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EVALUATION AND IMPROVEMENT OF RURAL WATER SUPPLY IN WEST JAVA - INDONESIA

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Engineering.

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ABSTRACT

Optimal design period, investment cost and o/m cost model equation, and imputed water supply benefit are presented to evaluate and to improve rural water supply in West Java. Those critical evaluations are needed, since the Indonesian Government through Directorate of Cipta Karya under Department of Public Works has decided to render a new inception phase, according to the new selection and design/planning criteria, and since the money is one of the three major constraints. LAURIA (1972) discovered that for design periods which are less or greater than optimal design period, the present value cost increases. Considering 12%, 15% and 18% rate of interest, the optimal design periods in West Java are 13 years, 10 years, and 9 years respectively.

To get investment cost model which can improve the construction of rural water supply, the samples were selected utilizing existing successful constructions in West Java. The investment cost for water system without any treatment plant and distributed by gravity, covering transmission lengths up to 4,000 m and 4,000-9,000 m are around US$30,000 and US$50,000 for one lps respectively.

O/M cost models were established in a similar manner as in the development of investment cost model. Around 6-7 c/m^3 for one lps average capacity is needed to maintain and operate rural water supply in West Java.

The imputed water supply benefit method is the tool to evaluate timing of implementation of water supply projects or to make decisions regarding the timing of new projects in the absence of budget constraints by comparing the value of water that would be assigned by constructing now with the true value of water inferred from the imputed water supply benefit. In west Java, by using this tool, the implicitly assigned value cannot exceed 13.00 c/m^3 for implementation to be currently acceptable.

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GLOSSARY

1. INPRES: INPRES is the abbreviation of a President's decree. There are five INPRES Programs in Indonesia, schools, health centers, infrastructures, rural water supply & sanitation, and family planning. All those programs are financed by INPRES funds.

2. Kabupaten:

   Kabupaten is also called the second level of government headed by a bupati. There are 20 kabupatens in West Java Province. This administrative boundary is equivalent to district.

3. Kecamatan:

   Kecamatan is third level of government headed by a camat.

4. Desa (village unit):

   Desa or the lowest level of government headed by a lurah. There are 4,500 desas in all of West Java.

5. BAPPENAS:

   BAPPENAS is the abbreviation of The National Development Planning Board. BAPPENAS is responsible not only for plan formulation but also, under the present circumstances, for many of the functions of implementatio, particularly those connected with project aid.

6. BAPPEDA:

   BAPPEDA is the abbreviation of The Regional Development Planning Board (province level).

7. IKK: IKK is the abbreviation of The Capital City on Kecamatan Level. In the Netherlands-Indonesian bilateral development cooperation the IKK Crash Program consists of two programs, one in West Java and the other one in North Sumatra/Aceh.

I INTRODUCTION

1.1 General

Indonesia is dominantly rural and presents great diversity of rural culture and social systems, derived from a common Malayan and Malayo-Polynesian Substratum.

About 85% of the population live in rural areas, in approximately 56,000 villages in all of Indonesia (Excluding East Timor Province). Based on census 1980, the population of Indonesia is 147,490,000. The population growth rate during 1961-1971 is 2.10% and 2.32% during 1971-1980, and it is expected that by a more intensive family planning program which is currently being implemented in the country, the annual growth rate will be reduced.

As shown on Figure 1.1, Indonesia is an archipelago country which consists of around 13,670 islands.

The Indonesian Government is now running a national development program across the country with emphasis on rural areas. Progress in the economic growth of rural areas, as well as in the nation, will enable the investment of a greater amount of money for rural water supply projects. As village incomes increases and a better level of education is attained, the villagers will contribute a greater portion of the cost of installation of safe water systems or even finance such installations.

Learning from the past experience, the Indonesian Government is aware that the best way to control cholera and other water borne diseases is to provide safe water in adequate quantity. The Indonesian Rural Water Supply Program began on April 1, 1969, during The First Five-Year Development Plan, as a pilot project. At the end of The First Five-Year Development Plan, it had served 721,250 peoples or about 0.6% of total rural population.

On April 1, 1974, the beginning of The Second Five-Year Development Plan, The Indonesian Rural Water Supply Program was integrated with the INPRES Program in Rural Development.

Within three years (1974-1977), this program served about 5.7 million people or about 4.7% of the total Indonesian Rural Population. The target of the INPRES Program in rural water supply is to supply safe water to 10% of the total rural population with a water consumption rate of 60 lpcd using public taps as a distribution system, by the end of The Second Five-Year Development Plan, March 31, 1979. The administrative procedures for the Indonesian Rural Water Supply Project Proposal are reported in Appendix A.

1.2 Background

The Indonesian Government has decided to start the IKK Crash Program of water supply for about 3000 capital cities on Kecamatan Level in the next coming years, of which some 400 IKK's are being implemented in the fiscal year 1981/1982.

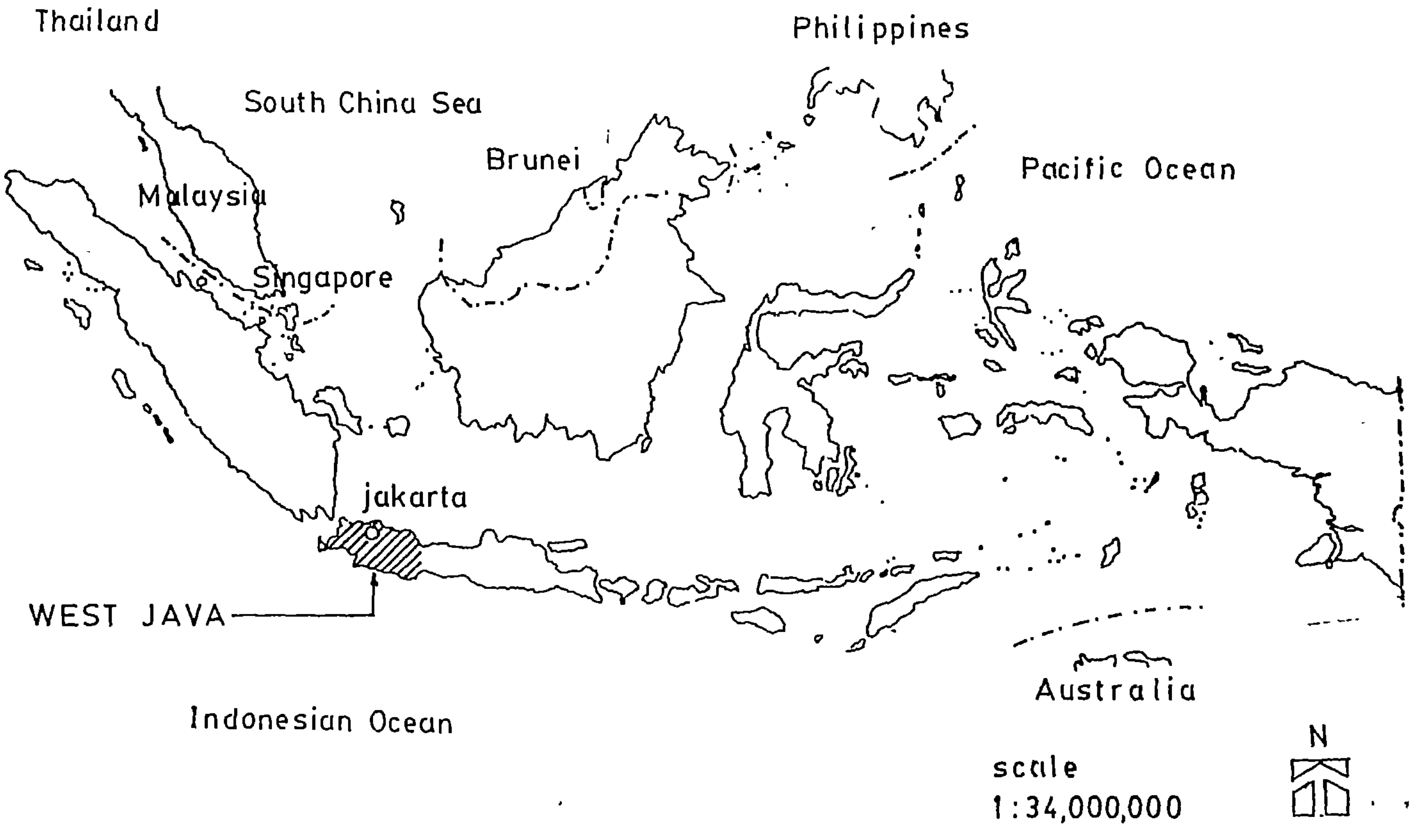


Fig.1.1 : A map of Republic of Indonesia denoting West Java Province

The Indonesian Government through Directorate of Cipta Karya under The Department of Public Works has decided to render a new inception phase, according to the new selection and design/planning criteria.

Those criteria for the IKK crash Program are shown in Table 1.1 and 1.2.

Table 1.1 - Standard Capacities for IKK Crash Program

No.	Population	Capacity (lps)	Unit Supply (lpcd)
1	3,000- 7,200	2.5	30-72
2	7,200-14,400	5	30-60

Table 1.2 - Maximum Construction Costs for The Water Supply System

No.	Supply System	US$ per Capita
1	Treatment Plants	40
2	Deep Wells	30
3	Springs	20

There are 27 provinces in Indonesia and West Java is one of them. At present time, the population of West Java is approximately 27,450,000, consisting of 87% who live in rural areas and 13% in urban areas. The annual growth rates during 1961-1971 and 1971-1980 were 2.09% and 2.66%, respectively.

Parallel with national level program, rural water supply is developed by Regional Government of West Java through INPRES Program. Table 1.3 indicates number of system and cost during 1974-1981.

There are three major constraints in executing the West Java Rural Water Supply Program, i.e. funds, time, and manpower. The scope of problem of this program is broad. It requires a considerable amount of money and a large number of competent personnel, appropriately organized for planning, design, execution, supervision, operation, maintenance and the development of the rural water supply systems.

On the other side, there is not much interest in construction of rural water supply projects by large and experienced contracting firms because the expected profit is not attractive to them and because some sub-projects are located in very remote areas, especially projects using spring protections with piped system, and they are quite difficult to reach. Therefore, only the small and unexperienced contructing firms are willing to work on rural water supply projects; consequently, the use of small contracting firms will require more qualified and experienced supervising teams, something which is very difficult to find at this time.

Table 1.3 - The Cost of Rural Water Supply Program in West Java during 1974-1981 by INPRES Program.

No.	Supply System	No. of System							
		74/75	75/76	76/77	77/78	78/79	79/80	80/81	
1	P.P.	21	20	24	20	20	20	20	195
2	S.A.	21	28	10	10	13	12	10	109
3	P.A.H.	30	50	90	90	90	38	30	268
4	P.M.A.	95	90	36	36	34	34	35	260
5	SPT.DK	2500	3777	3500	3980	3750	9500	9500	26007
6	SPT.DL	-	-	-	200	-	200	250	650
7	J.K.	26.000	49.000	25.000	25.000	24.000	18.000	18.000	135.200
Total Cost in Current Year (Rp.)		462.393.750	669.420.000	537.800.000	558.060.000	615.200.000	735.000.000	736.000.000	

P.P. : Spring captation with pipe distribution.

S.A. : Artesian well

P.A.H. : Rain Water Collector

P.M.A. : Spring Captation

SPT.DL. : Deep well with hand pump.

SPT.DK. : Shallow well with hand pump.

J.K. : Public bathroom.

From Table 1.3, it can be seen that as many as 145 spring captations with pipe distribution have been constructed since 1975 to 1981. Actually, some of the water systems were not well constructed/operated/maintained. Exposed pipes, for both transmission lines and main distribution are used in that areas. Sometimes these pipes are laid in the culvert or open channel road drainage system. Tapping are incorrectly conducted without any pipe accessory and unsuitable joint system. Also operation/maintenance (O/m) system are not well organized in some rural water supplies in which the water is distributed without any charge.

Almost all of the piped rural water supplies in West Java use spring as the water sources. These water sources should be within limit of The Water Supply Quality Standard issued by The Ministry of Health (see Appendix B).

At least, the water quality should not much be different from the criteria and is not dangerous to health, hence, no need to construct any treatment plant. On special cases, such as in the north-eastern part of West Java, where the safe water extremely difficult to get, the packaged treatments are built. However, only a few plants have been in operation since several months ago, in the form of pilot projects.

Topographically, the different altitude between spring and distribution area should be sufficiently high, since the water will be distributed by gravity. Only a few pumps have been installed to distribute this water, but not properly operated/maintained. In the distribution area, both house connections and standposts are not metered, so that the users are charged by flat rate system (open system).

At present, by the rule, the highest priority of the Indonesian Rural Water Supply as well as in West Java, is given to critical areas where water is extremely difficult to find and a high water borne disease incidence is present, although village contributions are expected.

In fact, the rural water supply is also developed if budget can be prepared by Kabupaten Government Level to develop spring captation plus pipe installation, and the water source based on quality and quantity are still in the limit value, with the transmission lines not more than 3.5 km. If the transmission line is more than that, the rest is under the responsibility of The Kabupaten Government Level.

In this case, because of the limitation of budget, design period is not strongly emphasized; the design capacity is to over-come existing population at current year, without considering population projection in the future.

1.3 Objective of Study

The cost systems become a critical issue, since the fund is one of the major constraints in West Java, The Government has also decided to render a new inception phase, following the new selection and design/planning criteria for IKK Program.

Since improvement and critical evaluation of the water systems are strongly needed, the objectives are expressed as follows:

1. to develop a water supply planning model for deciding optimal design period in rural West Java.
2. to develop a specific investment cost model of rural water supply in West Java.
3. to develop a specific o/m cost model of rural water supply in West Java.
4. to evaluate the implementation time of rural water supply in West Java utilizing imputed water supply benefit.
5. to make recommendation, wherever possible, to improve the present condition of water supply in rural West Java.

1.4 Scope of Study

This study is planned to develop an optimal model for fixing optimal design period while planning rural water supply facilities in West Java, taking into account the interest rate and economy of scale factor.

The models are designed for one type of rural water supply system, that is, spring as a water source which is distributed by gravity without any treatment or pump, by using selected data which are based on the successful construction and o/m system, from existing rural water supplies located at different villages of West Java.

Investment and o/m cost, as a function of daily average flow of the selected systems are determined for West Java rural area to facilitate planning and o/m of rural water works.

In the absence of budget constraints, it is possible to use the imputed values of publicly supplied water to make decisions regarding the timing of new projects. According to this method, a 40 successful constructions and well o/m systems of rural water supplies in West Java have been selected for evaluating implementation time.

All of those selected data are collected from rural water supplies in West Java, where springs are available. Hence, according to those data, the model equation cannot be applied for north-eastern part of West Java, since spring is extremely difficult to find.

II LITERATURE REVIEW

2.1 Optimal Design Period

MANNE (1967) has developed no backlog model for timing and scale of investment. The no backlog model is for the planning of a single isolated project. This implies that when the model is used for water supply in developing countries, selection has already been made of the town that is to receive a new system or expansion as shown in Fig. 2.1.

The mathematical model for determining the optimal expansion or construction scale and the cost of the system can be developed as follows:

$$C = K\ (XD)^{a} \qquad (2.1)$$

where X is the design period in years, D is the rate of demand increase in mgd per year, and XD is the scale of each expansion or construction.

The planning problem is to find the optimal design period X^{*} that minimize cost. The present value cost of n expansion denoted by M is equal to:

$$M = K\ (XD)^{a} + e^{-rX}K(XD)^{a} + e^{-2rX}K(XD)^{a} + \ldots .\ e^{-r(n-i)X}K(XD)^{a} \quad \text{or}$$

$$M = K(XD)^{a}\left[1 + (e^{-rX}) + (e^{-rX}) + \ldots . + (e^{-rX})^{n-1}\right] \qquad (2.2)$$

where r is the interest rate and discontinuing is obtained using the factor e^{-rX} which is equivalent to the conventional discount operator $\frac{1}{(1+r)}$ X.

