AN OPTIMIZATION MODEL - PRELIMINARY SELECTION OF APPROPRIATE TECHNOLOGY IN WASTEWATER TREATMENT ALTERNATIVES

by

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TABLE OF CONTENTS

PART 1 PRELIMINARY WORK AND REVIEW OF LITERATURE

PART 4 FURTHER DEVELOPMENT AND CONCLUSION

PART 1

PRELIMINARY WORK AND REVIEW OF LITERATURE

CHAPTER 1 --- SYNOPSIS AND INTRODUCTION

1.1 Synopsis

This research is concerned with the use of techniques of system analysis / operations research in the selection of the optimal - or most appropriate - wastewater treatment techniques in any given situation. An extensive investigation of existing treatment system optimization models, applying techniques of linear programming, dynamic programming and non-linear mathematical programming, has been carried out. None of these existing models deals with the socio-cultural and environmental conditions but merely with the economy of treatment. In this work the more subjective or intangible factors are included in the proposed optimization model in which twenty parameters are identified. These parameters are considered to be most important in the selection of appropriate alternatives for treating municipal wastewater. They include technical, economic, environmental and socio-cultural factors. The model was developed to rank a definite number (n) of wastewater treatment alternatives (decision variables) by the evaluation of the twenty parameters.

The model applies a recently developed system analysis technique called eigenvector prioritization (or analytic hierarchy process) and requires the use of a computer program to integrate a 20 x 20 parameter matrix with twenty n x n decision variable matrices for obtaining the final ranking of the treatment alternatives. The computer program is written in IBM-pc BASIC and can be run on any IBM personal computer (or any XT or AT). The model was tested using data collected from actual treatment plants in Malaysia, Thailand, Taiwan and Hong Kong. A sensitivity analysis was then carried out. As a result the model was extended to be able to forecast a change of appropriate technology as social and environmental conditions altered with time.

1.2 Introduction

Chapter 1 of this thesis, as can be seen from its title, gives a bird's eye view of the contents contained in the thesis. Chapter 2 is a brief but comprehensive description of existing wastewater treatment techniques which are commonly in use. Chapter 3 is an extensive survey on the development of treatment system optimization models since 1962. Models based on operations research techniques including linear programming, dynamic programming and non-linear mathematical programming proposed by various researchers are described in this chapter.

Chapter 4 begins to discuss the model proposed in this research. In the chapter, the complete sets of the parameters and the decision variables (or treatment alternatives) are described. Chapter 5 then gives a detailed discussion on the mathematical tool (eigenvector prioritization) applied in the model. It also explains the reasons for using this particular mathematical technique and discusses the advantages of it over the others. After a theoretical background is given in Chapter 5, Chapter 6 continues to describe the development of the model in detail, including the discussion of the computer program.

There are two distinctive methods in research --- deductive and inductive methods.(1) The deductive method uses logic that moves from the general to the specific. In such a method, a theory or an idea is obtained after a general consideration of all occurrences. The inductive method, however, uses logic that is launched from a specific occurrence and moves to inferences concerning the general. In other words, if a number of special cases occurs according to a general theory or idea then the latter is supported. The inductive method is applied in this research. The model is formulated firstly as a hypothesis, as described in Chapters 4, 5, and 6. It is then tested by using four different situations. Chapter 7 and Chapter 8 describe the tests using data collected from four different places, namely, Malaysia, Thailand, Taiwan and Hong Kong. The test results obtained are the four optimal (or most appropriate) treatment alternatives for the four given situations.

Chapter 9 is a description of the sensitivity analysis of the model, the technique of which is applied to forecasting change of appropriate technology as a result of change of situation. Chapter 10, the last chapter, gives an account on the merits and demerits of the model, which is then followed by a suggestion of further work to be done for improving the effectiveness of the model.

CHAPTER 2 --- CURRENT AVAILABLE WASTEWATER TREATMENT ALTERNATIVES

The wastewater treatment methods currently available are numerous. For the purpose of making a survey of them, they are categorized into eight groups so that the discussion can be made more systematically:

1. Clarification
2. Stabilization ponds
3. Aerated lagoons
4. Biofiltration
5. Activated sludge process
6. Small treatment plants
7. Land application
8. Tertiary treatment

Each group of the treatment methods will be discussed in the following sections.

2.1 Clarification

This is a physical form of treatment. A percentage of the insoluble pollutants will settle to the bottom under the influence of gravity when the wastewater is allowed to stand in a tank for a certain time (usually 2 to 6 hours). This method will remove only insoluble pollutants in wastewater. There are primary clarifiers and secondary clarifiers, the former allow settlement of pollutants to occur prior to secondary / biological treatment, and the latter do so following secondary treatment. Usually, secondary clarification is classified as a part of secondary treatment. There are basically three types of clarifiers --- horizontal flow, radial flow and vertical flow. The radial flow clarifiers are most commonly used, particular for secondary clarification.

Primary clarification can remove about 60% to 70% of s.s. and 35% to 40% of BOD_5 of a preliminarily treated municipal wastewater[23]. If the standard of effluent required is not high, this method of treatment is simple and cheap. It does not require very high technical skills of its operation and needs only small site area. However, attention has to be paid to the treatment and disposal of the settled solids (or primary sludge) in using primary clarification.

Pathogens in the wastewater settle partly to the sludge layer (in both primary or secondary clarifiers) either by direct sedimentation or by being adsorbed onto solids that are in the process of settling. In primary clarification, very little or no removal of virus (causing diseases such as diarrhoea, infectious hepatitis, yellow fever, etc.) is achieved[9]. About 50% of removal of bacteria (causing diseases such as diarrhoea, cholera, typhoid, etc.) may be achieved in about 4 hours retention time[9]. Protozoal cysts (causing diseases such as diarrhoea, amoebic disentery, malaria, etc.) in the crude sewage can be reduced by 30% to 50%[9]. Helminth eggs (causing diseases such as human round worm and hook worm, fish-borne parasites (Clonorchiasis), bilharzia, filariasis, etc.) can also be removed by 50% to 70%[9].

2.2 Stabilization Ponds

Stabilization ponds are shallow, large area flat bottomed ponds surrounded by an earth dike. Natural physical and biological treatment processes occur in the ponds. Stabilization ponds may be classified as anaerobic ponds, facultative ponds and maturation ponds.

An anaerobic pond functions similarly to an open septic tank. It is deeper (up to 5 m) than the other two types of ponds, with retention time of about a day, and is usually used together with other forms of treatment as a pre-treatment process. Odours are a problem with anaerobic ponds, and efficiencies of treatment are generally low. The major BOD_5 removal by an anaerobic pond, like primary clarification, is achieved through the removal of the suspended solids, as it is unreasonable to expect a crude anaerobic digestor such as a pond to further reduce the BOD_5 of a relatively weak municipal wastewater[7]. Therefore, an anaerobic pond is usually designed as a primary settlement unit, but instead of desluding the settled solids (as in the case of clarifiers), they are allowed to accumulate at the bottom of the pond and encouraged to stabilize anaerobically and so continual handling of sludge can be avoided.

Facultative ponds are typically 1 to 1.5 m deep and in them anaerobic breakdown occurs at the bottom layer while aerobic stabilization takes place at the top layer. They can be used alone but can also be used together with other types of ponds in series. If a facultative pond is used in series with other ponds, it must be put after an anaerobic pond and/or before a maturation pond. The oxygen necessary for biochemical oxidation at the upper layer of the pond is supplied by the photosynthetic activity of algae grown in the pond naturally and also by the direct adsorption of atmospheric oxygen through the air/water interface[7]. Retention times range from 10 to 40 days, achieving up to 95% removal of BOD_5.

Maturation ponds are shallow fully aerobic ponds normally used to receive effluent from facultative ponds so that the effluent may be improved. They have a depth of about 1.5 m and retention times of 5 to 10 days. Maturation ponds are used principally to achieve the removal of excreted pathogens, especially faecal bacteria and viruses. The presence of predators (e.g. rotifiers and various protozoa), algal competition, nutrient deficiencies, high D.O. concentration, high pH, and good sunlight penetration (ultraviolet radiation) are suggested to be the reasons for pathogen removal in maturation ponds[7]. Besides pathogen removal, the ponds can be employed to further lower the concentration of BOD_5 and the s.s. in the wastewater. They also oxidize any remaining ammonia to nitrate (ie. nitrification), and lower the concentration of the soluble nutrients, nitrates and phosphates[7]. These two nutrients are removed by anabolic uptake during the growth of algae and of other microorganisms. Phosphates are also removed by precipitation as hydroxyapatite $[Ca_5(PO_4)_3OH]$ at high pH values (8.2 or above) developed as the result of photosynthesis[7].

Anaerobic ponds, facultative ponds and maturation ponds may be designed, as mentioned previously, in series so as to accomplish the more complete treatment of wastewaters. Anaerobic and facultative ponds are mainly designed for BOD_5 and s.s. removal, whereas maturation ponds mainly for pathogen destruction and effluent polishing. If large site area is readily available and land cost is low, stabilization ponds can be the most economic method of wastewater treatment. The degree of purification by ponds, both in terms of BOD_5 and pathogen, is high and they can withstand both organic and hydraulic shock loads due to large pond volume, long retention period and hence high buffer capacity. At the same time, they require only low capital and maintenance costs and need minimal technical skill and attention in their operation.

Another advantage of ponds over other forms of treatment is that they do not require continual sludge removal. Desludging is only required once in a considerable long period of time. An anaerobic pond needs desludging perhaps every 3 to 5 years, whereas a facultative pond may only need that every 10 to 15 years if it is preceeded by an anaerobic pond[14]. However, climatic conditions are an important consideration, as ponds are much less efficient in cold weather when bacterial metabolism is slow; also the possibility of an ice cover exists. Another major disadvantage is that the effluent from a series of stabilization ponds will be heavily laden with algae. This can increase considerably the BOD of the effluent, sometimes by a factor of two to three[8]. Various techniques (e.g. sand filtration, dissolved-air flotation, rock filters, etc.) have been employed to remove algae from the effluent, but more attention is required in operating these techniques and a higher cost will be involved. If the reason for selecting stabilization ponds in treating wastewater is because of their simplicity and low cost in both construction and operation, the algal burden in the effluent is generally accepted as an unavoidable fact as a result of employing this treatment alternative.

A well designed pond system having a total retention time of 20 days will produce an effluent with complete elimination of protozoal cysts and helminth eggs, retaining only a very small fraction of excreted bacteria and viruses[9]. Bacteria and viruses can also be completely eliminated if a retention time of 40 days or more is allowed[9]. Stabilization ponds, however, can be favourable sites for mosquito breeding, particularly in reeds and weeds near to the banks. Mosquitoes serve as vectors for diseases such as malaria, filariasis and yellow fever. Consideration must be given as to whether or not ponds may be employed as treatment alternatives if these diseases are endemic.

2.3 Aerated Lagoons

Aerated lagoons resemble small stabilization ponds (about 1/10 the size[17]) but usually with surface mechanical aerators supplying oxygen for the biochemical mechanism taking place in the lagoons. They are more correctly considered as a simple modification of the activated sludge process (about 8 times the size[12,17] of a conventional activated sludge plant) and without sludge return system. Primary settlement, as with stabilization ponds, is not necessary for aerated lagoon treatment system. Retention time for lagoons is 2 to 6 days and lagoon depths are 2 to 4 m. There are two types of aerated lagoons --- fully-suspended aerated lagoons and partially-suspended aerated lagoons.

In a fully-suspended aerated lagoon, all solids are kept in suspension by the surface aerators and therefore secondary settlement is required. Settlement tanks (minimum retention of 2 hours) or maturation ponds (retention of about 2 days) are usually used as secondary settlement alternatives for such purpose. A pond should be preferred whenever land is available because it saves the necessity of continual sludge removal/handling and is easy to operate and maintain.

In a partially-suspended aerated lagoon, a lower rate of oxygen is added mechanically and a lower concentration of volatile solids is continually held in suspension. The mass of suspended solids again represents an embryonic mixed-liquor. Surface aerators can be put in a "tapered" fashion so that the section near the outlet of the lagoon will be most undisturbed, thus allowing it to require no secondary settlement in the design. Suspended solids concentrations of 50 to 100 mg/l are normally anticipated in the final effluent[8].

The two types of aerated lagoons can be put in series, normally with a fully-suspended one followed by a partially-suspended one[13,21]. Retention times of the two lagoons can be expressed as dependent variables in equations with BOD_5 concentration of the intermediate effluent as the independent variable. The minimum total retention time of the two lagoons can be found by differentiating the total retention time with respect to the independent variable.

BOD_5 removal by aerated lagoons can be 90% or higher, depending on the length of retention time. For pathogen removal, the efficiency is somewhere in between that of stabilization ponds and conventional activated sludge treatment plants, aerated lagoons have a better pathogen removal capacity than activated sludge processes but a lower one than ponds[9]. The pathogen removal efficiency of activated sludge will be discussed in Section 2.5.

2.4 Biofiltration

Biofiltration is a secondary treatment process and must be preceeded by primary settlement. The biological (or percolating or trickling) filter is a circular or rectangular bed of graded medium, usually 40 to 60 mm coarse aggregate and about 1.8 m deep (or specially manufactured plastics with greater depth), contained in a brick or concrete structure. Settled sewage is periodically dosed onto the surface of the filter and trickles down over the surface of the medium. On these surfaces, a biological film is formed which oxidizes and hence purifies the settled sewage as it flows through. The loading of the filter is normally measured by either the "hydraulic loading" or the "BOD_5 loading". The hydraulic loading measures the volume, in m^3, of settled sewage that is applied to each cubic meter of the filter media per day. The BOD_5 loading measures the kilograms of BOD_5 applied per cubic meter of media per day. The BOD_5 loading is more commonly used nowadays. For a conventional simple biofilter, a BOD_5 loading of between about 0.07 and 0.10 $kg/m^3/day$ is applied[20]. Thus, a simple biofilter plant needs quite a large volume of media and hence requires about 5 times the site area a conventional activated sludge plant does for treating sewage from the same population[12]. It is, however, about 15 times smaller than a stabilization pond. Biofilters require sludge handling facilities which increase both the capital and the running costs of biofiltration plants.

Modifications to the above-described simple biofilters have tended to lower the volume of the filter media required (ie. to increase the BOD_5 loading). The modifications include the recirculation of effluent and the alternating double filtration techniques. In such cases, settled sewage can be dosed to the filters at a higher rate than simple biofiltration, up to about 0.24 kg $BOD_5/m^3/day$[20]. In applying recirculation, a portion of the purified and settled effluent is returned to be mixed with the settled sewage and this mixed and diluted sewage is then dosed to the filter surfaces. In applying alternating double filtration, two filters are operated in series. The intermediate effluent from the first filter, after settlement, is applied to the second filter. At the end of a selected period (possibly a week) the order of the first and second filters is reversed. This system of alternating the two filters is continued indefinitely. In using the modified forms of biofiltration, the land area requirement of the plant can be reduced to about 3 times the size of a conventional activated sludge plant[12] due to the higher loading rate and the smaller volume of media required.

