1985

The valuation of industrial property with declining operation returns

Il Geon Yoo
Iowa State University

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THE VALUATION OF INDUSTRIAL PROPERTY WITH DECLINING OPERATION RETURNS

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The valuation of industrial property with declining operation returns

by

Il Geon Yoo

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Department: Industrial Engineering
Major: Engineering Evaluation

Approved:

Signature was redacted for privacy.

In Charge of Major Work
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For the Graduate College

Iowa State University
Ames, Iowa
1985
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I. INTRODUCTION

The valuation and appraisal of the industrial properties are necessary for many reasons [1]:

1. to provide information for management,
2. for tax assessment,
3. for sale or transfer of a business,
4. for condemnation,
5. for settling estates,
6. to set insurance rates, and
7. in issuing securities and financing purposes.

The problem or situation covered by this study came from the appraisal of industrial property and equipment especially for assessing taxes for ad valorem tax purposes. In Iowa and some other states, ad valorem taxes are based on the market value of a property. However, in the majority of situations, market values of the properties cannot be ascertained directly. This may be due to the uniqueness of a property or due to the rarity or nonexistence of market exchanges of comparable property. Thus, determining a procedure to estimate the value of such industrial items or groups of properties is desirable.

Since there are many interpretations of the words value and valuation, it is difficult to use the terms without defining them for estimating the value of industrial properties. Marston et al. wrote about value [1]

Value is a relative term by which the desirability of ownership of the property in question is stated in terms of other property or money.
For more specific concepts of value, Marston et al. and Bonbright explained into two basic concepts, which are the market value and value to the owner. For market value, Bonbright explained [2]:

The valuation of property under market value means merely an attempt to estimate the price for which the property could be sold by some stipulated seller to anyone else the conditions of the assumed sale being left for selection by reference to the purpose for which the valuation is being made.

Bonbright also called market value an exchange value. This arose from the definition of market value as the power a commodity commands in exchange of itself for other things. Another definition of the market value is [3]:

The amount at which property would exchange between a willing buyer and a willing seller, each having a reasonable knowledge of all pertinent facts, neither being under compulsion to buy or sell and with equity to both.

As one of the basic concepts of value, the value to the owner was illustrated by Bonbright [2]:

The value to the owner is a subjective value representing a state of mind, an attitude of the owner towards the thing valued. The value of a property to its owner is identical in amount with the adverse value of the entire loss, direct and indirect, if he were to be deprived of the property.

There are three different ways of interpreting value to the owner: 1) what the owner actually feels, 2) the results of an objective appraisal, and 3) hindsight evaluation. Thus, the value to the owner can be defined as the worth of the property to the owner himself, and thus, a subjective value. On the contrary, the market value is the price for which the specific property could actually be sold in the open market of
A. Evidences of Value

It is usually impossible to measure the value of a property directly. Thus, the appraisal process depends upon judgment based on various evidences of value. The valuation procedure is usually divided into four categories [2]: 1) define purposes of the valuation, the parties, place, and time, 2) define property to be considered, 3) develop the evidences, and 4) weigh the evidences and determine estimate of value.

From the above, the evidences of value are of interest and require further explanation. Marston et al. presented three evidences of value in their text [1]:

- Market price, cost of replacing the service rendered by the property, and present value of the future returns from the property are usually relatively good measures of the value of property to the owner.

Babcock divided the category of evidences as the income method, the replacement cost method, and the market comparison method [4].

Based on the sources cited above, three evidences of value can be defined. These are: 1) market evidence, 2) cost evidence, and 3) income evidence. These three approaches are commonly accepted as bases for judgmental determination of value. A description of each of these evidences follows.

B. The Market Evidence

The market evidence of value consists of an investigation of prices paid for similar properties in a ready and open market. The market
evidence usually provides the strongest indication of value among the three evidences, owing to the advantage of comparability with adjacent or similar items sold before. Bonbright supported this when he stated an opening to his market evidence discussion as follows:

The method of valuation which will now be discussed is given first place, sometimes to the exclusion of all other evidences, in the legal valuation of marketable forms of property [2].

Even though the market evidence is considered to be a strong evidence of value, many kinds of properties do not enjoy a readily marketable status. Again, quoting Bonbright:

But only with respect to highly marketable property, and not always even there, is a court or appraiser justified in accepting uncritically the record of current sales as the measure of market value [2].

The market evidence, therefore, is considered to be a strong evidence of value if the property has been frequently traded on the open market.

Therefore, with the support of a lot of relevant sales evidences in the market, the market evidence can be most valuable when market value is the objective.

C. The Income Evidence

Income evidence is based on the economic concept that the present value of any object of wealth is simply the discounted value of the anticipated benefits derivable by the owner. That is, the income approach entails an estimate of the net monetary benefits accruing to the prospective buyer of the property every year, and an estimate of the number of years that such benefits to their worth at the present time.
For this purpose, value engineers use a discount rate equal to the rate of return that the prospective buyer would consider reasonable and acceptable for an investment in the property.

Procedure for this income approach is in two steps:

1. Estimation of value of net benefits (income) and future date of realization.

2. Use appropriate rate of discount considering pure interest and risk factor.

However, the income evidence sometimes faces the difficulty in the estimation of accurate future income, discount rate, and related data.

D. The Cost Evidence

The basis of the cost evidence is that value is evidenced by the cost of the property adjusted for service consumed. Four kinds of cost have been identified. These are 1) the original cost, 2) the trended original cost, 3) the reproduction cost, and 4) the replacement cost. The original cost basis is not frequently used because of the effect of the passage of time on the monetary standard used to measure value.

Thus, the trended original cost, reproduction cost, and replacement cost are mostly used. Marston et al. defined them [1]:

1. Trended original cost: original cost converted to current cost by use of cost indexes.

2. Reproduction cost: the estimated cost of reproducing substantially the identical property at a price level as of the date specified.

3. Replacement cost: the estimated cost of replacing the service
of the existing property by another property to achieve the most economical and preferred service, but at prices as of the date specified.

In the estimation of the cost evidence, an appropriate adjustment on deduction is made from the estimated cost new, in an amount representing the loss of value in the property when compared to similar property in new condition.

The loss of value is broadly termed depreciation. The factors making up this loss in value include:

1. reduced service life expectancy,
2. physical deterioration,
3. functional obsolescence, and
4. economic obsolescence.

The cost evidence approach is frequently used for industrial properties since the required information is usually available.

E. Application of Three Evidences

The three approaches for developing value evidence which are commonly accepted were presented in the previous section. In the valuation of industrial property, however, these three evidences are not always applicable. Market evidence is sometimes unavailable due to the lack of sufficient sales data for relevant properties. Few transactions that have taken place often reflect only a scrap value received for the property. Similarly, the income evidence is often hard to obtain because each equipment unit may be only a part of an income-producing entity and it is difficult to estimate the future income stream of an
equipment from the total income. Since the bases for estimating the market and income evidences of value are not available for many industrial property valuation, the cost evidence is frequently used. This is supported by the Iowa Department of Revenue:

After considerable study it was determined that the cost approach should be used to determine the fair value of industrial machinery and equipment [5].

As such, data estimating the cost evidence of value are usually available and a reliable evidence of value for industrial property can be obtained. The procedure for developing cost evidences of value is the subject of this study.
II. REVIEW OF PREVIOUS WORK

The valuation procedure proposed in this dissertation begins with the concept of depreciation. First, a definition of depreciation will be discussed.

A fundamental notion of depreciation is the measure of inferiority of subject property compared to a new substitute. Perhaps one of the most useful definitions is that adopted by the Depreciation Committee of the National Association of Railroad and Utilities Commissioners [6]:

Depreciation is the expiration or consumption, in whole or in part, of service life, capacity or utility of property resulting from the action of one or more of the forces operating to bring about the retirement of such property from service; the forces so operating include wear and tear, decay, action of the elements, inadequacy, obsolescence, and public requirements; depreciation results in a cost of service.

Also, R. Winfrey defined depreciation as [7]:

Depreciation is the loss in value of a group of property resulting from a decrease in its ability or capacity to perform present and future service.

As a means of estimating depreciation, several methods have been developed for the proper allocation of the total depreciation over the periods of life. Some of these are straight line, sinking fund, present worth, declining balance, and sum-of-digits methods.

Of all these methods of depreciation, the present worth depreciation method is used in this dissertation because it is closely related to the economic theory of value and the slope of depreciation can be variable in this method, while the others represent only one slope of depreciation. A brief summary of the present worth
A. Present Worth Depreciation Method

According to Marston et al. [1], the present worth method is defined as follows:

This present worth actual depreciation principle is that the depreciated value of an industrial property unit, at any date during its service life, is the present worth at that date of the probable future operation returns yet to be earned by its probable future services.

The operation returns referred to in this quote are the after tax cash flows, that is, operating revenues, less cash operating costs, and cash income tax payments. The operation returns of a property were also defined as including both the periodic depreciation and the net return on the depreciated value [7]. Marston et al. [1] state:

For a property to justify its economic existence, its annual operation return should be at least sufficient to repay its yearly depreciation allocation and, in addition, pay each year a fair return on the allocated base of the unit at the beginning of the year [1].

It is seen that the present worth method is based on the fundamental notion of value that the value of a property is the present worth of its probable future services.

The depreciation in this method is measured by the amount of decrease in the present worth of these operation returns as the unit increases in age. As the unit becomes older in service, the number of expected future returns decreases, and this results in a lessening of
present value with an increase in age [8].

B. Mathematical Expression of Present Worth Method

The mathematical derivation of the present worth method is based on discounting the anticipated future annual operation returns and the estimated salvage value at retirement of a property. The discount rate used was specified as the fair rate of return for the property. These derivations are presented by Marston et al. [1] and Winfrey [8]. Winfrey's derivation is more detailed, but the result is the same as that of Marston's. A brief summary will be included for this dissertation.

The derivation of the formula proceeds on the bases of finding the present worth of the probable future operation returns, $R$:

$$V_n = V_{nd} + V_s = \frac{R_1}{(1+r)^1} + \frac{R_2}{(1+r)^2} + \frac{R_3}{(1+r)^3} + \ldots + \frac{R_n}{(1+r)^n} + \frac{V_s}{(1+r)^n}.$$  \hspace{1cm} (2.1)

where,

- $R_i$ = operation return for age $n$,
- $V_n$ = the unit's present value at age 0,
- $V_{nd}$ = the unit's depreciable value new,
- $V_s$ = salvage value,
- $r$ = the fair rate of net return on entire property, and
- $n$ = the unit's probable life in years.

If all operation returns, $R$, are assumed to be uniform, then this $R$ can
be represented as follows.

\[ R = V_{nd} \frac{r(1+r)^n}{(1+r)^n - 1} + rv_s \]  

(2.2)

And the equation for the value new and the equation for the present value at age \( x \), which is the present worth of the remaining annual operation returns plus the present worth of the salvage value, may be written as follows from Equation (2.1).

\[ V_n = V_{nd} + V_s = R \frac{(1+r)^n - 1}{r(1+r)^n-x} + \frac{V_s}{(1+r)^n} \]  

(2.3)

\[ V_p = R \frac{(1+r)^{n-x} - 1}{r(1+r)^{n-x}} + \frac{V_s}{(1+r)^{n-x}} \]  

(2.4)

where,

\[ V_p = \text{the unit's present value at age } x, \text{ and} \]

\[ x = \text{the unit's service age in year.} \]

The resulting equation for the present value at age \( x \) after substituting the value of \( R \) from Equation (2.2) in Equation (2.4) is:

\[ V_p = V_{nd} \frac{(1+r)^n - (1+r)^x}{(1+r)^n - 1} + V_s \]

(2.5)

The condition percent term, defined by Marston and Agg [9], is 100 times the Ratio of its present depreciable value divided by its depreciable value when new. Marston and Agg continued their definition by noting that four differing applications of the term exist. These are
the condition percents for: 1) a single property unit, 2) an average survivor unit of an age-group, 3) all survivors of an age-group, and 4) all units in service from an age-group where continued renewals maintain a constant population [8]. Though the basic definition of the condition percent does not change for these applications, the method of computing the condition percent value does.

Winfrey defined the condition percent in terms similar to Marston and Agg in a later publication [8]. Tables giving the condition percent values for properties at different ages for differing probable lives and discount rates, and based on the assumption of uniform annual operation returns, were also published at a later date [7]. In another later publication coauthored by Marston, Winfrey, and Hempstead [1], the condition percent term was called the "expectancy-life factor."

When derived for a unit of property, the mathematical expression for the condition percent factor is:

\[
C = \frac{(1+r)^n - (1+r)^x}{(1+r)^n - 1}
\]

(2.6)

where,

\(C\) = condition percent factor,
\(r\) = annual net rate of return,
\(n\) = probable life of unit in years, and
\(x\) = age of unit in years.

In common usage, the condition percent factor \(C\) is often multiplied by 100, thereby expressing it as a percentage; it is referred to simply as
the condition percent \((C_p)\).

C. Declining Operation Returns

Though the present-worth principle, as stated earlier, does not depend on the existence of a uniform annual operation return stream, the derivation of Equations (2.2-2.4) is based on the simplifying assumption of uniform annual operation returns. Convincing evidence exists [10], however, that operation returns may decrease with age for many properties rather than remaining constant.

The existence of decreasing operation returns was noted by Terborgh [10] in a book containing analyzed data from several sources having particular relevance to decreasing operation returns. Though the primary thrust of Terborgh's book concerned equipment replacement policy, he included two sets of charts showing a decrease in the quantity of measured service and an increase in repair costs as equipment ages. Figures 2.1 and 2.2 illustrate the two sets of charts. The decreasing quantity of service and increasing repair costs translated directly into a decreasing stream of operation returns, or after-tax-cash-flows, over the life span of an equipment unit. Both the sinking fund method, by definition, and the present worth method, by practice, utilized a constant level of operation returns to compute the amount of accrued depreciation. Therefore, Terborgh's studies suggest that the use of depreciation methods which are based on the assumption of uniform operation returns would not be appropriate.

Further support for the existence of a decreasing operation returns stream was given by Marston et al. As presented by this source, the
Figure 2.1. Relation between age and intensity of use of eight classes of equipment [10]
Figure 2.2. Relation between age and repair cost of service for twelve classes of equipment [10]
decrease was "... caused by lowered efficiency of the property, lowered output capacity, increased running costs, intermittent (stand-by) service, and operation at less than normal capacity" [1]. Recently, Griffith [11] also states the existence of decreasing operation returns in his economic depreciation model that are caused by the decreasing revenue and increasing operating costs with the passage of time. The existence of decreasing, as opposed to constant, operation returns has, therefore, been recognized by a number of authoritative sources for many years.

D. Methods of Handling Declining Operation Returns

The existence of decreasing operation returns has resulted in the need for some means of adjusting the formula used to find computed present value. Past methods for handling this nonuniformity have varied. Marston and Agg introduced a "probable future operations return ratio" (PFORR) into their equation for present value. The resultant expression then became:

\[ V_p = (V_{nd}) \left( \frac{\text{condition percent}}{100} \right) \text{PFORR} + V_s \]  \hspace{1cm} (2.7)

In a later source, Marston et al. defined a similar term, but called it a "service factor." In discussing the service factor, this source stated:

The service factor may be less than unity or greater than unity; its main function is to compensate, when necessary, for failure of the expectancy factor to produce the desired adjustment of the base new to current conditions [1].
The service factor was then inserted into Equation (2.7) in the same manner and with the same resulting expression as the PFORR terms.

Due to the very subjective method of selecting the service factor or PFORR, most appraisers and valuation engineers have simply ignored the term (or equivalently, set the value to unity) in the equation. The result has been to carry the initial assumption of a uniform annual operation return stream through to final cost evidence determination.

An alternate method for handling the nonuniform operation returns was proposed by Elfar [12]. This method incorporated a progression rate term, called a "T-factor," into the derivation of the condition percent factor. The T-factor was related to the operation return stream as shown in the following expression:

\[
R_X = R_1 \frac{T^N - T^{X-1}}{T^N - 1}
\]

(2.8)

where

- \(N\) = probable life of property unit or frequency group in half-year intervals,
- \(X\) = age of unit or property group in half-year intervals,
- \(R_X\) = operation return for age interval quantity, and
- \(T\) = progression rate of operation returns.

