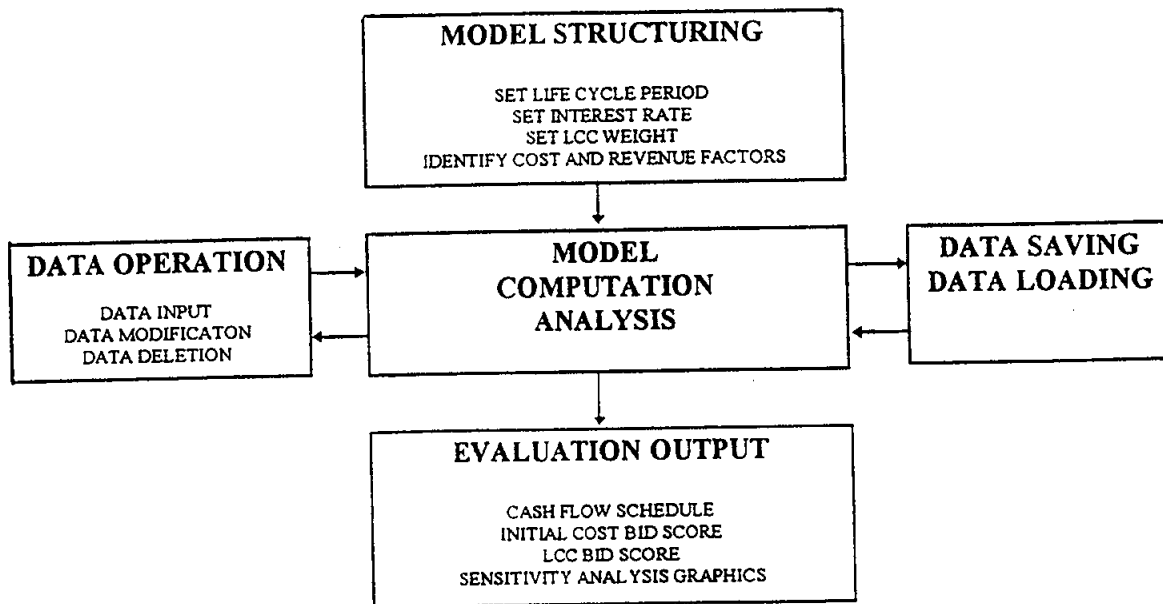


Figure 3.2

This conceptual computer model was expressed in the computer language C++ and an executable program LCCBID.EXE resulted. Please see Section IV of this report regarding the supporting computer program.

3.5 APPLICATION EXAMPLE

Let us consider a hypothetical problem. Rush Move Inc. of Fairbanks, Alaska advertized a Request For Bid for procurement of a pickup truck. The truck will be used for evening errands. Rush Move stated in the RFB that both life cycle cost and initial cost will be the criteria of bid evaluation. The award decision will depend on the total score of the bid evaluation method proposed in this report. Rush Move set a contract period of five years. Four cost factors and salvage value will be considered during the contract period (life cycle). The four cost factors are initial purchase cost, maintenance cost, labor wage cost, and utilities cost. The rate of return for Rush Move is considered to be 7.8%. A 55% life cycle score and initial cost score of 45% will be used to contribute to the total score, which is the basis for making the award. Four companies and an individual contractor submitted bids.

Figure 3-3 shows that the five bidders proposed very distinct cost schedules. Seekins Mobile and Trucking contractor proposed high initial costs with low future costs. The other three bidders proposed lower initial cost but higher future costs. It should be pointed out that we have purposely included very different proposals in this problem to produce obvious break-even points. When using a combination score of initial cost and life cycle cost, any rental proposals should be eliminated. Only proposals of the same transaction nature can be compared by combination scores.

Year	Seekins	A&B	Chevy	Nissan	Truckings
0	-60,000.00	-38000.00	-38,000.00	-15,500.00	-68,000.00
1	-7,900.00	-9,200.00	-11,500.00	-15,500.00	-1,000.00
2	-8,300.00	-9,500.00	-12,000.00	-15,500.00	-1,000.00
3	-8,300.00	-10,000.00	-12,300.00	-15,500.00	-1,000.00
4	-11,300.00	-10,100.00	-12,800.00	-15,500.00	-1,000.00
5	-1,600.00	1,600.00	2000.00	-15,500.00	4,000.00

Figure 3-3

LCC Score Report (at interest rate = 7.8%)		
Company Name	Life Cycle Cost	Score
Trucking	68579.24	5
A&B Auto	69071.08	4
Chevy Bros.	76917.32	3
Nissan Rental	77714.60	2
Seekins Mobile	90562.99	1

Figure 3-4

Initial Cost Score Report		
Company Name	Initial Cost	Score
Nissan Rental	15500.00	5
A&B Auto	38000.00	4
Chevy Bros.	38000.00	3
Seekings Mobile	60000.00	2
Trucking	68000.00	1

Figure 3-5

Total Score Report (at LCC weight = 1.0)	
Company Name	Score
Trucking	5
A&B Auto	4
Chevy Brothers	3
Nissan Rental	2
Seekins Mobile	1

Figure 3-6

Assume that the scoring rule was set forth so that 1) if there is no break-even point in the interest rate (7.82)% range, LCC will be used as the only criteria, i.e., $W_{LCC}=1.0$, $S_{LCC}=S_{TT}$. 2) If break-even points exist within the (7.82)% range, initial price and LCC will both be used as evaluation criteria. In this situation, $W_{LCC} = 0.45$, $S_{TT} = 4.45S_{LCC} + (1-0.45)S_{IP}$.