Percolating filters are quite efficient at removing BOD_5 and s.s. (85% to 95%) from municipal wastewaters, but they do not appear to be efficient at removing viruses (only about 30% to 40%)[9]. Removal efficiency of about 85% for bacteria and protozoal cysts can be achieved by biofilters, but much lower removal rates for helminth eggs are reported[9]. In general, effluent from biofiltration satisfying "Royal Commission Recommendations" will be of poor microbiological quality and still be highly pathogenic. Tertiary treatment (see Section 2.8) may be the only way to help produce a good final effluent from a public health viewpoint.

If the requirement of the quality of the final effluent is not high, then the high-rate filtration can be applied. This is simply an increase in dosage rate (e.g. 1.11 kg $BOD_5/m^3/day$[8] at the Dunstable Plant) to the filter. The sizes of the filter media used in this case will be larger so as to provide larger voids and hence reduce the chance of blocking and ponding. The high-rate filtration can also be facilitated by using plastic media (90% voids) in tall towers rather than the usual stone media (40% voids) so that the loading rate can be as high as 2.0, 4.0 and even 6.0 kg $BOD_5/m^3/day$[8,20]. To obtain a better effluent in using high-rate filters, low-rate (simple) biofilters are sometimes put in series after them as secondary filters to further treat the intermediate effluent. Recirculation can be incorporated in such so called double filtration systems[8].

2.5 Activated Sludge Process

Activated sludge process is a secondary treatment and therefore, similar to biofiltration, must be preceeded by primary treatment. The settled sewage flowing into an aeration basin (also termed reactor or mixed-liquor tank) contains organic polluting material (BOD) which acts as a food supply to the micro-organisms in the sewage. In the presence of abundant air (or more correctly oxygen) supply, the micro-organisms metabolize the BOD, producing new microbial cells and at the same time reducing the organic pollutants. The mixed-liquor in the reactor is in the form of biological floc and is continuously transferred to a clarifier (secondary settlement) for gravity separation of the floc and discharge of the clarified effluent. A high percentage of the settled floc (termed secondary sludge) is returned continuously to the aeration basin for mixing with fresh settled sewage while a small percentage of it is surplus and is led to the sludge treatment and disposal facilities.

In the conventional activated sludge process, atmospheric oxygen is supplied by either surface-aeration (ie. mechanical agitation) or diffused-aeration to the settled sewage. This is carried out in the reactor which normally has a hydraulic retention time of approximately 6 to 10 hours. The biological floc (or activated sludge floc) which is kept suspended by agitation in the reactor consists mainly of a high concentration of micro-organisms which is responsible for the carbonaceous oxidation and the nitrification of the organic polluting material. An equilibrium is reached in the system such that the rate of organism growth is equal to the rate of organism decay and the rate of discharging surplus secondary sludge[6,15]. The suspension in the reactor, as previously mentioned, is then led to a secondary clarifier in which the secondary sludge (mainly living and dead micro-organisms) is allowed to settle. The supernatant from the secondary clarifier (or final effluent) is thus highly purified, usually attaining 95% or higher BOD_5 and s.s. removal with respect to the raw sewage incoming to the plant. The purpose of continually recycling a major part of the secondary sludge from the secondary clarifier back to the reactor is to ensure that a high concentration of micro-organisms (usually referred to as MLVSS or mixed-liquor volatile suspended solids) in the reactor is maintained. The surplus secondary sludge and the primary sludge are handled together in the sludge treatment and disposal facilities which must be provided with in an activated sludge plant.

The activated sludge process is therefore expensive due to two reasons: (1) power needed for continual supply of atmospheric oxygen to the reactors, and (2) provision of sludge handling facilities. In addition, a high technical skill is required in the operation of an activated sludge plant as D.O. concentration, MLVSS level in the reactor, discharge of surplus activated sludge and so on have to be carefully and effectively monitored so as to allow the process to run smoothly.

There are a number of modifications to the conventional activated sludge plants. They include high-purity oxygen plants, deep-shaft plants, oxidation ditches and packaged activated sludge plants (extended aeration or contact stabilization). The first two modifications will be discussed here. The last two fall into the category of small treatment plants and will therefore be discussed in the next section (ie. Section 2.6).

High-purity oxygen plants are activated sludge plants in which pure oxygen is supplied to reactors instead of air (ie. atmospheric oxygen). The reactors in these plants allow for much higher oxygen transfer efficiencies than in conventional air-based plants so that the rate of biological oxidation is accelerated and therefore power costs are substantially reduced (but at the expense of additional oxygen cost). They have a better adaptability to variation of sewage strengths, and possibly produce less sludge than air-based plants[12]. The size of a pure oxygen plant is smaller so the resultant savings in capital cost may somehow offset the cost of the oxygen supply. High-purity oxygen plants are useful particularly to deal with relatively high strength wastes because of the increased rate of oxygen transfer. The disadvantages are that they require even a higher operation skill, besides a higher operation cost, than the conventional air-based plants. Also, with the enclosed UNOX-type plant, nitrification is rarely achieved in the process due to the effect of low pH value as a result of the presence of CO_2 in the mixed-liquor[22].

A deep-shaft plant consists of two vertical shafts (one called downcomer and one called riser) which are sunk 40 to 150 meters underground. Air is injected into the downcomer at a sufficient depth to cause the mixed-liquor to circulate at a velocity of 1 to 2 m per second[11]. The non-aerated section above the downcomer air injection position has a lower voidage and therefore a higher density than the corresponding section of the riser. The difference in density between downcomer liquid and riser liquid above the point of air injection produces a net driving force and hence the liquid motion in the shaft is maintained. High oxygen transfer efficiency can be achieved in deep shafts because of three reasons: (1) the high pressure (10 to 15 atmospheres) existed at the low part of the shafts, giving a 5 to 10 fold increase in solubility of oxygen, (2) the high bubble contact time of the order of 3 to 5 minutes (compared to 15 seconds in conventional air-based reactors), and (3) the high level of turbulence in the process. Deep-shafts are capable of treating sewage of high BOD strength and are more resistant to shock loads than conventional activated sludge plants. Because of the reduction of reactor volume due to their high treatment rate and of the saving in land area (shafts are usually less than 3 m in diameter although there is a tendency currently to build bigger ones), the disadvantage of their high construction cost may be offset if the land cost is high. The capital saving increases with the increase in plant size. Power consumption by deep-shafts compares favourably with conventional air-based plants. Lower sludge production rate is achieved. Also, no primary treatment is required for deep-shaft plants. It is, however, more difficult in separating sludge during secondary settlement[3], and it requires a very high standard of technical ability from the operators in order that the process be successfully monitored and controlled.

Activated sludge systems are more effective in removing viruses than trickling filters and up to 90% removal efficiency can be achieved[9]. Similar efficiency is also reported for removing bacteria. In respect of the removal of helminth eggs and protozoal cysts the activated sludge process is, however, inferior to biofiltration, but a considerable proportions of the eggs may be removed in the secondary clarifiers. On the whole, effluents from activated sludge plants are of marginally better quality than those produced by biofilters, but still contain significant numbers of any pathogen found in the raw sewage[9].

2.6 Small Treatment Plant

Small treatment plants are usually specially designed plants tailored to treat wastewaters from small communities of perhaps 5000 population equivalent or less. There are rotating biological contactors (or RBC), oxidation ditches and package activated sludge plants. The RBC is actually another form of fixed-film biological process, similar to biofiltration, while the other two are in fact modifications of the activated sludge process. They will be discussed in turn below.

Instead of dosing settled sewage onto stationary media (ie. conventional biofiltration), rotating biological contactors use a moving media (rotating discs) to contact the "stationary" sewage contained in tanks. It is a form of secondary treatment process. Vertical discs (1 to 4 m in diameter) mounted on horizontal shafts are partially submerged in the sewage so that organisms may adhere to the discs surfaces where they multiply. Due to the rotation (0.5 to 3 revolutions per minute) of the discs, the biological slimes adhering to them are alternatively exposed to the atmosphere and then to the wastewater, thus are provided with both fresh nutrient and an oxygen supply. Usually, several discs units (3 to 5) are put in series and plug-flow characteristics enhance the efficiency of the system. Secondary settlement is required after the process. RBCs are simple to operate and require little maintenance or supervision and hence require low operating and power costs. Capital costs can also be low in some parts of the world (e.g. Taiwan, Hong Kong and Thailand). With the increasing popularity of RBC plants, the discs are being manufactured through mass production (e.g. in China and Taiwan) so that the capital costs tend to go down substantially. Yet, they are capable of producing very good quality effluents. This treatment process is increasingly employed these days and the use of it is sometimes not limited to populations of less than 5000 persons. Pathogen removal by RBCs has not been studied but it is believed that it is about the same as for biofilters.

The Oxidation ditch is a modification of the activated sludge process. Aeration time for oxidation ditches is usually extended so that only a small quantity of surplus sludge is produced which requires handling. The ditches are race-course shaped tanks usually of about 1.5 m depth and between 2.5 to 4 m wide in which preliminarily treated crude sewage is aerated and circulated around. Hydraulic retention times are between 1 to 2 days. Conventional oxidation ditches (or Pasveer ditches) operate with horizontally rotating aerators and were originally operated on periodic aeration, settlement and effluent withdrawal basis. Modifications such as "twin-spur", "split-channel" and "alternating double" Pasveer ditches[4,8,19] were brought into use later to allow continual effluent withdrawal from the ditches without having any secondary settlement units. If secondary settlement is used, an oxidation ditch becomes an aeration unit of conventional activated sludge process and nearly all (>95%) the secondary sludge will be returned to the ditch. Carrousel ditches run with vertical rotors instead of horizontal ones, and have greater depths (usually 2 to 3 m) than Pasveer ditches[16]. They are usually constructed together with secondary clarifiers. In general, the advantages of oxidation ditches are that primary settlement is eliminated and that sludge production is low. Secondary settlement can also be avoided in the cases of twin-spur, split-channel and alternating double Pasveer ditches. The capital cost for an oxidation ditch plant is relatively low due to the facts that the ditch is a simple construction and that the machinery required is relatively simple. However, the process needs a little higher technical skill and attention to operate than RBC plants. The land area required is about 20 times less than that required by a stabilization pond[17] or about 4 times more as that required by the conventional activated sludge process. The effluent usually has a pathogen content similar to that of the effluent produced by a conventional plant, although as a result of the increased retention time slightly lower survivals may be achieved[9]. Oxidation ditches, like RBCs, are now sometimes used for populations larger than 5000.

Package plants are activated sludge based and therefore are also called package activated sludge plants. Pure oxygen system (see Section 2.5) can also be incorporated in a package plant (e.g. Vitox system of British Oxygen Company). The more usual types of package plants widely used nowadays are extended-aeration system and contact-stabilization system. The former requires long aeration time (24 to 48 hours) and the latter only half an hour in the first stage (for unsettled sewage) and then 4 hours in the second stage (for reaeration of settled activated sludge). These factory-built plants can achieve a high treatment efficiency and the performances are designed to be less sensitive to regular maintenance than conventional activated sludge plants[17]. Yet, the technical ability required to run these plants is still fairly high --- higher than both the RBC plants and the oxidation ditches. Saving in capital cost (but not operating cost), however, is possible because the components are standardized and produced in mass. Such plants are perhaps appropriate for small incoming sewage flows where conventional activated sludge treatment plant construction is not suitable. The pathogen removal efficiency for these plants has not been reported but it is believed to be similar to that of conventional activated sludge process.

2.7 Land Application

Land application is any treatment technique which utilizes the interactions between natural soil and vegetation and wastewaters to upgrade the quality of the wastewater. It can be classified into three main techniques: irrigation, overland flow and infiltration / percolation[8,15].

For irrigation, wastewater is applied to the land; being either evaporated, transpired, incorporated into plants, or percolated into the subsoil. Primary sedimentation is the minimum preapplication treatment which is usually provided[15]. Therefore, the wastewater applied to the land for irrigation usually passes through either a primary clarifier, septic tank or anaerobic pond before application. If the soil is suitable, salable crops may be grown and harvested, the income from which will partially offset the cost of treatment. The wastewater (or irrigation water) can be applied by spraying from fixed or moving sprinklers, by ridge-and-furrow spreading, or by border-strip flooding[8]. The groundwater level must be at least 0.75 m from land surface[15].

For overland flow, wastewater is fed onto and allowed to flow across gently sloping areas covered with natural vegetation but below which the subsoil is impervious. Primary treatment for the wastewater is optional in overland flow application(15). Biological treatment occurs as the wastewater contacts with the vegetation and the soil. The treated wastewater is then collected in ditches at the lower end of the ground for either discharge or reuse. The vegetation produced is not usually harvested(18), and grasses or pasture are usually preferred to cash crops as they are more deeply rooted and are more permanent in covering the land(8). Groundwater level is not a critical factor when this technique is used(15).

With the infiltration / percolation technique, wastewater is applied to permeable soils. Primary treatment, like irrigation, is usually necessary in applying this technique(15). The treatment occurs as it percolates through the soil. Wells may be installed to intercept the treated wastewater which is then extracted for reuse. A high level of wastewater purification can be achieved by the method. Vegetation growth is usually not encouraged in this technique(18). Groundwater level must be at least 3 m below the surface; lesser depths may be acceptable if underdrainage systems are provided(15).

Loamy soils are best for irrigation; clays or clay-loams are best for overland flow; and well drained sandy soils are best for infiltration/percolation. Usually, a very large land area is required in applying land treatment techniques. About 11 to 21 Ha per 1000 m^3/day is required for irrigation, 3 to 12 Ha for overland flow and 2 to 6 Ha for infiltration/percolation[8]. Therefore, the techniques require even a much larger area than stabilization ponds, which, for the same treatment capacity (ie. 1000 m^3/day), require about 1.5 Ha to 3 Ha of land. It should be noted that the constituents retained in the soil may accumulate to certain levels so that rest periods (about 2 to 3 weeks) are essential to allow the accumulated biodegradable organic matter to be broken down. It is possible that after a long period of time, when the toxic constituents retained in the soil have accumulated to intolerable levels, the land is no longer suitable for further wastewater application. This is another drawback of land application technique, besides the potential of creating polluted environment, ground water contamination and health hazards by improper management. Isolation from the public, therefore, is desirable when the techniques are used.