The purpose of the T-factor was to incorporate the effects of a variety of operation return streams, including the uniform case, into the present worth determination of value. The result of the derivation was a "modified condition percent factor" that was used in a manner similar to the original condition percent factor except that the modified
condition percent factor incorporated the original condition percent factor with the service factor or PFORR term.

Since the reconsideration of the Elfar model and its modified condition percent factor is one of the important subjects of this dissertation, a summary and brief discussion of the equations derived by Elfar are presented. A detailed derivation of the valuation model can be found in either Elfar's thesis [12] or Cowles-Elfar's paper [13].

Beginning with the present-worth principle as stated by Marston, and incorporating Equation (2.8) at the appropriate point, Elfar derived the following expression for the value at any age:

\[ V_x = V_N [C_x'(1-S)+S(C_x'(1-(p/f)^i) + (p/f)^{i}_{N-x})] \]  

(2.9)

where:

- \( V_x \) = value at age \( x \) of a unit or of survivors of a property group,
- \( V_N \) = value new of a unit or of survivors of a property group,
- \( C_x' \) = modified condition percent factor of age \( x \),
- \( S \) = salvage ratio = \( (V_S/V_N) \),
- \( V_S \) = estimated net salvage value,
- \( (p/f)^i_{N-x} \) = present worth of a future sum,
- \( i \) = effective semi-annual discount rate, and
- \( N \) = probable life of a property unit or a frequency group in half-year intervals.

Although the "modified condition percent factor" is analogous to the condition percent factor derived by Marston, Winfrey, and others, the significant difference is that the condition percent factor is a
special case of the more general modified condition percent factor. As
derived by Elfar, the general, closed form, mathematical expression for
the modified condition percent was:

\[ C'_x = \frac{q^{N-x-1}(T+iT^x-N) - q^{-1}(T+i) - q^{N-x} + 1}{q^{N-x-1}(T+iT^N) - q^{-x-1}(T+i) - q^{N-x} + q^{-x}} \]  

(2.10)

where \( q = (1+i) \) and all other terms are as previously defined.

By definition, the progression rate, \( T \), was in the range of
\( 0 < T < \infty \). Likewise, the semi-annual rate of return, \( i \), was some value
in the range of \( 0 < i < \infty \). Within these two ranges, however, the two
terms may assume values that resulted in unique forms of the general
expressions. These special cases, as defined by Elfar [12], occurred
when:

- \( T = 1 \) and \( i > 0 \),
- \( T = \infty \) and \( i > 0 \),
- \( T = 1 \) and \( i = 0 \),
- \( T = \infty \) and \( i = 0 \), and
- \( T < \infty \) and \( i = 0 \).

By selecting the correct equation for special cases, the modified
condition percent factor and corresponding value at any age could be
calculated based on the present-worth principle.

E. Procedure to Estimate the T-factor Value

The testing of a general procedure, proposed by Whelan [14], to
estimate T-factor values depends on establishing a relationship between
the rate at which operation returns decrease and the rate at which depreciation accrues. The rate of decrease in operation returns is reflected in the estimated T-factor value, whereas the amount of depreciation accrued reflects the decrease of value at any age.

Two estimation approaches were proposed by Whelan [14]. The first of these, referred to as the "Ratio" method, uses a ratio of the observed operation return from a property for the first year, $R_1$, and the observed return for the age interval $x-1$ to $x$, $R_x$, in the estimation of an appropriate T. The second approach, referred to as the "Delta" method, relates the difference between $R_1$ and $R_x$ with the determination of T. The explanation and derivation of these two methods for a subject property are presented below.

The Ratio method is based on the premise that a decreasing Ratio of operation returns was related to an increasing depreciation accrual rate. The operation return Ratio was specified as being $R_x$ divided by $R_1$. The Ratio method was tested with the information obtained from a major oil refining company [15]. The returns measured were operation returns for an existing and a new refinery given in units of net dollars per year. A Ratio of the existing refinery's net return ($R_x$) to a new refinery's returns ($R_1$) was then formed. The resulting Ratio was set equal to a function of the progression rate in accordance with the Ratio method equation. After the amount of the net returns and the probable life were estimated, the estimated T-factor was calculated for a specified age.

Derivation of the Ratio method equation begins with the basic
definition. Then, a slightly rearranged form of Equation (2.8) is substituted into the expression. The result is as follows:

\[
\text{RATIO} = \frac{R_x}{R_1} = \frac{R^N - T^{x-1}}{T^N - 1}.
\]  

(2.11)

If values for \( R_1, R_x, N, \) and \( x \) are either known or can be estimated, a value for the T-factor can be computed by trial and error.

Though the Ratio method offers an ideal approach and produces estimates of T-factor values with a reasonable degree of judgment, it is limited to the valuation of income producing entities where it is possible to estimate of annual operation returns. Adequate information to apply the Ratio method to industrial equipment is normally not available because most subject properties are components of an income producing entity rather than a whole. In these cases, the returns relate to the whole and normally cannot be assigned to the components outside of arbitrary allocation. The more generally applicable Delta method does offer an alternative for estimating T-factor values for these component properties.

1. Delta method

The assumption for the Delta method is that each piece of industrial equipment produces a constant level of annual gross revenue, \( G \) in Figure 2.3, from the date of installation onward. Annual costs of generating this revenue need to be deducted to give the true annual operation return. These costs would include actual cash outlays plus penalties in the form of higher costs resulting from such things as
obsolescence, less usage, or property inadequacies. Alternately, the penalties can be thought of in terms of diminished revenues or increased costs.

For individual property items or groups of items not all of the costs may be known or even estimable. In this case, the sum of the unknown costs, designated as $B$, is assumed to be constant over the property's life. Measurable operating costs are, in turn, denoted by $P_x$. The operation return $R_x$, for any year, $x$, is by definition:

$$R_x = G - B - P_x.$$ 

In general, it is expected that $R_x$ will diminish with age and it is assumed that a significant portion of that diminution can be sensed from observing the increasing measurable annual costs, $P_x$, for progressively older ages. Schematically, this is shown in Figure 2.3.

Application of the Delta method is based on the assumption that, though net operation returns are not known, periodic values of $P_x$ can be estimated. This assumption forms the basis of the following development of the Delta method.

The value of annual gross revenue at the end of the first year is

$$G = B + P_1 + R_1$$

(2.13)

Since $G$ is assumed to be constant,

$$B + P_1 + R_1 = B + P_x + R_x.$$ 

(2.14)

Rearranging this expression, and eliminating the unknown term $B$, results
in the following expressions:

\[ P_x - P_1 = R_1 - R_x \]  \hspace{1cm} (2.15)

If the quantity \((P_x - P_1)\) is defined as the term DELTA, and Equation (2.8)
is substituted into Equation (2.15), then,

\[ \text{DELTA} = R_1 - R \cdot \frac{T^N - T^{x-1}}{T^N - 1} \]  \hspace{1cm} (2.16)

If the derivation procedures presented by Elfar, Whelan, and Cowles and
Whelan are used, a closed form equation results:

\[ \frac{\text{DELTA}}{V_{\text{new}}} = \frac{(q^N - S)(T^{x-1} - 1)(T - q)(i)}{T^N(Tq^N - T - q^{N+1} + 1) + (iq^N)} \]  \hspace{1cm} (2.17)

Equation (2.17) is the general expression used to estimate the value of
T for a given property. The $\Delta/V^{\text{new}}$ term will be referred to as the Delta Ratio. As in the derivation of the original model by Elfar, a number of special cases occur when $T = 1$, $T = \infty$, and/or $i = 0$.

2. Application of the Delta method

The Delta method proposed by Whelan [14] involves several steps, the first being to quantify $P_X$, the measurable annual reduction of gross revenues. Significant components of $P_X$ include repair and maintenance costs, downtime expenses, productivity losses, and obsolescence penalties. Of these, repair and maintenance costs are normally the most readily available from a company's cost accounting records. Downtime expenses and productivity losses may or may not be available from the cost accounting records. If not, then these amounts must be estimated from whatever data might be available. The cost of obsolescence is rarely recorded as a part of a cost accounting system. It must, therefore, also be estimated on the basis of judgment or inferred indirectly from costs experienced with similar new equipment. When the major components of $P_X$ have been measured, computed, or estimated for as many age intervals or years as possible, they are adjusted to constant dollar units and summed by year of occurrence.

The second step involves the determination of the $\Delta$ terms, the Delta Ratio ($\Delta/V^{\text{new}}$), and the probable service life. The Delta term for a year or age interval $x$ is simply the difference between $P_X$ and $P_1$. The value new term is evidenced by the original cost, trended or untrended as appropriate, or the current replacement or reproduction cost of the property. With values of $\Delta$ and $V^{\text{new}}$ in hand, the
analyst can then compute the Delta Ratio for each age interval. The property's probable service life can be estimated using Iowa type survivor curves. The resulting T-factor values from the DELTA method for the property were then compared with the T-factor values of the market evidence data.
III. OBJECTIVES

The determination of value of an industrial property is important for several reasons. Unfortunately, in the majority of the situations, market evidences, which are the most reliable evidences of value, do not exist. Therefore, the objective of this dissertation is to develop a procedure to aid in estimating the value of such industrial property and equipment with the passage of age. For this study, the present worth depreciation method which relates with the economic theory of value was used within the cost approach. In the present worth depreciation method, the operation returns are assumed to be uniform for simplicity, but most of the actual operation returns of the industrial properties appear to be declining with age. Thus, the basic premise for this study is that there usually is a declining operation return over the ages of most property items or operating units. As the reasons for declining operation returns, increased repair and maintenance costs, decreased usage and the penalties of obsolescence are studied in this dissertation.

Elfar proposed a model in which the variable declining operation returns could be generated through the use of the T-factor value. The present worth method combined with the Elfar model produced the new equations of condition percent and the present value of a property. And Whelan proved the validity of the Elfar model with the Delta method he proposed.

However, the Elfar model is complicated if properly applied and seems to have difficulty in matching the value curve with the market
value over all ages. And further study is desired to demonstrate the validity of the declining operation return model. In addition, the Delta method seems to have difficulty in measuring the actual loss in property value.

Thus, the objectives of this study are as follows:

1. Refine the Elfar model or develop a simple modified equation or presentation which is realistic and easy to apply.

2. Continue the proof of the Elfar model with a variety of real world data.

3. Modify the Delta method so that it might produce results which better match market evidence data.

4. Develop practical microcomputer program and standard tables for convenient usage.
IV. MODEL DEVELOPMENT

The variation of the annual service worth of industrial property with the passage of time is important for evidence of values at different ages, especially at ages other than zero, since the fundamental basis of value of a property is the present worth of its probable future services. At age zero, the value of the equipment is assumed to be evidenced by its cost new. However, for the ages other than zero, it is desired to establish evidences of value of industrial property, especially when annual returns cannot be segregated from those of the whole enterprise. Here, the properly calculated annual operation returns, composed of annual recovery of the investment plus the annual return on the unrecovered investment, are considered as the measures of the annual service worths of the machinery and equipment in question.

As discussed earlier, the operation returns of a property unit through its service life could be uniform or variable from period to period. It was also stated by Marston et al. [1], however, the calculation of an equivalent operation return from an actual variable operation return pattern produced incorrect results for the condition percent and the value of property at any age other than zero. Thus, the annual operation returns of the machinery and equipment are assumed to decline with the passage of time. The reasons for this decline could be illustrated by a machine which produces the same quantity of the product while its annual operating costs are rising, or a machine that produces increasing percentage of rejects as it ages, or a machine which is superseded on the market by better and more economical substitutes which
relatively increase the former's cost of operation.

Accordingly, it was natural to try to suggest a valuation model which offers the possibility of representing the case of declining operation returns with the age of property.

In this context, the several models for the declining operation returns were collected and proposed.

A. Model Proposed

The conditions of selecting the best model among these models are divided into three categories. The first one is the model should represent the proper declining of the operation returns of industrial properties in general. The operation returns of different industrial properties are different from each other. Thus, the model should be able to include and represent the general change of operation returns with ages of a property. The second one is that the values of each age which are derived from the operation returns model have to fit well to the existing real market values of properties. This derivation is done by the present worth principle. The third one is that the model has to be simple and easy to use and apply since this model has to be made for practical usage in industry.

The following eight models were developed and examined with trial and error method.

1. \[
\frac{R_x}{R_1} = (1+T)^{x-1} 
\]
(4.1)

This model is used in engineering economy problems involving
geometric progression \[16\].

2. \[ \frac{R_X}{R_1} = \frac{N-T(x-1)}{N} \] \hspace{1cm} (4.2)

This model is based on a straight line decline.

3. \[ \frac{R_X}{R_1} = \frac{1}{(1 - \frac{x-1}{N})^T} \] \hspace{1cm} (4.3)

4. \[ \frac{R_X}{R_1} = \frac{T^N - T^{x-1}}{T^N - 1} \] \hspace{1cm} (4.4)

This model is used in Elfar's thesis to match market value with the present worth method.

5. \[ \frac{R_X}{R_1} = 1 - \left(\frac{x-1}{N}\right)^T \] \hspace{1cm} (4.5)

6. \[ \frac{R_X}{R_1} = \frac{T^N - T^{x-1}}{T^N - 1} - \frac{.1 \sin \frac{6(x-1)}{N}}{N} \] \hspace{1cm} (4.6)

7. \[ \frac{R_X}{R_1} = 1 - \left(\frac{x-1}{N}\right) - \frac{.1 \sin \frac{5(x-1)}{N}}{N} \] \hspace{1cm} (4.7)

8. \[ \frac{R_X}{R_1} = 1 - \left(\frac{7(x-1)}{N}\right)^K \]; \[ \frac{R_X}{R_1} = 0 \text{ at } x = N+1 \] \hspace{1cm} (4.8)

The first, second, and third models, after the investigation and the comparison with the actual real world data, are satisfactory in the first and third categories but have defects for the second criterion
category. The fourth model proposed by Elfar [12] results in better fitting in the second category but that was not enough. Because when the property is relatively new, the value at age x derived by using the Elfar model is bigger than market evidence value and in later ages, the value at age x is smaller than market evidence value all the time. Besides, the value of age x becomes smaller than indicated salvage value of the property in later ages if the average life of a property is somewhat larger than ten years. This will be shown later in Figure 4.10 and is one of the main reasons to develop alternate models to the Elfar proposal. Also, the model is not simple enough to satisfy the third category. Among the last four models, model No. 7 is almost perfectly fitted to the market value but the model induced the sine curve and became complicated. But, model No. 8 is simple and the fitting is better than others; thus, this model No. 8 is acceptable for all three categories. As a result, the model No. 8 was chosen and named "Y model" to distinguish it from the Elfar model. As a slope factor, K will be used instead of T. In the Y model, the constant, 0.7, was determined by the investigation and the comparison with the actual data collected for this study with the trial and error method. Various numbers were tested to find the best matching constant. It was found that the larger the constant was, the greater the drop of the operation returns in the first year. In this context, 0.7 was found as the best constant for the model of this study purpose.
B. Y Model Application

With the Y model, it will be shown that, in infinite mode, (when \( K = 0 \)) it represents the case of uniform periodic operation returns, and in normal mode, it represents the rapid drop of value in the very earlier ages and keeps slowly declining until the last age. In this model \( R_{N+1} = 0 \) and the last period that the property would have an operation return is \( N \). The slope factor \( K \) can take any value greater than zero.