By setting $\frac{dM}{dX} = 0$ the total present value cost can be minimized.

Then,

$$a = \frac{rX^{*}}{(e^{rX^{*}} - 1)} \quad \text{or} \quad X^{*} = \frac{2.6(1 - a)^{1.12}}{r} \qquad (2.3)$$

LAURIA (1971) discovered that the discount rate in developing countries lies in the range of 5 to 15%, and the economy of scale factor is between 0.6 and 0.8. Hence, the optimal design periods by no back logs model lies between 2.9 to 19.0 years. Figure 2.2 shows the relationship between optimal design period and economy of scale by different discount rate.

2.2 Unit and Total Cost Functions for Water Supply System

HINOMOTO (1971) assumed that the possible range of capacity for practical purposes is limited to the economies of scale, and that in general this relationship between capacity and investment cost or daily cost of any factor of water treatment at capacity is given by the following function proposed by Chenery (1952):

$$C = \alpha\ K^{\beta} \qquad (2.4)$$

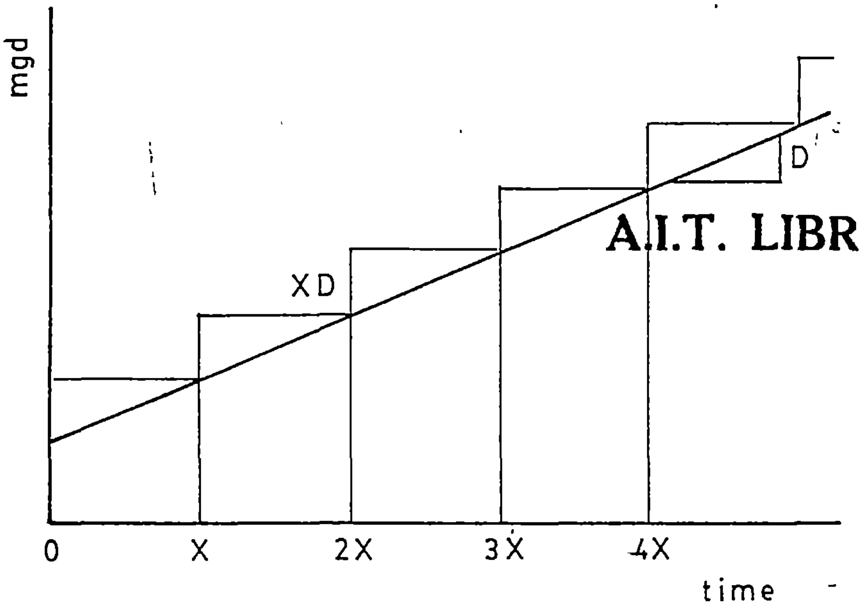


Fig.2.1 : Capacity & demand vs time
(no - backlogs model)

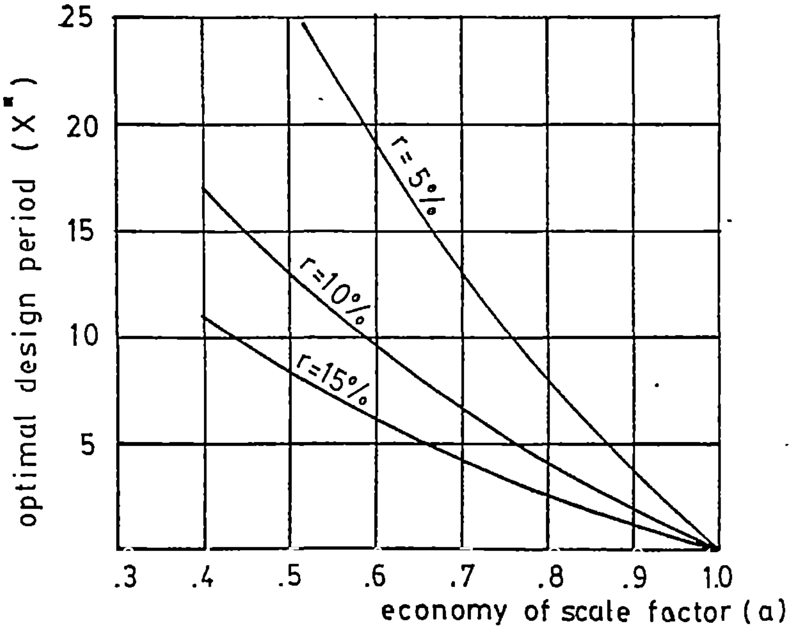


Fig. 2.2 : Optimal design periods
(no- backlogs model)

where C is the investment cost or daily factor cost, K is design capacity, α and β are the parameters.

When both sides of Eq. (2-4) are divided, the following function for the unit cost at capacity is given:

$$\frac{C}{K} = \alpha K^{\beta-1} \tag{2.5}$$

The logarithmic transformation of Eq. (2-5) gives:

$$\text{Log}\,\frac{C}{K} = \log \alpha + (\beta - 1)\log K \tag{2.6}$$

Eq. (2.6) is identical in form with the following regression line and will determine parameters α and β in Eq. (2.4) as follows:

$$\begin{aligned} \alpha &= \log^{-1} A \\ \beta &= B + 1 \end{aligned} \tag{2.7}$$

LAURIA (1972) observed that water systems reflect economies of scale and have a cost function of the form:

$$C(Z) = k\,(Z)^{a} \tag{2.8}$$

where Z is the scale variable with typical units in mgd, a is the economy of scale factor with values between 0 and 1, and k is the cost of one mgd system.

Eq. (2.8) can be linearized by taking the logarithm of each sides:

$$\log C(Z) = \log k + a \log (Z) \tag{2.9}$$

In this form, the parameters of the function, can be readily determined by least squares analysis given values for log C(Z) and log(Z).

a. <u>Development of Investment Cost Model</u>

ORLOB & LINDORF (1958) summarized the total investment cost of complete water treatment in California by a model equation. With the use of information from the various plants for which reliable data were available, Figure 2.3 was prepared. Although there is no theoretical basis for selection of the log-log form of the plot, it is apparent that a convenient fit of the data is obtained by a straight line whose equation in the Cartesian system is:

$$C_c = 257\,Q_n^{0.67} \tag{2.10}$$

where C_c is the total investment cost of complete water treatment facility in thousand of dollars, and Q_n is the design capacity of plant in mgd.

LAURIA (1972) collected the data from 65 water systems in Central America for the least square analysis. The systems were constructed between 1965 and 1969 are of the gravity type without filtration, and were designed for towns with population of 7,500 or less.

The least square analysis resulted in the following formation:

$$C(Z) = 300{,}000\ (Z)^{0.83} \tag{2.11}$$

where C(Z) is the investment cost in dollars, and Z is the scale variable with typical units in mgd. The data, however, from which (2.11) was developed did not adquately reflect planning and administration costs connected with project implementation. Had these costs been included, it is probable that economy of scale factor would be less than 0.83.

CLARK (1980) continued ORLOB & LINDORF (1958) experiments. If both sides of Eq. (2.10) are divided by Q_n, yields:

$$\frac{C_c}{Q_n} = 257\ Q_n^{-0.33} \tag{2.12}$$

The term C_c/Q_n is the unit cost of capacity, and the exponent of Q_n is negative. According to Eq. (2.12), unit cost therefore decreases with increasing Q_n of capacity, illustrating "economy of scale". Figure 2.4 is a plot of Eq. (2.12), and the tangents l_1, l_2, and l_3 illustrate the difference in slope of various curve segments. The slope of Eq. (2.12) is given by its first differential with respect to Q_n as follows:

$$\frac{\partial\left(\frac{C_c}{Q_n}\right)}{\partial\, Q_n} = -84.8\ Q_n^{-1.33} \tag{2.13}$$

As can be seen from Figure 2.4 significant differences exist in the slopes of various curve segments. One possible definition for small system is one with a high unit cost or, equivalently, one with a capacity that puts it within the segment of the cost curve having the maximum slope. Similarly, Figure 2.5 also depicts this relationship by separating distribution cost from the total cost.

b. Development of Operation and Maintenance Cost Model

ORLOB & LINDORF (1958) obtained the operating costs of existing facilities in California. These data are presented in Figure 2.6 where the line of best fit has the equation:

$$C_o = 68.4\ Q_a^{-0.41} \tag{2.14}$$

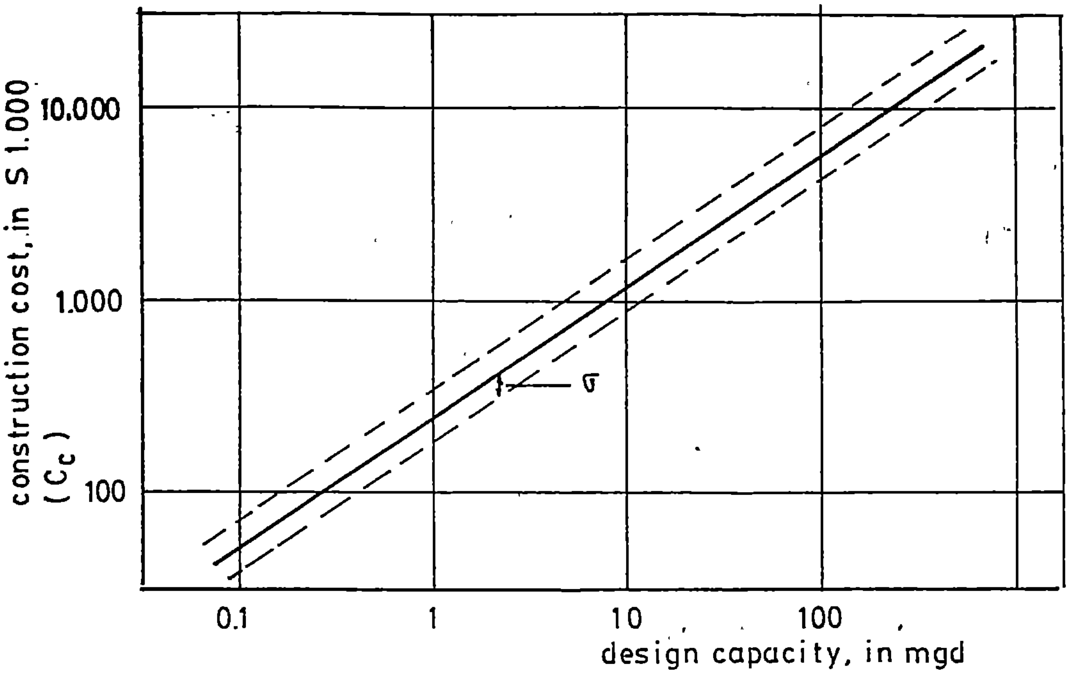


Fig.2.3 : Construction cost of treatment plants

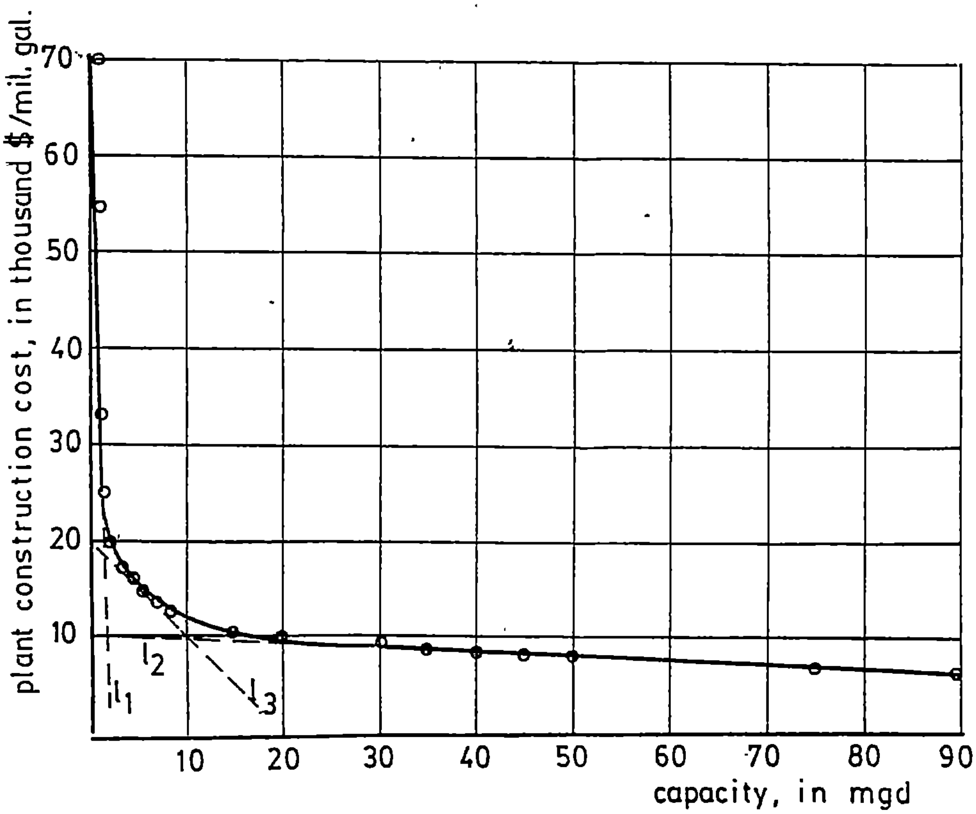


Fig.2.4 : Unit cost curve for water treatment technology

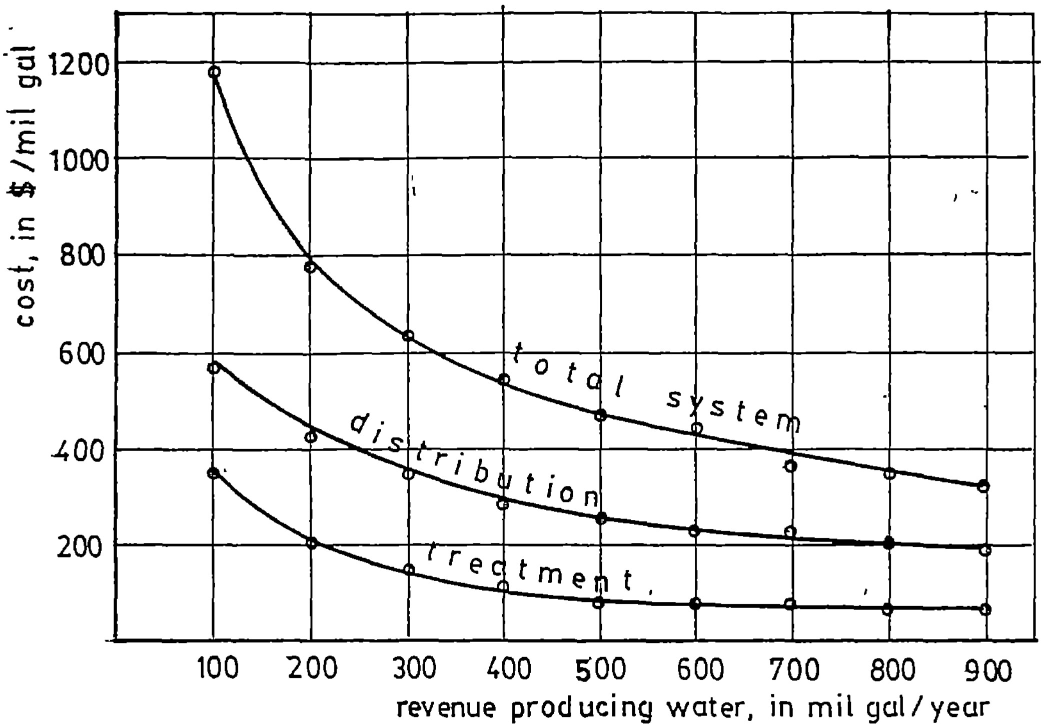


Fig.2.5 : Unit costs for total system

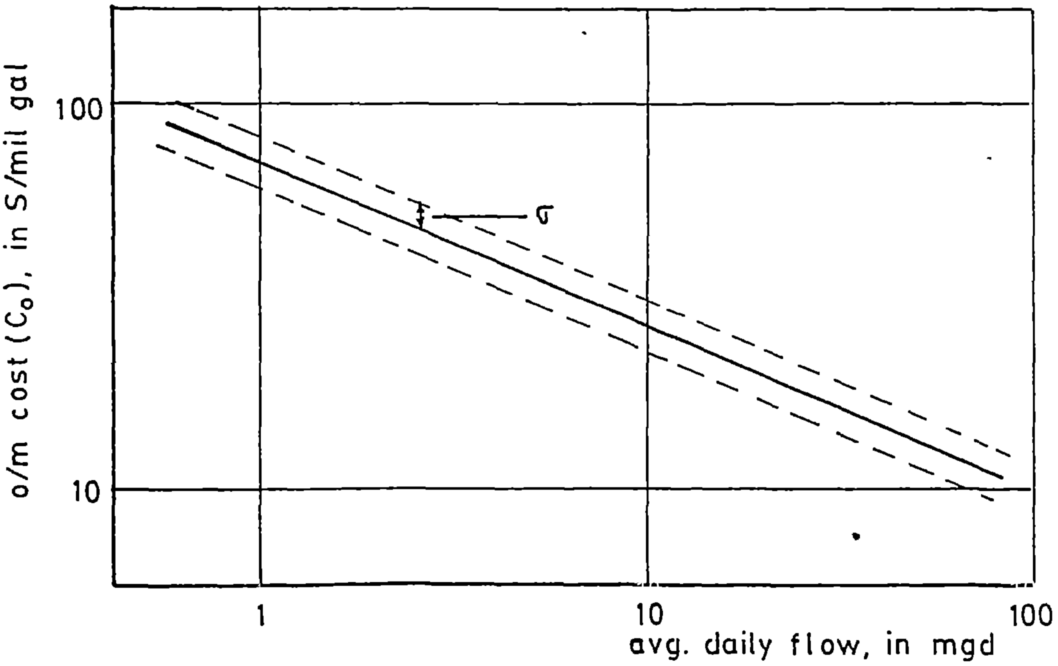


Fig.2.6 : Operation & maintenance costs

where C_o is the cost of operation and maintenance, and Q_a is the average daily flow in mgd.

CLARK & MORAND (1981) introduced the operation and maintenance models for various type of treatment plants, that is, conventional treatment (flocculation, sedimentation, filtration), direct filtration (sedimentation step removed), and package plants, in Kentucky, West Virginia, and Tennessee.

$$\text{Package plant} \quad : C_o = 16{,}300\ Q_o^{0.6} \tag{2.15a}$$

$$\text{Direct filtration} : C_o = 21{,}960\ Q_o^{0.8} \tag{2.15b}$$

$$\text{Conventional} \quad : C_o = 24{,}600\ Q_o^{0.8} \tag{2.15c}$$

where C_o is annual O/m in dollars per year, and Q_o is average flow in mgd. The majority of package plants consisted of flocculator, fewer others were tube settler, and one was a mixed media filter.

2.3 Imputed Water Supply Benefit

MANNE (1967) derived the mathematical expression for minimizing total present value cost, by assuming the cost functi-n Eq. (2.1) holds good for capacity expansion as well.

The total p.v. cost = p.v. backlog cost + p.v. expansion cost (2.16)

He considered only the first construction cycle and therefore at any time, t, in the backlog period $0 < t < y$. The present value cost of backlogging demand accure at the rate of:

$$p\ D\ t\ e^{-rt}$$

and the total present value cost (M) defined by Eq. (2.16) is:

$$M = \int_{t=0}^{y} p\ D\ t\ e^{-rt} + K\ (XD)^{a}\ e^{-ry}$$

or

$$M = \frac{pD}{r^2}\left[1 - e^{-ry}\ (1+ry) + e^{-ry}\ K\ (XD)^{a}\right] \tag{2.17}$$

where r is the rate of interest.

The optimal time of capacity expansion Y^* which minimized total present value cost, he found by solving $\frac{\partial M}{\partial y} = 0$, of Eq. (2.17).

The optimality result is:

$$Y^* = \frac{r\ K\ (XD)^{a}}{pD} \tag{2.18}$$

MANNE determined the optimal scale by developing expression for total present value cost over first two or more construction cycle and solving $\frac{\partial M}{\partial X} = 0$. The expression that he got for the optimality result was:

$$a = \frac{X^*/(e^{rX^*} - 1)}{Y^*/(e^{rX^*} - 1)} \tag{2.19}$$

LAURIA (1972) rearranged the Eq. (2.18) to other forms that are more useful to the planning policy for developing countries. The expression of Y^* is:

$$Y^* = \left(\frac{K\ D^a}{p\ D}\right) r\ X^a \tag{2.20}$$

or

$$p = \frac{r(K\ (XD)^a)}{D\ Y^*} \tag{2.21}$$

where the term in the bracket, Eq. (2.21), is the cost of expansion or the cost of construction if the system does not exist before and the numerator is the annual interest rate on investment in \$/year. The denominator is the unserved rate of demand at the time of construction in thousands gall/year and hence can be represented by the product of community population (w) at construction time and the percapita demand of water (q), for rural areas not previously served by water systems.

Therefore the expression for imputed water supply benefit (p) is:

$$p = \frac{r(K(XD)^a)}{wq} \tag{2.22}$$

and has the dimension of \$/thousands gall or ¢/thousands gall depend on the dimension of K.

The planning problem is to determine whether this price exceeds the true value of water or not. The true value of is that critical p value (p_c) which is the mean of population of p-s, where s is the standard deviation. If the calculated p value of the project is less than or equal to the population mean of p-s, the project should be implemented or otherwise it should not be constructed. Assuming that the sample follows t-distribution, the critical p value or the population mean of p-s with 95% confidence can be calculated by the statistical formula:

$$t = \frac{(\bar{p} - p_c)\ \sqrt{n}}{s} \tag{2.23}$$

where t is the value directly obtainable from t-distribution table with 95% confidence and (n-1) degree of freedom, p is the mean of sample of p-s, p_c is the critical p value, s is the standard deviation of the sample of p-s, and n is the number of samples.

RESULTS AND DISCUSSION

3.1 Economy of Scale Factor

Data were collected from 40 selected water systems in West Java to determine economy of scale factor using least square analysis. The systems which were constructed between 1975 and 1981, are of the gravity type without any treatment plant; they include piped house services and standposts and were designed for villages with populations of 8350 or less. Geographically, the distribution of collected samples is shown in Figure 3.1.

The economy of scale factor is obtained by calculation is 0.4 with confidence level of more than 95% for up to 4000 m as well as for 4000-9000 m transmission length (see Table 3.1). However, this factor reflects economy of scale for rural water supplies in West Java.

ADHIKARI (1977) discover that the economy of scale factor in Thailand varies between 0.43 to 0.66 and LAURIA (1972) introduced a value of 0.83 for Central America.

According to Lauria's statement, the concavity of the function is due to "a", the economy of scale factor, which is between 0 and 1. When "a" is equal to 1, costs vary linearly with scale and economies are absent; large economies on the other hand are associated with small values of "a".

Hence, the economy of scale factor for West Java is sigthly larger economies than that of Thailand or Central America.

The most obvious weakness of the statistical analysis is that it is based on a relatively limited data. Therefore, additional data from other successful water systems are needed to improve the confidence level of the economy of scale value.

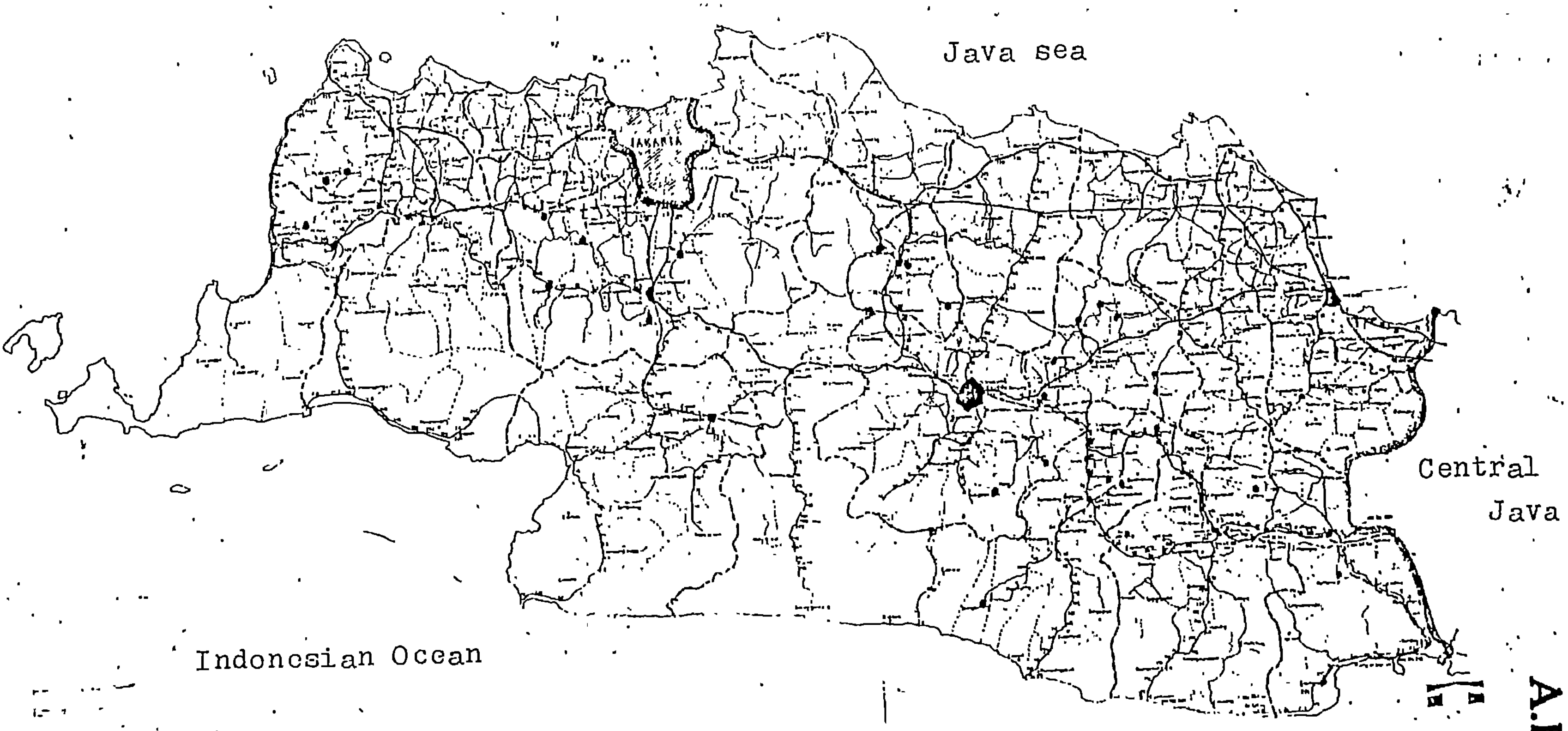
3.2 Optimal Design Period

MANNE's models show that the economy of scale factor of the expansion cost function plays a major role in determining the optimal design period. Figures 3.2, 3.3 and 3.4 depict the optimal design period in West Java.

During the last 10 years, the rate of interest in Indonesia varies between 12% up to 18% per year with an average of 15%. By use of Eq. (2.4), it can be calculated that the optimal design period lies between 9 to 13 years.

From Figures 3.2 and 3.3 it can be seen that the design period decreases when the rate of interest increases which shows that excess capacity should not be designed ahead of time.

Considering 12%, 15% and 18% rate of interest, the optimal design periods are 13 years, 10 years and 9 years, respectively. Figure 3.4 depicts the same logic and it can be seen that the optimal design period



Legends:

------ Kabupaten Adm. boundary

-- Kecamatan Adm. boundary

• Village where the data was collected.

Scale 1:3,200,000

Figure 3.1. Distribution of collected samples.

Table 3.1 - Investment Cost Model Equation

No.	Model Equation	Confidence Level	(n-2) d.f.	Student-t Val.		Transmission
				Cal.	Table	Length (m)
1	$C_c = 1.90\ W^{0.90}$	99.5 %	38	2.778	2.713	4000-9000
2	$C_c = 1.50\ W^{0.90}$	95.0 %	25	6.806	1.708	up to 4000
3	$C_c = 29.63\ Q^{0.90}$	99.5 %	38	5.919	2.713	4000-9000
4	$C_c = 24.60\ Q^{0.90}$	99.5 %	25	19.295	2.727	up to 4000

decreases when rate of interest increases. This figure also shows the relationship between the present value cost of a water supply system is minimum only when the design period is optimal. For design periods which are less or greater than optimal design period, the present value cost increases. The flatness of the curve suggests that slightly erroneous policies are not to serious, although the actual dollar amounts may be substantial.

In West Java, design capacity is based on the existing total amount of population at the year of construction.

By erronously using this design policy, the normalized present value costs are 8.8, 7.2, and 6.1 for rate of interest 12%, 15% and 18%, respectively, resulting in excess present value costs of 150%, 125%, and 100%, since the normalized present value costs for optimal design periods are 3.5, 3.2 and 3.0, for the same sequence of rate of interest. More generally, the consequence of underdesign can be seen in Figure 3.4 which is a graph of the above cost function.

The capacity of water supply facilities must always be equal to or exceeds demand. The capacity curve must therefore lie on or above the demand curve. Because demand and supply are presently in balance, now it is the right time for the next expansion while the next expansion will be required when demand has again grown to be equal to supply.

With constantly increasing demand, an infinite time horizon, and unchanging costs and discount rate, the future is identical from each point where supply and demand are in balance. Hence, the expansion scale that is optimal at the present point of balance is optimal at every such point.

The small "a" value obtained from this analysis implies that economies of scale associated with water supply systems are rather substantial. Referring to Figure 3.2, the period of excess capacity (x^*) for a discount rate of 15% should apparently be around 10 years. This is considerably longer than the present design policy currently in use; however, before recommending that the design periods in West Java be drastically increased, it is necessary to examine the basis on which the economy of scale factor was estimated.