The land application techniques (all the three) are very efficient in BOD_5 and s.s. removals, and are efficient in removing nitrogen and phosphorus. Bacteria and viruses will also be removed[18]. Protozoa and helminths are not reported but it is believed that they will also be removed by passing through soils. On the whole, high pathogen removal efficiency can be achieved by the techniques. It is necessary to be aware, however, that land application (especially irrigation) may lead to the creation of a foul and unsanitary bog if poorly managed, resulting fly/mosquito nuisance. A high level of technical control is therefore essential.

2.8 Tertiary Treatment

Tertiary treatment is a collective name given to the process used to improve the quality of secondary effluents from conventional treatment plants. BOD_5 and s.s levels of the secondary effluents can be substantially reduced following tertiary treatment. Rapid sand filtration is one of the tertiary treatment techniques and is usually applied in large treatment works. It has been conventionally operated at hydraulic loadings of between 120 to 140 $m^3/m^2/day$ [14] but higher rates are now commonly employed. The filter consists of a bed of sand (1 mm to 2.5 mm grading) of about 1.5 m depth supported on an under-drainage system provided with facilities for back-washing. Reduction in s.s. ranges from 65% to 85% with an associated BOD_5 removal of about 50% from a secondary effluent[14]. Because of the short retention time, little biological activity occurs and thus the technique is not expected to achieve much nitrification or pathogen removal.

Slow sand filtration, another tertiary treatment technique, which has been employed in small works, is operated at a hydraulic loading of only 3.5 to 7

$m^3/m^2/day$[24]. The filters are usually about 0.5 m deep, consisting of a layer of sand resting on a layer of coarse aggregates which in turn rests on a system of drainage pipes. Construction is simple and hence cheaper than that of the rapid sand filter because no back-washing facilities are required. The land area needed, however, is very much larger than that needed by the rapid sand filter. Slow sand filters also require lower operation and maintenance costs and lesser attention than that for rapid filters. They can be expected to remove 65% to 90% of s.s. and 65% to 75% of BOD_5 from a secondary effluent[24]. Significant biological activity occurs in these filters and therefore high pathogen removal efficiency (usually above 90%) can be achieved[24].

Microstraining, a tertiary treatment technique too, is good for removing s.s. but less good for BOD. Reported removals range from 35% to 75% s.s. and 12% to 50% BOD_5[20]. Little pathogen removal can be expected from microstraining. It is, therefore, not a very efficient "polisher" of secondary effluents from this point of view. The advantage of using microstrainers is that they need only very small installation space and can be easily placed under cover, thus rendering them suitable for large works.

Other tertiary treatment techniques include **upward-flow clarification** (pebble bed clarifiers), **land treatment** (overland flow on grass plots or infiltration for collection in underdrains[9]) and maturation lagooning. Tertiary treatment processes were not originally designed for pathogen removal but for "polishing" secondary effluents, particularly for the removal of residual suspended solids. However, some of them (slow sand filtration, land treatment and maturation lagooning) do have very good pathogens removal characteristics.

Another advance in effluent polishing is the use of nitrifying filters. In certain treatment processes (e.g. high-purity oxygen system or deep-shaft) only carbonaceous oxidation is achieved but not nitrification. In order to upgrade the secondary effluent and to nitrify it completely, nitrifying filters may be employed. They are similar to conventional biofilters but are deeper (or taller), being about 3.5 to 4 m in depth. The increased depth is acceptable because of the low content of the carbonaceous biodegradable material in the effluent applied to the filters which limits the demand for oxygen in the process compared with that of orthodox biofiltration. For the same reason, finer grades of media can be used in the filters. Nitrifying bacteria (different from those for carbonaceous oxidation) will grow on the media, but unlike conventional biofilters, blockage of filters as a result of excessive built-up of biological slime will rarely occur. It is supposed that the pathogen removal efficiency for nitrifying filters is low.

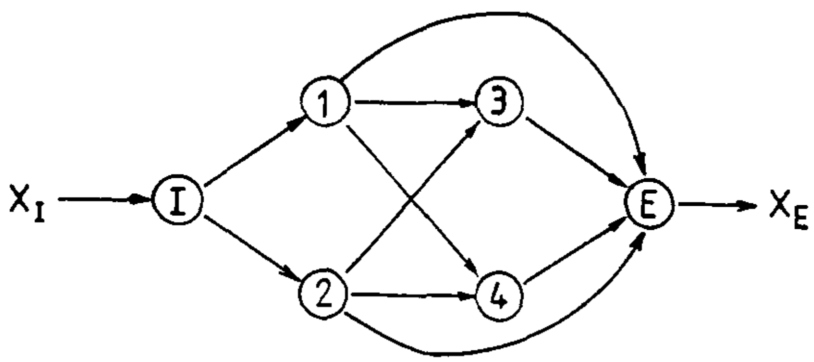
Other advanced tertiary treatment techniques include chemical clarification, recarbonation, activated carbon adsorption and regeneration, demineralization (reverse osmosis, electrodialysis and ion exchange) and so on[5,20]. Since these latter techniques are rarely necessary and generally not cost-effective for large scale use in treating municipal wastewater (at least in the context of this research), they will not be discussed and will not be considered in the proposed model contained in this thesis.

The above is a brief survey of existing wastewater treatment techniques which are commonly used. The formation of decision variables/treatment alternatives (see chapter 4) for the proposed optimization model will be based on these various techniques. In the next chapter (ie. Chapter 3), a survey of the existing treatment system optimization models will be made.

CHAPTER 3 --- SURVEY OF EXISTING MODELS

3.1 Linear Programming Optimization

There are quite a number of optimization approaches in wastewater treatment alternatives selection which have been developed over the past twenty-six years. Lynn, et. al.(17) were the first, in 1962, who attempted to use the method of operations research or system analysis techniques to optimally select treatment processes for a wastewater treatment plant. In this first attempt, a linear programming model was used to optimize treatment alternatives at minimum total costs. From the result of the analysis, one may be able to select the most cost-effective treatment alternative or alternatives. The example given in this paper is most famous and historic and is therefore worthwhile to be reproduced in Fig. 3.1 below:



(Node I: influent, Node 1: primary sedimentation with 850 gpd/ft², Node 2: primary sedimentation with 1700 gpd/ft² Node 3: activated sludge, Node 4: percolating filter, Node E: effluent)

Fig. 3.1: Linear Programming Model on Treatment Process optimization by Lynn, et. al.

The linear programming model for such a system is:

Minimize $$T_C = \sum_{j=1}^{4} C_{jj'} (X_{jj'} \; \varepsilon_j)$$

subject to:

$$\sum_{j} X_{Ij} = X_I \quad ; \quad j = 1,2$$

$$\sum_{i} X_{iE} \leqslant X_E \quad ; \quad i = 3,4$$

$$\sum_{i \neq j} X_{ij} - X_{jj'} = 0 \quad ; \quad j = 1,2,3,4$$

$$(1 - \varepsilon_j)\, X_{jj'} - \sum_{k \neq j} X_{jk} = 0 \quad ; \quad j = 1,2,3,4$$

and $X_{ij} \geqslant 0$

where

T_C = total costs

$C_{jj'}$ = cost to treat 1 kg of BOD applied to the jth process.

$X_{jj'}$ = the quantity of BOD (in kg) applied to the unit process j.

X_{ij} = the quantity of BOD (in kg) flowing from process i to process j.

ε_j = the fraction of BOD removal in process j.

X_I (influent BOD) and X_E (effluent BOD standard) are given quantities.

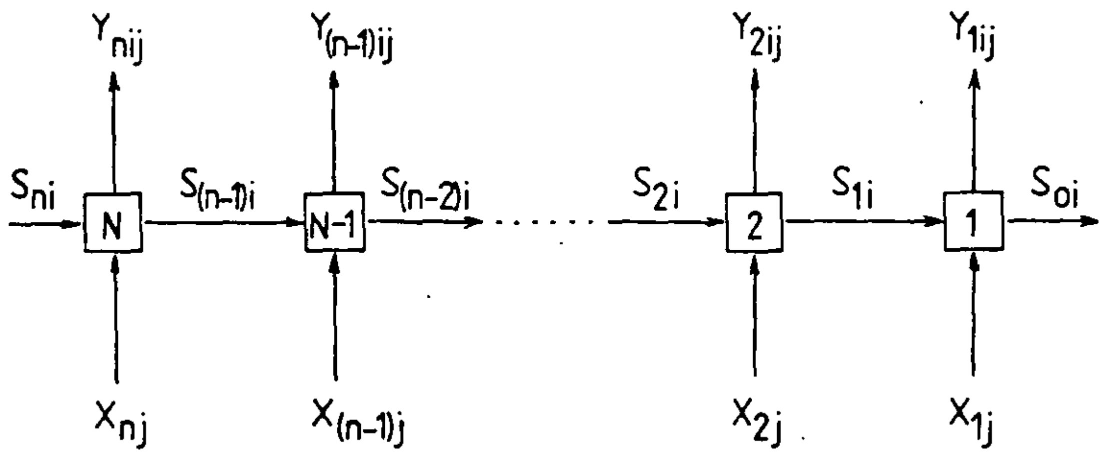
The model can, of course, be solved by any one of the many computer packages available on the market for analyzing linear programming problems. The solution for the example was that only primary sedimentation with 850 gpd/ft^2 (Node 1) should be used for meeting the required standard with which the processing cost could be reduced to a minimum.

Lynn, after two years, in 1964, developed a further linear programming model[18] for capital budgeting of sewage treatment plant construction. The objective of this model was to minimize treatment cost throughout the history of the project. The solution of the model indicated for each increment of time (a) the type and increment of treatment to be constructed, (b) the amount of funds available, (c) the amount of funds needed to be borrowed, (d) a per capita service charge, and (e) the schedule for investment of funds. It is more of a financial model than a process selection one and is therefore not to be further discussed.

3.2 Dynamic Programming Optimization

Linear programming techniques were soon found to be not a good tool for treatment processes optimization due to the fact that wastewater treatment formula, either rational or empirical, are usually non-linear. Dynamic programming, instead, began to gain popularity in this emerged field of interest.

In contrast to linear programming, there is no standard formulation of a specific dynamic programming problem[14]. It is a strategy of optimization that simplifies the decision-making process for a serial system (or system in stages). The procedures in dynamic programming suitable for analyzing wastewater treatment serial systems can, however, be generalized as shown in Fig. 3.2[12]:



(S = input state, X = decision variable, Y = return)

Fig. 3.2: Diagrammatic Presentation of A Dynamic Programming Problem

Each step at which a decision is made is called a stage and there are N stages in the diagram. For each stage a return, Y_{nij} (n = 1,2,...N), serves as the objective function in the optimization. In wastewater treatment alternatives optimization, the objective is usually to minimize the treatment cost. According to the Bellman's principle of optimality [1], a serial system is optimized when its downstream components are suboptimized with respect to the feed they received from upstream.

Starting from Stage 1 (see Fig. 3.2), an input state S_{11} is assumed and held constant while the decision variable X_{1j} is varied. For each value of X_{1j}, there will be an associated return Y_{11j}. The minimum cost m_{11} is the minimum of the values of Y_{11j} for different X_{1j}, and m_{11} is associated with decision $X_{1j'}$. If the above procedure is repeated for a number of different input states S_{1i}, the result will be information that gives the minimum costs m_{1i} as a function of the input state, and each value of m_{1i} will have associated with it a decision $X_{1j'}$.

After the suboptimization of Stage 1, Stage 2 must be suboptimized with respect to, firstly, the input state S_{21}. From the information, giving m_{1i} as a function of S_{1i}, the value of m_{1i} associated with each decision X_{2j} made in Stage 2 can be found. The total return associated with each decision X_{2j} is the return of Stage 2, Y_{21j}, plus the minimum return of Stage 1, m_{1i}. Having obtained $Y_{21j} + m_{1i}$ for a number of values of X_{2j}, the minimum value m_{21} (ie. minimum of $Y_{21j} + m_{1i}$) can be selected. If the procedure is repeated for a number of input states S_{2i}, the result will be information that gives the minimum costs of stages 1 and 2 together, m_{2i}, as a function of S_{2i}, with each value of m_{2i} associated with it a decision $X_{2j'}$.

The above will be repeated until all stages have been considered. When stage N is reached, the result will give the minimum cost of the entire system as a function of the input state S_{ni}. If S_{ni} is fixed (ie. a given quantity), the minimum overall process cost is also fixed and the optimal decision for stage N and all the others are known.

Grady[12] gave an example, in his paper of 1977, of the application of dynamic programming to optimize an activated sludge process as shown in Fig. 3.3 below:

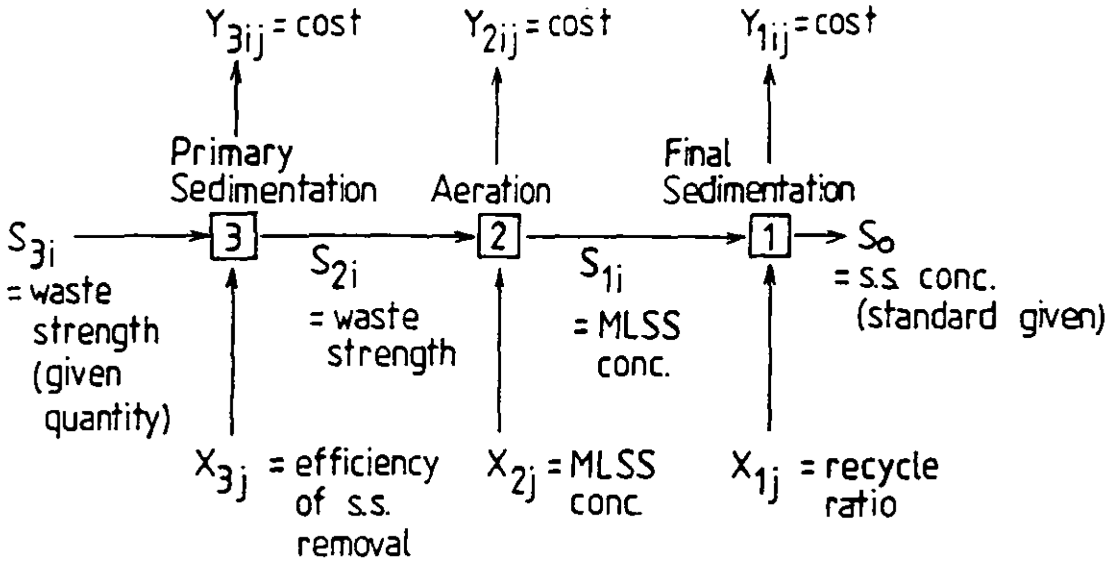


Fig. 3.3: Process Optimization Using Dynamic Programming

The method of solution, as already described, can be expressed mathematically as follows[3,4]:

$$Y_{nij} = Y_n(X_{nj}, S_{ni})$$

$$S_{(n-1)i} = T_n(X_{nj}, S_{ni})$$

where

Y_n = the cost function of nth treatment process

T_n = the performance function of nth treatment process

n = 1,2,..... N (N=3 in this particular example)