According to the present worth principle, the value of a property is the present worth of its future operation returns. The value new, \( V_N \), can then be written as follows:

\[
V_N = R_1(p/f)i + R_2(p/f)i + \ldots + R_N(p/f)i + V_S(p/f)i_N \quad (4.9)
\]

\[
= R_1(p/f)i + R_1 \left[ 1 - \left( \frac{1}{N} \right)^K \right] (p/f)i + \ldots
\]

\[
+ R_1 \left[ 1 - \left( \frac{7(N-1)}{N} \right)^K \right] (p/f)i_N + V_S(p/f)i_N
\]

\[
= R_1 \sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] (p/f)i_M + V_S(p/f)i_N \quad (4.11)
\]

from which \( R_1 \) can be expressed as:

\[
R_1 = \frac{V_N - V_S(p/f)i_N}{\sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] (p/f)i_M} \quad (4.12)
\]

Now, applying the present worth principle at any other age \( x \), \( V_x \) will
be:

\[ V_x = R_{x+1}(p/f)_{\frac{1}{2}} + R_{x+2}(p/f)_{\frac{1}{2}} + \ldots + R_N(p/f)_{\frac{1}{2-N}} + V_S(p/f)_{N-x} \]  \hspace{1cm} (4.13)

Substituting the values of \( R_{x+1}, R_{x+2}, \) etc., using the model, \( V_x \) becomes:

\[ V_x = R_1 \left[ 1 - \left( \frac{7(x)}{N} \right) (p/f)^{\frac{1}{2}} \right] + R_1 \left[ 1 - \left( \frac{7(x+1)}{N} \right) (p/f)^{\frac{1}{2}} \right] \]

\[ + R_1 \left[ 1 - \left( \frac{7(N-1)}{N} \right) (p/f)^{\frac{1}{2}} \right] N-x + V_S(p/f)_{N-x} \]  \hspace{1cm} (4.14)

\[ = R_1 \sum_{L=1}^{N-x} \left[ \left( 1 - \left( \frac{7(L+x-1)}{N} \right) \right) (p/f)^{\frac{1}{2}} \right] + V_S(p/f)_{N-x} \]  \hspace{1cm} (4.15)

Substituting the value of \( R_1 \), the expression for \( V_x \) will be:

\[ V_x = V_N - V_S(p/f)_{\frac{1}{N}} \sum_{L=1}^{N-x} \left[ \left( 1 - \left( \frac{7(L+x-1)}{N} \right) \right) (p/f)^{\frac{1}{2}} \right] + V_S(p/f)_{N-x} \]  \hspace{1cm} (4.16)

\[ = V_N - V_S(p/f)_{\frac{1}{N}} \sum_{M=1}^{N} \left[ \left( 1 - \left( \frac{7(M-1)}{N} \right) \right) (p/f)^{\frac{1}{2}} \right] + V_S(p/f)_{N-x} \]  \hspace{1cm} (4.17)

\( C_x \) will be called the "modified condition percent factor of the Y model" to differentiate it from the condition percent factor derived by Winfrey.
The ratio of operation return shows the relationship between the first operation return and the operation return of age \( x \). This ratio is
as follows in the proposed model,

\[ R_x/R_1 = 1 - \left( \frac{7(x-1)}{N} \right)^K. \]

In this model, the parameters are \( K \) and \( N \). The variations of the ratio according to the change of \( K \) and \( N \) are presented in Figures 4.1 and 4.2. The actual values of \( K \) are limited to non-negative values. In the case of zero, the graph becomes the horizontal axis and in the case of infinity, the graph will be always the horizontal line of 1. In this graph, a condition is that the ratio should be 0 at the end of life.

The interesting observation of these variations of \( K \) value is that the lower the \( K \) value, the steeper the graph of the early ages. Thus, usually the ratio graph is steep in the early ages and in the other ages the graph declines slower compared to the Elfar model as shown in Figure 4.10. That is the reason why the proposed model fits better to the market evidence than the Elfar model.

In this proposed model, it is interesting to note that there are large ratio changes at the first and the last age. Also, the intervals between the graphs become relatively smaller as the \( K \) values become larger. For example, the interval between the graphs of .2 of \( K \) and .4 of \( K \) is bigger than the interval of .8 and 1.0, even though the differences of figures are same. It is seen that the ratio of operation return increases with the increase of \( K \) value.
Figure 4.1. Y model graph with variation of K value

Figure 4.2. Y model graph with variation of N
2. **Modified condition percent**

The equation of modified condition percent represented in Equation (4.18) is:

\[
C'_{ix} = \frac{\sum_{L=1}^{N-x} \left[ 1 - \left( \frac{7(L+x-1)}{N} \right)^K \right] \left( \frac{p}{f} \right)^{\frac{i}{L}}}{\sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] \left( \frac{p}{f} \right)^{\frac{i}{M}}}
\]

In this modified condition percent, the parameters are \( K \), \( N \), and \( I \). Thus, it is necessary to make graphs with the change of these parameters. Figures 4.3, 4.4, and 4.5 show the change of modified condition percent values according to the change of \( K \), \( N \), and \( I \), respectively. A change in \( K \) results in considerable change in the \( C'_{ix} \) graph, but changes in \( N \) and \( I \) have little effects. That means the effect of discount rate almost zero within the common range of 0 to 0.1 and the effect of length of life on \( C'_{ix} \) is quite small since the length of the industrial property is usually in between 10 and 20.

3. **Value of property using Y model**

The equation of \( V_x \), value of property at age \( x \), as given by the proposed model is:

\[
V_x = V_N - V_S \left( \frac{p}{f} \right)^{\frac{i}{N}} \frac{\sum_{L=1}^{N-x} \left[ 1 - \left( \frac{7(L+x-1)}{N} \right)^K \right] \left( \frac{p}{f} \right)^{\frac{i}{L}}}{\sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] \left( \frac{p}{f} \right)^{\frac{i}{M}}} + V_S \left( \frac{p}{f} \right)^{\frac{i}{N-x}}
\]
The parameters which can have an effect on the value of age $x$ are $K$, $N$, $S$, and $I$. Figures 4.6, 4.7, and 4.8 show the effect of changing the $K$ value, salvage ratio, and discount rate, respectively. In Figure 4.6, $N$ is assumed to be 10 years, $S$ is 10 percent, and $I$ is 7 percent. The effect of changing the $K$ value is quite similar to the case of modified condition percent. That is, the $V_x$ becomes larger as the $K$ value increases. The $V_x$ decreases rapidly in early ages and decreases more slowly in later ages.

Figure 4.7 shows the effect of salvage ratios. It is interesting that the difference between $V_x$ when $S=0.1$ and $V_x$ when $S=0.2$ is very small in early life but becomes greater toward the end of life. This can be
Figure 4.4. Condition percent graph with variation of N

Figure 4.5. Condition percent graph with variation of I
thought of in such a way that if the difference of salvage ratios is small, the difference between $V_x$ values is small, especially in the early life. The effect of discount rate is seen in Figure 4.8. That plot shows the effect of change in discount rate is almost zero. Thus, the effect of the $K$ value on the value at age $x$ is greater than that of salvage ratio or discount rate.

The graphs for the effect of length of life with respect to the percent of age are illustrated in Figure 4.9. Finally, in Figure 4.10, there is the comparison between the $V_x$ graphs which were obtained by using the Elfar model and $V_x$ graph out of the $Y$ model proposed in this dissertation. From this comparison, it is seen that the $V_x$ of Elfar model is greater in the early ages of life and is smaller in the later ages. For example, the $V_x$ graph of the Elfar model at $T=.8$ is possibly the closest to the $V_x$ graph of the $Y$ model at $K=.15$. But, because of the difference of the basic model, there is a large gap in the early ages and also in the later ages.
Figure 4.6. Value graph with variation of $K$ value

Figure 4.7. Value graph with variation of $S$
Figure 4.8. Value graph with variation of $I$

Figure 4.9. Value graph with variation of $N$
Figure 4.10. Comparison of $V_x$ from Y model and Elfar model
V. PROCEDURE DEVELOPMENT

As has been previously noted by Marston et al. [1], value depreciation results from such causes as increasing repair and maintenance expenditures, decreasing production rates, reduced availability, and accumulating obsolescence. However, it is difficult to measure and record this factor. Thus, a basic assumption is made that the above factors can be condensed into the two factors: the increasing repair and maintenance costs and the decreasing of the service intensity. Griffith [11] also supported this assumption in his study. However, the level of service intensity may not change enough to sufficiently measure the effect of obsolescence.

In contrast to this assumption, Whelan [14], considered mainly the repair and maintenance costs and downtime costs. However, the downtime costs are not always available and are hard to express in actual costs.

A. Estimate of Service Intensity

As described before, the decreasing service intensity is one of the main reasons of the decreasing value with the increase in age. The effect of decreasing service intensity may be larger than the effect of increasing costs of repair and maintenance. Service intensity has the advantage of directly being related to the operation returns with the proportion to the usage hours or mileage operated with ages.

Level of service intensity is influenced by the decreasing production rate, reduced availability, obsolescence, risk, and downtime cost. Because the machine usage hours would be decreased at least as
much as the downtime, the influence of the obsolescence might lead to less usage if more modern equipment is available. Also, use of the machine is likely to be avoided as production rates become low. Thus, the decrease of the service intensity could include all of the above factors. The decreasing service intensity is one of the main factors, as well as increasing repair and maintenance costs, for the estimation of the value of a property with respect to its age.

Service intensity is represented as the ratio of yearly usage through ages of property. The biggest yearly ratio usage during ages of property life will be usually 1 and the other yearly usage will be the proportion of biggest one, namely, between 1 and 0. Ideally, the first year usage is the greatest one, if not, the first year usage has to be properly estimated with the smoothed curve of whole life yearly usages.

Service intensity with the respect to the age of the machinery is sometimes hard to obtain. Thus, if the data for specific equipment were not available, the representative intensity graph will be used. For example, each of three kinds of intensity graphs represents the overall intensity for light trucks, middle weight trucks, and heavy trucks, respectively.

B. Composition of Repair and Maintenance Costs with Service Intensity

Since the repair and maintenance costs are measured in dollars, and the usage intensity is the ratio of the yearly usage, the combination of these two is complicated. However, it is necessary to calculate the whole decrease of the operation returns of overall ages.
The assumption of the present worth principle using the symbols is represented as follows:

\[ V_N = R_1(p/f)^{\frac{i}{2}} + R_2(p/f)^{\frac{i}{2}} + \ldots + R_N(p/f)^{\frac{i}{N}} + V_S(p/f)^{\frac{i}{N}} \quad (5.1) \]

Here, \( R_x \) is supposed to be decreased with the age \( x \) according to the composition of the service intensity and the repair and maintenance costs. Suppose the intensity graph is \( f(x) \) and the repair and maintenance costs divided by value new, is \( t(x) \). Then,

\[ R_x = G \cdot f(x) - V_N \cdot t(x) \quad (5.2) \]

where \( R_x \) = net operation returns of age \( x \),

\( G \) = original returns without reduction of repair and maintenance costs and loss of usage intensity, and

\( V_N \) = value when a property was new.

A schematic diagram showing this relationship is shown in Figure 5.1. Substituting the \( R_x \) from Equation (5.2) into Equation (5.1), the expression for \( V_N \) will be:

\[ V_N = \sum_{x=1}^{N} [G \cdot f(x) - V_N \cdot t(x)](p/f)^{\frac{i}{x}} + V_S(p/f)^{\frac{i}{N}} \quad (5.3) \]

Therefore, if all the data, such as \( V_N \), \( N \cdot f(x) \), \( t(x) \), \( i \), and \( V_S \) are provided, the amount of \( G \) can be obtained. Then, the \( p_x \), the sum of repair and maintenance cost and usage intensity, can be calculated as follows:

\[ p_x = G - R_x = G \cdot [1-f(x)] + V_N \cdot t(x) \quad (5.4) \]
Figure 5.1. Schematic diagram of composition

One can also calculate the value of a property at age x directly from \( R_x \), but the \( f(x) \) and \( t(x) \) data for the calculation of \( R_x \) are not sufficient for the full data until the life, the value at age x from \( R_x \) might be acceptable but not reliable. Thus, the reliable data for this calculation is the \( P_x \) which are supported by exact data. These \( P_x \) data can be applied to the Delta method to obtain a \( T \) value.

Derivation of the \( G \) from the above Equation (5.3) is as follows:

\[
V_N = \sum_{x=1}^{N} \left[ G \cdot f(x) - V_N \cdot t(x) \right] (p/f)^i_x + V_S (p/f)^{i+1} \\
= \sum_{x=1}^{N} \left[ G \cdot f(x)^{i+1} - V_N \cdot t(x)(p/f)^{i+1} \right] + V_S (p/f)^{i+1} \quad (5.5)
\]
\[ N \cdot \sum_1^N f(x)(p/f)_x^i \cdot -V_N \cdot \sum_1^N t(x)(p/f)_x^i + v_{s}(p/f)_N^i \] (5.6)

\[ \therefore \quad N \cdot \sum_1^N f(x)(p/f)_x^i = V_N + V_N \cdot \sum_1^N t(x)(p/f)_x^i - v_{s}(p/f)_N^i \] (5.7)

\[ V_N \left[ 1 + \sum_1^N t(x)(p/f)_x^i + s(p/f)_N^i \right] \]

\[ \therefore \quad G = \frac{\sum_1^N f(x)(p/f)_x^i}{N} \] (5.8)

where \( S \) = salvage ratio

\[ \therefore \quad \frac{G}{V_N} = \frac{1 + \sum_1^N t(x)(p/f)_x^i + s(p/f)_N^i}{\sum_1^N f(x)(p/f)_x^i} \] (5.9)

Also,

\[ V_x = \sum_{g=x+1}^N \left[ G \cdot f(g)-V_N \cdot t(g) \right] (p/f)_g^i + v_{s}(p/f)_N^i \] (5.10)

And the \( P_x \) is

\[ P_x = G \cdot [1-f(x)] + V_N \cdot t(x) \]

\[ V_N \left[ 1 + \sum_1^N t(x)(p/f)_x^i + s(p/f)_N^i \right] \]

\[ = \frac{\sum_1^N f(x)(p/f)_x^i}{N} \] [1-f(x)] + V_N \cdot t(x)
\[ V_N \left[ \frac{[1+ \sum_{x=1}^{N} t(x)(p/f)^{i/2} + S(p/f)^{i/2}][1-f(x)]}{\sum_{x=1}^{N} f(x)(p/f)^i} + t(x) \right] \]  

Starting this \( P_x \) value, the next procedures are as follows:

1. Finding the \( K \) value using standard curves of the Delta method.
2. Applying the \( K \) value to the \( Y \) model.
3. Finding the value at age \( x \).
4. Comparing the above \( V_x \) with the actual market value.

C. Standard Curves for Finding \( K \) Values

Standard curves are helpful in finding the \( K \) values. They are used as a basis for the fitting of the data which are derived from the \( P_x \) of the previous section. The derivation of the standard curve equation was presented by Whelan [14] in detail. Thus, the summary and the differences will be shown.

\[ G = R_x + (G-R_x) \]
\[ = R_x + P_x \]

Since \( G \) is constant all over the ages,

\[ G = R_x + P_x = R_1 + P_1 \]

\[ \therefore P_x - P_1 = R_1 - R_x \]

Set Delta (\( \Delta \)) = \( P_x - P_1 \)
Then, $\Delta = R_1 - R_x$. Substituting the Y model to the equation above,

$$= R_1 - R_1 \left[ 1 - \left( \frac{7(x-1)}{N} \right)^K \right] \quad (5.12)$$

From the previous chapter, Equation (4.12),

$$R_1 = \frac{V_N - V_S(p/\ell)^{\hat{i}}_N}{\sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] (p/\ell)^{\hat{i}}_M}$$

Therefore,

$$\Delta = \frac{V_N \left( 1-S(p/\ell)^{\hat{i}}_N \right)}{\sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] (p/\ell)^{\hat{i}}_M} \left[ 1 - \left( \frac{7(x-1)}{N} \right)^K \right]$$

$$= \frac{V_N \left( 1-S(p/\ell)^{\hat{i}}_N \right)}{\sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] (p/\ell)^{\hat{i}}_M} \left( \frac{7(x-1)}{N} \right)^K \quad (5.13)$$

$$\therefore \frac{\Delta}{V_N} = \frac{1-S(p/\ell)^{\hat{i}}_N}{\sum_{M=1}^{N} \left[ 1 - \left( \frac{7(M-1)}{N} \right)^K \right] (p/\ell)^{\hat{i}}_M} \left( \frac{7(x-1)}{N} \right)^K$$

where

$$(p/\ell)^{\hat{i}}_N = \left( \frac{1}{1+1} \right)^N$$

From the above Equation (5.13), all the other factors are known
except $\Delta$ and $x$. Therefore, $\Delta/v_N$ will be in the vertical axis and age $x$ will be in the horizontal axis in the standard curves.