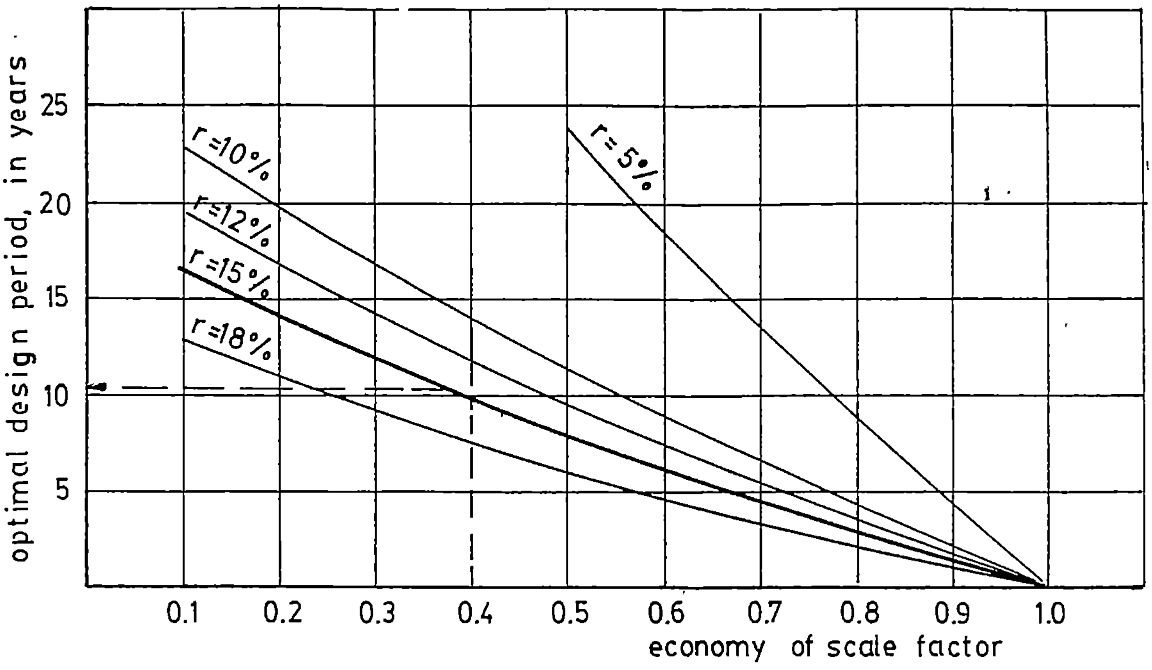


Fig.3.2 : Optimal design period vs economy of scale factor

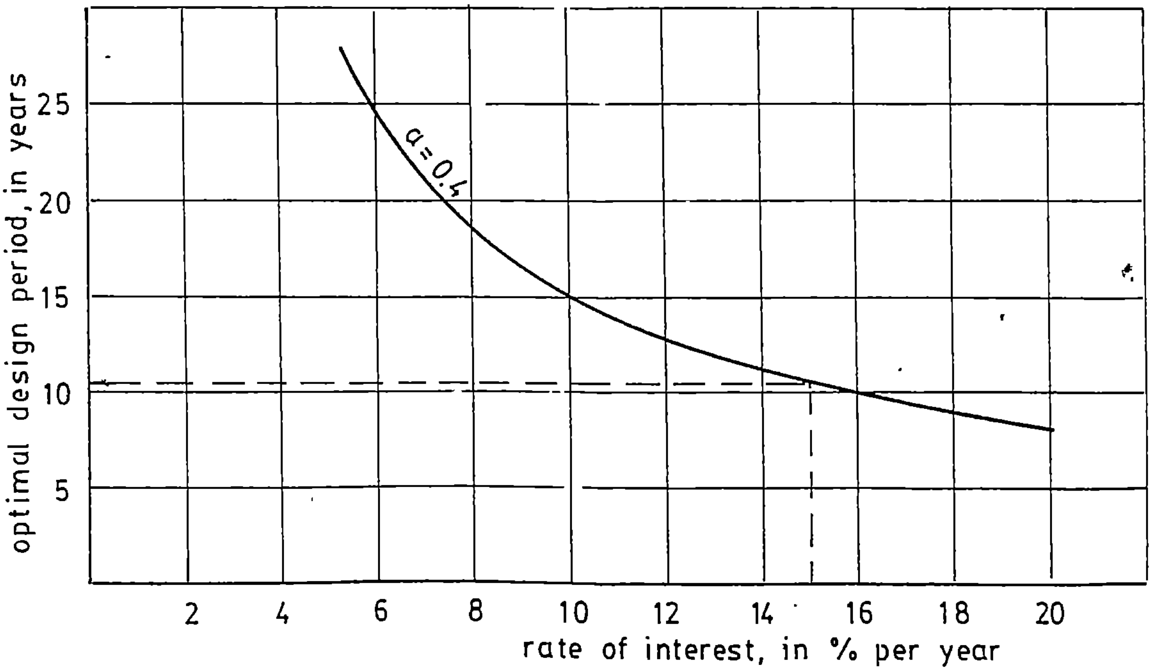


Fig.3.3 : Optimal design period vs rate of interest

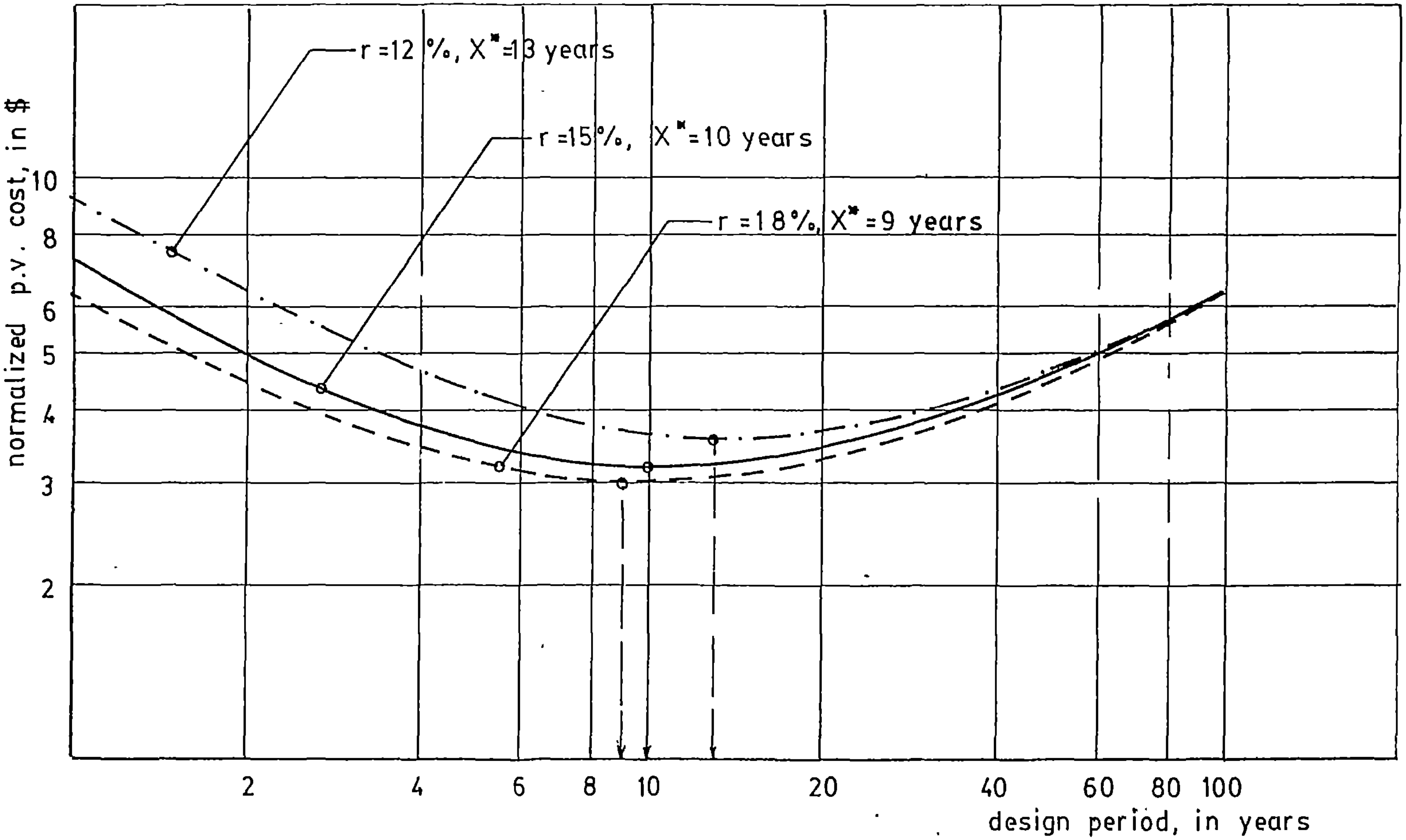


Fig 3.4 : Present value cost vs design period

3.3 Investment Cost Model Equation

To obtain improved investment cost model, 40 samples were selected from 75 visited rural water supplies in West Java.

At present, around 150 piped rural water supplies have been developed to cover 600,000 people who live in West Java rural area, or around 3% of the total villagers. At least as many as 45 water systems were built by relatively good construction at various lengths of transmission line. Springs are used as water sources, which are qualitatively under limit of Indonesian Water Supply Standard, for all of those selected systems. There are no treatment plant and pump installed for those systems.

To develop investment cost model, the samples are analyzed by different lengths of transmission line. These differences create different model equations as shown in Table 3.1, where C_c is investment cost in thousand dollars, W is designed population and Q is designed capacity in lps. The logarithmic transformation from all of those variables gave the best fit since the confidence level is above 95%.

Log-log plot of the investment cost model for the two types of length of the transmission lines are shown in Figure 3.5 through 3.10, while Figure 3.11 depicts their relationshipon linear graph.

The points shown on the graph corespond to the cost data obtained from the existing successful water systems.

All mathematical expressions shown in the Table 3.1 are calculated from the existing water systems in West Java for both types of model which are based on design population (W) and design capacity (Q).

When the water demand is generalized as much as 57 lpcd (existing average demand, unmetered), the design population for a one lps system is about 1,515. The corresponding costs of this scale system calculated by the above equations are approximately US$35,560, and US$28,070 for the transmission line length of 4,000-9,000 m and 500-4,000 m, respectively. Hence, the cost equations in its original form are:

$$C_c = 35.56\ Q^{0.40}, \text{ for transmission length } 4{,}000\text{-}9{,}000 \text{ m}$$

$$C_c = 28.07\ Q^{0.40}, \text{ for transmission length } 500\text{-}4{,}000 \text{ m}$$

where design scale (Q) is in lps.

By the same logical procedure, the model equation can be developed for various water demand percapita.

In West Java, Hygiene and Sanitation Officer should approach Bupati for his support in construction cost (see Appendix A, 9th Step). Those models enable to guide in estimating budget for a new system, including spring captation, transmission pipes, distribution systems, administration and engineering cost.