If Y = total system costs, then

$$Y = \sum_{n=1}^{N} Y_{nij}$$

$$= \sum_{n=1}^{N} Y_n(X_{nj}, S_{ni})$$

If B_m is defined as the total subsystem costs up to stage m such that

$$B_m = \sum_{n=1}^{m} Y_n(X_{nj}, S_{ni}) \quad ; \qquad m=1,2,\ldots,N$$

then $\quad B_m = B_m(X_{1j}, X_{2j}, \ldots, X_{mj}, S_{mi})$

and $\quad B_m = Y_m(X_{mj}, S_{mi}) + B_{m-1}(X_{1j}, X_{2j}, \ldots, X_{(m-1)j}, S_{(m-1)i})$

Let $G_m(S_{mi}) \leqslant B_m(X_{1j}, X_{2j}, \ldots, X_{mj}, S_{mi})$ in which $G_m(S_{mi})$ is the optimal total m-stage subsystem costs with input S_{mi} and

$$G_{m-1}(S_{(m-1)i}) \leqslant B_{m-1}(X_{1j}, X_{2j}, \ldots, X_{(m-1)j}, S_{(m-1)i})$$

Now, $G_m(S_{mi})$ can be expressed mathematically as:

$$G_m(S_{mi}) = \underset{X_{mj}}{\text{Min}}\{Y_m(X_{mj}, S_{mi}) + G_{m-1}(S_{(m-1)i})\}$$

or $\quad G_m(S_{mi}) = \underset{X_{mj}}{\text{Min}}\{Y_m(X_{mj}, S_{mi}) + G_{m-1}[T_m(X_{mj}, S_{mi})]\}$

and for the entire system, the optimal treatment costs, Y_{min}, will be:

$$Y_{min} = \underset{X_{Nj}}{\text{Min}} \{Y_N (X_{Nj}, C) + G_{N-1} [T_N (X_{Nj}, C)]\}$$

where $\quad S_{Ni} = C =$ a given quantity (usually the quality of incoming sewage to plant)

In using dynamic programming, one trend has been to optimize the design of a single and prefixed system of treatment processes, such as Grady's work(12). The other trend has been to optimize treatment systems by selection from among many alternative processes, such as the works by Chia & Krishnan(4) (1969), Evenson, et. al.(11) (1969), and Chia & DeFilippi(3) (1970).

In Chia & DeFilippi's dynamic programming, percentage of BOD removal was used to be the input state S_{2i} at stage 2 at which treatment alternatives were to be selected. Alternative treatment processes with a range of treatment efficiency for each process were used as the decision variables X_{2j}. The results obtained from the dynamic programming model would indicate the type of treatment alternative that would give the minimum total costs.

In Evenson's model, 11 alternative treatment processes were tested. They were: (a) sedimentation, (b) chemical precipitation, (c) chemical oxidation, (d) trickling filtration, (e) activated sludge, (f) aerated lagoon, (g) aerobic ponds, (h) facultative ponds, (i) anaerobic ponds, (j) spray irrigation, and (k) evaporation ponds. The model was applied a number of times to different flow conditions: plant sizes from 0.5 mgd to 8.0 mgd. In contrast to Chia & DeFilippi's model, percentage of BOD removal was used as decision variable X_{nj} and s.s. as input state S_{ni}. The objective was, of course, to minimize total treatment costs.

3.3 Non-linear Programming Optimization

Another approach, besides linear programming and dynamic programming, for treatment processes optimization is non-linear programming (or called mathematical programming in general). Mathematical programming models for optimizing problems involving treatment costs can be generalized in the following format[19]:

$$\text{Minimize } Z = f(X_1, X_2, \ldots, X_n) \qquad \text{----------(0)}$$

subject to

$$g_1(X_1, X_2, \ldots, X_n) \leqslant L_1 \qquad \text{-----------------(1)}$$

$$g_2(X_1, X_2, \ldots, X_n) \geqslant L_2 \qquad \text{-----------------(2)}$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \vdots$$

$$g_m(X_1, X_2, \ldots, X_n) = L_m \qquad \text{-----------------(m)}$$

Equation (0), the objective function (or the cost function) is equal to the total costs of the wastewater treatment system. The total costs is the sum of the capital costs and the present worth[21,25] of the annual operation and maintenance costs for a given discount rate and time horizon [24]. The decision variables X_1, X_2, ..., X_n, are quantities describing the system such as tank volumes, solids concentrations, detention times, and so on.

Equations (1), (2),..., (m) are constraint equations which set limits for the performance functions of the decision variables. They are derived from limitations on equipment, space and other scarce resources, effluent quality standard, and from mathematical descriptions (either rational or empirical) on various unit process performances.

Different researchers, such as Middleton & Lawrence [19] (1976), CIRIA [2,5,6,7] (1976), Lauria, et.al.[15] (1977), Craig,et.al.[8] (1978), Rossman[22] (1980), Narbaitz & Adams[20] (1980) and Dick[9] (1984), used different cost functions in formulating the objective function as well as different performance functions in formulating constraints. However, all models have a common feature that there is an objective function which minimizes total treatment costs followed by constraints which are mathematical expressions describing treatment performances and so on. These cost functions and performance functions can be found in the works by Smith[23] (1969), Lawrence & McCarty[16] (1970), U.S.E.P.A.[26] (1975), WRC[27] (1977), Craig, et.al.[8] (1978), and Hasit & Vesilind[13] (1981).

With the exception of Lauria's model which simply used the calculus of Lagrangian analysis for solutioning, all the models required the use of computer oriented optimization techniques such as Box-Complex algorithm (Craig, et.al.), RSSRSSR* (Narbaitz & Adams), and Powell's hill-climbing algorithm (CIRIA and Dick).

It is worthwhile to note that all non-linear programming models developed before Rossman (1980) were for optimizing the design of a single pre-structured stream of

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* Random Search with Systematic Reduction of the Size of Search Region

treatment system. They were not used to optimize systems by selecting alternative treatment process streams. Only until Rossman and later researchers, the models developed were capable of selecting optimal treatment alternatives. This was accomplished by the introduction of zero-one decision variables in the constraints so the problems become one of non-linear integer programming. Assuming that there are N stages in the treatment system with J alternative treatment processes at any stage i available for selection, and z_{ij} be a decision variable whose value is 1 if alternative j is chosen at stage i and is 0 otherwise, then the mathematical formulation can be generalized in the following form[22]:

$$\text{Minimize } T_C = \sum_{i=1}^{N} \sum_{j=1}^{J} z_{ij} \, C_{ij}$$

subject to

$$X_{i+1} = \sum_{j=1}^{J} z_{ij} \, f_{ij} \, (X_i) \qquad ; \qquad i = 1,2,\ldots,N$$

$$S_i = \sum_{j=1}^{J} z_{ij} \, g_{ij} \, (X_i) \qquad ; \qquad i = 1,2,\ldots,N$$

$$X_{L+1} = \sum_{i=1}^{L} S_i$$

$$X_1 = X_0 + \sum_{i=L+1}^{N} S_i$$

$$\sum_{j=1}^{J} z_{ij} = 1 \qquad ; \qquad i = 1,2,\ldots,N$$

$$z_{ij} = 1 \text{ or } 0 \qquad ; \qquad i = 1,2,\ldots,N \ \& \ j = 1,2,\ldots,J$$

where

T_c = total costs

L = number of stages which belong to the liquid treatment (there is a stream of L stages for liquid treatment and another of (N-L) stages for sludge treatment while the sidestreams from sludge treatment are returned to head of the plant)

X_i = influent quality to stage i

X_{i+1} = effluent quality from stage i (or influent quality to stage i+1)

S_i = quality of sidestream from stage i (to sludge treatment stream)

f_{ij} = performance function describing how X_i is changed to X_{i+1} at stage i if alternative j is chosen

g_{ij} = performance function describing how X_i is changed to S_i at stage i if alternative j is chosen

C_{ij} = cost incurred by choosing alternative j at stage i (C_{ij} is a function of X_i and X_{i+1})

X_0 = incoming wastewater quality to the plant (given)

The first two constraints express the stage-wise transformation of influent waste flows and the generation of sidestreams. The third constraint expresses the influent to the sludge treatment stream as the sum of the sludge sidestreams generated in the liquid treatment stream. The fourth constraint closes the loop by adding the sludge treatment sidestreams to the plant influent. The last two constraints model that only one alternative is chosen at each stage. Constraints on effluent discharges are not shown in the above but should be included in an actual model so that the effluent standard is regarded as a fixed design parameter rather than a variable. A computer package called "EXECUTIVE" developed by U.S.E.P.A.[10] was used by Rossman to solve the non-linear integer programming model and the optimal stream of treatment alternatives was found. Such an approach overcomes the limitation that the system structure (ie. choice of treatment processes) be prefixed as it operates on a discrete set of candidate treatment alternatives.

3.4 The Proposed Model

An extensive survey on the development of treatment system optimization models has been made. A summary of it is shown on Fig. 3.4 (see next page). It can be seen that the accuracy and the degree of sophistication of the models increases with time as the theory of treatment and the mathematical tools for system analysis progress in the past twenty-six years. It is the opinion of the author that researchers who attempt to improve significantly the latest existing models based on the same techniques will most likely only waste their efforts in view of the already well developed state of the art. A break-through can be made only if a different mathematical technique (system analysis other than linear programming, dynamic programming or non-linear programming) or a different approach, if more basically, were applied.

Authors	Year	Technique	With treatment alternatives selection
Lynn, et.al.	1962	Linear programming	Yes
Chia & Krishnan	1969	Dynamic programming	Yes
Evenson, et.al.	1969	Dynamic programming	Yes
Chia & DeFilippi	1970	Dynamic programming	Yes
Middleton & Lawrence	1976	Non-linear programming	No
CIRIA	1976	Non-linear programming	No
Lauria	1977	Lagrangian analysis	No
Grady Jr.	1977	Dynamic programming	No
Craig, et.al.	1978	Non-linear programming	No
Rossman	1980	Non-linear programming	Yes
Narbaitz & Adams	1980	Non-linear programming	Yes
Dick	1984	Non-linear programming	Yes

Fig. 3.4: Summary of Treatment System Optimization Models

A common drawback of the existing models is that none of them considers other objectives besides minimizing cost. They are excellent models, of course, if cost minimization is to be achieved under perfect performance conditions for which can they be represented by a full set of mathematical relations. However, reality is more than a set of mathematical expressions. The questions now are: would it be possible to develop a model, though it may be one from a completely different approach, which considers other very basic factors affecting the optimal selection of treatment alternatives? Would it be possible to produce a model which includes some investigation into environmental, social, cultural etc. factors which are most important contributing factors towards successful plant performance? Could there be a model for preliminary selection of optimal treatment alternatives by considering, besides cost, the motives, drives, abilities and discipline of the people who construct, operate and use the treatment plant? The following chapters will describe a model of this kind and it is the hope of the author that it represents a breakthrough in both the approach and the application of treatment system optimization models.

PART 2

DEVELOPMENT OF MODEL

CHAPTER 4 --- PARAMETERS & DECISION VARIABLES

4.1 Problem Definition

In a similar manner to that employed in existing models, there are one set of parameters and one set of decision variables in the proposed model. The parameters are no longer merely flow rates, BOD or MLSS etc. but are more general or basic descriptions of technical, economic, social, environmental and cultural factors affecting the appropriate choice of treatment processes. The decision variables, likewise, are no longer just retention time or percentage of BOD removal etc. but are definite candidate treatment alternatives from which the optimum one is to be selected.

In the proposed model, the quantity and quality of influent and the effluent standard required will be given; the size and location of the site on which the plant is to be built will also be given. The problem is to select an optimal wastewater treatment alternative.

In the following sections, full sets of parameters and decision variables for the model will be discussed.

4.2 Parameters

4.2.1 Identifying and Describing The Parameters

There are 20 parameters in the model. They are:

1. Flow
2. Influent / Effluent
3. Size of site
4. Nature of site
5. Land cost
6. Local money for construction
7. Foreign money for construction
8. Local skill for construction
9. Community support
10. Power source
11. Availability of local material
12. Cost of operation and maintenance
13. Professional skill available for operation and maintenance
14. Local technical skill available for operation and maintenance
15. Administration set-up
16. Training
17. Professional ethics
18. Climate
19. Local water-borne diseases
20. Endemic vector-borne (water-related) diseases

Each of the parameter above is associated with a set of indicators which give detailed explanations on the relevance of the parameter. The indicators corresponding to each parameters are listed below:

Parameters	Indicators
1. Flow	a. Maximum design flow
	b. Variation in flow on daily basis
	c. Variation in flow on long term basis (present and future)
2. Influent/Effluent	a. Strength of influent
	b. Variation of influent strength on daily basis
	c. Variation of influent strength on long term basis
	d. Effluent standard required
3. Size of site	a. Size of land available
	b. Possibility of future extension
4. Nature of site	a. Topography
	b. Possibility of flooding
	c. Proximity to sludge disposal facilities
	d. Ground water level
	e. Proximity to municipality
5. Land cost	a. Cost of land for plant construction

6.	Local money for construction	a.	Cost of construction in local currency
		b.	Availability of fund
7.	Foreign money for construction	a.	Cost of construction in foreign currency
		b.	Availability of fund
8.	Local skill for construction	a.	Availability of local skill
		b.	Level of local skill
9.	Community support	a.	Religion or tradition affecting hygiene practices and technology choice
		b.	Willingness and enthusiasm of community / politician to improve the existing wastewater treatment facilities
		c.	Educational level of the general public and their attitude towards public health
10.	Power source	a.	Availability of power source
		b.	Reliability of power source
11.	Availability of local material	a.	Availability of local material and components for plant operation and maintenance
		b.	Ease of obtaining the components
12.	Cost of operation and maintenance	a.	Continuing availability of operation and maintenance fund

13.	Professional skill available for operation and maintenance	a.	Availability of professional skill to operate works
		b.	Level of professional skill to operate works
14.	Local technical skill available for operation and maintenance	a.	Availability of local technical skill to operate works
		b.	Level of technical skill to operate works
15.	Administration set-up	a.	Ability of local administration set-up to adequately support the work's operation
16.	Training	a.	Likelihood of upgrading or at least maintaining present professional skill level
		b.	Level of training at present for professionals
		c.	Likelihood of upgrading or at least maintaining present technical skill level
		d.	Level of training at present for technicians
17.	Professional ethics	a.	Commitment to the job of professionals
		b.	Commitment to the job of technical staff and supporting staff
18.	Climate	a.	Average monthly maximum temperatures and average monthly minimum temperatures in a year
		b.	Intensity and amount of rainfall

		c.	Length of dry season
		d.	Intensity and duration of sunshine
19.	Local water-borne diseases	a.	Infectious hepatitis
		b.	Diarrhoeal diseases
		c.	Cholera, typhoid
		d.	Amoebic dysentery
		e.	Human round worm and hook worm, fish-borne parasites (Clonorchiasis), Schistoso miasis (Bilharzia)
20.	Endemic vector-borne (water-related) diseases	a.	Yellow fever
		b.	Malaria
		c.	Filariasis

The above 20 parameters will be the basis for the selection of the most appropriate treatment alternative. The selection process will utilize a recently developed operations research technique named eigenvector prioritization which will be explained in the next chapter (Chapter 5). The most appropriate alternative is to be selected from a set of decision variables which are definite candidate treatment processes and will be described in Section 4.3.