By means of LCCbid system, evaluation report and sensitivity analysis results are shown in the following Figures 3-4 through 3-6. Figures 3-4 and 3-6 show that when using LCC as the only criteria, i.e., $W_{LCC}=1.0$, Trucking Contractor has the lowest LCC bid.

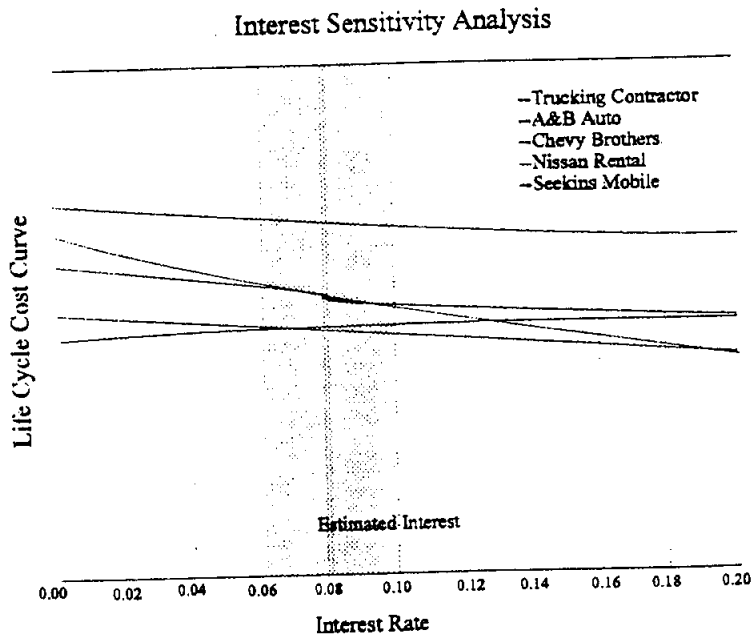


Figure 3-7

However, from the interest sensitivity analysis graph (see Figure 3-7), we can see that there is a break-even point within the range stated in RFB. Therefore the final decision should be made based on both life cycle cost and initial price. According to the

Total Score Report (at LCC weight = 0.45)

Company Name	Score
A&B Autot	4.00
Nissan Rental	3.65
Chevy Bros	3.00
Trucking	2.80
Seekins	1.55

Figure 3-8

scoring rule set forth in the RFB, W_{LCC} is adjusted to 0.45. The recalculated total score is shown in Figure 3-8. A&B Auto now has the highest score.

3.6 SUMMARY

This part of the report outlined a methodology for determining life cycle cost. A general life cycle cost model structuring platform was presented and a LCC

evaluation scoring method proposed. The suggested equipment procurement LCC bid elements are summarized as follows:

1. Decide equipment life cycle period.
2. Estimate the organization's minimum rate of return.
3. Identify cost and revenue factors.
4. Specify LCC bid evaluation sensitivity analysis methods.
5. Set a bidding evaluation scoring rule.
6. Set forth in the RFB all the above elements among others.
7. Implement LCC bidding with a computer aided evaluation system.

Through solution of an LCC bid example problem, the supporting computer software is shown to be easy and effective. The software can be used to solve other LCC analysis problems and bid evaluation problems. Sensitivity analysis was shown to be necessary and important in LCC bid evaluation. As an example, interest sensitivity analysis was conducted on the example problem. Future maintenance cost is also subject to sensitivity analysis; this issue was discussed in another research paper by the author.

IV. LCCbid User's Guide

4.1 INTRODUCTION

Welcome to Version 1.0 of LCCbid (Life Cycle Cost Bid Evaluation System). LCCbid is a program designed to evaluate bids by life cycle cost rather than by the conventional initial price method. LCCbid can also evaluate bids by a combination of life cycle cost and initial cost. You do not have to be an expert in life cycle cost bid analysis to use this software package. With a general understanding of life cycle cost concepts, you can flexibly build your own life cycle cost model by simply typing in any cost factor you think is proper. LCCbid's analysis features allow you to have better insight on the bids proposed than conventional methods. This program is a demonstration program developed for Alaska DOT&PF; it may be modified for official or commercial purposes. Commercial rights are reserved. The basic features of this program perform the following tasks:

- Establish an LCC model by simply entering relevant cost factors
- Establish database records of bids proposed
- Enter, view, delete and modify records
- Rank bids proposed by life cycle cost
- Rank bids proposed by initial cost
- Rank bids proposed by a combination of the above two
- Perform sensitive analysis by interest rate
- Perform sensitive analysis by weight of combination
- Provide an evaluation report

4.2 SYSTEM REQUIREMENTS

LCCbid can be run on any IBM PC or compatible computer with 640k RAM and DOS 5.0 or higher. For good graphic view, EGA (Enhanced Graphic Adopter) or VGA (Video Graphic Adopter) is required. Eight common laser printer drivers can be called through the "Printer Selection" menu of this program.