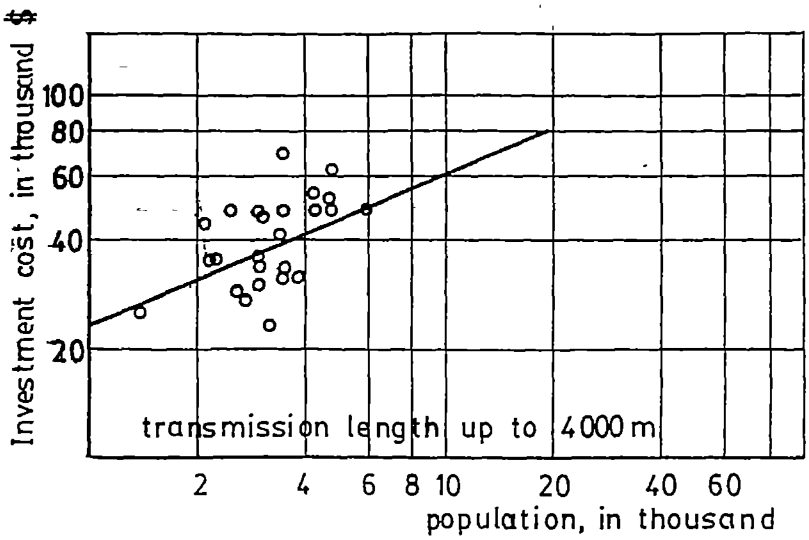


Fig. 3.5 : Investment cost vs design population

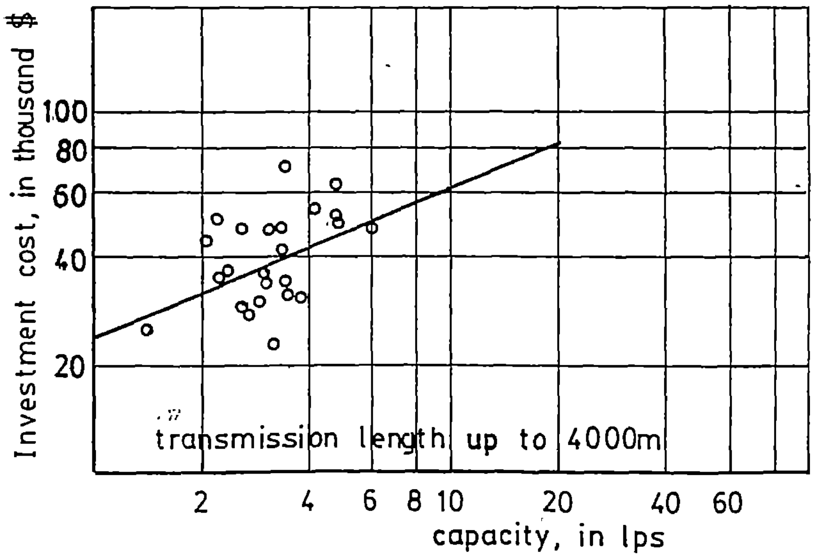


Fig. 3.6 : Investment cost vs design capacity

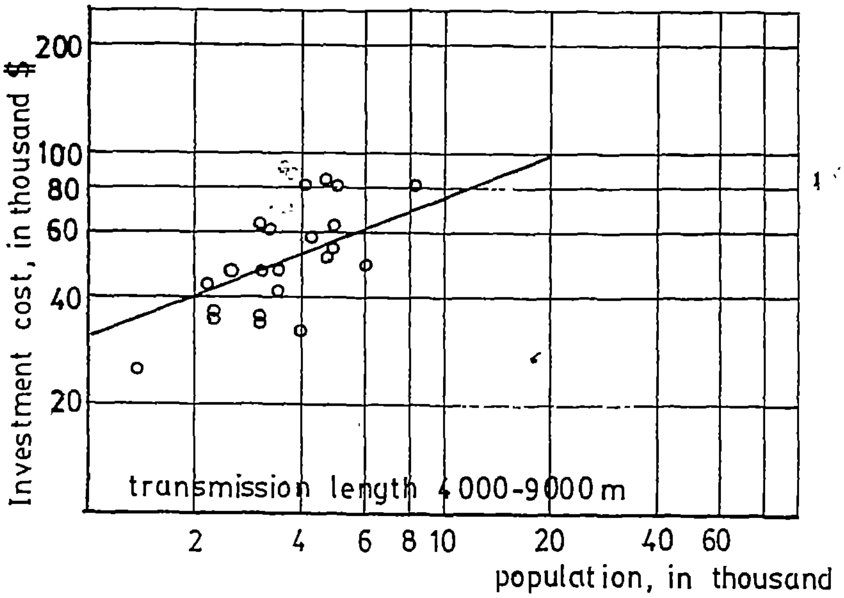


Fig. 3.7 : Investment cost vs design population

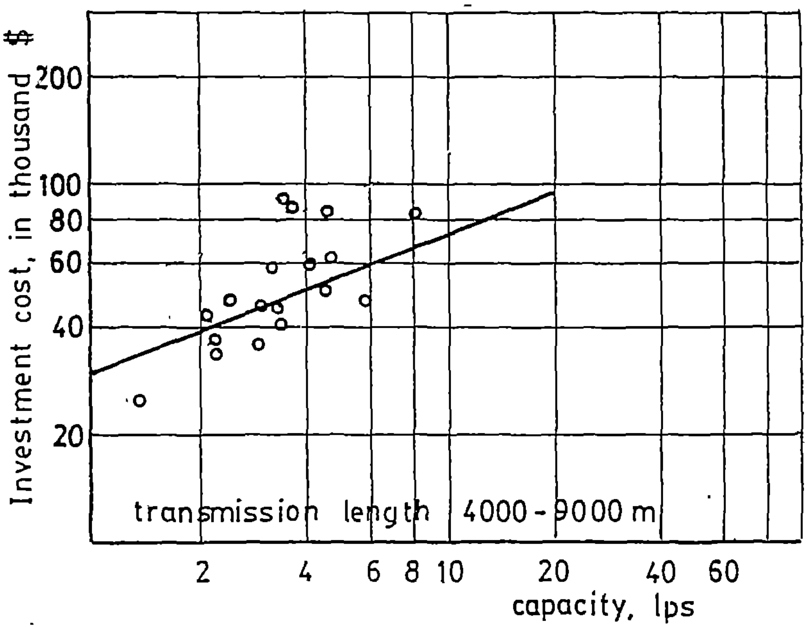


Fig. 3.8 : Investment cost vs design capacity

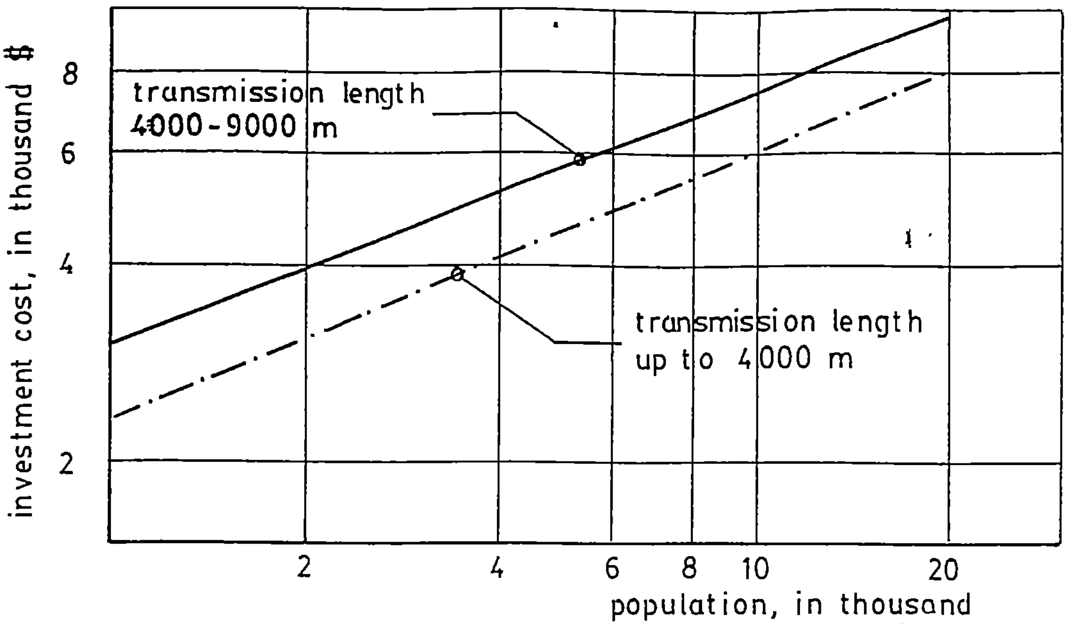


Fig. 3.9 : Investment cost vs design population

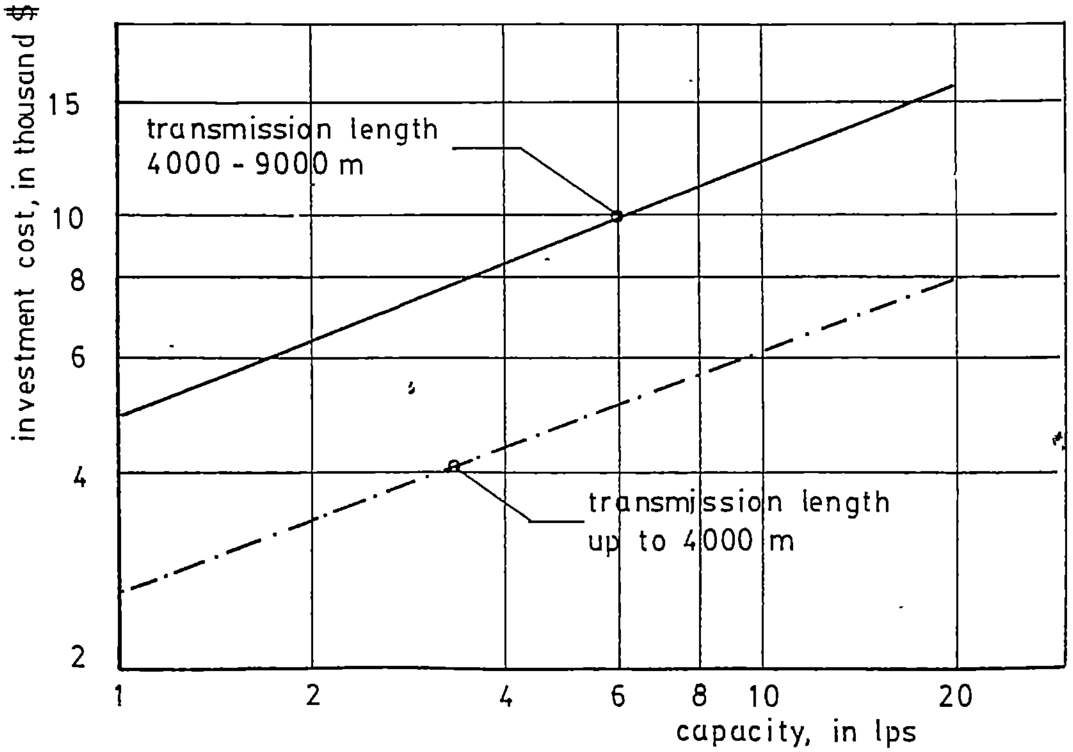


Fig. 3.10 : Investment cost vs design capacity

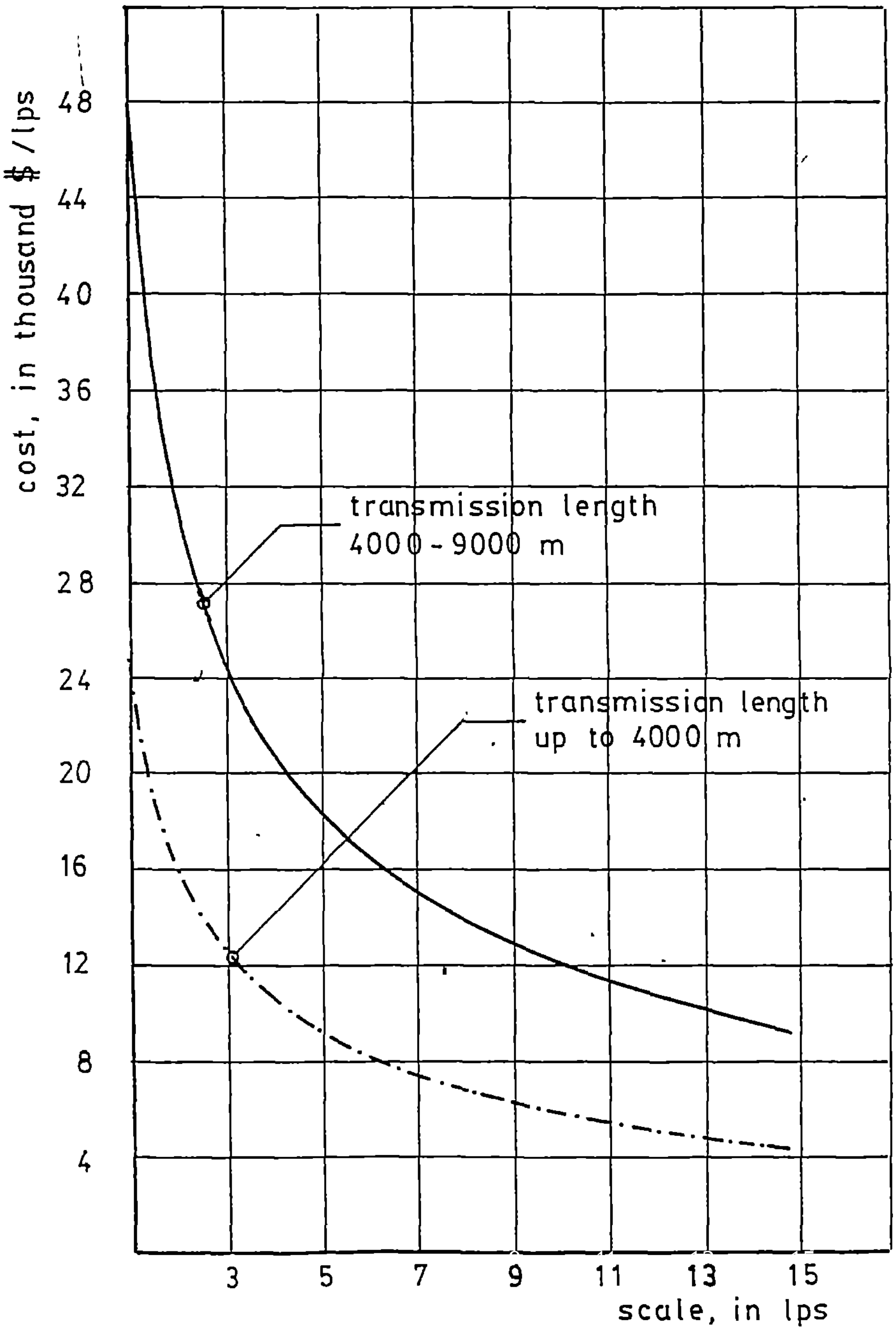


Fig. 3.11 : Unit cost vs scale

By knowing design capacity as well as design population, the answer can immediately be estimated, both through model equation or graph. For example, suppose a village of 7,000 inhibitants will be supplied by a new system with unit demand as much as 40 lpcd and tramsmission pipe length 3,500 m. Utilizing Eq. 4 in Table 3.1, the cost of the system is around US$43,100. Similar result can be found by using graph in Figure 3.10.

3.4 Operation/Maintenance Cost Model Equation

Operation and maintenance cost models for four different types of analysis were established in a similar manner as in the development of investment cost model by running regression analysis of the 45 successful selected samples which are shown in Appendix C, to improve o/m system in West Java.

The o/m systems of those samples are relatively good. For those results, they spent US$100 to US$700 monthly per water system. Galvanized iron pipe, which is produced in Indonesia, is used both for transmission lines and main distribution. For all of these water systems, taps (stand post valves), which are damaged very often, are regularly replaced, and leakage pipes are repaired immediately. Around 2-3 persons are working in every water system for regular activities, such as administration and technical job.

Since house connections and public stand posts are not equipped with water meter, the water consumption is rather high if compared to metered system; it is between 29 lpcd up to 79 lpcd with an average of 57 lpcd. Thailand villagers need 30.7 to 134.6 lpcd for their water supply utilizing unmetered system (SHOUVANAVIRAKUL, 1970).

Based on these successful o/m systems, the model equations are developed. The results obtained by utilizing different type of statistical analysis and different transmission line length are tabulated in Table 3.2. In this case C_{om} is o/m cost in US$/m^3 and Q is capacity in m^3/day.

Table 3.2 - O/M Cost Model Equation

No.	Model Equation	Confidence Level	(n-2) d.f	Student-t Value		Transmission Length (m)
				Cal.	Table	
1	$C_{om} = 0.66\ Q^{-0.54}$	95 %	43	1.7483	±1.677	4,000-9,000 based on log
2	$C_{om} = 0.76\ Q^{-0.55}$	99.5 %	43	-41.029	±2.697	4,000-9,000 based on ln.
3	$C_{om} = 0.99\ Q^{-0.61}$	99.5 %	24	- 6.79	±2.797	up to 4,000 based on ln.

Figure 3.12 through 3.15 show the relationship between the o/m cost and capacity which are drawn by using those model equations. Figure 3.12 and 3.13 show those relationship by logarithmic scale and Figure 3.14 and 3.15 by linear graph.

Figure 3.13 and 3.15 show the cross section lines between transmission lines up to 4,000 m and 400-9,000 m on ±175 m^3/day. This in dicates that for capacities higher than that, the o/m cost transmission lines 4,000-9,000 m is more expensive, since it consists of more river/stream crossing and bigger pipe sizes. For a capacity of less than 175 m^3/day, statistically, the o/m cost of transmission lines of less than 4,000 m cheaper. In this case, the effect of the complexity of distribution system, which is not expressed in the graph, is appreciable.

Figure 3.12 shows log-log plot, which is based on ten, of the o/m cost and capacity. Eventhough the confidence levels are quite different, but the model equations are very close to the model which based on e (2.71828). From statistical point of view, the model which is based on e is better.

Some of the visited rural water systems, such as Campaka Mekar, Sindang Sari and Tenjonagara Water Supplies, are not properly maintained/operated. The problems are due to volunteer workers/operators who are not assigned on and water is distributed without regular charge. By using volunteers, the responsibility of workers/operators are not fully understood. Also technical problems (pipe leakage and other damage) are slowly solved because of unavailability of budget. They have to collect the money from house connection customers on damage by damage basis. O/m model equation enables to help solved their problems which are dependent on the complexity of distribution system as well as on the number of the population served. Suppose the number of the population served on Campaka Mekar Water System is 5,000 and 50 lpcd as unit demand. Since the transmission pipe length lies between 4,000-9,000 m, hence Eq. 2 from Table 3.2 can be used to estimate o/m cost. As much as 0.035 $/m or US$262.5 monthly is needed to operate/maintain the water system, or around 5.25 ¢/capita/month (26.25 ¢/family/month). Similar result can be found utilizing Figure 3.13. This cost includes the salaries of two workers (one is administrative job and other one is technical operator).

3.5 Imputed Water Supply Benefits

Whenever a decision is made to construct a new water system or an extension, a certain value is implicitly assigned to publicly supplied water in the community.

In West Java, a decision was made in the past to construct a water system, the planner felt it was correctly sized and timed. In this case, both the design scale of the system and size of the village to be served are assumed to be optimal. Using these assumptions, the implicitly assigned value of water can be imputed (estimated) by Eq. (2-21).