4.2.2 Significance of The 20 Parameters

The parameters were selected based on (1) the experience of the author, (2) the ideas gained from reading

References 1 to 9 of this chapter and (3) the advice of the author's research supervisor. The 20 parameters were obtained from a synthesis of the three.

Parameters 1 to 4 are technical factors. The design flow (Parameter 1) affects significantly the choice of treatment methods. For example, a large flow (e.g. 100,000 m^3/day) may not be suitable for treatment by small/package plants or stabilization ponds. On the contrary, a small flow (e.g. 100 m^3/day) is not suitable to be treated by activated sludge deep shaft process. Variation in flow or shock flows can be accepted by certain treatment methods but vulnerable to others; the monsoon climate in some tropical situations can lead to shock flows if the combined sewerage system is used or if the separate sewerage system is poorly constructed (leakage). Treatment efficiency (Parameter 2) is an importance consideration too. Primary treatment, for instance, will not be able to satisfy the requirement if a high standard of treatment is required. Variation in strength of influent or shock loads can be more adaptable by some treatment methods but less by the others. This is particularly significant when the influent is a mixture of industrial and municipal wastewaters. Size of site (Parameter 3) is, without question, another very basic and essential technical consideration, as some treatment alternatives (e.g. stabilization ponds and land applications) cannot be applied in small sites. Nature of the site (Parameter 4) where the treatment plant is to be built is also a technical factor. For example, a site with high ground water table is not suitable for constructing ponds or applying infiltration (land treatment), nor these alternatives are suitable to be adopted to build on sites which are not isolate enough. Whether the site is near to sludge disposal sites also affects the choice, for certain treatment alternatives (e.g. ponds) do not require regular sludge disposal and hence are more advantageous than other methods in that respect.

Parameters 5 to 7 are economic factors concerned with capital cost. Land cost (Parameter 5) is considered separately from construction costs (Parameters 6 and 7) because it may represent a significant part of the capital cost and so merits an individual consideration. If the land cost is high, those treatment methods requiring large land area (e.g. ponds and land treatment) are less suitable. High purity oxygen activated sludge or deep shaft plants which require much less land area are probably more appropriate in situations where land cost is extremely high. Local money for construction (Parameter 6) in general refers to the cost of civil engineering works incurred in local currency and that of equipment supplied locally to build the plant. Foreign money (Parameter 7) for purchasing imported equipment may form an important component of the construction costs for certain more sophisticated treatment alternatives. It is considered separately from the construction cost incurred in local money because this parameter may be crucial for situations in which there is a lack of foreign currency or stringent control of foreign exchange.

Local skill for construction (Parameter 8) is a subjective factor because skill is something difficult to quantify. The complexity of the construction techniques required for building a wastewater treatment plant must be compatible with the level of the local skill available for the construction. This factor is important in order to avoid later troubles arised from bad construction (e.g. leakage etc.) when the plant is in operation.

Community support (Parameter 9) is a social factor. It is concerned with the attitude of the users of the treatment facilities, which, in some cases, is decisive for their successful operation. Whether or not the politicians are enthusiastic enough to improve such "less visible" infrastructure in the country? Whether or not the general public are willing to accept the facilities and to pay the price for living in a better environment in order that the recurrent expenditure for the latter can be covered? Are there any religious inhibitions and/or traditions which do not favour the choice of certain technology? These are factors which, though indirectly related to the problem, should be considered.

Parameters 10 to 14 are factors related to operation and maintenance. The availability and reliability of power supply (Parameter 10) to the treatment plant are most basic to certain more advanced treatment techniques and are therefore of paramount importance as the selection criteria. The availability of local material and components (Parameter 11) is essential for plants to be built in remote sites, particularly in developing countries. The availability of construction materials (e.g. pipes, cement etc.) for plant maintenance and the ability to make locally the mechanical parts of the machinery used in the plant, or if not, the ease and speed of reordering them from places of origin or otherwise, can be significant in the smooth operation of a treatment plant. Operation and maintenance costs (Parameter 12) differ for different treatment alternatives. The more sophisticated treatment alternatives (e.g. high-purity oxygen plant) require much higher operation / maintenance costs than that of the less advanced ones (e.g. stabilization ponds), and therefore the former should be avoided when the funds are limited. It is not unusual that adequate funds are available for plant construction but not sufficiently for operation and maintenance (a one-time commitment is always easier than a long-term one). It is not uncommon that treatment plants do not work as planned, or do not function at all, largely due to the lack of continuing availability of operation and maintenance funds. There is a serious danger of placing too much emphasis on construction but neglecting maintenance of the works already built. This parameter, therefore, should be one of the most important considerations in the appropriate technology selection. Professional and technical skill available for operation and maintenance (Parameters 13 and 14) are again subjective factors. These parameters must be considered because the level of the treatment technology chosen must be, similar to Parameter 8, compatible with the level of the skill of the professionals and the technicians who will look after the treatment plant. The two (ie. professional and technical) are considered separately because experience reveals that there are cases where good professionals do not always have good local technical supports and vice versa.

The ability of the local administration set-up (Parameter 15) which looks after the planning and the implementation (ie. design, construction and running) of the treatment plant is another factor that should not be ignored. Whether or not there is a good liaison between those responsible for planning and for implementation for situations where these two functions are not discharged by the same body is a question of some importance. For the administration set-up which implements, whether or not those who design and construct are sufficiently aware of the problems usually faced by those who support the operation and maintenance is again a vital question. (The effectiveness of the operation and maintenance arrangements is usually a more significant test of administrative capability and poor maintenance performance is often the first signal that the administration set-up is inadequate). There are a number of additional questions that need to be considered too. Whether or not there are too many independent organizational set-ups with confused division of responsibility and authority over the implementation of the works? Whether or not those who are responsible for the supply of portable water and those for the treatment of wastewaters (the whole water cycle) are grouped under one administration? Whether or not there is a practicable legislation on water quality control with adequate enforcement of the legislation so that the design influent quality to the treatment plant will not be hampered by illegal industrial wastewater discharges? The answers to these questions will reflect whether or not the ability of the administration set-up will adequately support the work's operation. Obviously, the more sophisticated the technology of treatment is, the more effective the administration set-up will need to be.

Parameters 16 and 17 are socio-cultural factors. They are, of course, at present largely subjective factors. Training (Parameter 16) has only an indirect effect on successful plant operation but it has great long-term significance. Good plant operation must be supported by well trained staff. The education / training provided in the situation under consideration must be able to maintain / upgrade the professional / technical skill.

The fact that good training will ensure a continuing supply of good professionals and technicians for continual successful plant operation and also technology upgrading / improvement in the future is something which should not be neglected, particularly in a situation where the quality of training is declining. Professional ethics (Parameter 17) is a very sensitive parameter but is, indeed, very important in selecting appropriate treatment technology. Are the operating staff committed to their job? Do they incline to avoid responsibilities? Is it usual to find them taking unnecessarily long breaks for drinking coffee or doing irrelevant things during their working hours? On the other hand, is corruption a serious problem in the situation under consideration? Will the cost for purchasing foreign equipment, for instance, become unreasonably high or will the supply of materials be unnecessarily delayed as a result of corrupted administration? This parameter is therefore again a factor of paramount importance in the selection of appropriate treatment alternatives. It has been said that a less knowledgeable person with good ethics is no worse than a more knowledgeable one but without. The author completely agrees with this view.

Parameters 18 to 20 are environmental factors. Climate (Parameter 18) is an important consideration as certain treatment alternatives are only suitable in hot or dry climates. The prevalence of certain water-borne diseases (Parameter 19) and/or vector-borne (water-related) diseases (Parameter 20) describes the general sanitary / health conditions of a given situation and so by considering these two parameters some treatment alternatives should be avoided and some be encouraged. For example, if cholera or typhoid (diseases due to bacteria) are causing health hazard in a particular situation, then perhaps percolating filtration should be preferred rather than activated sludge process (see page 15) in order that a higher percentage of bacteria can be removed. But if infectious hepititis or diarrhoea (diseases due to viruses) are the hazard causers, then activated sludge process would be preferred to percolating filtration (see page 20) in order to remove viruses more effectively. However, treatment by stabilization ponds will be more effective for both bacteria and viruses removal than either percolating filtration or activated sludge process. In general, diseases described in Parameter 19 are transmitted mainly by contacting with waters, whereas those described in Parameter 20 are transmitted mainly by vectors. The former is significant if the effluent from the selected treatment process is likely to be in contact with people either directly or indirectly; the latter is significant if the treatment process is located near to where people live so the diseases will be easily transmitted to people by vectors. This may be a vital factor in deciding for or against the use of stabilization ponds.

The above is an initial discussion of the significance of the twenty parameters to the selection of appropriate wastewater treatment technology for a given situation. Further discussions on these parameters will be found in Section 6.3 of Chapter 6.

4.3 Decision Variables

The decision variables, as mentioned before, are sets of treatment alternatives. Altogether, 46 decision variables have been formulated. Where not otherwise stated, all of them are assumed to have included prior preliminary treatment and they are:

A. Stabilization Ponds

1. Facultative pond
2. Anaerobic pond + Facultative pond
3. Facultative pond + Maturation pond
4. Anaerobic pond + Facultative pond + Maturation pond

B. Aerated Lagoons

5. Fully-suspended aerated lagoon + Secondary settlement
6. Septic tank + Fully-suspended aerated lagoon + Secondary settlement
7. Anaerobic pond + Fully-suspended aerated lagoon + Secondary settlement
8. Fully-suspended aerated lagoon + Partially-suspended aerated lagoon

9. Septic tank + Fully-suspended aerated lagoon + Partially-suspended aerated lagoon

10. Anaerobic pond + Fully-suspended aerated lagoon + Partially-suspended aerated lagoon

11. Partially-suspended aerated lagoon

12. Septic tank + Partially suspended aerated lagoon

13. Anaerobic pond + Partially-suspended aerated lagoon

C. Biofiltration (humus tanks/final clarifier included)

14. Primary clarifier + Simple percolating filtration

15. Septic tank + Simple percolating filtration

16. Primary clarifier + Simple percolating filtration + Tertiary treatment

17. Primary clarifier + Percolating filtration with recirculation

18. Septic tank + Percolating filtration with recirculation

19. Primary clarifier + Percolating filtration with recirculation + Tertiary treatment

20. Primary clarifier + Alternating double filtration

21. Primary clarifier + Alternating double filtration + Tertiary treatment

22. Primary clarifier + High-rate filtration + Low-rate filtration

D. Activated Sludge Processes (final clarifier included)

23. Primary clarifier + Conventional activated sludge process

24. Septic tank + Conventional activated sludge process

25. Primary clarifier + Conventional activated sludge process + Tertiary treatment

26. Deep shaft

27. Deep shaft + Nitrifying filter

28. Primary clarifier + High-purity oxygen activated sludge process

29. Primary clarifier + High-purity oxygen activated sludge process + Tertiary treatment

E. Primary Settlement

30. Primary clarification

31. Anaerobic pond

32. Septic tank

F. Land Application

33. Primary clarifier + Land application

34. Septic tank + Land application

35. Anaerobic pond + Land application

36. Land Application

G. Small Plants (final clarifier included unless otherwise stated)

37. Primary clarifier + Rotating biological contactor

38. Septic tank + Rotating biological contactor

39. Primary clarifier + Rotating biological contactor + Tertiary treatment

40. Oxidation ditch without final clarifier

41. Oxidation ditch

42. Oxidation ditch + Tertiary treatment

H. Package Activated Sludge Plants

43. Package activated sludge plant

44. Package activated sludge plant + Tertiary treatment

45. Package high-purity oxygen plant

46. Package high-purity oxygen plant + Tertiary treatment

4.4 Hierarchical Structure of Decision Variables

The hierarchy of the decision variables has, in fact, already been partly reflected in the above listings. A diagram (Fig. 4.1) is drawn to show the hierarchical structure:

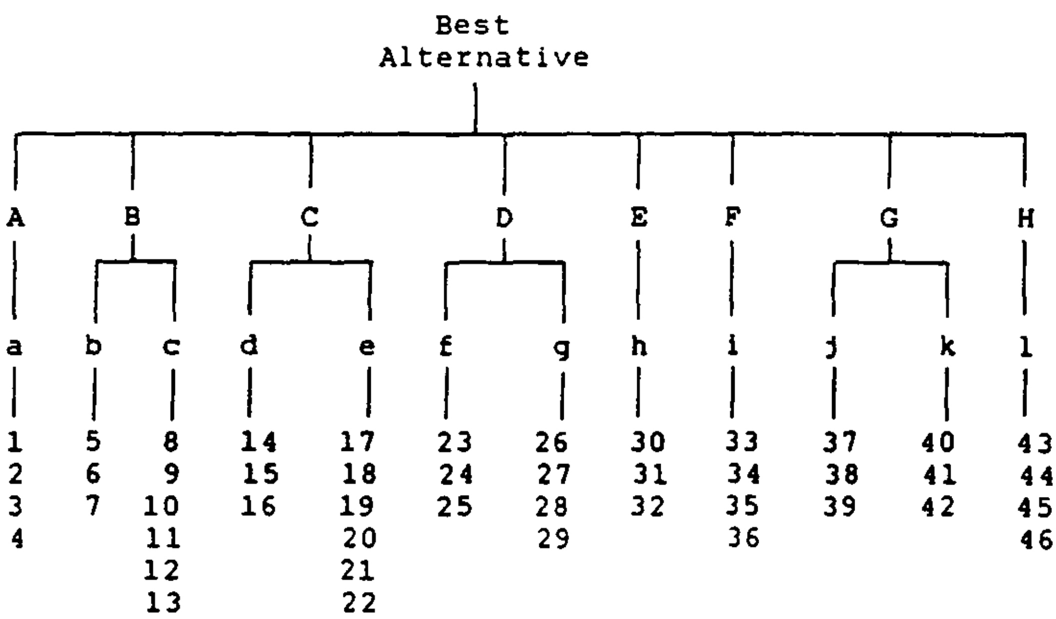


Fig. 4.1: Hierarchical Structure of Decision Variables

The category of A to H has been classified as shown in Section 4.3. The category of a to l is a further subdivision of the previous category. They are:

a. Stabilization ponds

b. Fully-aerated lagoons + Secondary settlement

c. Fully/Partially aerated lagoons

d. Simple percolating filtration

e. Modified percolating filtration

f. Conventional activated sludge process

g. Deep-shaft/High-purity oxygen processes

h. Primary settlement

i. Land application

j. Rotating biological contactors

k. Oxidation ditches

l. Package activated sludge plants

The last category, 1 to 46, consists of all the individual treatment alternatives which have been shown in Section 4.3.