4.3 LCCbid PROGRAM RESTRICTIONS

Because LCCbid Version 1.0 is a demonstration program developed for AKDOT&FF, there are some restrictions with respect to both the function and capacity of the program. Though this version can be used for bid evaluation, its restrictions may limit a user's broad usage. It is important that you clearly realize all the restriction before using this version of LCCbid for official evaluation. The following are some of the restrictions:

- 1) The maximum number of bidders is 15.
- 2) The maximum number of cost factors is 10.
- 3) This program does not have a printout subroutine; rather it supports <Print Screen> in both text mode and graphic mode, allowing you to print anything displayed on the screen at any time.

4.4 INSTALLING LCCbid

The LCCbid original diskette includes 3 files: 1) a stand-alone executable file, LCCBID.EXE; 2) a README.TXT file; and 3) a INSTALL.BAT file.

Floppy: using LCCbid from a floppy disk requires no installation. As with most other software, making a copy of the master disk for safe keeping is a good idea. All files are copyable, so you may copy them to any other disk and or directory. To use the program, simply type "lccbid" and press the <Enter> key. Data files created will automatically be saved in the floppy disk containing the LCCbid program, unless otherwise specified.

Hard Disk: there are two ways to install LCCbid to a hard disk:

- 1) At any DOS prompt (C:>, etc), type B:INSTALL, and then press <Enter>. This procedure will first create a subdirectory C:\LCCBID on the C drive, and then copy the LCCbid program files to this subdirectory. Any data files created later will be saved here unless you otherwise specify when saving them.

- 2) If you would like to create a subdirectory with a name other than LCCBID, you can use the DOS commands MKDIR and COPY to install this program. See a DOS manual for details.

4.5 WORKING WITH LCCbid

LCCbid is a menu driven program. The menu is operated only with keys (a mouse is not supported by this program). All instructions needed to use this program will be shown on the screen. Figure 4-1 shows the structure of the program's subroutines.

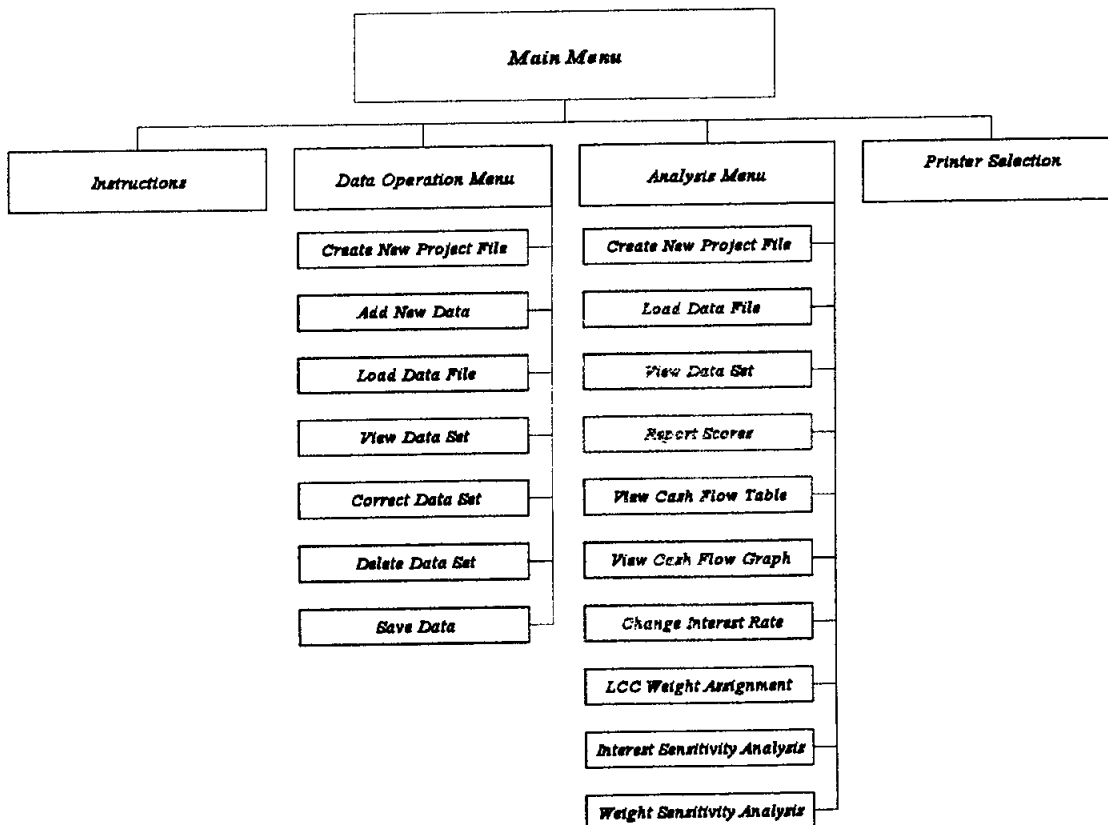


Figure 4-1

Main Menu: To start the LCCbid program, type "LCCBID" at the directory containing the LCCBID.EXE file and press <Enter>. The program will briefly display software information, and then the Main Menu. The choices on the Main Menu provide access to the displayed subroutines. Press one of the keys corresponding to a boldface letter. See Figure 4-2.