For communities which have not been previously served by water systems, the nominator, Dy, can be replaced by the product of village population at construction time (w), and the percapita demand for water (q). Hence, Eq. (2.22) can be used to evaluate water supplies in West Java. The data in

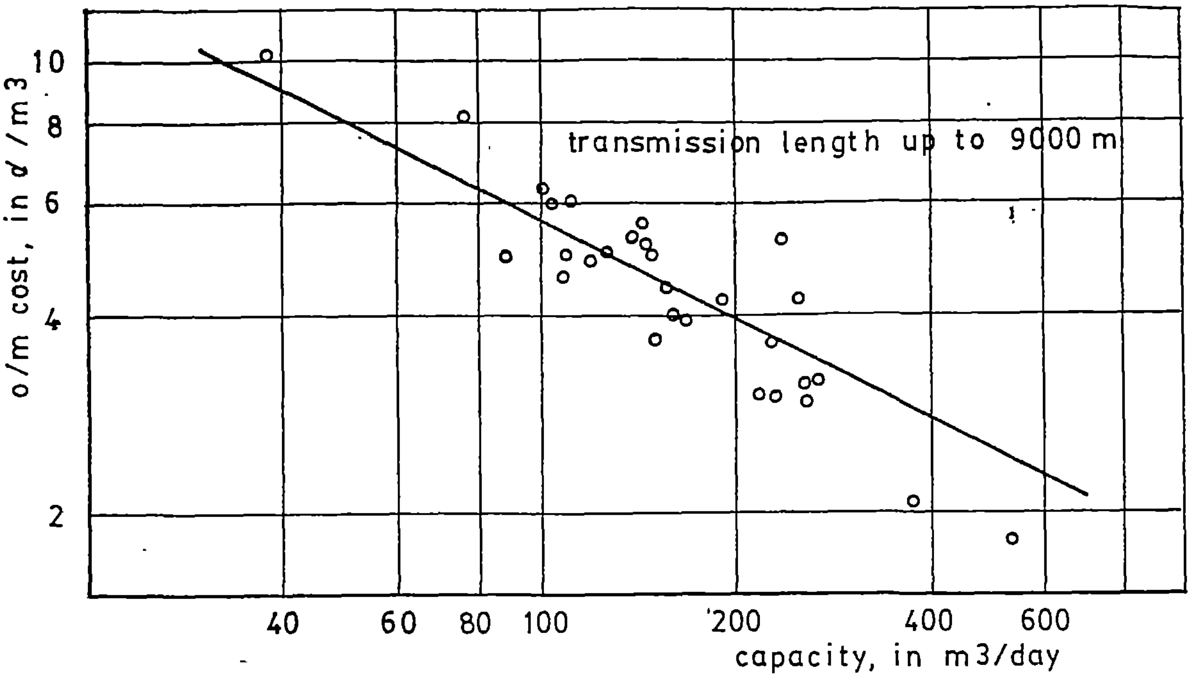


Fig. 3.12 : O/m cost vs capacity, based on log

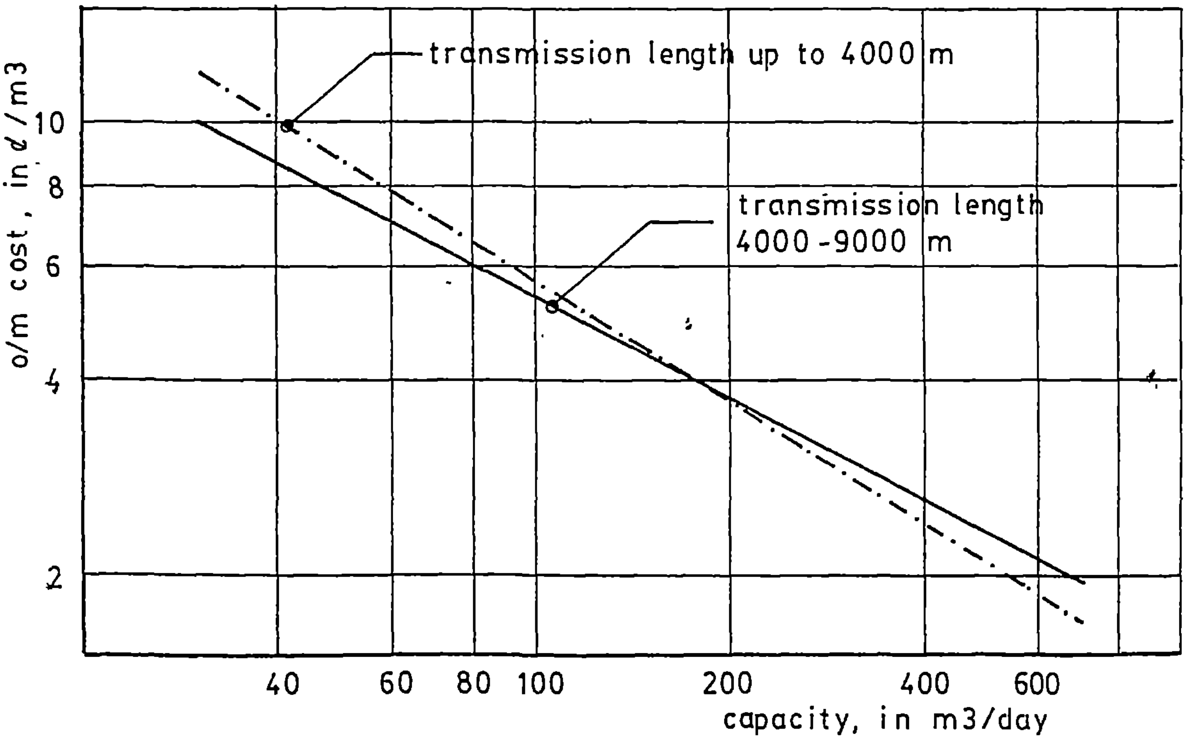


Fig. 3.13 ; O/m cost vs capacity, based on ln

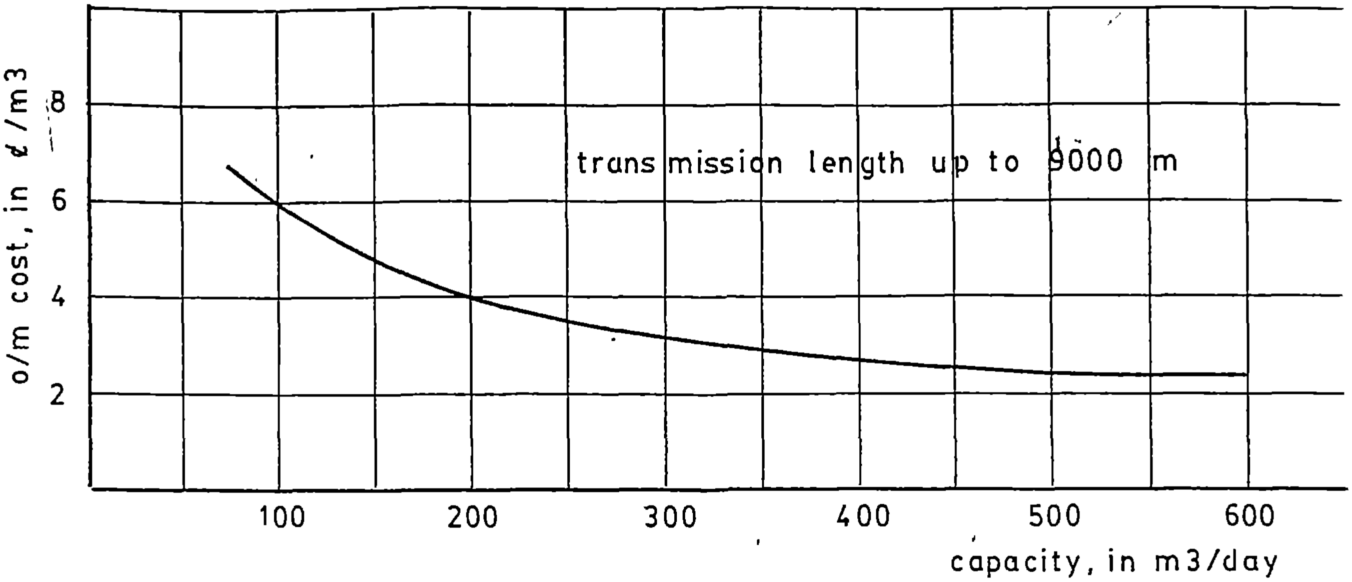


Fig. 3.14 : O/m cost vs capacity, based on log

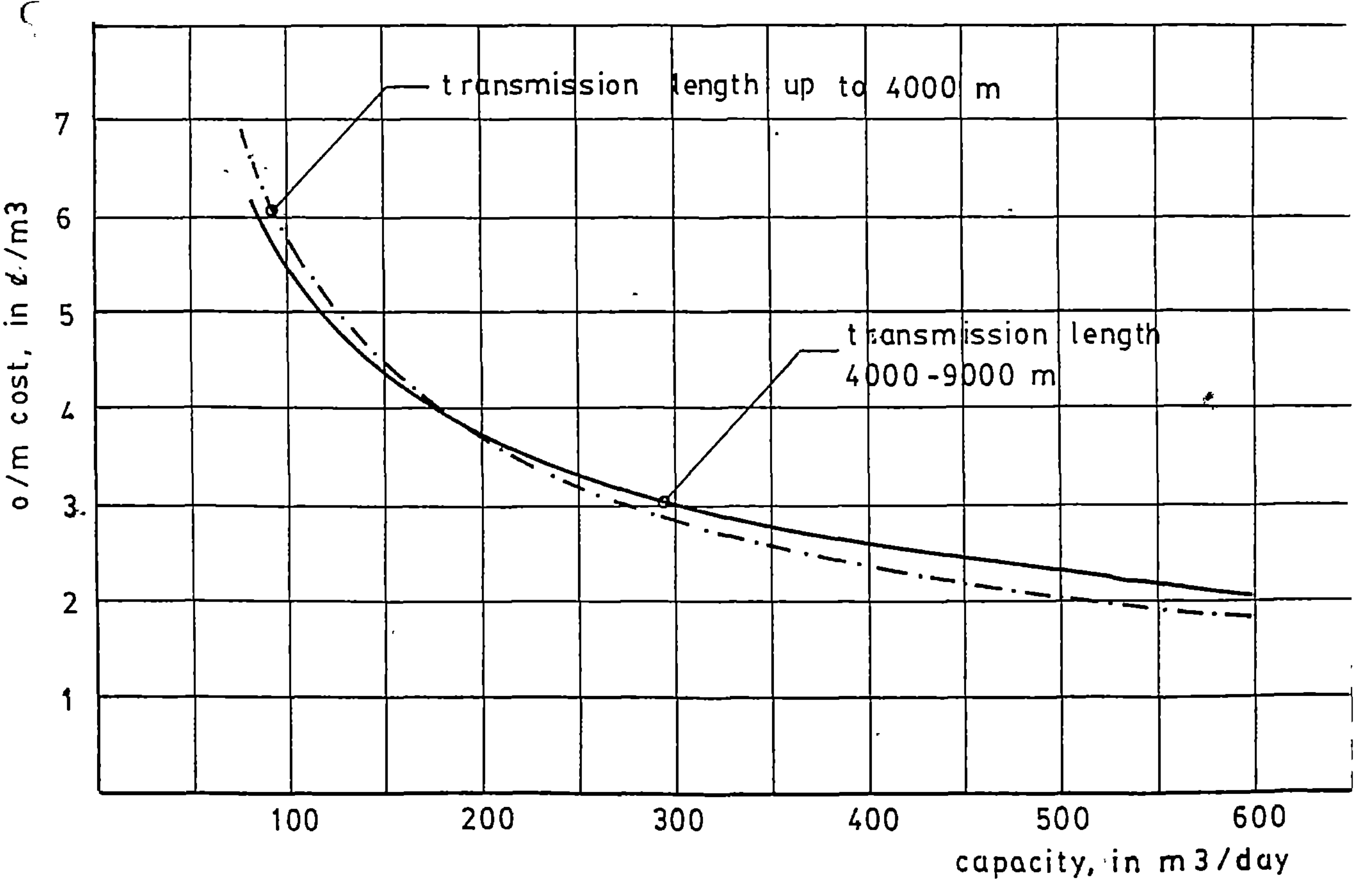


Fig. 3.15 : O/m cost vs capacity, based on ln

Table 3.3 for imputing the value of publicly supplied water include population at construction time and project cost. Assuming a discount rate of 15%, the annual interests on project cost are shown in the fourth row of Table 3.3, in thousand dollars per year. If a desire demand is assumed to be 57 lpcd, the unsupplied rate of demands immediately prior to project implementation are depiected in the fifth row of the same table, in m^3 per year. Hence, p-values can be calculated which are shown in the sixth row.

The p-values in that table range from 2.0 to 33.6 ¢/m^3 with an average of 11.61 ¢/m^3. The variance of the p's is 38.63 and the standard deviation is about 6.21. The variation is due in part to differences in community size which ranges from 1,450 to 8,350.

The assumption that publicly supplied water has the same value is based on the fact that supply systems in villagers essentially satisfies only the basic necessities of life.

It follows from this assumption that the imputed p's are measures of the true values of water.

To determine whether the prices in West Java exceed the true value of water, a null hypothesis is made that the mean of the population of p's equal or exceed the value of the sixth row on Table 3.3.

For testing the hypothesis a significance level of 5% is used. Hence, if rejected, the probability of being in error is equal to or less than 0.05.

Assuming the null hypothesis is true, the statistic $(\bar{p} - p_o) \sqrt{N}/S$ has the standard normal distribution, where $\bar{p}$ is the sample mean, p_o is the hypothesized value, N is sample size, and S is the standard deviation. The hypothesis should be rejected if the value of the statistic is less than -1.685.

By a similar logical calculation, it can be shown that the implicity assigned value cannot exceed 13.27 ¢/m^3 for implementation to be currently acceptable.

From Table 3.3 it can be seen that as many as 14 samples are rejected by this analysis, since their values of the statistic are less than -1.685. Hence, it is more economical if the implementation of those water systems are delayed until an increase in population reduces it to the acceptable limit. Delaying implementation until the population increases causes the assigned value of p to decrease.

On the contrary, a few of the values of the statistic are extremely larger than -1.685 or the implicity assigned values fall short of the true value. In this case, it would have been better had the investment been made earlier.

Another important observation need to be made is that, for a given policy related to design period, p-values in small villages will generally

be greater than those in larger communities. This is because the denominator of the Eq. (2.22) for p increases directly as village population increases, but the numerator increases at a decreasing rate due to economies of scale. Hence, communities of different size will have different p's even if the period of excess capacity is identical.

Table 3.3 - Imputed Water Supply Benefit

No.	Village	Population at time of Construction	Interest on the Capital (US$1,000/ year)	Unsatisfied Rate of Demand (m^3/year)	Imputed Water Supply Benefit (¢/m^3)	The Value of the Statistic
1	Legok Jawa	4480	12.968	93206	13.91	-3.41
2	Bangunharja	3260	3.480	67824	5.13	7.00
3	Panawangan	2660	4.383	55391	7.92	3.05
4	Pamarican	6020	7.273	125246	5.81	5.33
5	Gereba	4820	9.893	100280	9.57	2.20
6	Kadipaten	2150	6.696	44523	15.04	-3.70
7	Lengkong Jaya	2790	10.882	58046	18.75	-8.64
8	Leles	4800	7.672	99864	7.68	9.24
9	Margaluyu	3500	10.532	72817	14.46	-3.08
10	Bungbulang	4800	7.561	99864	7.57	4.36
11	Karang tengah	3500	5.138	72817	7.06	4.91
12	Situgede	3500	14.937	72817	19.83	-8.88
13	Sukaraja	3500	18.239	72817	25.05	-14.52
14	Tenjonagara	2750	4.155	57214	7.26	4.70
15	Cikajang	9800	7.561	99864	7.57	4.36
16	Sanding	3000	9.521	62915	7.24	4.72
17	Citamiang	2280	5.449	47435	11.49	0.13
18	Parakan lima	3750	13.906	78019	17.18	-6.02
19	Pasanggrahan	2200	10.757	95771	23.50	-13.77
20	Cisarua	2300	5.290	47851	11.05	0.60
21	Cikuda	4100	13.035	35300	15.28	-3.76
22	Cijeruk	3200	9.138	66576	13.72	-2.28
23	Cibuntu	8350	12.929	173722	7.15	4.82
24	Cigudeg	3500	9.888	72817	6.71	5.29
25	Rabak	2700	18.899	56173	33.64	-23.80
26	Citaringgul	5250	2.139	107146	2.00	10.38

Table 3.3 - Cont'd

No.	Village	Population at time of Construction	Interest on the Capital (US$1,000/year)	Unsatisfied Rate of Demand (m^3/year)	Imputed Water Supply Benefit (¢/m^3)	The Value of [illegible] the Statistic
27	Nagrak	3400	7.102	70737	10.04	1.69
28	Hariang	3400	6.291	70737	8.82	3.01
29	Kadu	1450	3.829	30167	12.69	-1.17
30	Cijambe	3050	5.515	63455	8.69	3.15
31	Conggeang	5850	12.913	121709	10.20	1.52
32	Parakan Muncang	3000	5.203	62915	8.34	3.53
33	Gudang	3050	9.151	63455	19.92	-3.03
34	Pasir Biru	3150	7.235	65536	11.09	0.61
35	Baros	2550	7.451	53053	19.04	-2.62
36	Cikaroo	4150	3.218	86391	9.52	2.26
37	Tarikolot	3350	10.776	69697	15.96	-9.16
38	Warnasari	3000	2.004	62415	3.21	9.07
39	Cipeundeuy	3300	7.282	68656	10.61	1.08
40	Cibodas	3850	4.740	80099	5.92	6.15

IV CONCLUSION

In West Java, the economy of scale factors of successful rural water supplies is 0.4 for transmission lines 500-4000 m as well as 4000-9000 m.