In the optimization process, one can either select the most appropriate treatment alternative from the category of A, B, ..., H, or from the category of a, b, ..., l, or from the category of 1, 2, ..., 46. Examples will be given in Part III of this thesis.

Further discussions on the decision variables (or treatment alternatives) will be found in Section 6.5 of Chapter 6.

CHAPTER 5 --- MATHEMATICAL TOOL FOR THE MODEL

5.1 Theoretical Background

The operations research technique used in the proposed model is called, as already mentioned in Chapter 4, eigenvector prioritization (or analytic hierarchy process). This technique was invented by T.L. Saaty[4,8] about ten years ago and the theory was then further developed by his student L.G. Vargas[11] in some later years. As the technique is only recently developed and is applied here for the first time in civil/environmental engineering, it is worthwhile to give a very brief description of what the technique is before going on with discussing the application of it in the model.

5.1.1 Similarity Transformation

In matrix similarity transformation[10,13], any $n \times n$ square matrix A can be transformed, by applying $Q^{-1}AQ$ (where Q is an appropriate matrix[12,14] related to A), to either:

a) a $n \times n$ diagonal matrix Λ if matrix A has n linear independent eigenvectors where:

$$\Lambda = \begin{bmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_n \end{bmatrix}$$

($\lambda_1, \lambda_2, \ldots, \lambda_n$ are the eigenvalues of matrix A) or

b) a n x n Jordan matrix J (a nearly diagonal one) if matrix A is defective[13] and has less than n linear independent eigenvectors where:

$$J = \begin{bmatrix} \lambda_1 & 1 \text{ or } 0 & & 0 \\ & \lambda_2 & \ddots & \\ & & \ddots & 1 \text{ or } 0 \\ 0 & & & \lambda_n \end{bmatrix}$$

Since similarity transformation does not alter the rank[1], R(A), of the matrix A, therefore, the rank of A is equal to that of Λ and J, ie. R(A) = R(Λ) or R(A) = R(J). By applying the rule[1] in finding the rank of matrices Λ or J, and hence R(A), the following theorem can be deduced: **if A is any n x n square matrix and R(A) = r for $r \leqslant n$, then A has r non-zero eigenvalues.**

5.1.2. Pairwise Comparison Matrix

In assessing the relative weighting of n alternatives, pairwise comparisons are used which mean that any particular alternative is not compared to all others simultaneously but rather one at a time. If the results of each and every pairwise comparisons on the relative weighting of the alternatives are known, the priority of the alternatives can be found by evaluating the priority vector of a matrix whose elements are the pairwise comparisons of the weightings. Suppose a set of n alternatives are to be compared in pairs and the alternatives are denoted by Alt_1, Alt_2, ..., Alt_n and their individual weighting (assumed known) by x_1, x_2, ..., x_n respectively, then the pairwise comparisons may be represented by a n x n square matrix A as follows:

$$A = \begin{array}{c|cccc} & Alt_1 & Alt_2 & \ldots\ldots & Alt_n \\ \hline Alt_1 & 1 & \frac{x_1}{x_2} & \ldots\ldots & \frac{x_1}{x_n} \\ Alt_2 & \frac{x_2}{x_1} & 1 & \ldots\ldots & \frac{x_2}{x_n} \\ \vdots & \vdots & \vdots & & \vdots \\ Alt_n & \frac{x_n}{x_1} & \frac{x_n}{x_2} & \ldots\ldots & 1 \end{array}$$

The above is a positive reciprocal matrix, satisfying the conditions that all the elements are positive and that $a_{ij} = 1/a_{ji}$ where a_{ij} and a_{ji} are the elements of matrix A. If a column vector X such that the elements of X are x_1, x_2, ..., x_n (ie. the individual weightings of Alt_1, Alt_2, ..., Alt_n) is introduced, then

$$AX = nX$$

and therefore n is, by definition, an eigenvalue of matrix A and the column vector X an eigenvector corresponding to the eigenvalue n. The rank of matrix A, R(A), is equal to 1 as the matrix has all rows equal to each other after applying elementary operations[(1)] to it. By the theorem mentioned at the end of Section 5.1.1, it can be deduced that matrix A has only one non-zero eigenvalue, and this eigenvalue is equal to n. This point is confirmed by the fact that the trace of matrix A is equal to n, that is, $Tr(A) = n$. As matrix A is a positive matrix and by the

Perron-Frobenius Theorem[2,9], it is also known that n is the maximum eigenvalue of A and that there exists an eigenvector, X (the same X), which has positive components and is the solution eigenvector of $AX = \lambda X$ for taking $\lambda = n$.

5.1.3 Inconsistency in Reality

The theories contained in Section 5.1.2 are based on the assumption that all entries of the positive reciprocal matrix A are consistent which means that $(a_{ij})(a_{jk}) = a_{ik}$, or $(x_i/x_j)(x_j/x_k) = x_i/x_k$. Such perfect consistency is possible only if we can construct matrix A based on the weightings of individual alternatives (ie. x_1, x_2, ..., x_n). However, in the application of the technique, this will not be the case, that is, one can only construct matrix A first and then find out the values of x_1, x_2, ..., x_n. This will create inconsistency in the reciprocal matrix. The following will explain why it is so.

Just take a simple example of comparing three alternatives. If the relative weighting of Alt_1 and Alt_2 is estimated to be 3 and that of Alt_2 and Alt_3 to be 2, it is not necessarily true that, in reality, the relative weighting of Alt_1 and Alt_3 will be 6 (ie. consistent case). Take an analogy of three football teams: if team 1 beats team 2 by 3:1 and team 2 beats team 3 by 2:1, it is not necessarily the case that team 1 will beat team 3 by 6:1, and if not, inconsistency occurs.

When inconsistency occurs, the problem AX = nX becomes one of $A'X' = \lambda_{max}X'$. For the positive reciprocal matrix A', λ_{max} will not be exactly equal to n and all other eigenvalues will not be equal to zero. But from the Perron-Frobenius theorem, it is known that matrix A' has a real positive eigenvalue with multiplicity of one which is equal to λ_{max}, whose corresponding eigenvector (or called priority vector) has positive components. This priority vector is not unique and its solutions differ by a multiplicative constant[14]. It is therefore desirable to have it normalized so that its components sum up to unity and when it is normalized it is unique.

It has been proved by Saaty[8] that λ_{max} is closer to n when matrix A' is closer to consistency (ie. A' is consistent if and only if $\lambda_{max} = n$) and $\lambda_{max} > n$ always if A' is inconsistent. The larger the λ_{max} is, the more inconsistent the matrix A' will be.

5.2 An Illustrative Example

An example given by Saaty[8] is reproduced below to illustrate how this mathematical technique is applied.

Selecting a plan for vacation out of Philadelphia:

With a view to spending a week on vacation, four places were evaluated in terms of the following criteria:

F_1: Cost of the trip from Philadelphia

F_2: Sight-seeing opportunities

F_3: Entertainment

F_4: Mode of travel

F_5: Eating places

The places considered were:

S: Short trips (ie. New York, Washington D.C. etc.)

Q: Queoec

D: Denver

C: California

The comparison matrix of the criteria with respect to overall satisfaction with a vacation plan is given by:

	F_1	F_2	F_3	F_4	F_5
F_1	1	1/5	1/5	1	1/3
F_2	5	1	1/5	1/5	1
F_3	5	5	1	1/5	1
F_4	1	5	5	1	5
F_5	3	1	1	1/5	1

The priority vector of the above positive reciprocal matrix, X_b, after normalized, is given by:

$$X_b = \begin{pmatrix} 0.09 \\ 0.13 \\ 0.23 \\ 0.43 \\ 0.13 \end{pmatrix}$$

The comparison matrices of vacation sites with respect to the criteria are:

For F_1: Cost

	S	Q	D	C
S	1	3	7	9
Q	1/3	1	6	7
D	1/7	1/6	1	3
C	1/9	1/7	1/3	1

$\lambda_{max} = 4.21 > n = 4$

Normalized priority vector $= X_1 = \begin{bmatrix} 0.58 \\ 0.30 \\ 0.08 \\ 0.04 \end{bmatrix}$

For F_2: Sight-seeing

	S	Q	D	C
S	1	1/5	1/6	1/4
Q	5	1	2	4
D	6	1/2	1	6
C	4	1/4	1/6	1

$\lambda_{max} = 4.34 > n = 4$

Normalized priority vector $= X_2 = \begin{bmatrix} 0.06 \\ 0.45 \\ 0.38 \\ 0.12 \end{bmatrix}$

For F_3: Entertainment

	S	Q	D	C
S	1	7	7	1/2
Q	1/7	1	1	1/7
D	1/7	1	1	1/7
C	2	7	7	1

$\lambda_{max} = 4.06 > n = 4$

Normalized priority vector $= X_3 = \begin{bmatrix} 0.36 \\ 0.06 \\ 0.06 \\ 0.52 \end{bmatrix}$

For F_4: Node of travel

	S	Q	D	C
S	1	4	1/4	1/3
Q	1/4	1	1/2	3
D	4	2	1	3
C	3	1/3	1/3	1

$\lambda_{max} = 5.38 > n = 4$

Normalized priority vector $= X_4 = \begin{bmatrix} 0.21 \\ 0.19 \\ 0.41 \\ 0.19 \end{bmatrix}$

For F_5: Eating

	S	Q	D	C
S	1	1	7	4
Q	1	1	6	3
D	1/7	1/6	1	1/4
C	1/4	1/3	4	1

$\lambda_{max} = 4.08 > n = 4$

Normalized priority vector $= X_5 = \begin{pmatrix} 0.43 \\ 0.38 \\ 0.05 \\ 0.14 \end{pmatrix}$

If a 4x5 composite matrix, C, is constructed by using the normalized priority vectors of X_1, X_2, X_3, X_4 and X_5 as columns given by:

$$C = \begin{pmatrix} 0.58 & 0.06 & 0.36 & 0.21 & 0.43 \\ 0.30 & 0.45 & 0.06 & 0.19 & 0.38 \\ 0.08 & 0.38 & 0.06 & 0.41 & 0.05 \\ 0.04 & 0.12 & 0.52 & 0.19 & 0.14 \end{pmatrix}$$

then, the resultant (overall) priority vector for the vacation sites will be the result of C x X_b and is equal to

$$\begin{pmatrix} 0.29 \\ 0.23 \\ 0.25 \\ 0.24 \end{pmatrix}$$

Therefore, the ranking of the four places obtained is:

S = 0.29
Q = 0.23
D = 0.25
C = 0.24

and this shows that the four are almost equally preferred, with short-trips (ie. S) having a slight edge over the others.

In the proposed model of this research work, the parameters (see Chapter 4) are equivalent to the criteria in the example (ie. F_1, F_2, F_3, F_4 and F_5) and the decision variables are equivalent to the vacation sites (ie. S, Q, D and C). In the model, the decision variables will be ranked through the evaluation of the 20 parameters so that a resultant priority vector (or final ranking) for the decision variables will be obtained. This will be further discussed in detail in Chapter 6.

5.3 Suitability of The Mathematical Tool for The Model

5.3.1 Size of Problem

The objective of the proposed model is to prioritize a set of decision variables (or treatment alternatives) so that the best one can be selected by obtaining the ranking from the resultant priority vector. Since there are many parameters and treatment alternatives to be considered, it is extremely difficult, if not impossible, for a human brain to compare the treatment alternatives simultaneously and prioritize them through the consideration of all the 20 parameters without using techniques of system analysis. The mathematical technique just described provides one with a systematic procedure that facilitates comparisons and that not only is in harmony with but also supplements the insufficiency of intuition and human feelings over large problems.

5.3.2 Intangible Factors

Unlike the mathematical techniques used by existing models as described in Chapter 3, the proposed model, while applying this particular technique, enables one to consider intangible parameters (such as parameters 8, 9, 13, 14, 15, 16 and 17 identified in Chapter 4) which are believed to be most important in optimal treatment alternatives selection. This represents a break-through in the approach of the current techniques as all the existing treatment selection optimization models, using other mathematical tools, do not easily enable one to include such intangible factors in the selection process.

5.3.3 Inconsistency in Real Application

As seen in the example and the analogy given in Section 5.1.3, one must prepare to accept the fact that inconsistency will occur in the parameter matrix and the decision variables matrices if they are to be constructed in a way so as to be closer to reality. (Parameter matrix and decision variable matrices are to be discussed in detail in Chapter 6). For example, if parameter 4, say, is three times more important than parameter 6 and parameter 6 is twice as important as parameter 11, it is not necessary that parameter 4 be six times more important than parameter 11. The importance of parameter 4 over parameter 11 is only four instead of six (see Fig. 6.3 of Chapter 6). As a matter of fact, improving consistency does not always mean getting an answer closer to reality[5,8], and on the contrary, the reverse is true in some cases. In the application of the proposed model, inconsistency in the reciprocal matrices constructed should be allowed for if a more realistic result is desired.

One extraordinary feature of the proposed model is that, while applying the priority vector approach, it does not reject inconsistent input data but allows them to be taken in. However, one cannot allow the input matrices to be too inconsistent if the theory discussed in Section 5.1 is to be applicable. Hence, some form of mathematical technique must be used to test for consistency. L.G. Vargas, following T.L. Saaty, published a paper in 1982[11] in which he illustrated that if the inconsistency of a positive reciprocal matrix is 10% or less, it can be accepted that the result of the priority vector is reliable. The inconsistency of the reciprocal matrix can be measured by a consistency index, μ, which is defined as (λ_{max}-n / n-1). Such consistency testing will be further discussed and illustrated in Section 6.3 of Chapter 6.