Instruction: When you choose this subroutine from the Main Menu, the screen will display the instruction information contained in this USER'S GUIDE. You may start reading the instructions by pressing the <Enter> key to continue. Press the <Esc> key to return to the Main Menu.

Printer Selection: If you want to print the evaluation report output, either table text or graphs, choose this routine to set up a proper printer driver. Eight commonly used laser printers can be used with proper driver selection, as shown in Figure 4-3. Choose one of the printers listed by pressing the corresponding letter; that printer will become the default printer. You won't have to set the printer in the future unless you change your driver. If your printer is not one of the types listed in the printer selection routine, please check the DOS graphics section for help.

Data Operations: When you choose Data Operations from the Main Menu, the Data Operation Menu will appear on the screen. You can choose the desired operation by pressing the bold-faced letters (see Figure 4-4).

Create New Project Data File:
LCCbid is designed to evaluate several procurement alternatives or proposed bids

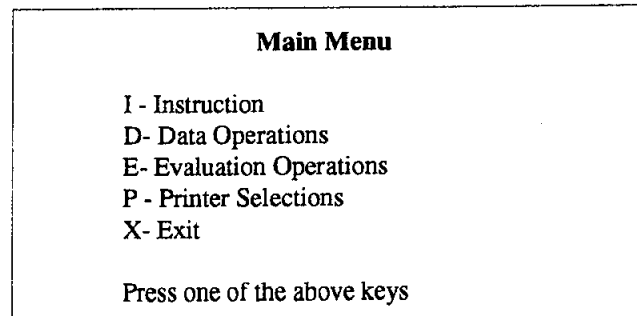


Figure 4-2

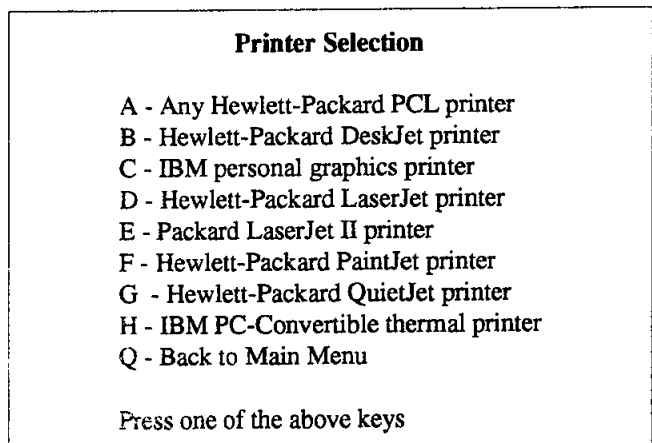


Figure 4-3

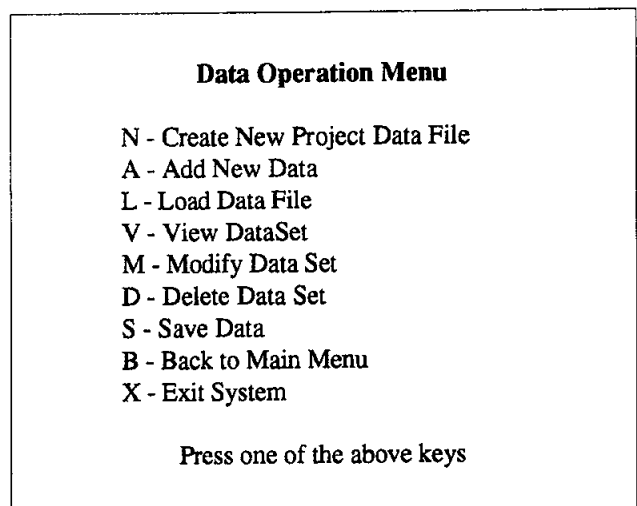


Figure 4-4

and decide which one is the best according to life cycle costs. First, you must create such a problem by establishing a database that includes all alternatives. This is accomplished by using the Create New Project Data File subroutine (see Figure 4-5). After choosing Create New Project File in the Main Menu, the program will prompt you to type in the problem parameters. As usual, the bold faced text are computer prompted.

```
Life Cycle Years (1-15): 5
Factors to be considered (1-10): 4
Interest rate (0-20%): 8
LCC weight: 1.0

Press any key to continue.
```

Figure 4-5

Life Cycle Year is the period of time set for the equipment you are going to use. At the end of this period, it is assumed you will sell the equipment. For this example there are four cost factors to be considered. If you were to think that the rate of return of your organization is 8%, you would type 8 after the Interest Rate prompt.