The variation of average life $N$ and salvage value $S$ can provide a variety of standard curves for the Delta method.

D. Procedural Steps for Delta Procedure

The proposed procedure for estimating slope factor values, $K$, has several steps. The procedure is almost the same for estimating $T$-factor values. These steps, and a brief explanation of each, are summarized below:

1. Quantify $P_x$ (Periodic Reduction in Operation Returns): The most readily available data concerning the reduction in operation returns are the repair and maintenance records compiled by most companies. Intensity ratios are often not recorded as a part of normal cost accounting procedures, so they may have to be estimated from incomplete records or ready made representative data records. When these major components of $P$ for each period have been computed, measured, or estimated, adjusted to units of constant dollars, and expressed in units of dollars per period, they can be summed by the method of composition of repair and maintenance costs and intensity ratios to determine the total periodic amount of the reduction of operation returns.

2. Compute $A$: The term is the numerical difference between $P_{x-1}$ and $P_x$, where $P_x$ is the reduction in operation returns for the period $x-1$ to $x$. The computation of $A$ is accomplished by
subtracting the value of \( P_1 \) from successive values of \( P_x \) determined in the previous step.

3. Determine \( V_N \): The \( V_N \) term is the value of the property when it was new. Normally, the replacement cost is the best indication of the value new term.

4. Compute \( \Delta/V_N \): Computation of Delta Ratio is performed for each successive period by dividing the \( V_N \) determined in the previous step into the values computed in an earlier step.

5. Determine the Probable Service Life: The probable service life is determined using the Iowa type curves, or other comparable methods, if sufficient life analysis data are available. If not, it must be estimated based on the best information available.

6. Estimate the value of \( K \) using a set of Standard Curves: Since the solution of Equation (5.13) of the previous section for a \( K \) value is at best a trial and error procedure, a procedure based on the visual matching of observed data to theoretical, calculated results will be used to estimate \( K \) values.
VI. PROCEDURE

A number of actual data sets were collected for the test of the proposed model and procedure. The test will be done by the comparisons of K values of market evidences with those obtained by use of the proposed model and procedure, and the validity of them will be estimated by the closeness of K values. For this test, the data should include market value evidences, repair and maintenance cost data, service intensity rate data, and data indicating salvage values, probably average service lives and the value at age 0 for selected industrial properties. In the case of group properties, operating costs, data, and operating revenue data were sought for the substitute of repair and maintenance costs data and service intensity rate data, respectively.

A. Data for Unit Property

The data sets of twenty-two different types of equipment were used for this experiment. These are as follows:

1. Gas tractor
2. Diesel tractor
3. Self-propelled combine
4. Corn picker
5. Forage harvester
6. Hay baler
7. 35-ton truck
8. 50-ton truck
9. D9 dozer
10. D9 C dozer
11. 10M water tanker
12. Cat. 637 scraper
13. Cat. 666 scraper
14. Cat. 815 compactor
15. Potable air compressor
16. 6" rotary drill
17. 35-ton motor crane
18. 150-ton C. crane
19. Diesel generator
20. D8 dozer
21. Industrial forklift
22. Pickup truck

These data were sought for several reasons. First, information appeared to be readily available. Data concerning value new, estimated salvage values, and probable service lives could be obtained from equipment dealers or the people who are related to the equipment. Data concerning the repair and maintenance costs, and operational characteristics were usually routinely recorded and analyzed by owners or construction contractors. Finally, data which display market evidence were taken from routinely published books as well as from equipment auction firms.

A second reason for these choices was the characteristic similarity of construction and farm equipment with industrial equipment. In other words, the above equipment could be representative of various industrial
equipment and their characteristics.

A third reason for pursuing these data was because of an extensive resale market for used equipment. The large number of sales in a given year improved the reliability of this market evidence curve.

The value when new was easily determined for most properties, since the basic assumption is that the value new equals the costs of a property when it was new. This original cost included the total purchase price, any transportation or freight charges, and all installation costs. Also, this original cost should reflect the inflation rate to get the "today's" dollar or the date corresponding to the date of the rest of data.

The salvage value was evidenced by the net cash flow received from the sale of the property upon retirement. Net earnings were equal to gross salvage price less any costs of removing the property. Since the actual salvage value was unknown until the actual point of retirement, an estimated value was used. For most of the equipment, the salvage value was estimated considering the market evidence curve and information from experienced consultants who work in this field. That is, the salvage value was set equal to the value of the market evidence curve at the estimated probable life value and adjusted appropriately.

In the determination of the probable service life, an appropriate Iowa-type curve had to be found. Although the equipment was handled as a unit property, the Iowa-type curves were still needed to compute the probable life values for any age other than zero because, as the unit ages, the probable life increases.
For the actual rate of return, or discount rate, it should be chosen to reflect a reasonable and inflation free rate of return for the company rather than the erroneous reflection of the company's financial policy or prevalent economic conditions at the time of the valuation. As a reasonable approximation of an inflation free rate of return, an annual rate of 7 percent was used for this dissertation [17].

1. Repair and maintenance costs data

Repair and maintenance costs are one of the main factors which affect the operation returns of that equipment. Thus, the collection of this data is necessary for this analysis.

Most of the repair and maintenance cost data of farm equipment was selected from the Hunt's paper [18] titled "Eight Years of Farm Machinery Cost Monitoring." These data are shown in Figure 6.1. The figures represent the relationship between ratio of repair and maintenance costs against value new and accumulated services used. These graphs show the slow increase in the early ages and rapid growth in the later ages. However, the data needed are the R and M costs (repair and maintenance costs) per the unit period of time or age. These collected data, represented by the accumulated unit period of time or service, are needed to translate to the data per unit period of time. The procedures are represented in Table 6.2 for gas tractor as an example. In these procedures, the average usages per year of each piece of equipment are collected for further calculation. The data of average usage per year are shown in Table 6.1 for each piece of equipment. These average usage data were obtained from the Journal of American
Figure 6.1. Accumulated R and M costs for farm equipment [18]
Society of Agricultural Engineers [19] and Hunt's paper [18]. Finally, adjustment of average usage data was made by the discussions with an agricultural engineer [20] and a consultant [21].

In the case of construction equipment, which are numbered from 7 to 19 of collected equipment, the data of R and M costs were derived from the record of the Green International Construction Company [22]. In the records of the Green Company, the R and M costs were divided into two sections: labor costs and parts costs. The calculation for the R and M costs of the unit period of time (year) was done in the same way as was the farm equipment. The procedure for the combination of labor costs and parts costs represented in Tables 6.3, 6.4, and 6.5. Also, the data of average usage per year, value new, and hourly wages were obtained from the contractors' equipment cost guide [23]. These data are necessary for the calculation of R and M costs of equipment. Table 6.1 shows these data. In the calculation of parts, the inflation rate was considered. The average inflation rate of the past 20 years has been about 7% per year [24]. Since there was one year and four months difference between the date of issue of the contractors' equipment cost guide [23] and that of reports for R and M costs of the Green Company, 9% of inflation was accepted for the calculation. Therefore, the inflation-free observed time is 1974 for farm equipment, 1984 for construction equipment, and 1978 for the other equipment which were obtained from Whelan's thesis and adjusted with new information.

The repair and maintenance costs data are shown in Appendix A. These figures were divided by the value new of each equipment, so that
Table 6.1. Data needed for the calculation of R&M costs

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Avg. Usage/Yr. Hours (Acres)</th>
<th>Value New ($) (Standard Year)</th>
<th>Hourly Wage ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Tractor</td>
<td>500</td>
<td>8093 (74)</td>
<td>-</td>
</tr>
<tr>
<td>Dis Tractor</td>
<td>500</td>
<td>8505 (74)</td>
<td>-</td>
</tr>
<tr>
<td>Combine</td>
<td>(600)</td>
<td>16365 (74)</td>
<td>-</td>
</tr>
<tr>
<td>Corn Picker</td>
<td>(250)</td>
<td>2084 (74)</td>
<td>-</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>(200)</td>
<td>4042 (74)</td>
<td>-</td>
</tr>
<tr>
<td>Hay Baler</td>
<td>80</td>
<td>2552 (74)</td>
<td>-</td>
</tr>
<tr>
<td>35-Ton Truck</td>
<td>1450</td>
<td>289700 (84)</td>
<td>17</td>
</tr>
<tr>
<td>50-Ton Truck</td>
<td>1450</td>
<td>384500 (84)</td>
<td>17</td>
</tr>
<tr>
<td>D9 Dozer</td>
<td>1450</td>
<td>283820 (84)</td>
<td>16.5</td>
</tr>
<tr>
<td>D9 c Dozer</td>
<td>1450</td>
<td>372610 (84)</td>
<td>16.5</td>
</tr>
<tr>
<td>10M W. Wagon</td>
<td>1300</td>
<td>348700 (84)</td>
<td>17</td>
</tr>
<tr>
<td>637 Scraper</td>
<td>1520</td>
<td>473200 (84)</td>
<td>16.5</td>
</tr>
<tr>
<td>666 Scraper</td>
<td>1520</td>
<td>359630 (84)</td>
<td>16.5</td>
</tr>
<tr>
<td>Cat 825 Compactor</td>
<td>1200</td>
<td>142470 (84)</td>
<td>16.5</td>
</tr>
<tr>
<td>900 Air Comp.</td>
<td>1480</td>
<td>56500 (84)</td>
<td>16.5</td>
</tr>
<tr>
<td>6-in. Rot. Drill</td>
<td>800</td>
<td>76895 (84)</td>
<td>16.5</td>
</tr>
<tr>
<td>35 M. Crane</td>
<td>1330</td>
<td>241540 (84)</td>
<td>17</td>
</tr>
<tr>
<td>150 C. Crane</td>
<td>1460</td>
<td>553600 (84)</td>
<td>17</td>
</tr>
<tr>
<td>Dis Generator</td>
<td>1100</td>
<td>18422 (84)</td>
<td>17</td>
</tr>
<tr>
<td>D8 Dozer</td>
<td>1400</td>
<td>165000 (78)</td>
<td>-</td>
</tr>
<tr>
<td>Ind. Forklift</td>
<td>2000</td>
<td>18350 (78)</td>
<td>-</td>
</tr>
<tr>
<td>Pickup Truck</td>
<td>1800</td>
<td>5450 (78)</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 6.2. Example of the calculation for R and M costs per year

<table>
<thead>
<tr>
<th>Cum. hrs</th>
<th>Cum. R and M costs/V_N</th>
<th>R and M/V_N of periodic 400 hrs</th>
<th>R and M/V_N of periodic 500 hrs</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>0.001</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>800</td>
<td>0.011</td>
<td>0.01</td>
<td>0.0035</td>
<td>1</td>
</tr>
<tr>
<td>1200</td>
<td>0.032</td>
<td>0.021</td>
<td>0.018</td>
<td>2</td>
</tr>
<tr>
<td>1600</td>
<td>0.064</td>
<td>0.032</td>
<td>0.0345</td>
<td>3</td>
</tr>
<tr>
<td>2000</td>
<td>0.1</td>
<td>0.036</td>
<td>0.044</td>
<td>4</td>
</tr>
<tr>
<td>2400</td>
<td>0.14</td>
<td>0.104</td>
<td>0.051</td>
<td>5</td>
</tr>
<tr>
<td>2800</td>
<td>0.184</td>
<td>0.044</td>
<td>0.055</td>
<td>6</td>
</tr>
<tr>
<td>3200</td>
<td>0.228</td>
<td>0.044</td>
<td>0.0565</td>
<td>7</td>
</tr>
<tr>
<td>3600</td>
<td>0.274</td>
<td>0.046</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.3. Labor costs for D9 Dozer

<table>
<thead>
<tr>
<th>Hours Range</th>
<th>Repair Hrs./ Machine Hrs.</th>
<th>Age</th>
<th>Yearly (1450 Hrs.) Repair Hrs./ Yr.</th>
<th>Times Hourly Wage ($16.50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 2000</td>
<td>0.088</td>
<td>1</td>
<td>0 - 1450</td>
<td>127.6</td>
</tr>
<tr>
<td>2000 - 4000</td>
<td>0.154</td>
<td>2</td>
<td>1450 - 2900</td>
<td>187</td>
</tr>
<tr>
<td>4000 - 6000</td>
<td>0.205</td>
<td>3</td>
<td>2900 - 4350</td>
<td>241.2</td>
</tr>
<tr>
<td>6000 - 8000</td>
<td>0.265</td>
<td>4</td>
<td>4350 - 5800</td>
<td>297.3</td>
</tr>
<tr>
<td>8000 - 10000</td>
<td>0.298</td>
<td>5</td>
<td>5800 - 7250</td>
<td>372.3</td>
</tr>
<tr>
<td>10000 - 12000</td>
<td>0.310</td>
<td>6</td>
<td>7250 - 8700</td>
<td>407.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>8700 - 10150</td>
<td>433.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>10150 - 11600</td>
<td>449.5</td>
</tr>
</tbody>
</table>
# Table 6.4. Parts costs for D9 Dozer

<table>
<thead>
<tr>
<th>Hours Range</th>
<th>Costs ($)/Machine Hr.</th>
<th>Times Inflation Factor (9% for 1.25 Yrs.)</th>
<th>Age</th>
<th>Yearly Cost ($) (1450 Hrs.)</th>
<th>Cost ($)/Yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 2000</td>
<td>8.478</td>
<td>9.241</td>
<td>1</td>
<td>0 - 1450</td>
<td>13399</td>
</tr>
<tr>
<td>2000 - 4000</td>
<td>10.264</td>
<td>11.188</td>
<td>2</td>
<td>1450 - 2900</td>
<td>15152</td>
</tr>
<tr>
<td>4000 - 6000</td>
<td>18.833</td>
<td>20.528</td>
<td>3</td>
<td>2900 - 4350</td>
<td>19492</td>
</tr>
<tr>
<td>6000 - 8000</td>
<td>30.049</td>
<td>32.753</td>
<td>4</td>
<td>4350 - 5800</td>
<td>29766</td>
</tr>
<tr>
<td>8000 - 10000</td>
<td>33.066</td>
<td>36.042</td>
<td>5</td>
<td>5800 - 7250</td>
<td>45047</td>
</tr>
<tr>
<td>10000 - 12000</td>
<td>17.036</td>
<td>18.569</td>
<td>6</td>
<td>7250 - 8700</td>
<td>49794</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>8700 - 10150</td>
<td>49640</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>10150 - 11600</td>
<td>26925</td>
</tr>
</tbody>
</table>

# Table 6.5. Total R and M costs for D9 Dozer

<table>
<thead>
<tr>
<th>Age</th>
<th>Labor Cost ($)</th>
<th>Parts Cost ($)</th>
<th>Total Cost</th>
<th>Total Cost/V_N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2105</td>
<td>13399</td>
<td>15504</td>
<td>0.0546</td>
</tr>
<tr>
<td>2</td>
<td>3086</td>
<td>15152</td>
<td>18238</td>
<td>0.0827</td>
</tr>
<tr>
<td>3</td>
<td>3979</td>
<td>19492</td>
<td>23471</td>
<td>0.0827</td>
</tr>
<tr>
<td>4</td>
<td>4905</td>
<td>29766</td>
<td>34671</td>
<td>0.1222</td>
</tr>
<tr>
<td>5</td>
<td>6142</td>
<td>45047</td>
<td>51189</td>
<td>0.1804</td>
</tr>
<tr>
<td>6</td>
<td>6721</td>
<td>49794</td>
<td>56515</td>
<td>0.1991</td>
</tr>
<tr>
<td>7</td>
<td>7159</td>
<td>49640</td>
<td>56799</td>
<td>0.2001</td>
</tr>
<tr>
<td>8</td>
<td>7417</td>
<td>26925</td>
<td>34342</td>
<td>0.1210</td>
</tr>
</tbody>
</table>
Table 6.6. Final repair and maintenance costs per value new of each age