Considering of 12%, 15% and 18% interest rate, the optimal designed periods are 13 years, 10 years, and 9 years, respectively.

By different lengths of transmission line range, the investment model equations are developed as follows:

$C_c = 1.50\ W^{0.40}$, for transmission lines 500-4000 m

$C_c = 1.90\ W^{0.40}$, for transmission lines 4000-9000 m

or

$C_c = 24.60\ Q^{0.40}$, for transmission lines 500-4000 m

$C_c = 48.35\ Q^{0.40}$, for transmission lines 4000-9000 m

Where C_c is investment cost in thousand of dollars, W is designed population, and Q is designed capacity in lps.

Also o/m model equations were developed by different length of transmission lines, that is:

$C_{om} = 0.99\ Q^{-0.60}$, for transmission lines 500-4000 m

$C_{om} = 0.71\ Q^{-0.55}$, for transmission lines 4000-9000 m

In West Java Rural Water Supply, the implicity assigned value cannot exceed 13.27 ¢/m^3 for implementation to be currently acceptable.

The most obvious weakness of the statistical analysis is that it is based on relatively limited data sample and short running time of the systems (1975-1981).

Additional data from other successful water system are needed to improve the confidence level.

V RECOMMENDATION FOR FUTURE STUDY

Usually, the West Java Rural Water Supplies, which were built after 1974/1975, consist of very simple systems. Springs are used as water sources, which are distributed by gravity, without any pump or chlorination. The models are developed on this condition, hence it cannot be applied for north-eastern part of West Java, such as Kabupaten Karawang, Bekasi, Subang and Indramayu in which springs are not available.

Acutally, those areas have only two water treatment plants, which were built as package treatment plants. Those pilot projects have been run for only a few months.

To get real picture about model equation of water treatment plants for rural water supply in West Java, the study should be conducted for a few more years, since Indonesian Government decided to construct these systems in the fiscal year 1980 - 1981 for West Java and North Sumatra/Aceh Provinces.

Otherwise, Indonesian Government should use the experiences of other less developed countries.

In this thesis work, the variation of the design population especially above 5,000 inhibitants should be added, since only four samples have been collected.

Also, because it is based on relatively limited data and quite short running time of the systems, additional data are needed, at least from other successful water systems that will improve the confidence level.

The outstanding works required to complete this thesis work includes the following: Additional theoretical models are needed that more closely reflect the water supply planning conditions of West Java Rural Water Supply; also, studies should be continued to obtain and analyze field data for implementation of planning model.

For this purpose, the data were analyzed utilizing multiple regression model which was developed by MUIGE & REID (1978) for Asia, Africa and Latin America. The models cannot be statistically accepted, since the coefficient of determinations are too low, i.e. 0.22 and 0.39 for investment cost and o/m cost models, respectively.

Also, those models were formulated for Central America, with population density around 40 inhibitants per km^2; this density is very much smaller than in West Java (590 inhibitants per km^2).

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APPENDIX A

THE ADMINISTRATIVE STEPS IN INITIATING AND DEVELOPING INDONESIAN RURAL WATER SUPPLY PROJECT PROPOSALS

The Administrative Procedure for the Indonesian Rural Water Supply Project Proposal is illustrated in Figure A.1 and described by the following steps:

1. Community complains.

2. Health Center Officer discusses this complaint with the Camat.

3. Sanitarian from the Health Center explores complaint.

4. Health Center Officer reports to HS[1] Section at Kabupaten Level.

5. HS[1] personnel and Kecamatan sanitarian go to area of complaint.

6. HS[1] Section Officer reports information collected from area to the Bupati.

7. Bupati sends agreement of need to HS[1] Section.

8. HS[1] Section Officer proposes need of safe water system to Sub-Directorate of HS[1] at Provincial Level.

9. HS[1] Section Officer approaches Bupati for his support in construction and maintenance costs.

10. Bupati instructs the Camat and Lurah to approach community for contribution to construction and maintenance costs.

11. Staff of Sub-Directorate of HS[1] visits area to review preliminary proposal.

12. Staff of Sub-Directorate of HS[1] discusses revised preliminary proposal with the Governor to get financial contribution from provincial level.

13. Proposal is sent to Directorate of HS[1] for approval.

14. Directorate of HS[1] formulates program and refers to the BAPPENAS.

15. BAPPENAS discusses the program with the Meeting Board consisting of BAPPENAS, BAPPEDA, Ministry of Health, Ministry of Public Works and Ministry of Home Affairs to determine ceiling budget provided for rural water supply projects.

16. BAPPENAS sends final decision to Directorate of HS through Ministry of Health and to Ministry of Home Affairs.

17. Based on ceiling budget, Directorate of HS makes final decision about the projects which are found to be urgent and notifies HS Section at Kabupaten Level through Sub-Directorate of HS concerning this final decision.

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[1] Hygiene & Sanitation.

18. At the same time, Ministry of Home Affairs notifies Bupati through the Governor about final decision of BAPPENAS.

19. Directorate of HS sends standard designs of selected systems to Bupati through HS Section.

20. Bupati, as project manager, forms tender committee consisting of technical and administrative officials from Kabupaten Public Works, HS Section, Sub-Directorate of HS and, for systems using artesian wells, Directorate of Geology, Ministry of Mining to perform a tender. Based on evaluation of tender committee, Bupati assigns selected contractor and notifies Camat and Lurah for their support in implementing the projects.

There are two ministries that are responsible for the implementation of the Indonesian Rural Water Supply Program; the Ministry of Health through the Directorate of Hygiene & Sanitation which is responsible for technical problems such as surveys, designs and supervision of the construction as well as operation and maintenance, and Ministry of Home Affairs through the Bupati who is responsible for administrative and financial problems such as the selection of project localities and collection of funds from INPRES, Province and local resources.

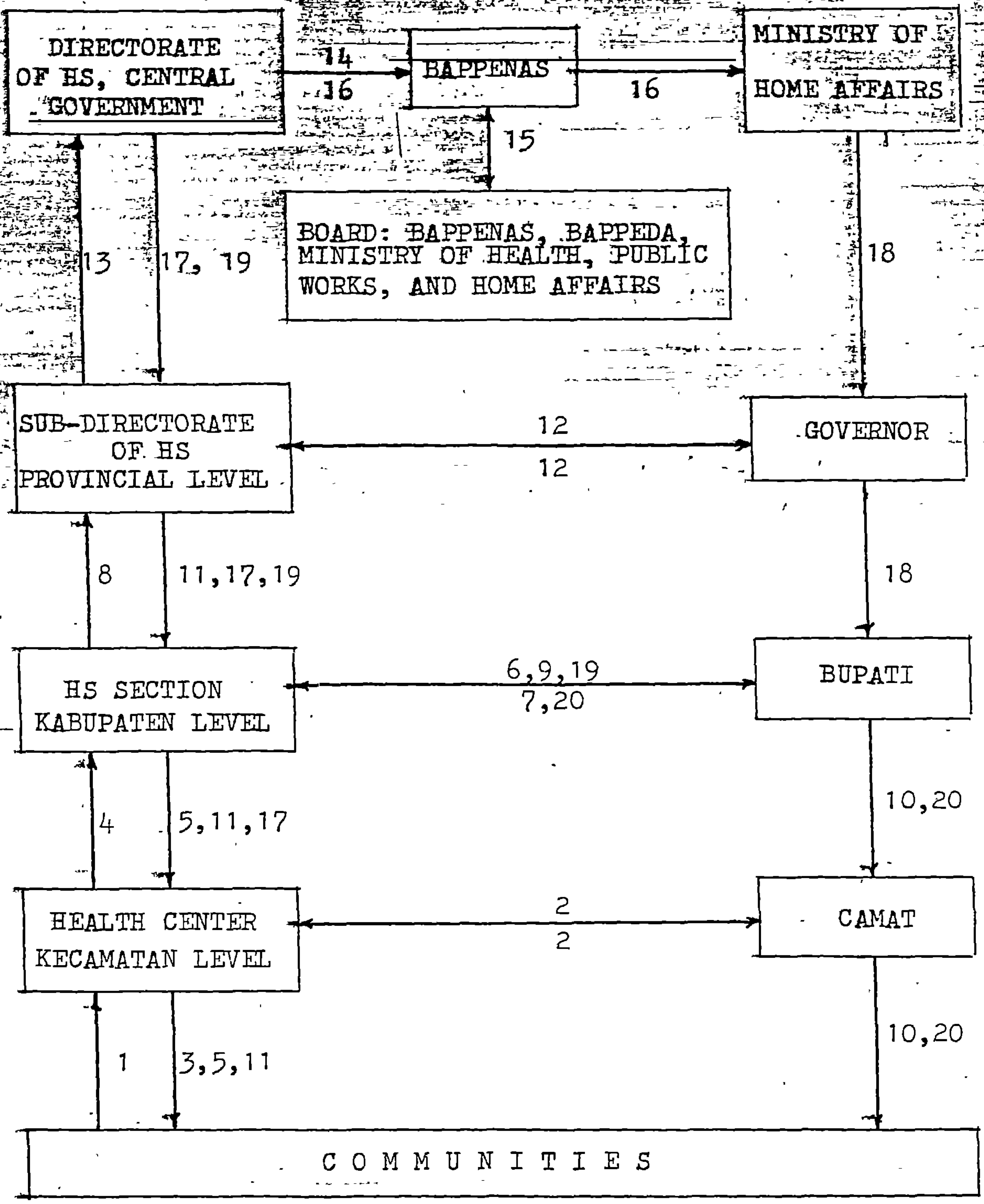

Fig.A.1: Administrative procedure for the Indonesian Rural Water Supply Project Proposals.

APPENDIX B

WATER SUPPLY QUALITY STANDARD

INDONESIAN WATER SUPPLY QUALITY STANDARD

No.		Unit	Minimum Allowable	Maximum Suggested	Maximum Allowable
I.	Physically				
1.	Temperature	°C	-	-	air temp
2.	Colour	unit*	-	5	50
3.	Smell	-	-	-	-
4.	Taste	-	-	-	-
5.	Turbidity	unit**	-	5	25
II.	Chemically				
6.	pH	-	6.5	-	9.2
7.	Total solid	mg/ℓ	-	500	1500
8.	Organic (as $KMnO_4$)	mg/ℓ	-	-	10
9.	Aggressive CO_2 (as CO_2)	mg/ℓ	-	-	0.0
10.	Total Hardness	°C	5	-	10
11.	Calcium (as Ca)	mg/ℓ	-	75	200
12.	Magnesium (as Mg)	mg/ℓ	-	30	150
13.	Total iron (as Fe)	mg/ℓ	-	0.1	1.0
14.	Manganese (as Mn)	mg/ℓ	-	0.05	0.5
15.	Copper (as Cu)	mg/ℓ	-	0.05	1.5
16.	Zinc (as Zn)	mg/ℓ	-	1.00	15
17.	Sulfate (as SO_4)	mg/ℓ	-	200	400
18.	Chloride (as Cl)	mg/ℓ	-	200	600
19.	Sulfide (as H_2S)	mg/ℓ	-	-	0.0
20.	Flouride (as F)	mg/ℓ	1.0	-	2.0
21.	Ammonia (as NH_4)	mg/ℓ	-	-	0.0
22.	Nitrate (as NO_3)	mg/ℓ	-	-	20.0
23.	Nitrite (as NO_2)	mg/ℓ	-	-	0.0
24.	Phenol (as Phenol)	mg/ℓ	-	0.001	0.002
25.	Arsenic (as As)	mg/ℓ	-	-	0.05
26.	Lead (as Pb)	mg/ℓ	-	-	0.10
27.	Selenium (as Se)	mg/ℓ	-	-	0.01
28.	Chromium (as Cr)	mg/ℓ	-	-	0.05
29.	Ciyanide (as CN)	mg/ℓ	-	-	0.05

INDONESIAN WATER SUPPLY QUALITY STANDARD (Continued)

No.		Unit	Mininum allowable	Maximum Suggested	Maximum Allowable
30.	Cadmium (as Cd)	mg/ℓ	-	-	0.01
31.	Mercury (as Mg)	mg/ℓ	-	-	0.001
III.	Radioactive				
32.	Alpha rays	uc/mℓ	-	-	10^{-9}
33.	Betha rays	uc/mℓ	-	-	10^{-8}
IV.	Microbiologically				
34.	Parasitic	-	-	-	0.0
35.	Pathogenic	-	-	-	0.0

unit* PtCo scale
unit** Silica scale

APPENDIX C

BASIC DATA: WEST JAVA

A: Selected Existing Investment Cost in West Java (US$1 = Rp.630)

No.	Desa (Village)	Kecamatan (Sub-district)	Kabupaten (District)	Design Population	Spring Captation		Pipe + install.		Length of Transmission (m)
					Cost (Rp.)	Yr.	Cost (Rp.)	Yr.	
1	Legok Jawa	Cimerak	Ciamis	4480	2.320.00	1970	51.400.000	1981	4254
2	Bangunharja	Cisaga	Ciamis	3260	2.900.000	1980	11.570.000	1981	1962
3	Panawangan	Panawangan	Ciamis	2660	2.750.000	1978	12.370.000	1980	936
4	Pamarican	Pamarican	Ciamis	6020	2.600.000	1977	19.600.000	1979	2952
5	Gereba	Cipaku	Ciamis	4320	1.872.000	1980	36.990.000	1981	3870
6	Kadipaten	Ciawi	Tasikmalaya	2150	3.320.000	1978	23.875.000	1981	2130
7	Lengkong Jaya	Cigalontang	Tasikmalaya	2790	2.900.000	1980	42.370.000	1981	4392
8	Leles	Leles	Garut	4800	2.200.000	1974	11.400.000	1975	2256
9	Margaluyu	Leles	Garut	3500	2.750.000	1979	40.600.000	1981	3366
10	Bungbulang	Bungbunglang	Garut	4800	2.200.000	1974	11.300.000	1975	3060
11	Karangtengah	Kadungora	Garut	3500	2.530.000	1975	13.410.000	1979	1992
12	Situ gede	Karang pawitan	Garut	3500	2.170.000	1976	37.000.000	1978	7002
13	Sukaraja	Banyuresmi	Garut	3500	2.170.000	1976	47.500.000	1978	9000
14	Tenjonagara	Wanaraja	Garut	2750	2.530.000	1977	9.850.000	1979	1500
15	Cikajang	Cikajang	Garut	4800	2.200.000	1974	11.200.000	1978	3000
16	Sanding	Malangbong	Garut	3000	2.750.000	1979	15.350.000	1981	1200
17	Citamiang	Plered	Purwakarta	2280	764.650	1975	12.076.100	1977	2990