The LCC Weight is used for making bidding award or procurement decisions, considering both life cycle cost and initial purchase price. In this example you would like to make the award decision only on life cycle cost, so you weighted LCC 1.0. Note that the numbers in the brackets are the number of ranges you could type in; you will be asked to retype if you input numbers beyond these ranges. (Because this is a demonstration program, the capacity is relatively small.)

The next screen will ask you to specify cost or revenue factors to be considered, up to the number you defined in the last screen. If you were to input 4, four unnamed factors would be prompted for you to specify. You might type in price, maintenance, labor and utilities as the four cost factors (see Figure 4-6). When you finish inputting the four cost factors, press any key, and the screen will display the list of cost or revenue factors you have input (see Figure 4-7).

```
Identify Factors To Be Considered

Factor 1: Price
Factor 2: Maintenance
Factor 3: Labor
Factor 4: Utilities

Press any key to continue
```

Figure 4-6

You have now established a new database, but as yet it has no records in it. When you continue, the program will open the database for you to input data.

Add New Data Set: If you have just created a new project file, the program will automatically go to the Add New Data Set subroutine. In other situations, you must choose this routine at the Data Operations Menu. Your task of adding a new data set actually requires creating new data records. First you are asked to input the bidder's identification information (see Figure 4-8). For example, the bidder is the Chen Group. When you continue, you are prompted to input the values of the cost or revenue factors you specified while creating this project file. You identified price, maintenance, labor and utilities as the cost factors and input this data from the bidder's proposal. The first screen displays the initial cost at <Year 0>. The four cost factors you specified will be prompted here for value input. For example, the Chen Group proposed an initial cost of \$100,000. No other cost was bid for year 0. So, you type 100000 after "Year <0> <Price> cost:" (see Figure 4-9). Please do not type "\$" sign or "." with the number 100000. "\$100000" or "100.000" are illegal input and will cause an error. Note that this program is designed for bid evaluation by life cycle cost. Revenue is

List of Factors to Be Considered

Price
Maintenance
Labor
Utilities

Press any key to continue

Figure 4-7

Input Data Set: 1

Company name: Chen Group
Address: 888 University Ave., Fairbanks, AK 99999
Phone number: (907) 474-5094
Representative name: Lijia Zeng
Date Received: May 8, 1994

Press any key to continue

Figure 4-8

Company: Chen Group

Year<0><Price>Cost: 100000
Year<0><Maintenance>Cost: 0
Year<0><Labor>Cost: 0
Year<0><Utilities>Cost: 0

Press any key to continue

Figure 4-9

assumed to be the savings for each piece of equipment. If you identified some revenue factors, input their values with negative signs, because the LCC total is calculated as dollars.

The next screen will repeat these same four factors for the first year end values; see Figure 4-10. From that point on, the program will continually prompt for the four cost factors for each year end value until the end of the equipment life cycle period that you specified when creating this project file. At the end of the final year, in addition to these four costs, you will be asked to input the salvage value of the equipment that the bidder guaranteed. For example the Chen Group guaranteed the salvage value of the

equipment at \$50,000 in their bid proposal, so you input 50000 after the "guaranteed back value:" prompt. Please note: you must enter a positive value here (see Figure 4-11).

When you continue, you will be asked if another data set is to be inputted. If you answer "y", you will repeat the same data input procedure; when you answer "n", the program will ask if you would like to save the data you have already input.

View Data: You may review the data you have input for errors by using View Data. When you press the "v" key at the Data Operations Menu, the screen will display a list of numbered data sets (records). You can review a data set by typing in the corresponding number then pressing <Enter>. The screen will then display the data set in a format similar to that used when inputting.

Modify Data: If you find there is an error in a data set, you can correct it by using this subroutine. When you press "m" at the Data Operations Menu, the screen will display a list of

```
Company: Chen Group
Year<1><Price>Cost: 0
Year<1><Maintenance>Cost: 5000
Year<1><Labor>Cost: 20000
Year<1><Utilities>Cost: 3000

Press any key to continue
```

Figure 4-10

```
Company: Chen Group
Year<5><Price>Cost: 0
Year<5><Maintenance>Cost: 10000
Year<5><Labor>Cost: 20000
Year<5><Utilities>Cost: 5000

Guaranteed back value: 50000

Press any key to continue
```

Figure 4-11

numbered data sets. You can access a data set by typing in the corresponding number then pressing <Enter>. The program will redisplay the data set you chose. You can modify data following the cursor. Initially, the cursor will be at the first character of a data line. You can accept this line buy pressing <Enter>, or you can modify the text. You must rewrite the whole line to correct it. Press <Enter> when through. The program will give you another chance to modify this screen. Press "y" to modify one more time, or "n" to continue.

Save Data: Whenever you complete a session of data input, modification or deletion, the program will ask you if the processed data should be saved. If the project is unnamed, you will be prompted for a file name. For example, you might type in "example1.dat" as the file name and then press <Enter>. The screen will ask you to confirm that name. Press "y" to confirm. Press "r" to save the file by another name.