In 1979, after Saaty but prior to Vargas, Johnson, Beine and Wang jointly published an article[7] questioning the reliability of the eigenvector prioritization technique. They observed that disagreed results between a right eigenvector (ie. $AX = \lambda_{max}X$) and a left eigenvector (ie. $X^T A = \lambda_{max} X^T$) could sometimes be obtained by using the technique and they believed that there was no reason for a right eigenvector to yield a better solution than the left. This observation was interesting and such disagreement between the left and right eigenvectors is still not fully understood and is yet to be explained. However, the Johnson-Beine-Wang observation was based on random positive reciprocal matrices of a relatively high inconsistency. Vargas, three years later in 1982, as mentioned in the previous paragraph, proved that the result of the right priority vector be reliable if the inconsistency of the reciprocal matrix is 10% or less. Therefore, the data matrices for entering into the proposed model must be consistent enough to yield a reliable result. The model will automatically test every pairwise comparison matrix entered and will instruct the user to adjust it if a consistency higher than 10% is detected.

5.3.4 Measure of Differences in Priorities

The eigenvector prioritization technique can provide one with the knowledge from the resultant priority vector of how much one alternative is better than the others in exact scores. This has already been illustrated by the resultant priority vector in the example given in Section 5.2. Intuition and human feeling can never give such exact value of differences unless they are helped by systematic procedures, as what are being used in the proposed model.

5.4 Evaluation of Priority Vector

In the above discussions, it has been seen that λ_{max} is the most important root of the characteristic polynomial equation[3,13] of a pairwise comparison reciprocal matrix. It is the only eigenvalue that is required in the computation of the priority vector. The Power Method[3,6], a method for finding the largest eigenvalue of a matrix, is used in the proposed model for evaluating λ_{max}, and hence the priority vector. As this method requires performing iterations, a computer sub-routine (see sub-routine 1.1 of Appendices B.1.2 and B.1.3) is written for finding λ_{max} such that the loop will stop when the eigenvalues computed in the last two iterations differ by less than 0.1%. The computer program will store in a separate memory the result of the priority vector corresponding to the λ_{max} calculated by the above sub-routine.

Now, the theoretical background for developing the proposed model has been discussed. In the next chapter, the details of the model will be described.

CHAPTER 6 --- THE MODEL

6.1 Hierarchy of Objectives and Alternatives

Consider a hierarchy of three levels[5] shown in Fig. 6.1:

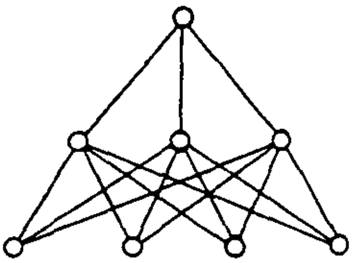


Fig. 6.1: Hierarchy of Principal Objective, Immediate Objective and Alternatives

As shown in Fig. 6.1, the first level has a single principal objective. The second level has m subordinate objectives (ie. the parameters in this model) and their priorities are derived from reciprocal matrix of pairwise comparisons with reference to the principal objective of the first level. The third level has n alternatives (ie. decision variables) which are to be prioritized. One has to determine how can the decision variables in Level 3 be ranked to meet the principal objective in Level 1 through the consideration of the m parameters given in Level 2 (m = 20 in this case). The priority vector for the decision variables with respect to each parameter can be obtained from a pairwise comparisons matrix with reference to that single parameter as objective. Thus, m resultant priority vectors of Level 3 are obtained after considering all the parameters and then they are weighed by the priority vector of the second level to obtain a resultant priority vector (ie. overall ranking) of the decision variables. The procedures are described as follows:

Step 1: Construct a parameter matrix (called matrix B) of dimension m x m with pairwise comparisons of the parameters with respect to the principal objective as the elements of B. Then find the priority vector of matrix B and denote it by X_b.

Step 2: If there are n decision variables (ie. treatment alternatives) to be ranked, a total of m reciprocal matrices A_i ($i = 1,2,...,m$) of size n x n are to be formed, each of which consists of elements of pairwise comparisons of the n decision variables with respect to a single parameter as objective, that is:

$$A_1 = \begin{array}{c|l} & 1 \; 2 \; \ldots\ldots \; n \\ \hline 1 & \\ 2 & \\ . & \\ . & \\ . & \\ n & \end{array} \qquad \text{using parameter 1 as objective}$$

$A_2 =$

	1 2 ...... n
1	
2	
.	
.	
.	
n	

using parameter 2 as objective

. . . .

$A_m =$

	1 2 ...... n
1	
2	
.	
.	
.	
n	

using parameter m as objective

Step 3: If X_i ($i = 1,2,\ldots,m$) is the priority vector of the corresponding A_i, then a n x m composite matrix C is formed by taking X_i as columns in C in sequence such that:

$$C = [\ X_1,\ X_2,\ \ldots\ldots,\ X_m\ ]$$

The resultant priority vector, X_c, is the result of the multiplication of matrices C and X_b, that is:

$$X_c = C \times X_b$$

From the result of X_c, the ranking of the decision variables can be obtained. The optimal treatment alternative can be selected from the top of the ranking list.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of on over another	Experience and judgement slightly favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence of favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed

Fig. 6.2: Scales of 1 to 9 for pairwise comparisons (a reproduction of figure from Chapter 3 of Saaty's book[5])

6.2 Scale of Pairwise Comparison

T.L. Saaty[5] proposed a scale of values from 1 to 9 as shown in Fig. 6.2. With the use of such scale values, L.G. Vargas[7] later further proved that the technique of eigenvector prioritization remains valid provided the inconsistency of the reciprocal matrix is 10% or less. The warnings given by Johnson C.R. et.al. (see Section 5.3.3 of Chapter 5) about the use of the technique can be neglected as the examples illustrating difficulties or disagreed results quoted in their paper were in general of reciprocal matrices with inconsistency much higher than Vargas' recommendation.

It was recommended by Saaty that the number of alternatives to be ranked (n) should not be larger than 9 to maintain a reasonable consistency if the coefficients of the matrix were randomly entered[5]. Such a recommendation was made after he had carried out an experiment on randomly filled reciprocal matrices. In the experiment, he used 50 random reciprocal matrices for each n (order of matrix) tested and the n he used was ranging from 2 to 16. In other words, he tested 750 (ie. 50x15) random matrices. It was found that the consistency of nearly all the random matrices became poor when n exceeds 9.

In a random matrix, comparisons of alternatives are not made logically. For example, if Alternative 1 is 3 times more important than Alternative 2 for a certain objective, and Alternative 2 is 3 times more important than Alternative 3, then Alternative 1 should be, logically, 9 times more important than Alternative 3. But in the random matrix, it can happen that the coefficient of element 1-3 be 1/9 (ie. Alternative 1 be 9 times less important than Alternative 3) while the coefficients of elements 1-2 and 2-3 remain unchanged. This, however, can never happen, at least within the context of this research, if the comparisons of the alternatives are made in a realistic manner.

Therefore, it is the author's suggestion that a reasonably good consistency can still be expected even if n is larger than 9 provided the coefficients are not entered randomly but are entered with realistic and logical comparisons, although limited inconsistency will still be expected even though comparisons are realistically and logically made. Such a suggestion can be proved by evaluating the consistency of a matrix whose n is larger than 9 and the result can then be compared with the Vargas' recommendation.

In the model, the parameter matrix is one of n = 20 — much greater than 9! The coefficients, however, are carefully, realistically and logically entered, and so its consistency is found to be good (see Section 6.3). The author's suggestion is hence supported. This parameter matrix will be discussed in detail in the next section below.

6.3 The Parameter Matrix

The parameter matrix is a 20x20 square matrix. Each and every one of the 20 parameters has been described in detail in Chapter 4. For easy reference, they are reproduced below (indicators are neglected to avoid complexity):

Parameters	Description	No of Indicators
1	Flow	3
2	Influent / Effluent	4
3	Size of site	2
4	Nature of site	5
5	Land cost	1
6	Local money for construction	2
7	Foreign money for construction	2
8	Local skill for construction	2
9	Community support	3
10	Power source	2
11	Availability of local material	2
12	Cost of operation and maintenance	1
13	Professional skill for operation and maintenance	3
14	Local technical skill for operation and maintenance	2
15	Administration set-up	1
16	Training	4
17	Professional ethics	2
18	Climate	4
19	Local water-borne diseases	5
20	Endemic local water-related diseases	3

Fig. 6.3 shows the coefficients of the parameter matrix which are pairwise comparisons on the relative importance of the parameters. λ_{max} of the matrix is found to be 20.56. The consistency index μ (see Section 5.3.3)

PARAMETER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1/5	1/5	2	4	4	4	5	5	1/3	5	3	5	5	5	5	3	2	3	3
2		1	1	4	7	7	7	9	9	3	9	5	9	9	9	9	5	4	5	5
3			1	4	7	7	7	9	9	3	9	5	9	9	9	9	5	4	5	5
4				1	3	3	3	4	4	1/4	4	2	4	4	4	4	2	1	2	2
5					1	1	1	2	2	1/5	2	1/2	2	2	2	2	1/2	1/3	1/2	1/2
6						1	1/2	1	1	1/5	2	1/2	1	1	1	1	1/2	1/3	1/2	1/2
7							1	2	2	1/5	2	1/2	1	1	1	1	1/2	1/3	1/2	1/2
8								1	1	1/6	1	1/3	1/2	1	1	1	1/3	1/4	1/3	1/3
9									1	1/6	1	1/3	1/2	1	1	1	1/3	1/4	1/3	1/3
10										1	6	4	6	6	6	6	4	3	4	4
11											1	1/3	1/2	1	1	1	1/3	1/4	1/3	1/3
12												1	3	3	3	3	1	1/2	1	1
13													1	2	1	1	1/2	1/3	1/2	1/2
14														1	1	1	1/2	1/3	1/2	1/2
15															1	1	1/2	1/3	1/2	1/2
16																1	1/2	1/3	1/2	1/2
17																	1	1/2	1	1
18																		1	2	2
19																			1	1
20																				1

All lower triangular entries $= b_{ji} = \frac{1}{b_{ij}}$ for $1 \leqslant i < j \leqslant 20$

Fig. 6.3: The Parameter Matrix (ie. Matrix B)

is obtained as follows:

$$\mu = \frac{\lambda_{max} - n}{n-1}$$

$$= \frac{20.56 - 20}{20 - 1}$$

$$= 0.030 \quad \text{(ie. 3\%)}$$

As μ is within the acceptable limit recommended by Vargas[7], it is assumed that the parameter matrix is good enough to give a reliable result after integrating with the other twenty decision variable matrices. The integrating exercise requires the use of a computer program due to the size and the complexity of the problem. A detailed description of the computer program will be given later in Section 6.4.

The pairwise comparisons of the parameter matrix given in Fig. 6.3 are made based on the author's knowledge and experience, and will be a built-in feature of the model (see Section 6.4 for details). This matrix is a subjective and original product of the author. The validity of his judgements will be revealed or confirmed from the the final results given by the model.

In the pairwise comparisons of the parameter matrix, the author has given a very high weighting to parameter 3 (ie. size of site). In Fig. 6.3, it can be seen that elements 3-10 and 3-11, say, are 3 and 9 respectively, which means that parameter 3 has weak importance over parameter 10 (see Fig. 6.2) and that it has absolute importance over parameter 11. This parameter is regarded as being of very high importance because the size of the site is an absolute determinant of the appropriate alternative which one can select. The reason is simple: if a small and confined site in a densely populated area is given for building a STP it will be impossible for stabilization ponds or land application to be used as appropriate alternatives. With the exception of parameter 2, all the other eighteen parameters are not as absolute a determinant as parameter 3, although they are as well very important parameters (with, naturally, various degrees of importance). Parameter 2 (ie. influent / effluent) is also an absolute determinant. Since the effluent standard has to be met in a given situation, the treatment efficiency of the alternative selected must be able to satisfy the requirement. For example, it will be impossible for primary treatment alone to achieve a high percentage of pollutants removal, nor will it be possible to obtain a very high quality effluent if tertiary treatment is not used. Parameters 2 and 3, therefore, are regarded as the most important parameters among all and this has been reflected in the parameter matrix in Fig 6.3.

Parameter 10 (ie. power source) is the next most important parameter, just second to parameters 2 and 3. Elements 3-10 and 1-10, for instance, are 3 and $\frac{1}{3}$

respectively, which means that parameter 3 is slightly more important than (ie. weak importance over) parameter 10 but parameter 1, on the other hand, is slightly less important than parameter 10. Power source is close to an absolute determinant because all treatment alternatives cannot be successfully operated without it. In essence, this parameter is as important as parameters 2 and 3, but since it is a changeable factor (the other two are not), it has been assigned a slightly lower weightage than the latter two.

The next most important parameters, then, are 1, 4 and 18 (ie. flow, nature of site and climate). The importance of these three parameters has already been discussed in Section 4.4.2 of Chapter 4. They are given high weightages because they are all unchangeable factors. Their level of significance, on the other hand, is lower than that of parameters 2, 3 and 10. This is because that parameters 1, 4 and 18 are not as absolute as parameters 2, 3 and 10. The following example will explain this statement: it is impossible for a stabilization pond to be built on a small site but is possible for it to be constructed in any climatic conditions, although it may not be an appropriate form of treatment in a certain type of climate (e.g. cold weather). Hence, parameter 3 (ie. size of site) is absolute and parameter 18 (ie. climate) is not so absolute.

The next most important parameters are 12, 17, 19 and

20 (ie. cost of operation and maintenance, professional ethics, water-borne and vector-borne diseases). Their importance has been explained in detail in Section 4.4.2 as well. As discussed in the Section, plant maintenance is always more difficult than plant construction and the most basic problem in plant maintenance is the availability of funds for such a purpose. Poor professional ethics stifle the successful operation of any plant and it is the feeling of the author that this parameter should be given a high weightage (the parameter matrix is a subjective product anyway). The spreading of diseases, either water-borne or vector-borne, should not be taken lightly because it can cause chain public health effects which may lead to unexpected big national losses. However, these four parameters, like parameters 1, 4 and 18, are not absolute ones, but on the other hand, unlike 1, 4 and 18, are changeable factors. Because of this reason, they (ie. parameters 12, 17, 19 and 20) are considered as less important than parameters 1, 4 and 18 (and parameters 2, 3 and 10 of course) but more important than the rest ten parameters.