A: Selected Existing Investment Cost in West Java (US$1 = Rp.630) Cont'd

No.	Desa (Village)	Kecamatan (Sub-district)	Kabupaten (District)	Design Population	Spring Captation		Pipe + install.		Length of Transmission (m)
					Cost (Rp.)	Yr.	Cost (Rp.)	Yr.	
18	Parakan Lima	Purwakarta	Purwakarta	3750	1.289.000	1978	47.256.250	1980	4100
19	Pasanggrahan	Wanayasa	Purwakarta	2200	1.533.300	1979	43.151.700	1981	2864
20	Cisarua	Jatiluhur	Purwakarta	2300	2.000.000	1978	14.500.000	1979	2448
21	Cikuda	Parungpanjang	Bogor	4100	2.000.000	1974	32.500.000	1978	5600
22	Cijeruk	Cijeruk	Bogor	3200	2.300.000	1975	25.000.000	1979	4500
23	Cibuntu	Ciampea	Bogor	2350	2.300.000	1975	35.450.000	1979	6600
24	Cigudeg	Cigudeg	Bogor	3500	2.300.000	1975	11.500.000	1979	1000
25	Rabak	Rumpin	Bogor	2700	2.300.000	1976	65.000.000	1980	5220
26	Citaringgul	Citeureup	Bogor	5150	2.300.000	1976	73.500.000	1980	5700
27	Nagrak	Buah dua	Sumedang	3900	2.000.000	1975	14.411.000	1977	2886
28	Hariang	Buah dua	Sumedang	3900	2.000.000	1975	12.343.000	1977	3000
29	Kadu	Cadasngampar	Sumedang	1950	2.000.000	1975	6.550.000	1977	1980
30	Cijambe	Conggeahg	Sumedang	3050	2.700.000	1976	12.360.000	1978	1668
31	Conggeang	Conggeang	Sumedang	5850	2.300.000	1976	32.237.000	1978	5948
32	Parakan Muncang	Cikeruh	Sumedang	3000	2.170.000	1976	11.500.000	1978	1998
33	Gudang	Cikeruh	Sumedang	3050	2.800.000	1976	22.280.000	1978	4134
34	Pasir biru	Rancakalong	Sumedang	3150	2.300.000	1976	16.938.000	1978	3372

A: Selected Existing Investment Cost in West Java (US$1 = Rp.630) Cont'd

No.	Desa (Village)	Kecamatan (Sub-district)	Kabupaten (District)	Design Population	Spring Captation		Pipe + install.		Length of Transmission (m)
					Cost (Rp.)	Yr.	Cost (Rp.)	Yr.	
35	Baros	Tanjungkerta	Sumedang	2550	2.530.000	1978	23.866.000	1980	1004
36	Cikareo	Wado	Sumedang	4150	2.530.000	1978	26.666.000	1980	2490
37	Tarikolot	Wado	Sumedang	3350	2.530.000	1978	36.011.000	1980	4506
38	Warnasari	Warnasari	Sumedang	3000	800.000	1976	3.368.000	1976	512
39	Cipeundeuy	Cipeundeuy	Sumedang	3300	700.000	1975	14.400.000	1976	3504
40	Cibodas	Cibodas	Sumedang	3850	1.434.000	1974	6.050.000	1974	1302

B: Selected Existing o/m Cost in West Java (US$1 = Rp.630)

No.	Desa (Village)	Kecamatan (Sub-district)	Kabupaten (District)	Population Served	Aver. o/m Cost at 1981		Water Used (m^3/day)	o/m Unit Cost (US$/$m^3$)
					Rp./month	US$/month		
1	Legok Jawa	Cimerak	Ciamis	3136	155,470.00	246.78	191.3	0.043
2	Bangunharja	Cisaga	Ciamis	1956	149,820.00	237.81	140.8	0.056
3	Panawangan	Panawangan	Ciamis	2834	94,680.00	150.29	108.2	0.046
4	Pamarican	Pamarican	Ciamis	5418	292,030.00	463.54	335.9	0.046
5	Gereba	Cipaku	Ciamis	3422	205,298.00	325.87	253.2	0.043
6	Kadipaten	Ciawi	Tasikmalaya	1391	118,700.00	188.42	76.5	0.082
7	Margasari	Ciawi	Tasikmalaya	2790	238,030.00	377.82	153.4	0.082
8	Lengkong Jaya	Cigalontang	Tasikmalaya	1820	119,400.00	189.53	125.6	0.050
9	Leles	Leles	Garut	10.987	145,500.00	230.95	685.6	0.011
10	Margaluyu	Leles	Garut	2100	104,430.00	165.76	109.2	0.051
11	Bungbulang	Bungbulang	Garut	9272	171,950.00	183.92	196.5	0.031
12	Karangtengah	Kadungora	Garut	2660	115,870.00	168.28	151.6	0.037
13	Situ Gede	Karang Pawitan	Garut	3185	126,150.00	200.24	162.4	0.041
14	Sukaraja	Banyuresmi	Garut	3010	168,570.00	267.57	168.6	0.053
15	Tenjonagara	Wanaraja	Garut	1925	64,340.00	102.13	94.3	0.036
16	Cikajang	Cikajang	Garut	4128	147,470.00	276.94	198.1	0.047

B: Selected Existing o/m Cost in West Java (US$1 = Rp.630)(Cont'd)

No.	Desa (Village)	Kecamatan (Sub-district)	Kabupaten (District)	Population Served	Aver. o/m Cost at 1981		Water Used (m^3/day)	o/m Unit Cost (US$/$m^3$)
					Rp./month	US$/month		
17	Sanding	Malangbong	Garut	2150	124,630.00	197.83	103.2	0.064
18	Citamiang	Plered	Purwakarta	1983	85,750.00	136.12	128.9	0.035
19	Parakan Lima	Purwakarta	Purwakarta	2812	131,810.00	209.22	222.1	0.031
20	Pasanggrahan	Wanayasa	Purwakarta	1386	84,830.00	134.65	88.7	0.051
21	Cisarua	Jatiluhur	Purwakarta	1702	139.110.00	220.81	119.1	0.062
22	Sindangpanon	Darangdan	Purwakarta	2963	162,480.00	257.91	231.1	0.034
23	Cikuda	Parungpanjang	Bogor	3903	204,480.00	324.57	210.9	0.051
24	Cijeruk	Cijeruk	Bogor	2304	133,270.00	211.54	156.7	0.045
25	Cibuntu	Ciampea	Bogor	7264	310,960.00	493.59	544.8	0.019
26	Cigudeg	Cigudeg	Bogor	2334	156,760.00	248.82	144.5	0.057
27	Rabak	Rumpin	Bogor	2052	121,200.00	192.38	106.7	0.060
28	Citaringgul	Citeureup	Bogor	3708	138,630.00	200.05	233.6	0.031
29	Nagrak	Buah Dua	Sumedang	3162	128,950.00	204.68	164.4	0.041
30	Hariang	Buah Dua	Sumedang	2856	109,550.00	173.89	117.1	0.049
31	Kadu	Cadasngampar	Sumedang	1320	87,590.00	139.03	38.3	0.121
32	Cijambe	Conggeang	Sumedang	2806	142,210.00	225.73	148.7	0.051

B: Selected Existing o/m Cost in West Java (US$1 = Rp.630)(Cont'd)

No.	Desa (Village)	Kecamatan (Sub-district)	Kabupaten (District)	Population Served	Aver. o/m Cost at 1981		Water Used (m^3/day)	o/m Unit Cost (US$/$m^3$)
					Rp./month	US$/month		
33	Conggeang	Conggeang	Sumedang	5206	452,830.00	718.78	385.2	0.022
34	Parakan Muncang	Cikeruh	Sumedang	2580	70,910.00	112.56	172.9	0.022
35	Gudang	Cikeruh	Sumedang	2928	145,910.00	231.61	143.5	0.054
36	Pasir Biru	Rancakalong	Sumedang	2865	134,750.00	213.89	146.1	0.049
37	Baros	Tanjungkerta	Sumedang	1963	155,090.00	246.18	149.2	0.055
38	Cikareo	Wado	Sumedang	3071	78,330.00	124.33	92.1	0.045
39	Tarikolot	Wado	Sumedang	2445	191,620.00	304.16	141.8	0.071
40	Warnasari	Warnasari	Sumedang	3761	197,560.00	313.59	191.8	0.054
41	Cipeundeuy	Cipeundeuy	Sumedang	3814	178,100.00	277.94	183.1	0.051
42	Cibodas	Cibodas	Sumedang	4210	149,200.00	236.82	252.6	0.031
43	Tagog Apu	Padalarang	Bandung	3550	93,780.00	148.86	205.9	0.024
44	Cihideung	Cisarua	Bandung	3500	60,780.00	96.47	127.1	0.025
45	Sindangsari	Paseh	Bandung	4200	161,220.00	255.91	264.1	0.032

APPENDIX D

STATISTICAL PROCEDURE

A. Capital Cost Model

The construction cost function of a water treatment plant is a function of design population, and can be represented by the following form:

$$C_c = K_1 W^a \qquad \text{(D-1)}$$

Where C_c is the cost of construction a treatment plant in thousands of dollar, W is the design population that the treatment plant is going to serve at the end of design period, K_1 and a are the constants to be determined which are the characteristics of the time and geographical location of construction.

Taking logarithms of Eq. (C-1):

$$\log C_c = \log K_1 + a \log W$$

$$Y' = u + v\ X \qquad \text{(D-2)}$$

A probabilistic mathematical model for the regression line can be represented by:

$$Y = p + q\ X + \varepsilon \qquad \text{(D-3)}$$

where Y' is the estimated value of Y for a given value of X and ε is a random variable and can be thought of as a disturbance term causing Y to take a different value from that given by the exact relationship. The mean of the values of ε is assumed to be zero and its variance equal to σ_{YX}^2. In addition, ε_i and ε_j coresponding to two observations, Y_i and Y_j, are independent and normally distributed and Y is linearly related to X and that observed values Y will deviate above and below this line by a random about ε. It can be shown that:

$$u = \bar{Y} - v\ \bar{X}$$

where $\bar{Y}$ and $\bar{X}$ are the means of Y and X values and therefore substituting this value of u in Eq. (C-2):

$$Y' = (\bar{Y} - v\bar{X}) + vX \qquad \text{(D-4)}$$

where $(\bar{Y} - v\bar{X}) = p$ and $v = q$ = economy of scale

a) Estimation of p and Economy of Scale Factor (v=q=a)

The coefficients p and q are estimated by v. The simplified form of the equation of v from the least square analysis is:

$$v = \frac{\Sigma xy}{\Sigma x^2} \qquad \text{(D-5a)}$$

where: $v = a$ = economy of scale factor (D-5b)

$$x = X - \bar{X} \quad \text{(D-6)}$$

$$y = Y - \bar{Y} \quad \text{(D-7)}$$

$$\Sigma x^2 = \Sigma X^2 - (\Sigma X)^2/n \quad \text{(D-8)}$$

$$\Sigma y^2 = \Sigma y^2 - (\Sigma Y)^2/n \quad \text{(D-9)}$$

$$\Sigma xy = \Sigma XY - (\Sigma X)(\Sigma Y)/n \quad \text{(D-10)}$$

Here $\bar{X}$ and $\bar{Y}$ are the mean of the sets of values of X and Y and n is the number of observation.

b) Analysis Variance and Test of Regression Significance

Two type of errors:

(i) Deviations from the regression line due to variance of random error ε

(ii) The second type of error is due to the regression itself.

Because of these two errors, therefore, the parameters from the fitted regression line should be further analyzed to examine the above two errors to find out the significance and confidence level of the regression coefficiency for which the analysis of variance will have to run. The standard analysis of variance table is usually available as well as in table C.1.

In this calculation the null hypothesis will be tested and the confidence level of the regression line will be determined. Starting that Y and X are not linearly related by a regression equation is equivalent to saying that $\beta = 0$. Thus the null hypothesis that $\beta = 0$ against the alternative that $\beta \neq 0$ should be tested.

Null hypothesis H_o : $\beta = 0$ (No regression line exists)

Alternate hypothesis H_1 : $\beta \neq 0$ (linear regression exists)

If the null hypothesis is true, the regression line does not exist, otherwise the alternate hypothesis is true.

Hypothesis test procedure:

(i) The null hypothesis and alternate hypothesis.

(ii) Student's value.

(iii) Critical value of t will be obtained from t-table using (n-2) degree of freedom, and a desired confidence level α (90 or 95%).

(iv) If the t value obtained in step (ii) lies within the critical range t, the null hypothesis will be rejected. Hence the regression coefficient is significant at the desired level α.

Table C.1 - Analysis of Variance Table for Test of Significance of v.

Source of Variation (1)	Degree of Freedom - d.f. (2)	Sum of Squares-s.s. (3)	Mean Squares (4)	Expected sum of Squares (5)
Due to regression	1	$\frac{(\Sigma xy)}{\Sigma(x)^2}$	$\frac{s.s.}{d.f.}$	$\sigma_{YX}{}^2 + \beta^2\Sigma_{x_i}{}^2$
Due to deviation from regression	n-2	$\Sigma Y^2 - \frac{(\Sigma xy)^2}{\Sigma(x)^2}$	$\frac{s.s.}{d.f.}$	σYX^2
Corrected total deviation from mean	n-1	Total uncorrected sum of square mean $= \Sigma Y^2 - \frac{(\Sigma Y)^2}{n}$		

c) <u>Confidence Interval Determination for Y' for a Given Value of X</u>

Eventhough the estimated value of Y which is denoted by Y' can be calculated for a given value of X from the developed regression model, the confidence limit of Y' should be calculated to examine the variations of Y' for a given value of X. The regression model developed above is expressed as well as in Eq. (C-4).

The variance and standard deviation of the estimated value of Y are given by the formula:

$$\text{Variance} = S_{YX}{}^2 \left(\frac{1}{n} + \frac{x^2}{\Sigma x^2}\right) \tag{D-11}$$

$$\text{Standard deviation} = S_{YX}\sqrt{\left(\frac{1}{n} + \frac{x}{x}\right)} \tag{D-12}$$

Where X_{YX} is the standard deviation of ε which is the random error of Y', n is the number of observations, and $x = (X - \bar{X})$. Because of the second term under bracket is small and therefore can be neglected.

So,

$$S_{Y'} = S_{YX}\sqrt{\frac{1}{n}} \tag{D-13}$$

The confidence level of Y' at different probabilities for a given value of X can be calculated by

$$Y' - t_{\alpha,(n-2)\mathrm{d.f.}} \times S_{Y'} < Y' < Y' + t_{\alpha,(n-2)\mathrm{d.f.}} \times S_{Y'} \tag{D-14}$$

Where Y' is the estimated value of Y for a given X from regression model, α is the probability with (n-2) degree of freedom which is directly available from the t-table, and $S_{Y'}$ is the standard deviation of the estimated Y. The maximum and minimum value of Y' gives the upper and lower boundary of the value of Y for a given probability α.

d) Interpretation of the Model

The regression model developed above is:

$$Y' = (\bar{Y} - v\bar{X}) + vX$$

in which all the parameters are already determined.

Here:
$$\bar{Y} - v\bar{X} = \log K_1 = p \tag{D-15}$$

$$v = a = \text{economy of scale} \tag{D-15b}$$

and therefore the value of K_1 and a can be determined. Hence the model of Eq. (C-1) can be establish. Knowing the percapita consumption, this model can be transferred to the model of the form:

$$C_c = K_1' (Q)^a$$

where K_1' is the cost of one m^3/d system, Q is the design capacity in m^3/d, and C_c is the cost in thousand dollars.

Eq. (3-1) can be used in predicting the construction cost of a water treatment plant when the design population is known. In the model development it was assumed that:

$$Y = \log C_c, \text{ and}$$

$$X = \log W$$

Therefore the log-log plot of the model will be as shown in Fig. 3.1. Putting 95% confidence in the value of Y, two straight lines are drawn as shown corresponding to the two values of Y'.

Now, if it is required to predict the construction cost of a water treatment for a given population P, then which 95% confidence we can say that the cost will range between D_1 dollars to D_2 dollars.

B. Operation/Maintenance Cost Model

Orlob & Lindorf developed the operation and maintenance cost function and found to be related to the daily average treated flow Q by an expression:

$$C_{om} = K_2 \, Q^b \tag{D-16}$$

where C_{om} is the cost of operation and maintenance in $\$/m^3$

Q is the average daily flow in m^3/d

b and K_2 are constants

Similarly, statistical procedures of operation and maintenance are the same as well as capital cost model.