Press "n" to abort the save routine. If you do not specify a path, the data file will be saved in the same directory as the LCCbid program file. (See Figure 4-12.) If you want the data file to be saved in other directory, you should specify the path as part of the file name. For example, if you wanted to save a data file in a directory called BID, you might press "r" after the "Save data in <example1.dat> now (y/n/r)?" prompt. The program will then again ask you to "Type file name in which data will be saved:". You now have a chance to specify a desired path or to save the file with another name. For example you might type "C:\BID\EXAMPLE2.DAT".

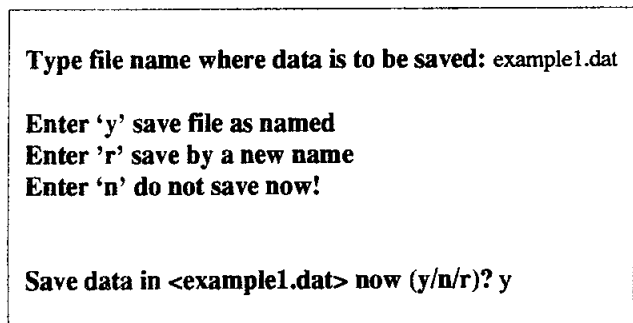


Figure 4-12

Load Data File: If you want to append a new data set to a project data file or if you want to edit the data of an exisiting project data file, you need to load the data. Also, if you want to conduct any analysis, you have to load a project data file first. Only one data file can be loaded for processing at a time. If no data file is loaded in the system, the program will ask you to load one when you try to conduct any analysis or try to edit a file. Just as you saved a project data file, you simply type the file name if the file is saved in the default directory, i.e. in the same directory where LCCBIB.EXE is saved. If you want to load a file from a directory other

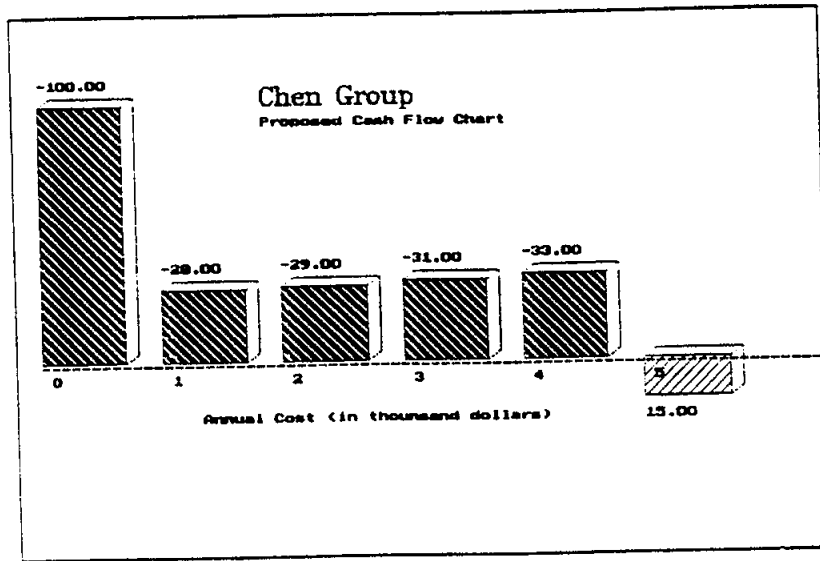


Figure 4-16

Graphic View of Cash Flow: This subroutine has the same function as the table view of cash flow, but the data is displayed in a bar chart graphic format. See Figure 4-16.

Report Score: The LCCbid Report Score subroutine has three report tables. The first table is the Life Cycle Cost Score Report, which displays a ranked bidder name list with the lowest (and best) bid on top and each bidder's present value life cycle cost ranked below. Each bidder's ranking score is also included in the table. The score is determined by the number of bidders + 1 - ranking position. The interest rate shown is the interest rate set forth in the RFB or the value you set for sensitivity analysis (see Figure 4-17).

Company Name	Life Cycle Cost	Score
Trucking Center	68579.24	5
A&B Auto	69071.08	4
Chevy Brothers	76917.32	3
Nissan Rental	77714.60	2
Seekins Mobile	90562.99	1

Press any key to view INITIAL COST score...

Figure 4-17

than the default, you must specify the path as part of the file name (see Figure 4-13). In the example, a data file is loaded from the C drive directory \bid.

Delete Data Set: To delete a data set (record) from a project data file, first load the data file. Then choose the Delete Data subroutine by pressing 'd' at the Data Operations Menu. The computer will display a list of numbered data sets (records). You can delete a data set by typing in the corresponding number and then pressing <Enter>. The program will then automatically go to the Save Data subroutine and ask if you want to save the data file with the record(s) deleted.

Analysis Menu: The Analysis Menu allows you to access the analysis subroutines of this program. Before you can conduct any analysis, you must load a project data file. The Analysis Menu is shown in Figure 4-14.