<table>
<thead>
<tr>
<th>Equip. Age</th>
<th>Gas Tractor</th>
<th>Diesel Tractor</th>
<th>S.P. Combine</th>
<th>Corn Picker</th>
<th>Forage Harvester</th>
<th>Hay Baler</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0035</td>
<td>0.0025</td>
<td>0.003</td>
<td>0.003</td>
<td>0.018</td>
<td>0.017</td>
</tr>
<tr>
<td>2</td>
<td>0.018</td>
<td>0.009</td>
<td>0.007</td>
<td>0.012</td>
<td>0.034</td>
<td>0.0431</td>
</tr>
<tr>
<td>3</td>
<td>0.0345</td>
<td>0.01725</td>
<td>0.017</td>
<td>0.0265</td>
<td>0.043</td>
<td>0.0593</td>
</tr>
<tr>
<td>4</td>
<td>0.044</td>
<td>0.02125</td>
<td>0.024</td>
<td>0.0405</td>
<td>0.046</td>
<td>0.066</td>
</tr>
<tr>
<td>5</td>
<td>0.051</td>
<td>0.02625</td>
<td>0.028</td>
<td>0.076</td>
<td>0.052</td>
<td>0.0747</td>
</tr>
<tr>
<td>6</td>
<td>0.055</td>
<td>0.02625</td>
<td>0.040</td>
<td>0.05</td>
<td>0.059</td>
<td>0.0693</td>
</tr>
<tr>
<td>7</td>
<td>0.565</td>
<td></td>
<td>0.045</td>
<td>0.059</td>
<td>0.0717</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>0.053</td>
<td>0.056</td>
<td>0.0726</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.067</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6.6. (continued)

<table>
<thead>
<tr>
<th>Equip. Age</th>
<th>35-Ton Truck</th>
<th>50-Ton Truck</th>
<th>D9 Dozer</th>
<th>D9 C Dozer</th>
<th>10M Water Tanker</th>
<th>Cat 637 Scraper</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1056</td>
<td>0.0217</td>
<td>0.0546</td>
<td>0.0497</td>
<td>0.0389</td>
<td>0.0892</td>
</tr>
<tr>
<td>2</td>
<td>0.0571</td>
<td>0.0173</td>
<td>0.0643</td>
<td>0.0678</td>
<td>0.0468</td>
<td>0.0856</td>
</tr>
<tr>
<td>3</td>
<td>0.0285</td>
<td>0.0192</td>
<td>0.0827</td>
<td>0.0862</td>
<td>0.0560</td>
<td>0.0945</td>
</tr>
<tr>
<td>4</td>
<td>0.0316</td>
<td>0.0339</td>
<td>0.1222</td>
<td>0.1092</td>
<td>0.0712</td>
<td>0.1144</td>
</tr>
<tr>
<td>5</td>
<td>0.0860</td>
<td>0.0658</td>
<td>0.1804</td>
<td>0.1424</td>
<td>0.0779</td>
<td>0.1458</td>
</tr>
<tr>
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<td>0.1094</td>
<td>0.0896</td>
<td>0.1991</td>
<td>0.1658</td>
<td>0.0866</td>
<td>0.1390</td>
</tr>
<tr>
<td>7</td>
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</tr>
<tr>
<td>Equip. Age</td>
<td>Cat 666 Scraper</td>
<td>Cat 825 Compactor</td>
<td>900 Air Loss</td>
<td>6&quot; Rotary Drill</td>
<td>35 ton M. Crane</td>
<td></td>
</tr>
<tr>
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<td>-----------------</td>
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<td>-----------------</td>
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</tr>
<tr>
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<td>0.0296</td>
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<td>0.0070</td>
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<td>0.1401</td>
<td>0.0908</td>
<td>0.0955</td>
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</tr>
<tr>
<td>4</td>
<td>0.1664</td>
<td>0.0954</td>
<td>0.0935</td>
<td>0.0725</td>
<td>0.0704</td>
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</tr>
<tr>
<td>5</td>
<td>0.2060</td>
<td>0.0976</td>
<td>0.0810</td>
<td>0.0822</td>
<td>0.0742</td>
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<td>6</td>
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<tr>
<td>7</td>
<td>0.3288</td>
<td>0.2149</td>
<td>0.1681</td>
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</tr>
<tr>
<td>8</td>
<td>0.1299</td>
<td>0.2990</td>
<td>0.1668</td>
<td>0.0447</td>
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<td></td>
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<td>9</td>
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<td>0.2105</td>
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</table>
Table 6.6. (continued)

<table>
<thead>
<tr>
<th>Equip. Age</th>
<th>150 ton C. crane</th>
<th>DSL Generator</th>
<th>D8 Dozer</th>
<th>Ind. Forklift</th>
<th>Pickup Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0655</td>
<td>0.0268</td>
<td>0.1258</td>
<td>0.0210</td>
<td>0.1728</td>
</tr>
<tr>
<td>2</td>
<td>0.0566</td>
<td>0.0637</td>
<td>0.1314</td>
<td>0.0322</td>
<td>0.2294</td>
</tr>
<tr>
<td>3</td>
<td>0.0589</td>
<td>0.1178</td>
<td>0.1523</td>
<td>0.0360</td>
<td>0.2437</td>
</tr>
<tr>
<td>4</td>
<td>0.0804</td>
<td>0.1342</td>
<td>0.1619</td>
<td>0.0657</td>
<td>0.1688</td>
</tr>
<tr>
<td>5</td>
<td>0.0673</td>
<td>0.0855</td>
<td>0.1629</td>
<td>0.0722</td>
<td>0.1354</td>
</tr>
<tr>
<td>6</td>
<td>0.0657</td>
<td>0.0855</td>
<td>0.1937</td>
<td>0.0583</td>
<td></td>
</tr>
<tr>
<td>7</td>
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<td></td>
<td>0.0755</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
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<td>0.0929</td>
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<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0850</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The figures are the ratios of the value new. The reasons for using the ratios are the simplicity of use and the facility of comparisons. Table 6.6 shows that the final R and M costs data for the equipment collected according to the ages of life. In this table, the figures of farm equipment are usually smaller than those of construction equipment. That seems construction equipment works more per unit time and more severely than farm equipment.

The smoothed curves of repair and maintenance costs are shown in Table 6.7. These curve equations were obtained by using the least-sum-of-squares method with the help of the SAS computer program. Usually, these are represented by $x$ and $x^2$ with the minus sign between them.
Table 6.7. Smoothed curves of repair and maintenance costs data

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Curve Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. Tractor</td>
<td>$0.012296 x - 0.000550 x^2$</td>
</tr>
<tr>
<td>D. Tractor</td>
<td>$0.006006 x - 0.000140 x^2$</td>
</tr>
<tr>
<td>Combine</td>
<td>$0.005641 x + 0.000123 x^2$</td>
</tr>
<tr>
<td>Corn Picker</td>
<td>$0.004163 x^2 - 0.000286 x^3$</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>$0.015001 x - 0.000910 x^2$</td>
</tr>
<tr>
<td>Hay Baler</td>
<td>$0.019071 x - 0.001078 x^2$</td>
</tr>
<tr>
<td>35 ton truck</td>
<td>$0.016445 x - 0.000024 x^2$</td>
</tr>
<tr>
<td>50 ton truck</td>
<td>$0.007808 x + 0.000973 x^2$</td>
</tr>
<tr>
<td>D9 Dozer</td>
<td>$0.028089 x - 0.000075 x^3$</td>
</tr>
<tr>
<td>D9 C Dozer</td>
<td>$0.032187 x - 0.000117 x^3$</td>
</tr>
<tr>
<td>10 M W. Tanker</td>
<td>$0.021518 x - 0.001099 x^2$</td>
</tr>
<tr>
<td>Cat 637 Scraper</td>
<td>$0.040468 x - 0.002672 x^2$</td>
</tr>
<tr>
<td>Cat 666 Scraper</td>
<td>$0.049399 x - 0.000165 x^3$</td>
</tr>
<tr>
<td>825 Compactor</td>
<td>$0.028939 x - 0.001001 x^2$</td>
</tr>
<tr>
<td>900 Air Comp.</td>
<td>$0.022543 x + 0.000007 x^3$</td>
</tr>
<tr>
<td>6&quot; Rot. Drill</td>
<td>$0.021981 x - 0.0001622 x^2$</td>
</tr>
<tr>
<td>35 T. M. Crane</td>
<td>$0.013166 x - 0.000570 x^2$</td>
</tr>
<tr>
<td>150 T. C. Crane</td>
<td>$0.021637 x - 0.001239 x^2$</td>
</tr>
<tr>
<td>DSL Generator</td>
<td>$0.025669 x - 0.001323 x^2$</td>
</tr>
<tr>
<td>D8 Dozer</td>
<td>$0.045279 x - 0.002418 x^2$</td>
</tr>
<tr>
<td>Ind. Forklift</td>
<td>$0.018699 x - 0.000752 x^2$</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>$0.058844 x - 0.003569 x^2$</td>
</tr>
</tbody>
</table>
That shows the normal shape of the smoothed curves for R and M costs. This shape will be used to determine the standard curves of R and M costs later.

2. Service intensity data

The service intensity is one of the important factors in estimating the declining operation returns for this study. Whelan [14] tried to prove the validity of the Elfar model with the R and M costs and downtime costs, but this procedure with those factors seems to have difficulty in measuring the actual loss in property value. Thus, the new trial with the R and M costs and service intensity rates is done in this dissertation. As discussed before, there could be many factors which reduce the annual operation returns. These factors can be summarized by three factors: rising operating cost, impaired service quality, and improved alternatives. Here, service intensity seems the only estimated data that are easily obtained and directly influenced by the second and third factors above. Thus, the assumption is that the service intensity rates reduce with the rate of impaired service quality and improved alternatives, and this reduction seems to make the operation returns of equipment to decline with almost the same rate of the reduction. Thus, these service intensity data are one of the most important sets of data to be collected.

The intensity data for farm equipment were collected from a journal [19] and the others were collected from a government publication [25] and Dynamic Equipment Policy [10]. These were summarized in Table 6.8. According to the data collected, farm equipment data show a slower
<table>
<thead>
<tr>
<th>Name</th>
<th>Tractor Age (hrs)</th>
<th>Combine</th>
<th>Corn Picker</th>
<th>Hay Baler</th>
<th>Forage Harvester</th>
<th>Pickup truck (1000 miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>472</td>
<td>222</td>
<td>124</td>
<td>71</td>
<td>84</td>
<td>14.4</td>
</tr>
<tr>
<td>2</td>
<td>483</td>
<td>231</td>
<td>120</td>
<td>76</td>
<td>91</td>
<td>15.2</td>
</tr>
<tr>
<td>3</td>
<td>495</td>
<td>207</td>
<td>87</td>
<td>76</td>
<td>78</td>
<td>14.9</td>
</tr>
<tr>
<td>4</td>
<td>554</td>
<td>157</td>
<td>91</td>
<td>89</td>
<td>53</td>
<td>13.9</td>
</tr>
<tr>
<td>5</td>
<td>504</td>
<td>148</td>
<td>71</td>
<td>60</td>
<td>57</td>
<td>12.4</td>
</tr>
<tr>
<td>6</td>
<td>449</td>
<td>128</td>
<td>74</td>
<td>65</td>
<td>26</td>
<td>11.7</td>
</tr>
<tr>
<td>7</td>
<td>468</td>
<td>99</td>
<td>77</td>
<td>63</td>
<td>77</td>
<td>10.9</td>
</tr>
<tr>
<td>8</td>
<td>471</td>
<td>80</td>
<td>76</td>
<td>54</td>
<td>—</td>
<td>10.3</td>
</tr>
<tr>
<td>9</td>
<td>485</td>
<td>99</td>
<td>57</td>
<td>51</td>
<td>—</td>
<td>9.6</td>
</tr>
<tr>
<td>10</td>
<td>455</td>
<td>68</td>
<td>63</td>
<td>41</td>
<td>68</td>
<td>8.6</td>
</tr>
<tr>
<td>11</td>
<td>461</td>
<td>64</td>
<td>48</td>
<td>34</td>
<td>—</td>
<td>8.2</td>
</tr>
<tr>
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<td>52</td>
<td>41</td>
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<td>66</td>
<td>32</td>
<td>74</td>
<td>—</td>
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<td>52</td>
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<tr>
<td>15</td>
<td>382</td>
<td>54</td>
<td>35</td>
<td>31</td>
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<tr>
<td>16</td>
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<td>39</td>
<td>35</td>
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<tr>
<td>18</td>
<td>281</td>
<td>31</td>
<td>50</td>
<td>24</td>
<td></td>
<td></td>
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<tr>
<td>19</td>
<td>455</td>
<td>30</td>
<td>63</td>
<td>20</td>
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<tr>
<td>20</td>
<td>284</td>
<td>29</td>
<td>34</td>
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</table>
Table 6.8. (continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Construction Age (hr)</th>
<th>Construction Heavy Tractor (1,000 miles)</th>
</tr>
</thead>
<tbody>
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<td>650</td>
<td>14.1</td>
</tr>
<tr>
<td>2</td>
<td>630</td>
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<tr>
<td>3</td>
<td>590</td>
<td>11.6</td>
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<tr>
<td>4</td>
<td>575</td>
<td>10.5</td>
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<tr>
<td>5</td>
<td>550</td>
<td>9.4</td>
</tr>
<tr>
<td>6</td>
<td>525</td>
<td>8.4</td>
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<td>445</td>
<td>6.3</td>
</tr>
<tr>
<td>10</td>
<td>420</td>
<td>5.7</td>
</tr>
<tr>
<td>11</td>
<td>395</td>
<td>5.2</td>
</tr>
<tr>
<td>12</td>
<td>365</td>
<td>4.8</td>
</tr>
<tr>
<td>13</td>
<td>345</td>
<td>4.5</td>
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<tr>
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</tr>
<tr>
<td>15</td>
<td>290</td>
<td>4.1</td>
</tr>
</tbody>
</table>

...
decrease of service intensity than the other types of equipment. The smoothed curves for this service intensity data were obtained by use of least sum of squares method. These are represented in Table 6.9.

In these service intensity data, there was a tendency for heavier equipment to last longer and decline at a slower rate of intensity than light equipment. Though the data for farm equipment were found [19] and analyzed item by item, data for each of the other types of equipment were not found and only the representative service intensity data were obtained [10,25]. These representative service intensity data will be used for all of the other equipment except farm equipment.

3. Market evidence data

Market evidence data are important because the K values of these data are used as criteria to compare with those of R and M costs and service intensity. These market evidence data were obtained from the routinely published valuation guide [26,27] for farm equipment. On the other hand, the other data were derived from auction companies [28], Green Construction Company where they collected the auction data and made a simple table [22], and the valuation guide [29]. Usually, they have two kinds of value for equipment. These are average resale values and average as-is values.

According to the Blue Book [27], the average resale value is a guide as to the probable price a standard "as advertised" model will bring on the open market when sold in single lots, after having been properly exposed to the market, by a dealer usually engaged in the implement business to a purchaser willing and able to buy, assuming the
Table 6.9. Smoothed curve graphs for service intensity

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Graph Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor</td>
<td>$1 - 0.0965689 - .00009793 x^3$</td>
</tr>
<tr>
<td>Combine</td>
<td>$1 + 0.13487819 - 0.11647211 x + 0.00354272 x^2$</td>
</tr>
<tr>
<td>Corn Picker</td>
<td>$1 + 0.06129428 - 0.09206833 x + 0.0029727 x^2$</td>
</tr>
<tr>
<td>Hay Baler</td>
<td>$1 + 0.02445473 - 0.05817998 x + 0.00117404 x^2$</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>$1 - 0.14617940 - 0.02683363 x$</td>
</tr>
<tr>
<td>Pickup Truck</td>
<td>$1 - 0.01110414 - 0.00679704 x^2 + 0.00026015 x^3$</td>
</tr>
<tr>
<td>Construction Heavy</td>
<td></td>
</tr>
<tr>
<td>Tractor</td>
<td>$1 + 0.03916597 - 0.044736842 x$</td>
</tr>
<tr>
<td>Construction Truck</td>
<td>$1 + 0.09784117 - 0.10183356 x + 0.00322060 x^2$</td>
</tr>
</tbody>
</table>
sale is an "arm's length" transaction and that neither party is under duress to buy or sell. According to the Official Guide [26], average resale values are applicable to machines with average amount of reconditioning made by the reporting dealers.