View Cash Flow Table: This subroutine allows you to view the cash flow projected for a proposed bid. You can continue viewing another data set's cash flow by pressing the "y" key. Any other key will take you back to the Analysis Menu (see Figure 4-15).

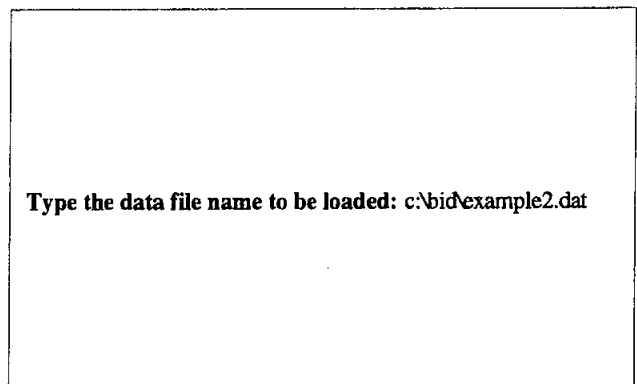


Figure 4-13

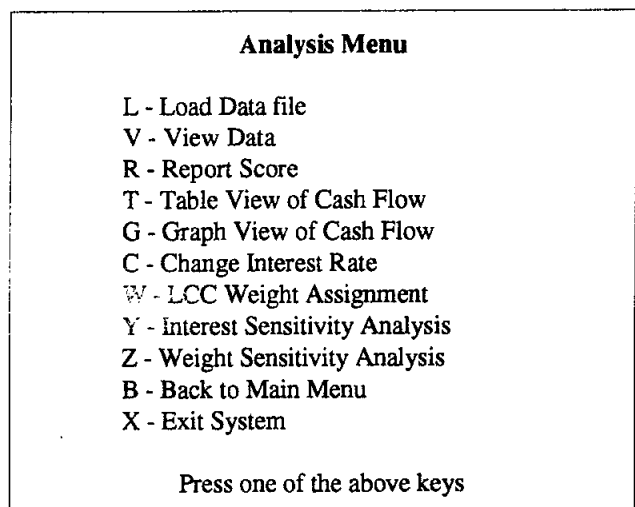


Figure 4-14

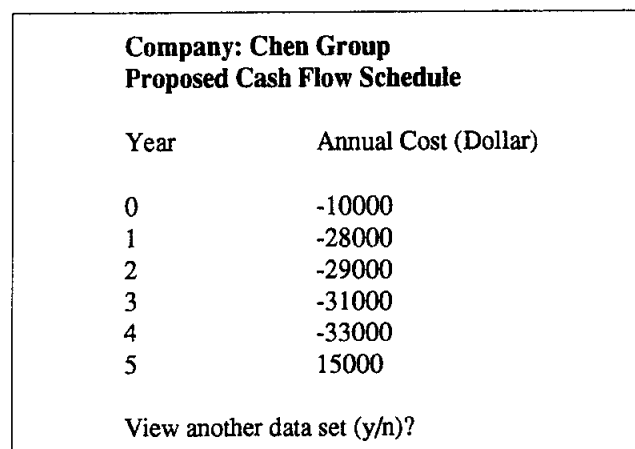


Figure 4-15

The second table is the Initial Cost Score Report, which has a format similar to the Life Cycle Cost Score Report table (see Figure 4-18).

The third table is the Total Score Report of the LCC score and initial cost score. The weight displayed is the weight set forth in the RFB or set for sensitivity analysis. The score is calculated by combining the LCC score and initial cost score with the weighting factor (see Figure 4-19).

Interest Sensitivity Analysis: The Interest Sensitivity Analysis subroutine provides a graph that summarizes the LCC rankings to show how bidders' rankings vary when the interest rate changes. You can also see how each bid's life cycle cost changes when the interest rate changes (see Figure 4-20).

Change Interest Rate: According to the procurement statutes, the interest rate set forth in the RFB must not be changed under any circumstances. The Change Interest Rate subroutine provided in LCCbid is for sensitivity analysis only. When you are asked whether to save the changed interest rate, choose "n" if the interest is not the value set forth in the RFB (see Figure 4-21). If you save an interest rate other than the rate set in the RFB with your project data file, you should change the interest rate to the value set in the RFB before using the LCCbid result to make an award decision.

Weight Sensitivity Analysis: Similar to Interest Sensitivity Analysis, the Weight Sensitivity Analysis subroutine provides a graph that summarizes the total score ranking, showing how Bidder's rankings may vary when the LCC weight changes (see Figure 4-22).

Initial Cost Score Report		
Company Name	Initial Cost	Score
Nissan Rental	15500.00	5
A&B Auto	38000.00	4
Chevy Brothers	38000.00	3
Seekins Mobile	60000.00	2
Trucking Center	68000.00	1
Press any key to view TOTAL SCORE...		