The average "as-is" value of the Blue Book [27] is expressed as follows. These figures represent the average value of tractors and farm machines in usable as-is condition prevailing throughout the country. Within this general group of values would fall trade-in allowance by dealers, direct sales between farmers, and equipment sold at auction. In the official guide, the average as-is values are in all instances applicable to machines with standard or regular equipment and rubber tires except where otherwise noted. A deduction from these values must be made by the dealer for machines on which any of the standard or regular equipment is missing. This average as-is value is computed by subtracting average reconditioning costs from average resale values, then deducting 15% from that difference. Thus, the resale values seem to be close to buyer's prices and the as-is values are seller's prices.

As criteria in this dissertation, the resale values are used and collected since the values of average, dependable, well-conditioned machines and the auction sale values are close to the resale values. Furthermore, the as-is value is usually the bottom price and the real value to the owner is always greater than that. The average as-is values can be easily calculated as around four-fifths of the average resale values according to the reference books mentioned above.

These collected data are shown in Table 6.10. It is also
<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Value New</th>
<th>Age</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
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<td>Gas Tractor</td>
<td>7620</td>
<td>PCT</td>
<td>84.3</td>
<td>77.6</td>
<td>71.4</td>
<td>65.7</td>
<td>60.4</td>
<td>55.6</td>
<td>51.1</td>
<td>47.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel Tractor</td>
<td>8032</td>
<td>PCT</td>
<td>86.3</td>
<td>79.4</td>
<td>73.0</td>
<td>67.2</td>
<td>61.8</td>
<td>56.8</td>
<td>52.3</td>
<td>48.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.P combine</td>
<td>16350</td>
<td>PCT</td>
<td>68.5</td>
<td>62.0</td>
<td>56.1</td>
<td>50.8</td>
<td>45.9</td>
<td>41.6</td>
<td>37.6</td>
<td>34.0</td>
<td>30.8</td>
<td>27.9</td>
</tr>
<tr>
<td>Corn Picker</td>
<td>2084</td>
<td>PCT</td>
<td>66.8</td>
<td>58.8</td>
<td>51.7</td>
<td>45.5</td>
<td>40.0</td>
<td>35.2</td>
<td>31.0</td>
<td>27.2</td>
<td>23.9</td>
<td>21.0</td>
</tr>
<tr>
<td>Hay Baler</td>
<td>3303</td>
<td>PCT</td>
<td>67.4</td>
<td>61.0</td>
<td>55.6</td>
<td>49.9</td>
<td>45.1</td>
<td>40.8</td>
<td>36.9</td>
<td>33.4</td>
<td>30.2</td>
<td></td>
</tr>
<tr>
<td>F. Harvester</td>
<td>2552</td>
<td>PCT</td>
<td>68.9</td>
<td>61.4</td>
<td>54.6</td>
<td>48.6</td>
<td>43.2</td>
<td>38.5</td>
<td>34.2</td>
<td>30.5</td>
<td>25.1</td>
<td>20.7</td>
</tr>
<tr>
<td>35 ton End dump truck</td>
<td>289,700</td>
<td>PCT</td>
<td>64.8</td>
<td>54.6</td>
<td>47.2</td>
<td>43.8</td>
<td>41.8</td>
<td>32.4</td>
<td>26.4</td>
<td>24.0</td>
<td>18.0</td>
<td>12.2</td>
</tr>
<tr>
<td>50 ton End dump truck</td>
<td>384,500</td>
<td>PCT</td>
<td>64.8</td>
<td>54.6</td>
<td>47.2</td>
<td>43.8</td>
<td>41.8</td>
<td>32.4</td>
<td>26.4</td>
<td>24.0</td>
<td>18.0</td>
<td>13.2</td>
</tr>
<tr>
<td>D9 dozer</td>
<td>283,820</td>
<td>PCT</td>
<td>78.0</td>
<td>66.0</td>
<td>60.0</td>
<td>50.4</td>
<td>42.0</td>
<td>36.0</td>
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<td>50.4</td>
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<td>33.6</td>
<td>30.0</td>
<td>24.0</td>
<td>18.0</td>
</tr>
<tr>
<td>10 M Gal Water Wagon</td>
<td>348,700</td>
<td>PCT</td>
<td>80.0</td>
<td>67.8</td>
<td>52.2</td>
<td>37.8</td>
<td>36.0</td>
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<td>69.6</td>
<td>62.4</td>
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<td>CAT 666 Scraper</td>
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<td>44.4</td>
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<td>14.4</td>
<td>13.2</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>Compactor</td>
<td>900 Portable Air Compressor</td>
<td>6&quot; Rotary Drill</td>
<td>35 Ton Motor Crane</td>
<td>150 Ton Crawler Crane</td>
<td>90 KW Diesel Generator</td>
<td>D8 dozer</td>
<td>Industrial Forklift</td>
<td>Pickup Truck</td>
<td></td>
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<td>-----------------------------</td>
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<tr>
<td>CAT 825</td>
<td>142,470</td>
<td>56,500</td>
<td>76,895</td>
<td>241,540</td>
<td>553,600</td>
<td>18422</td>
<td>165,000</td>
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<tr>
<td></td>
<td>PCT 75.6</td>
<td>PCT 75.6</td>
<td>PCT 78.0</td>
<td>PCT 82.8</td>
<td>PCT 84.0</td>
<td>PCT 84.0</td>
<td>PCT 82.2</td>
<td>PCT 81.9</td>
<td>PCT 80.4</td>
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<td></td>
<td>64.8</td>
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<td>66.0</td>
<td>70.8</td>
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<td>58.8</td>
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<td>62.4</td>
<td>63.6</td>
<td>72.0</td>
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<tr>
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<td>36.0</td>
<td>46.8</td>
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<td>24.0</td>
<td>42.0</td>
<td>44.4</td>
<td>48.0</td>
<td>63.6</td>
<td>51.0</td>
<td>40.7</td>
<td>35.5</td>
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<tr>
<td></td>
<td>42.0</td>
<td>16.8</td>
<td>36.0</td>
<td>38.4</td>
<td>44.4</td>
<td>60.0</td>
<td>42.0</td>
<td>35.8</td>
<td>28.4</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>37.8</td>
<td>10.8</td>
<td>30.0</td>
<td>33.6</td>
<td>40.8</td>
<td>56.4</td>
<td>39.0</td>
<td>33.3</td>
<td>22.5</td>
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</tr>
<tr>
<td></td>
<td>32.4</td>
<td></td>
<td>28.8</td>
<td>30.0</td>
<td>37.2</td>
<td>52.8</td>
<td>33.6</td>
<td>31.2</td>
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<td></td>
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<tr>
<td></td>
<td>22.8</td>
<td></td>
<td>26.4</td>
<td>18.0</td>
<td>33.6</td>
<td>46.8</td>
<td>28.8</td>
<td>27.0</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>24.0</td>
<td>12.0</td>
<td></td>
<td></td>
<td></td>
<td>23.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
represented as a percent of its value new. Since the times of collected R and M cost data are different, the value new data are collected according to the year of R and M costs data collected. Thus, the value new of farm equipment, based on 1974 data, D8 dozer, Industrial forklift, and pickup truck are based on 1978, and the other construction equipment is derived from 1984 data, and the costs data are consistent with the year of the value new of each equipment.

4. **Probable life and salvage value data**

These data are necessary to determine the K values of the market evidence data and the K values of the Delta method with the R and M cost data and service intensity data. Probable service life can often be estimated with a reasonable degree of accuracy based on lifespans of similar units and various life analysis techniques. However, no life analysis studies for this equipment were found. Therefore, the probable service lives for farm equipment was estimated based on reference books [30,31,32] and discussion with experienced people [20,21]. The probable service lives of the other equipment were estimated based on the cost guide [23] and industry experience [22]. The salvage values were estimated based on the same procedure as probable service lives. These are shown in Table 6.11.

Most of the construction equipment lifespans were 10 years and usually the probable service lives of farm equipment were longer than construction equipment since construction equipment works hard and severe compared with farm equipment. Also, the service lives of heavy equipment have a tendency of longer life. Usually, the economic life is
shorter and the salvage value is bigger than the probable lives and salvage values shown in Table 6.16. Thus, there is an inverse relationship between probable lives and salvage values.

Selection of the most appropriate Iowa type curve was made by the trial and error curve fitting procedure. Based on this procedure, the L5, S6, and R5 curves were selected for most of the equipment as giving the best fit of the computed value curve to the market evidence data.

Further analysis made by Whelan [14], revealed that, even though the degree of fit between the computed curve and the market evidence data were better for some curve types than for others, the best fit for each curve always resulted in the selection of the same value of T. Namely, the Iowa type curve selection affected the closeness of it, but made no apparent difference in the T-factor value selected as being the best estimate.

B. Data for Group Property

Procedures previously presented are either based on or biased toward unit properties. However, group properties are also important since a lot of portion of industrial properties is the vintage groups. Although the application of the proposed procedures to group properties is more complicated than unit properties, the basis of procedure and validity of results are unchanged. The significant differences, however, will be explained and the data for group properties will be presented.
Table 6.11. Probable life and salvage value

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Estimated (yr) Probable Life</th>
<th>Salvage Percent Per Value New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas tractor</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Diesel tractor</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>combine</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Corn Picker</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Hay Baler</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>35 ton truck</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>50 ton truck</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>D9 dozer</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>D9C dozer</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>10M water wagon</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>637 scraper</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>666 scraper</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>CAT 825 compactor</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>900 Air compressor</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>6&quot; Rotary drill</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>35 ton M. Crane</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>150 ton C. crane</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Diesel generator</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>D8 dozer</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Industrial forklift</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>13</td>
<td>0</td>
</tr>
</tbody>
</table>
1. Group property considerations

The consideration of group properties as opposed to unit properties is another important subject in the valuation of industrial properties. Group property can be either a group of identical pieces of equipment or a group of un-identical equipment which make an operation unit for common functions or objectives like assembly lines, oil refineries, etc. The difference between unit property and group property is in the consideration of frequency curves of retirement.

The procedure for handling group property is called "unit-summation procedure" or "equal life group procedure." The basic concept of this procedure is to separate the surviving units comprising the group into frequency groups of units of like probable life as predicted from a forecasted retirement dispersion pattern like the Iowa type curves. Since the units of a frequency group have the same expected life, they can be treated in total as a single item having that life.

The modified condition percent factor for all the survivors of the group at a given age is then obtained by weighting each modified condition percent factor, calculated on a unit basis for each frequency group surviving, by the number of units in each frequency group. Then, the weighted average modified condition percent factor of the entire group property is obtained. Figure 6.2 shows the SO Iowa type curve with a 5 year average service life and how the survivors are segregated into frequency groups with the increasing probable lives as frequency group ages.

Furthermore, each of the segregated frequency groups can be
Figure 6.2. Application of unit summation procedure to declining operation returns case [12]
considered as a unit property of unique average service life. For example, the average service life of the first frequency group at the top of Figure 6.2 is 1 year while that of the last frequency group is 9 years. Thus, they have different average service lives and the assumed operation returns of the first age for each frequency group would be proportional to the size of each frequency group. Thus, for the unit property of each frequency group, the decrease in operation returns would be different each case due to the different average service lives and salvage ratios. That means that the K values of each frequency group are different. Therefore, the K values of an overall property of a group seem to be the weighed average of the K values of each frequency group. Consequently, the weighed average of K values which are obtained by using the procedures for unit property would be the K values of the group property in question.

2. Data collected

In the case of group property, data for the service intensity and the repair maintenance costs as the factors of declining operation returns of unit property were not easy to obtain because of the difficulty of record keeping for a particular group of properties. Thus, as the substitutes for the decrease of service intensity and the increasing R and M costs, the decrease in gross operating revenue and the increasing operating costs were assumed to be the main factors of declining operation returns in group property. The decrease in gross operating revenue is thought to be caused by the decreasing service intensity which might be affected by lowered efficiency and quality,
downtime, obsolescence, etc. The increasing operating costs is mostly due to the increasing repair and maintenance costs caused by the increasing usage of power, labor, material, parts, etc. These two main factors of group property were treated in the same way as those of unit property in the Delta method. In Figure 5.1, the $f(x)$ is the decreasing gross operating revenue and $t(x)$ is the increasing operating costs in case of group property.

The data of two oil refineries as group properties were collected [15] and used in the experiment. Sufficient data were available for one of the refineries to allow an analysis at three different ages. Thus, four sets of data of two refineries were in effect available for analysis. In order to ensure anonymity, the four sets of data will hereafter be referred to as 1) Alpha-1, 2) Alpha-2, 3) Alpha-3, and 4) Beta refineries. The three sets of data for "Alpha" refinery were obtained from the same refinery but collected at three different ages, i.e., 5, 10, and 16 years old. The data for "Beta" refinery were obtained at the age of 10. The Income statements of these refineries are shown in Table 6.12. The operating costs statements for these refineries are also represented in Table 6.13.

The decreasing gross operating revenue which is assumed to play the same role as the declining service intensity of unit basis is represented as differences with the gross operating revenue of the modern replacement. These differences for Alpha-1, -2, -3, and Beta refineries are 2.9, 5.1, 7.5, and 12.9, respectively. The units of the figures are also $\text{MM/yr}$. The average life of the Alpha and Beta
### Table 6.12. Income statements for Alpha-1, -2, -3, and Beta refineries vs. modern replacement

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Modern Replacement</th>
<th>Alpha</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(5 yrs old)</td>
<td>(10 yrs old)</td>
<td>(16 yrs old)</td>
</tr>
<tr>
<td>Taxable income</td>
<td>13.2</td>
<td>12.0</td>
<td>9.9</td>
</tr>
<tr>
<td>Tax (federal)</td>
<td>6.4</td>
<td>5.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Net income</td>
<td>6.9</td>
<td>6.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Depreciation</td>
<td>7.8</td>
<td>5.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Cash income after tax</td>
<td>14.7</td>
<td>12.0</td>
<td>8.9</td>
</tr>
</tbody>
</table>

*aAll figures in units of $MM/yr.*
Table 6.13. Operating costs statements for Alpha-1, -2, -3, and Beta refineries vs. modern replacement

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Alpha</th>
<th>Beta</th>
<th>Modern Replacement</th>
<th>Alpha-1 (5 yrs old)</th>
<th>Alpha-2 (10 yrs old)</th>
<th>Alpha-3 (16 yrs old)</th>
<th>Modern Replacement</th>
<th>Beta (10 yrs old)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs</td>
<td>Alpha</td>
<td>Alpha-1</td>
<td>Alpha-2</td>
<td>Alpha-3</td>
<td>Beta</td>
<td>Beta</td>
<td>Beta</td>
<td>Beta</td>
</tr>
<tr>
<td></td>
<td>Modern</td>
<td>(5 yrs old)</td>
<td>(10 yrs old)</td>
<td>(16 yrs old)</td>
<td>(5 yrs old)</td>
<td>(10 yrs old)</td>
<td>(10 yrs old)</td>
<td>(10 yrs old)</td>
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<tr>
<td>Labor</td>
<td>6.8</td>
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<td>0.4</td>
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<td>1.3</td>
<td>1.3</td>
<td>2.8</td>
<td>3.1</td>
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<tr>
<td>Utilities</td>
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<td>14.7</td>
<td>17.3</td>
<td>19.4</td>
<td>37.3</td>
<td>47.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aAll figures in units of $MM/yr.*
refineries is 20 years. The replacement costs for the Alpha and Beta refineries is reported as 150 million dollars and 246 million dollars, respectively. The salvage values are around 5 percent of the replacement costs.

The above collected data will be used to find the K values for each refinery. The K values will be obtained by using the ratio method and the Delta method. Since the group property like a refinery can provide the income statement, that is, operation returns for some ages, the operation returns can be directly fit to the basic model which describes the relationship between $R_1$ and $R_X$. For this direct fitting, the ratio method will be used. The data for operating costs, operating revenues, value new, salvage ratio, and average life will be used for the Delta method in the same way as unit property. These K values from both the ratio method and Delta method will be compared.
VII. RESULTS AND DISCUSSION

Using the data collected and procedures developed, K values for a number of properties were estimated. The K values derived from the only R and M data, R and M plus intensity data, and market evidence data were compared and determined the most realistic approach to estimate the value of industrial property in addition to the choice of better model. K values for group property were also obtained and discussed. The standard tables of property value at x were developed and presented in this chapter.

A. Estimation of K Values for Market Evidence Data

K values were estimated for all equipment. The computed value curves according to the variation of K values were compared to the corresponding market evidence data using a least sum of squares method to measure the goodness of fit. The K values resulting in the best fit were then selected as a slope factor exhibited by the properties.

1. Comparison of Elfar model and Y model

Depending upon the model used, the goodness of fitting were varied. The comparisons of the $V_x$ of Y model, the $V_x$ of Elfar model, and the $V_x$ from market evidence data are shown in Appendix E. Two of the collected equipment are illustrated as examples in Figures 7.1 and 7.2. These figures showed that the $V_x$ of Elfar model is usually further from that of Y model with the $V_x$ of market evidence data. That means the $V_x$ of the Y model produces a better fit with market evidence data than the $V_x$ of the Elfar model. Usually, the variation of K value and T factor
Figure 7.1. Comparison of Y model and Elfar model with market evidence

Figure 7.2. Comparison of Y model and Elfar model with market evidence
value can produce different shape of graph in either the Y model or the Elfar model, respectively. However, since the basic characteristics of each model are different and the basic shape of graph, namely the rate of decline at each age, is different from each other, the shapes of $V_x$ of the figures are different from each other after all. Usually, market evidence data have a rapid decline of value in the first year after equipment was purchased. This decline of value appears to be caused by a dealer's large sales profit, the tendency of people to buy a new product, freight and installation charges at the beginning, substantial obsolescence in the first year, investment tax credit for the new product or so many unknown factors; however, the Elfar model did not represent rapid decline in the first year and slow decline in subsequent years. Thus, the Y model seems superior to the Elfar model. Afterwards, all the analyses in this study were done by using the Y model instead of the Elfar model.

Thus, the $K$ values were estimated through all the experimental procedures described in the previous chapter with analyzed data of every industrial property. The fundamental data sets were market evidence data, R and M costs data, service intensity rate data, probable life and salvage value for every one of the items. For all these analyses, the rate of return was selected to be 7 percent per year [17] as the most reasonable value for an inflation free annual rate of return. Moreover, according to the analysis of Chapter IV, Figure 4.8, the rate of return term had little effect on the completed equipment values as long as a reasonably accurate rate was used.
2. **K values of market evidence**

The K values were obtained by using least sum of squares method with collected market evidence data. These results were shown in Table 7.1. The error bound of these K values was around $\pm 0.05$. However, the values in Table 7.1 were usually the best.

**B. Estimation of K Value Using Delta Method**

Estimation of K values using the Delta method required collection of data related to the components of depreciation. The components of normally increasing depreciation with the passage of time commonly include the following:

1. rising repair and maintenance costs as parts wear out or fail in service, and
2. decreasing service intensity due to increasing downtime, falling production rate, and increasing functional or economic obsolescence.

The R and M costs data were derived from field reports of time and costs. A regression analysis and time adjustment were applied to the field date during the summation process. The results were plotted as constant dollar, smoothed curves. These accumulated data were translated to the data for unit ages by calculating with annual usage data. Then, the data for unit were applied to the standard curve of the Delta method after appropriate calculations to make same unit with the standard curves. After that, the K values were derived by matching or fitting the Delta values with the standard curves. These fittings were also done by visual fitting based on least sum of squares
<table>
<thead>
<tr>
<th>Equipment</th>
<th>K value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas tractor</td>
<td>0.85</td>
</tr>
<tr>
<td>Dis. tractor</td>
<td>0.9</td>
</tr>
<tr>
<td>Combine</td>
<td>0.5</td>
</tr>
<tr>
<td>Corn picker</td>
<td>0.3</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>0.5</td>
</tr>
<tr>
<td>Hay baler</td>
<td>0.45</td>
</tr>
<tr>
<td>35 ton truck</td>
<td>0.4</td>
</tr>
<tr>
<td>50 ton truck</td>
<td>0.4</td>
</tr>
<tr>
<td>D9 dozer</td>
<td>0.45</td>
</tr>
<tr>
<td>D9 C dozer</td>
<td>0.45</td>
</tr>
<tr>
<td>10M w. wagon</td>
<td>0.45</td>
</tr>
<tr>
<td>637 scraper</td>
<td>0.45</td>
</tr>
<tr>
<td>666 scraper</td>
<td>0.3</td>
</tr>
<tr>
<td>825 compactor</td>
<td>0.5</td>
</tr>
<tr>
<td>900 air comp.</td>
<td>0.65</td>
</tr>
<tr>
<td>6&quot; Rot. drill</td>
<td>0.32</td>
</tr>
<tr>
<td>35 M crane</td>
<td>0.8</td>
</tr>
<tr>
<td>150 C crane</td>
<td>0.45</td>
</tr>
<tr>
<td>Dis generator</td>
<td>0.8</td>
</tr>
<tr>
<td>D8 dozer</td>
<td>0.45</td>
</tr>
<tr>
<td>I. forklift</td>
<td>0.5</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>0.3</td>
</tr>
</tbody>
</table>
method. The standard tables of Delta values with the variety of K values, average lives, and salvage ratios are represented in Appendix B.

1. **K values with R and M costs and service intensity**

The service intensity rate was assumed in this dissertation as one of the main reasons for declining operation returns in addition to R and M costs. Thus, K values were derived with the consideration of both R and M costs and service intensity rates. Smoothed curves of these data and the composition of these two smoothed curves were the main procedures to obtain the value, $(P_x - P_1)/V^*$. This value was compared to the Delta value of standard curves which were derived by using the Y model.

The examples for estimation of the K values using standard sets of curves according to the determined probable service lives and salvage ratios of each piece of equipment were shown in Figures 7.3 and 7.4. The K values with R and M costs and service intensity rate are summarized in Table 7.2.

2. **K values with R and M costs**

This analysis method was developed by Whelan [14]. In this section, the K values were derived by using only R and M costs with numbers of real world data. These K values will be used for the comparison with those of R and M costs and intensity rate and those of real market evidence data. The procedure to find the K values was explained in Chapter V. The only difference is to set the decline of the intensity rate as zero, namely, $f(x)$ equals 1. Table 7.3 shows the
Figure 7.3. Standard curves for Delta method and fitting

Figure 7.4. Standard curves for Delta method and fitting
<table>
<thead>
<tr>
<th>Equipment</th>
<th>K value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas tractor</td>
<td>0.85</td>
</tr>
<tr>
<td>Dis. tractor</td>
<td>0.90</td>
</tr>
<tr>
<td>Combine</td>
<td>0.48</td>
</tr>
<tr>
<td>Corn picker</td>
<td>0.50</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>0.81</td>
</tr>
<tr>
<td>Hay baler</td>
<td>0.58</td>
</tr>
<tr>
<td>35 ton truck</td>
<td>0.42</td>
</tr>
<tr>
<td>50 ton truck</td>
<td>0.45</td>
</tr>
<tr>
<td>D9 dozer</td>
<td>0.40</td>
</tr>
<tr>
<td>D9 C dozer</td>
<td>0.40</td>
</tr>
<tr>
<td>10M w. wagon</td>
<td>0.47</td>
</tr>
<tr>
<td>637 scraper</td>
<td>0.45</td>
</tr>
<tr>
<td>666 scraper</td>
<td>0.28</td>
</tr>
<tr>
<td>825 compactor</td>
<td>0.50</td>
</tr>
<tr>
<td>900 air comp.</td>
<td>0.78</td>
</tr>
<tr>
<td>6&quot; Rot. drill</td>
<td>0.38</td>
</tr>
<tr>
<td>35 M crane</td>
<td>0.82</td>
</tr>
<tr>
<td>150 C crane</td>
<td>0.44</td>
</tr>
<tr>
<td>Dis generator</td>
<td>0.68</td>
</tr>
<tr>
<td>D8 dozer</td>
<td>0.40</td>
</tr>
<tr>
<td>I. forklift</td>
<td>0.62</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>0.33</td>
</tr>
</tbody>
</table>
K values with the data of R and M costs. The error boundary for these values is within ±.1.

C. Comparisons of K Values out of R and M, R and M and Intensity and Market Evidence

Three sets of K values were finally obtained and compared. The first one was derived from the market evidence data. The second one was made with the R and M costs data and service intensity rate data through the Delta method. The last one was similar to the second one but using only R and M costs data without service intensity rate. These three sets of K values are summarized in Table 7.4.

The comparison of the three sets of K values revealed several characteristics. First of all, the K values of R and M costs and intensity were always smaller than those of R and M costs. The difference in range of these two sets of K values was from 0.2 to 0.5. These differences were supposed to be in same ratio with the steepness of the intensity rate decrease. But, owing to the model characteristics, the differences between the K values do not represent the same differences on the intensity graph. The smaller the figure of K value becomes, the smaller the change in K value becomes for the same change of the intensity rate. Thus, the same difference of K value in Table 7.4 does not mean the same rate of gap in the intensity rates.

The second observation is that the K values of R and M costs are always bigger than those of market evidence. That indicates that there should be other factors which reduce the operation return with age in addition to the R and M costs.
Table 7.3. K values with R and M costs

<table>
<thead>
<tr>
<th>Equipment</th>
<th>K value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas tractor</td>
<td>1.1</td>
</tr>
<tr>
<td>Dis. tractor</td>
<td>1.2</td>
</tr>
<tr>
<td>Combine</td>
<td>1.1</td>
</tr>
<tr>
<td>Corn picker</td>
<td>0.8</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>1.2</td>
</tr>
<tr>
<td>Hay baler</td>
<td>1.0</td>
</tr>
<tr>
<td>35 ton truck</td>
<td>0.9</td>
</tr>
<tr>
<td>50 ton truck</td>
<td>0.9</td>
</tr>
<tr>
<td>D9 dozer</td>
<td>0.6</td>
</tr>
<tr>
<td>D9 C dozer</td>
<td>0.6</td>
</tr>
<tr>
<td>10M w. wagon</td>
<td>0.9</td>
</tr>
<tr>
<td>637 scraper</td>
<td>0.7</td>
</tr>
<tr>
<td>666 scraper</td>
<td>0.4</td>
</tr>
<tr>
<td>825 compactor</td>
<td>0.7</td>
</tr>
<tr>
<td>900 air comp.</td>
<td>1.0</td>
</tr>
<tr>
<td>6&quot; Rot. drill</td>
<td>0.5</td>
</tr>
<tr>
<td>35 M crane</td>
<td>1.1</td>
</tr>
<tr>
<td>150 C crane</td>
<td>0.9</td>
</tr>
<tr>
<td>Dis generator</td>
<td>1.0</td>
</tr>
<tr>
<td>D8 dozer</td>
<td>0.6</td>
</tr>
<tr>
<td>I. forklift</td>
<td>0.9</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Table 7.4. Comparison of K values

<table>
<thead>
<tr>
<th>Equipment</th>
<th>K value of market</th>
<th>K value of R and M and Int.</th>
<th>K value of R and M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas tractor</td>
<td>0.85</td>
<td>0.85</td>
<td>1.1</td>
</tr>
<tr>
<td>Dis. tractor</td>
<td>0.90</td>
<td>0.90</td>
<td>1.2</td>
</tr>
<tr>
<td>Combine</td>
<td>0.50</td>
<td>0.48</td>
<td>1.1</td>
</tr>
<tr>
<td>Corn picker</td>
<td>0.30</td>
<td>0.50</td>
<td>0.8</td>
</tr>
<tr>
<td>F. Harvester</td>
<td>0.50</td>
<td>0.81</td>
<td>1.2</td>
</tr>
<tr>
<td>Hay baler</td>
<td>0.45</td>
<td>0.58</td>
<td>1.0</td>
</tr>
<tr>
<td>35 ton truck</td>
<td>0.40</td>
<td>0.42</td>
<td>0.9</td>
</tr>
<tr>
<td>50 ton truck</td>
<td>0.40</td>
<td>0.45</td>
<td>0.9</td>
</tr>
<tr>
<td>D9 dozer</td>
<td>0.45</td>
<td>0.40</td>
<td>0.6</td>
</tr>
<tr>
<td>D9C dozer</td>
<td>0.45</td>
<td>0.40</td>
<td>0.6</td>
</tr>
<tr>
<td>10M W. wagon</td>
<td>0.45</td>
<td>0.47</td>
<td>0.9</td>
</tr>
<tr>
<td>637 scraper</td>
<td>0.45</td>
<td>0.45</td>
<td>0.7</td>
</tr>
<tr>
<td>666 scraper</td>
<td>0.3</td>
<td>0.28</td>
<td>0.4</td>
</tr>
<tr>
<td>825 compactor</td>
<td>0.5</td>
<td>0.50</td>
<td>0.7</td>
</tr>
<tr>
<td>900 Air Comp.</td>
<td>0.65</td>
<td>0.78</td>
<td>1.0</td>
</tr>
<tr>
<td>6&quot; Rot. drill</td>
<td>0.32</td>
<td>0.38</td>
<td>0.5</td>
</tr>
<tr>
<td>35 M. crane</td>
<td>0.8</td>
<td>0.82</td>
<td>1.1</td>
</tr>
<tr>
<td>150 C. crane</td>
<td>0.45</td>
<td>0.44</td>
<td>0.9</td>
</tr>
<tr>
<td>Dis. generator</td>
<td>0.8</td>
<td>0.68</td>
<td>1.0</td>
</tr>
<tr>
<td>D8 dozer</td>
<td>0.45</td>
<td>0.40</td>
<td>0.6</td>
</tr>
<tr>
<td>Ind. forklift</td>
<td>0.5</td>
<td>0.62</td>
<td>0.9</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>0.3</td>
<td>0.33</td>
<td>0.5</td>
</tr>
</tbody>
</table>
The third observation is that the K values out of R and M costs and intensity were always closer to those of market evidence than those of R and M costs. Furthermore, the difference between K values of R and M costs with intensity and those of market evidence were quite small; that is, the gap of K values of 16 equipments out of 22 were within 0.1. That means the market values obtained by using the K values out of R and M costs and intensity fit quite close to the actual market evidence values. Thus, the proposed Delta method using R and M costs and intensity rate were shown to be reliable and valid. Therefore, these three observations above indicate that the proposed Y model,

\[ R_x/R_1 = 1 - \left( \frac{7(x-1)}{N} \right)^T \]

with the condition, \( R_x/R_1 = 0 \) at \( X = N + 1 \), represents a realistic relationship between operation returns and market values according to age of the equipment. Also, the Delta method using R and M costs and service intensity rate was shown to give better estimation of K than the Delta method using only R and M costs. Furthermore, the decline of service intensity rates with the age of the equipment might represent and include the whole other factors except R and M costs factor which cause the decline of operation returns of industrial property.

However, the role of experienced judgment in all the procedures is also recommended. The experienced judgment in the collection, interpretation, and utilization of the input data will lead to more reliable results.
Since the proposed Y model and Delta method were proved to be valid and reliable, if R and M costs and service intensity rates were provided every year, one can determine the market value at age x of an industrial property by using Y model and Delta method. Since most of the industrial properties do not keep the market values with their ages due to the scarcity of records of sale the procedures of this dissertation could make a good standard or criterion for the values of them. However, to keep track of all the steps for the determination of value is sometimes a lot of work. To avoid this inconvenience, the concept of standard tables for value at age x was induced. Detailed concepts and explanations for the standard tables will be discussed in a later section.

D. Comparison of K Values of Group Property

Estimation of K values of group properties using the ratio method was obtained from the income statement data. The procedure and K values were shown in Table 7.5. The best fitting K values were obtained by the trial and error method. The average service life was 20 years and the probable service lives for group properties were determined by using the $S_3$ or $R_3$ Iowa type survivor curves which are close to the survivor curve of the oil refineries. The results of the ratio method seem to be reliable since the method uses the exact operation returns data. Thus, the results of the ratio method would be good criteria for checking the results of the Delta method in which service intensity (reduction of revenue) and repair and maintenance costs (operating costs) were used to determine the close actual operation returns. The K values of the Delta
Table 7.5. K values of ratio method

<table>
<thead>
<tr>
<th>Refinery</th>
<th>$R_1$</th>
<th>$R_X$</th>
<th>X</th>
<th>PL</th>
<th>Ratio (%)</th>
<th>K value</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-1</td>
<td>14.7</td>
<td>12.0</td>
<td>5</td>
<td>20</td>
<td>81.63</td>
<td>0.86</td>
</tr>
<tr>
<td>α-2</td>
<td>14.7</td>
<td>8.9</td>
<td>10</td>
<td>21</td>
<td>60.54</td>
<td>0.77</td>
</tr>
<tr>
<td>α-3</td>
<td>14.7</td>
<td>6.2</td>
<td>16</td>
<td>22</td>
<td>42.18</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>23.2</td>
<td>11.0</td>
<td>10</td>
<td>21</td>
<td>47.41</td>
<td>0.55</td>
</tr>
</tbody>
</table>

method for the refineries were derived from the data of increasing operating costs and decreasing gross revenue. The procedure to get the $\Delta$ and K values is shown in Table 7.6.