Figure 4-18

Total Score Report (at LCC weight = 0.45)	
Company Name	Score
A&B Autot	4.00
Nissan Rental	3.65
Chevy Brothers	3.00
Trucking Contractor	2.80
Seekins Mobile	1.55
Press any to return to main menu	

Figure 4-19

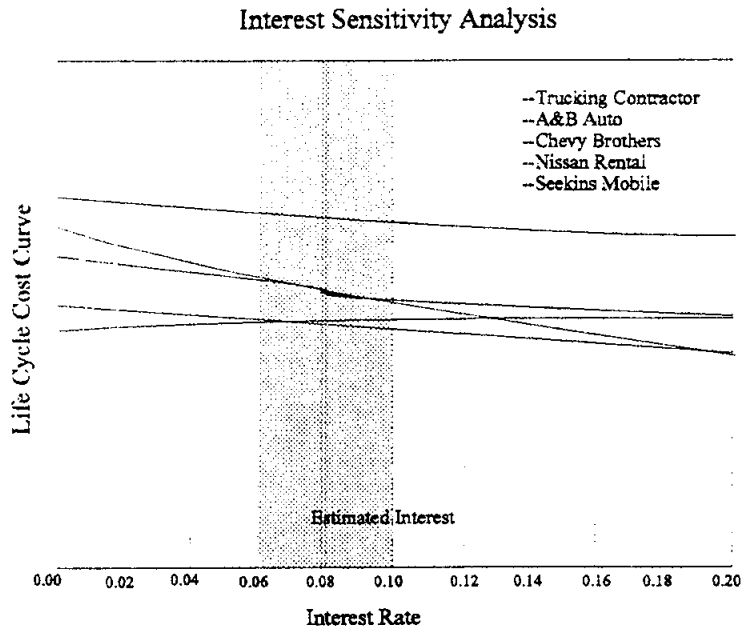


Figure 4-20

Current Interest Rate: 7.80%
Inteneded Interest Rate: 10.50%

Save this interest rate with data file now? (y/n)

Figure 4-21

LCC Weight Adjusting: Like the interest rate, the LCC weight set forth in the RFB must not be changed under any circumstances.

Weight Sensitivity Analysis

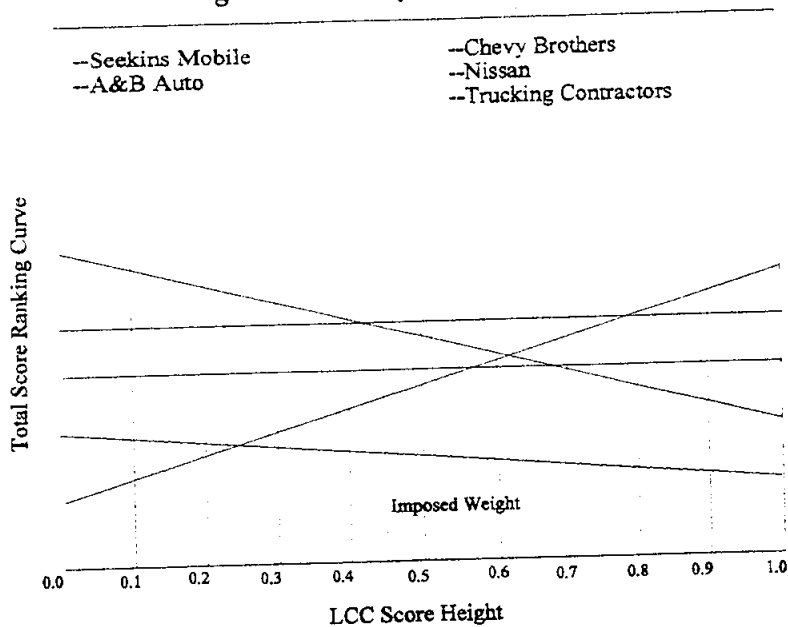


Figure 4-22

The LCC Weight Adjusting subroutine provided in LCCbid is for sensitivity analysis purpose only (see Figure 4-23). When you are asked whether to save the LCC weight, choose "n" if the weight is not the value set forth in the RFB. If you save an LCC weight other than the value set

Current LCC Weight: 1.0
Intended Lcc Weight: 0.45

Save this interest rate with data file now? (y/n)

Figure 4-23

in the RFB with your project data file, you should change the weight to the value set in the RFB before using the LCCbid result to make an award decision.

VI. CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this project, the LCC bidding system can be implemented legitimately within AKDOT&PF for equipment procurement. The methodologies and supporting computer program proposed in this report can significantly improve the LCC bid process with respect to ease of implementation, efficiency, and user transparency.

Three areas of research needs appear most significant in improving the life cycle cost bidding evaluation process: 1) There is a crucial need for more good usable cost data on heavy equipment maintenance, which can be used to establish cost distribution patterns, making sensitivity analysis more effective and precise; 2) Research is needed to define appropriate sensitivity analysis methods applicable to very limited data sources; and 3) An interdisciplinary team composed of members of the AKDOT&PF fleet, management and procurement divisions, representation of the affected vendor sectors, and representatives of the Attorney General's office should pursue the question of implementing life cycle cost bidding. No single agency or agent can effectively accomplish this task.

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