The K values of a ratio method and Delta method were represented in Table 7.7 for comparison. The K values of ratio method and those of Delta method were close to each other. Therefore, the assumptions for the group property procedures as well as the unit property procedures are proved to be reasonable and realistic. These assumptions are that increasing repair and maintenance costs and decreasing service intensity with the passage of time are the main factors of declining operation returns for unit properties, and increasing operating costs and decreasing gross operating revenue are the main factors for group properties. Thus, the K values of a Alpha and Beta oil refineries were determined to be 0.75 and 0.54, respectively. The value of age $x$ can be derived from the K values obtained.

The comparisons between $V_x$ of unit property and group property
Table 7.6. K values of Delta method

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Age</th>
<th>Increasing of Operating Costs</th>
<th>Decreasing of Gross Revenue</th>
<th>Δ</th>
<th>Δ/ν_ν_ν_ν_ν</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-1</td>
<td>5</td>
<td>1.0</td>
<td>2.9</td>
<td>3.9</td>
<td>0.026</td>
<td>0.83</td>
</tr>
<tr>
<td>α-2</td>
<td>10</td>
<td>3.6</td>
<td>5.1</td>
<td>8.7</td>
<td>0.058</td>
<td>0.76</td>
</tr>
<tr>
<td>α-3</td>
<td>16</td>
<td>5.7</td>
<td>7.5</td>
<td>13.2</td>
<td>0.088</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>10.0</td>
<td>12.9</td>
<td>22.9</td>
<td>0.093</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Table 7.7. Comparison of K values of ratio method with Delta method

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Age</th>
<th>K value of Ratio Method</th>
<th>K value of DELTA method</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-1</td>
<td>5</td>
<td>0.86</td>
<td>0.83</td>
</tr>
<tr>
<td>α-2</td>
<td>10</td>
<td>0.77</td>
<td>0.76</td>
</tr>
<tr>
<td>α-3</td>
<td>16</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.55</td>
<td>0.53</td>
</tr>
</tbody>
</table>

were considered to estimate the differences between them. The graphical comparison of \( V_x \) are shown in Figures 7.5 and 7.6. There are three graphs, for example, that represent the \( V_x \) for each \( R_1, R_3, \) and \( R_5 \) Iowa type survivor curves for group property and one graph for \( R_5 \) Iowa type unit property. Consideration of \( L \) and \( S \) Iowa type survivor curves was skipped because of little influence of those to determine the \( V_x \) \([14]\). These figures are the results from \( K \) values of 0.6 and 0.9 with common
conditions of 10 year probable service life, 10 percent salvage ratio and 7 percent discount rate. These figures show that the group basis with frequency of equal life group does not make a big difference with unit basis even though slight differences occur when the dispersion pattern is quite different. It, therefore, seems that frequency for a group property normally have little effect on the analysis of $V_x$.

E. Standard Tables of Value of R and M and Intensity

Standard tables of value were developed for easy application in the industry since all the procedures had to be done for every determination of value for the properties in question. Thus, the role of the standard table is to reduce the complexity and time for the final goal of finding $V_x$. If the basic data, R and M costs and intensity rate, were given the value of age $x$ can be easily obtained by using these standard tables. These standard tables start from setting the standard curves for each of R and M costs and intensity rates. With the standard curves, which can generally represent the normal shape of R and M cost and intensity rate, all the procedures will be completed for final standard tables.

These standard curve equations were determined by the trial and error method to find the best fitting general equations on the basis of collected data for this study.

The standard curve equation for service intensity rate is was set as:

$$ I = J(x-1) $$

(7.1)
Figure 7.5. Comparison of $V_x$ between group (—) and unit (---) when $K=0.6$
Figure 7.6. Comparison of $V_x$ between group (---) and unit (---) when $K = 0.9$
where \( I \) = service intensity rate,
\[ x = \text{age}, \text{and} \]
\[ J = \text{variable}. \]

The standard curve equation for \( R \) and \( M \) costs was determined as:
\[ R = H(x-1) \cdot 0.67 \]  
(7.2)

where \( R = R \) and \( M \) costs/\( V_N \)
\[ H = \text{variable}. \]

Usually, the \( J \) factor of Equation (7.1) in service intensity rate equation changes from 0.86 to 1.0, and the \( H \) factor of Equation (7.2) varies 0 to 0.04 in normal situations. Thus, intensity curves were divided into four cases in the above range with the value of \( J \) as .98, .94, .90, and .86. \( R \) and \( M \) curves were also divided into four according to the value of \( H \) as .01, .02, .03, and .04. The standard curves of \( R \) and \( M \) costs begin at 0% of age 1 so that the curves represent the differences between \( R \) and \( M \) costs of age \( X \) and those of age 1.

These two sets of four curves can be named as \( I_1, I_2, I_3, \) and \( I_4 \) in case of intensity and \( R_1, R_2, R_3, \) and \( R_4 \) for \( R \) and \( M \) curves, respectively. The composition of the combination of 4 Is and 4 Rs will work through the same procedures described before. The variables of these equations are also probable life (\( N \)) and salvage ratio (\( S \)). These standard curves were illustrated in Figures 7.7 and 7.8. The results of \( K \) values after some procedures with the variation of \( N \) and \( S \) were shown in Table 7.5. As expected, the effect of \( H, J, \) and probable life (\( N \)) was significant but effect salvage rate (\( S \)) was quite small and negligible within the normal range.
The values with passage of age \( V_x \) corresponding to \( K \) value, probable life \( (N) \), and salvage ratio \( (S) \) in the standard table were listed in Appendix C. Thus, the applications of the theories of this thesis become very simple. The procedures to obtain the \( V_x \) value of a piece of equipment are just four steps as follows:

1. Prepare \( R \) and \( M \) costs data, service intensity data, probable life \( (N) \), and salvage ratio \( (S) \) of a property in question.
2. Match the standard curves with the \( R \) and \( M \) cost data and service intensity data and find out which curve fits best for each of data. For example, \( R_1 \) for \( R \) and \( M \) costs data and \( I_3 \) for intensity data.
3. Find the \( K \) value for obtained standard curves \( (R_1, I_3) \) in the standard table.
4. Find the \( V_x \) value corresponding to the \( K \) value obtained with a given probable life \( (N) \) and salvage ratio \( (S) \).

As a specific example, the data for 1.50 ton C. crane were used. The data from Table 6.6 and the smoothed curve of \( R \) and \( M \) costs from Table 6.7 were drawn in Figure 7.7 as points and a dotted line. The value at age 1 was 0.0204 which was derived from the smoothed curve for drawing the points. This illustration shows that the \( R \) and \( M \) costs curve is close to the \( R_2 \) standard curve. Also, the smoothed curve for the intensity rates from Table 6.9 is illustrated in Figure 7.8 as well as the points of original data from Table 6.8. This figure shows that the curve is close to the \( I_2 \) standard curve. The probable life of the equipment is 15 years and the salvage rate is 10 percent. These
informations are then applied to Table 7.8 for the K value of it. The K value for these informations is found as 0.4. With this K value, the value at age X can be obtained from the standard table of value at Appendix C.
Figure 7.7. Standard curves for R and M costs

Figure 7.8. Standard curves for intensity rate
<table>
<thead>
<tr>
<th></th>
<th>N (yr.)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>R</td>
<td>I</td>
<td>S(%)</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>I₁</td>
<td>.85</td>
<td>.85</td>
<td>.85</td>
<td>.85</td>
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VIII. CONCLUSIONS AND FURTHER STUDY

A. Conclusions

Conclusions were drawn from this research as follows:

1. The proposed Y model appears to be valid. The Y model is simple to apply compared to the Elfar model. Furthermore, the value of the Y model fits close to the market evidence value for all of the data used. Thus, the Y model appears to be better than the Elfar model in its ability to predict value curves and application.

2. There are several factors that reduce the operation returns of an industrial property with the passage of time. Among these factors, two factors were chosen and analyzed. These are the increasing repair and maintenance costs and the decreasing service intensity rate for unit property. From the results, the proposed Delta method using R and M costs and service intensity rates appears to valid in fitting with market evidence value.

3. The two factors chosen for group property which are comparable to those of unit property are the increasing operating costs and decreasing gross operating revenue. The slope factor values of the Delta method using these two factors agree with the results of the ratio method which uses the operating returns directly. Therefore, the proposed Delta method for group property also seems valid in valuation procedures.

4. As a result of the above (No. 2 and 3), the R and M costs
(operating costs) and service intensity rates (operating revenue) appear to be the main factors of declining operation returns of industrial property. Furthermore, the service intensity rate seems to include other factors like obsolescence, downtime cost, decrease in production rate, etc.

5. The market evidence appears to have a tendency to rapidly drop in value in the early part of life and to slowly decline for the rest of its life for all the properties. In case of the intensity rate, the decline in the early part of life was usually bigger than that of the rest of life and these graphs were usually in a convex shape. In contrast, the shape of R and M costs graph was usually concave, showing that the increase in costs in the early part of life is bigger than the increase in the latter part of life.

6. If repair and maintenance costs data, average life and salvage ratio at retirement are provided, the value at age \( x \) which is reasonably close to the market evidence can be obtained using the procedure of this study for the industrial property.

7. The standard curves for R and M costs and intensity rate and the standard tables were developed. These standard curves and tables are used for easy application of the procedures of this dissertation to determine the value of age \( x \).
B. Further Study

Further study is recommended in the following areas:

1. **Collection of data for the actual change of operation returns over the passage of age for unit and group properties and comparison of these data with the models described in this dissertation.**

2. **Study of market evidence which decreases greatly in value in the early part of property life.**

3. **Finding the relationship between the intensity rates and the other factors, especially obsolescence, in the decrease of operation returns.**

4. **Developing the procedure and proving that the weighted average of slope factor values of each frequency group of a group property would be the slopee factor value of the whole group property.**
IX. BIBLIOGRAPHY


21. Schwitters, D. Executive Vice President of Iowa, Nebraska Farm Equipment Association Inc., Des Moines, Iowa, 985.


I greatly appreciate my major professor, Dr. Harold A. Cowles for his guidance and effort throughout the whole research and writing of this dissertation. Without his aid and encouragement, this dissertation would not have been completed. Also, I am grateful to Drs. Herbert T. David, Thomas A. Barta, Gerald W. Smith and Wallace E. Huffman who willingly served as committee members.

I am also greatly thankful to all my family, especially my mother and my wife, Insook, whom I really love as well as Koun, my daughter, for their great devotion, encouragement and long patience.
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#### 80-KW DSL Generator

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XII. APPENDIX B. STANDARD TABLE OF DELTA METHOD

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OF K, PL, AND S

Probable Life 10  Salvage Ratio .1

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PROBABLE LIFE 15  
SALVAGE RATIO 0.1

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XIV. APPENDIX D. MODEL APPLICATION OF GROUP PROPERTY TO FIND VX

10 REM ------
20 REM Y MODEL APPLICATION OF GROUP PROPERTY TO FIND VX
30 REM ------
40 REM
50 REM ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
60 REM THE PROGRAM USED BASIC COMPUTER PROGRAMMING LANGUAGE
70 REM
80 REM DEFINITION OF SYMBOLS
90 REM VN=VALUE WHEN NEW VX=VALUE WHEN AGE X
100 REM I=DISCOUNT RATE S=SALVAGE RATE
110 REM N=AVERAGE LIFE PL=PROBABLE LIFE
120 REM ST=START OF LOOP EN=END OF LOOP
130 REM SP=STEP OF LOOP FREQ=FREQUENCY
140 REM K=SLOPE FACTOR
150 REM
160 PRINT
170 PRINT " Y MODEL APPL. OF GROUP (WEIGHTING COND% AND PL) "
180 PRINT
190 PRINT " R3-10 IOWA TYPE SURVIVAL CURVE FOR FREQ. AND PL"
200 PRINT
210 READ VN, S
220 LET I=.07
230 LET G=1+I
240 LET V=VN*(1-S)
250 READ ST, EN, SP
260 DATA 100, 1
270 DATA .2, .1, .2, .1
280 FOR K=ST TO EN STEP SP
290 PRINT
300 PRINT " K VALUE "; K
310 PRINT
320 FOR X=0 TO 17
330 GRANSUM=0
340 FOR N=1 TO 17
350 SUM1=0
360 FOR M=1 TO N
370 LET C1=(1-(.7*(M-1)/N)^K)*(1/G)^M
380 SUM1=SUM1+C1
390 NEXT M
400 SUM2=0
410 FOR L=1 TO (N-X)
420 LET C2=(1-(.7*(L+X-1)/N)^K)*(1/G)^L
430 SUM2=SUM2+C2
440 NEXT L
450 LET C=SUM2/SUM1
460 GOSUB 570
470 GRANSUM=C*FREQ+GRANSUM
480 NEXT N
490 GOSUB 760
500 LET A=VN*(1-S*(1/G)^PL)*GRANSUM/100+VN*S*(1/G)^PL-X)
510 PRINT
520 PRINT "AGE", "CONDITION %", GRANSUM, "VALUE", A
530 NEXT X
540 PRINT "...................................................
550 NEXT K
560 END
570 REM SUBROUTINE FOR FREQUENCY OF RETIREMENT OF R3-10
580 IF N=1 THEN LET FREQ=.23
590 IF N=2 THEN LET FREQ=.48
600 IF N=3 THEN LET FREQ=.88
610 IF N=4 THEN LET FREQ=1.52
620 IF N=5 THEN LET FREQ=2.43
630 IF N=6 THEN LET FREQ=3.67
640 IF N=7 THEN LET FREQ=5.3
650 IF N=8 THEN LET FREQ=7.47
660 IF N=9 THEN LET FREQ=10.18
670 IF N=10 THEN LET FREQ=13.1
680 IF N=11 THEN LET FREQ=15.13
690 IF N=12 THEN LET FREQ=14.83
700 IF N=13 THEN LET FREQ=11.86
710 IF N=14 THEN LET FREQ=7.59
720 IF N=15 THEN LET FREQ=3.87
730 IF N=16 THEN LET FREQ=1.33
740 IF N=17 THEN LET FREQ=.13
750 RETURN
760 REM SUBROUTINE FOR PROBABLE LIFE OF GROUP OF R3-10
770 IF X>=0 AND X<=5 THEN LET PL=10
780 IF X>=6 AND X<=8 THEN LET PL=11
790 IF X>=9 AND X<=10 THEN LET PL=12
800 IF X>=11 AND X<=12 THEN LET PL=13
810 IF X>=13 AND X<=13 THEN LET PL=14
820 IF X>=14 AND X<=15 THEN LET PL=15
830 IF X>=16 AND X<=17 THEN LET PL=X
840 RETURN
### XV. APPENDIX E. COMPARISONS OF VALUES

#### Gas Tractor

<table>
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<tr>
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#### Diesel Tractor

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#### S.P combine

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# 35 ton End dump truck

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# 50 ton End dump truck

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# D9 dozer

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### CAT 666 Scraper

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### CAT 825 Compactor

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### 900 Portable Air Compressor

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### 6" Rotary Drill

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### 35 Ton Motor Crane

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### Industrial Forklift

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### Pickup Truck

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For the heavy equipment items: Diesel Generator, D8 dozer, and Forklift, the values in the table represent performance metrics such as fuel efficiency or output capacity. The values are given in increments of time or age, with the T and K values indicating some form of performance decrement over time. The Pickup Truck values are similarly formatted, possibly representing other types of performance metrics, such as fuel consumption or efficiency.