The remaining ten parameters are 5, 6, 7, 8, 9, 11, 13, 14, 15 and 16. Out of the ten, parameters 5, 6 and 7 (ie. land cost, costs of construction in local and foreign currency), are given slightly higher weightage than the other seven. This is because that the availability of construction funds is nevertheless important. Without it,

Parameters	Description	X_b
1	Flow	0.0812
2	Influent / Effluent	0.1828
3	Size of site	0.1828
4	Nature of site	0.0585
5	Land cost	0.0240
6	Local money for construction	0.0187
7	Foreign money for construction	0.0216
8	Local skill for construction	0.0144
9	Community support	0.0144
10	Power source	0.1192
11	Availability of local material	0.0140
12	Cost of operation and maintenance	0.0386
13	Professional skill for operation and maintenance	0.0194
14	Local technical skill for operation and maintenance	0.0160
15	Administration set-up	0.0165
16	Training	0.0165
17	Professional ethics	0.0353
18	Climate	0.0556
19	Local water-borne diseases	0.0353
20	Endemic local water-related diseases	0.0353

Fig. 6.3(a) : Normalized Priority Vector of Parameter Matrix

there will be no need of any selection. The remaining seven parameters (ie. local skill for construction, community support, local material, professional and technical skill for operation and maintenance, administration set-up, training) are all playing a supporting role to the successful plant construction and operation. They are changeable and are not absolute determinants. Therefore they are given the lowest weighting. Nevertheless, their importance assigned in the parameter matrix is significant enough tc affect the choice of appropriate technology in the ranking process.

6.4 The Computer Program

The computer program is written based on the mathematical theories described in Chapter 5 and the procedures already described in this chapter. The parameter matrix, as described in Section 6.3, is a built-in feature of the model and is stored in a separate file named "PARAMAT". Users do not have to know what the values are inside the parameter matrix when they use the model. They only have to input matrices A_1, A_2, ..., A_{20} (see Section 6.1) into the computer. Users may choose the number of decision variables, n, to be ranked, that is, if decision variables in category A, B, C, ... (see Fig. 4.1 of Chapter 4) are to be ranked, then n is put equal to 8 (see Section 7.3 of Chapter 7); if decision variables in category a, b, c, ... are to be ranked, then n is put equal to 12 (see Section 7.4 of Chapter 7); and so on. Due to the limitation on the sizes of the input matrices, it is recommended that the number of decision variables taken should not be greater than fifteen (ie. $n \leqslant 15$), although the model will still work, probably with lesser accuracy, if $n > 15$. The 46 decision variables at the lowest category (Fig. 4.1) can be easily cut down to 15 or less using a simple screening process which will be illustrated in Section 7.5 of Chapter 7. The computer program is written[1] in BASIC language[3,4] on an IBM personal computer[6]. As the program requires a considerable amount of memory space, it can be run on a PC (or XT or AT) only after it is compiled by an IBM BASIC compiler[2]. The IBM personal computer was chosen because it is believed to be most convenient and easily accessible by all prospective users and this should be so for a number of years to come.

A flow chart of the program and a listing of it are given in Appendices B.1.2 and B.1.3 respectively. A users' manual of the program is given in Appendix B.1.1.

It should be noted that elements of the decision variable matrices should be entered in six decimal places, but they will be shown afterwards on the screen in three decimal places (see users' manual in Appendix B1). This however, will not affect the accuracy of the calculation in which data of six decimal places will be used throughout.

After the program is run once, twenty new data files (ie. decision variable matrices) named PARA1.LIQ, PARA2.LIQ, ..., PARA20.LIQ will be formed if they were originally not existing. In addition, two files named "COMPOMAT.LIQ" and "REPORT.LIQ" will also be formed --- the former stores the data of the composite matrix C (see Section 6.1) and the latter stores a record of all interactions between the user and the computer when the model was in use. Once can view at the contents of these files by using the 'TYPE' command.

6.5 Decision Variable Matrices

6.5.1 Matrix Construction

The construction of the decision variable matrices is done according to the same principle which is used in constructing the parameter matrix. The scales as shown in Fig. 6.2 are adhered to as well. As already mentioned in Section 6.1, a total of 20 reciprocal decision variable matrices will be formed for each situation under test as the number of parameters considered in the model is 20. Each decision variable matrix consists of elements of pairwise comparisons of the n decision variables with respect to a single parameter as objective where n is the number of decision variables to be ranked. For the situation of Malaysia under test, n is equal to 8 (see Section 7.3 of chapter 7 and Section 8.1 of Chapter 8).

Therefore, there are twenty 8x8 decision variables matrices constructed in this test. As an illustrative example, let us take a look at the 8x8 decision variable matrix for parameter 12 shown in Section 8.1. For easy reference, this matrix is reproduced hereunder in Fig. 6.4.

	Pond	Lagoon	Bio-filter	A.S. Process	Primary Treatment	Land Treatment	Small Plant	Package Plant
Pond	1	3	4	5	3	3	3	5
Lagoon		1	2	4	1	1	1	4
Bio-filter			1	3	$1/2$	$1/2$	$1/2$	3
A.S. Process				1	$1/3$	$1/3$	$1/3$	1
Primary Treatment					1	1	1	3
Land Treatment						1	1	3
Small Plant							1	3
Package Plant								1

All lower triangular elements $= a_{ji} = \dfrac{1}{a_{ij}}$

Fig. 6.4: Decision Variable Matrix for Parameter 12 (Malaysia)

Parameter 12 is the cost of operation and maintenance. Therefore, as far as the cost of O & M is concerned, a stabilization pond is slightly cheaper (and hence better) than an aerated lagoon. Element 1-2 entered is therefore equal to 3. If a pond is compared to an activated sludge plant, the former is significantly cheaper to operate and maintain than the latter, and hence element 1-4 is entered as 5. This principle is used for entering all the elements in the matrix, and the author calls this the first principle, which is simple but basic in the theory of eigenvector prioritization.

However, elements 1-2 and 1-4 entered as 3 and 5 must be done with a knowledge of the economic situation of Malaysia in question. If the alternatives are to be considered in another situation (ie. a place other than Puchong of Malaysia), the entries for the matrix will not be the same. For instance, the decision variable matrix for the same parameter (ie. parameter 12) for Hong Kong situation will be quite different. For easy reference, this parameter (shown in Section 8.4.1 of Chapter 8) is reproduced hereunder in Fig. 6.5. It can be seen that in this case the pond is only very slightly better than the activated sludge process. Element 1-4 is 2 only for Hong Kong whilst the same element for Malaysia is 5. This is because that funds for operation and maintenance of a wastewater treatment plant are readily available in Hong Kong and that funds for such a purpose are less stringent in Hong Kong than in Malaysia. The author calls the principle described in this paragraph the second principle in constructing decision variable matrices. Matrices of parameter 5 (ie. land cost) for Malaysia and Hong Kong situations reveal another example of this principle. In other words, the degree of influence to the selection of the appropriate treatment alternative due to a particular parameter is reflected by the values entered. If the parameter is a pressure point in a given situation, the values in the decision variable matrix will be high and vice versa.

	Pond	Lagoon	Bio-filter	A.S. Process	Primary Treatment	Land Treatment	Small Plant	Package Plant
Pond	1	1	1	2	1	1	1	2
Lagoon		1	1	2	1	1	1	2
Bio-filter			1	2	1	1	1	2
A.S. Process				1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
Primary Treatment					1	1	1	2
Land Treatment						1	1	2
Small Plant							1	2
Package Plant								1

All lower triangular elements $= a_{ji} = \frac{1}{a_{ij}}$

Fig. 6.5: Decision Variable Matrix for Parameter 12 (Hong Kong)

There is a third principle also. If the decision variable matrices of Parameters 13 and 14 of Thailand are compared (see Section 8.2), it can be observed that the relative importance of the decision variables are basically the same for the two parameters but the scores entered in parameter 14 is slightly higher than those in parameter 13. This is because of the fact that the technical skill available in that situation is inferior to the professional skill available (see Appendix C.3.2).

Therefore, the first principle is intra-matrix oriented; the second principle is inter-situations oriented; the third principle is inter-matrices and intra-situation oriented. In constructing the decision variable matrices, these three principles are used throughout.

6.5.2 Comparison of Decision Variables Using Each Parameter as Objective

Various kinds of treatment alternatives have been described in Chapter 2. Their merits and demerits with respect to certain parameters have been mentioned in that chapter. Section 4.2.2 of Chapter 4 has also included some discussions on the same topic. Since the subject has been partly covered in the above two places, the author is not going to enter into it too deeply in this section. A summary only will be given in the following pages.

Parameter	Stabilization Ponds	Aerated Lagoons	Bio-Filtration	A.S. Process	Primary Treatment	Land Treatment	Small Plants	Package A.S. Plants
1. Flow	not suitable for large flow; resistant to shock flow	not suitable for very large flow; quite resistant to shock flow	suitable for small and medium flow; not quite resistant to shock flow	suitable for medium and large flow; not resistant to shock flow	suitable for any quantity of flow; not resistant to shock flow	not suitable for large flow; resistant to shock flow	suitable for small flow; moderately resistant to shock flow	suitable for small flow; not quite resistant to shock flow
2. Influent/ Effluent	treatment efficiency is quite high; resistant to shock load	treatment efficiency is high; quite resistant to shock load	treatment efficiency is quite high; not quite resistant to shock load	treatment efficiency is high; not resistant to shock load	treatment efficiency is low; not resistant to shock load	treatment efficiency is high; resistant to shock load	treatment efficiency is high; moderately resistant to shock load	treatment efficiency is high; not quite resistant to shock load
3. Size of site	very large	large	moderately large	small	very small	extremely large	moderately small	moderately small
4. Nature of site	low water table; must be isolate; no sludge disposal; no flooding	low water table; must be isolate; no or little sludge disposal; no flooding	better to be isolate; sludge disposal is essential	sludge disposal is essential	sludge disposal is quite essential	low water table; must be isolate; no flooding	sludge disposal is essential	sludge disposal is quite essential
5. Land cost	Very high	high	quite high	low	very low	extremely high	moderately low	moderately low
6. Local money for construction	low	moderately low	moderately high	high	low	moderately low	moderately high	high
7. Foreign money for construction	very low	low	moderately low	can be high	low	low	moderately low	can be moderately high
8. Local skill for construction	low	moderately low	moderately high	very high	moderately low	moderately low	moderately high	high

Parameter	Stabilization Ponds	Aerated lagoons	Bio-Filtration	A.S. Process	Primary Treatment	Land Treatment	Small Plants	Package A.S. Plants
9. Community support	can easily obtain support; may be disliked due to religions reasons	not difficult to obtain support; may be disliked due to religions reasons	moderately difficult to obtain support	difficult to obtain support	not difficult to obtain support	not difficult to obtain support, may have negative psycho-logical effects	moderately difficult to obtain support	difficult to obtain support
10. Power source	least important	quite important	important	most important	quite important	quite important	important	important
11. Availability of local material	available easily	available quite easily	may not be too easily available	may not be easily available	available quite easily	available quite easily	may not be too easily available	may not be easily available
12. Cost of O & M	low	quite low	average	high	low	low	average	high
13. Professional skill for O & M	very low	low	average	high	low	quite high	low	average
14. Local technical skill for O & M	very low	low	average	high	low	quite high	low	average
15. Adminis-tration set-up	least important	moderately important	moderately important	important	not too important	moderately important	moderately important	moderately important
16. Training	least important	not too important	moderately important	very important	not too important	important	moderately important	important
17. Professional ethics	least important	moderately important	important	very important	moderately important	very important	moderately important	important
18. Climate	not suitable for cold climate; sunshine is essential	not suitable for cold climate	not much affected	not much affected	not much affected	dry climate and sunshine are essential	not much affected	not much affected
19. local water-borne diseases	very good in pathogen removal	moderately good in pathogen removal	bad in pathogen removal	moderately bad in pathogen removal	extremely bad in pathogen removal	very good in pathogen removal	moderately bad in pathogen removal	moderately bad in pathogen removal

Parameter	Stabilization Ponds	Aerated Lagoons	Bio-Filtration	A.S. Process	Primary Treatment	Land Treatment	Small Plants	Package A.S. Plants
20. Endemic vector-borne (water-related) diseases	very easy to spread the diseases	easy to spread the diseases	moderately easy to spread the diseases	least easy to spread the diseases	least easy to spread the diseases	extremely easy to spread the diseases	less easy to spread the diseases	less easy to spread the diseases

PART 3

TESTING OF MODEL

CHAPTER 7 --- MODEL TESTING (I)

7.1 Selection of Plants for Testing

The model can be tested by feeding into it data collected from actual wastewater treatment plants. By using data collected from an actual plant, the result that the model indicates (ie. the most appropriate treatment alternative) can be compared with the real situation. Assuming that the model works satisfactorily, the result it gives should be more or less in agreement with the treatment process used by the plant if the latter works successfully, or it will indicate some other more appropriate treatment alternative if the plant works unsatisfactorily (if at all it works).

The next question then is which plants are to be chosen for the test? Without doubt they must be municipal wastewater treatment plants as the model is designed for ranking treatment alternatives for treating municipal wastewaters. They must also represent a wide spectrum of environmental and socio-cultural differences in which they were built. However, the number of plants and their locations used for testing must be within a practicable limit, although a wide spectrum of differences is desirable. Having considered all these factors, four existing sewage treatment plants were selected. They are:

1. Puchong Sewage Treatment Plant in Malaysia
2. Pattaya South Sewage Treatment Plant in Thailand
3. Min Shen Sewage Treatment Plant in Taiwan
4. Shatin Sewage Treatment Plant in Hong Kong

7.2 Collection of Data

The data were collected using questionnaires[1,2] supported by site visits. There were three different questionnaires. The first one was of a general type, acquiring general information about sewerage systems and sewage treatment of a particular country (see Appendix C.1). This same questionnaire was given to university lecturers and practicing sanitation engineers of various countries in the south-east Asia with whom the author had had previous connections. The completed questionnaires were carefully studied so that a general picture of wastewater engineering in each country was known. In addition, each returned questionnaire provided the names and addresses of several sewage treatment plants in each of the countries so that further contact with individual treatment plants was made possible. Then, a second questionnaire, asking for much more detailed information about an individual plant (see Appendix C.2), was sent to all those treatment plants whose addresses were obtained from the first questionnaire. Less than 50% of the questionnaires sent were completed and returned. From the results of the second questionnaire, four plants (as mentioned in Section 7.1) were selected as candidate plants for testing the model. They were selected for three reasons: (1) they are in different environmental and socio-cultural contexts, (2) they are of different sizes (ie. capacities) and (3) the returned questionnaires from these plants (except the plant in Thailand) were completed in greater detail and with greater care (not all returned questionnaires were so) and it was therefore assumed that the data of these plants would be more reliable and that further contact with these plants would be more profitable. The plant in Thailand was selected because of reasons (1) and (2) but not (3). However, there was another reason for choosing this particular plant and the reason will be discussed in Section 7.4.

Then, a third questionnaire was designed to acquire further information concerning the candidate plants (see Appendix C.3). This questionnaire was not sent but was taken along with the author during his visit to these plants. The questions contained in it were put by the author when he met with the plant managers and the staff during the visits. The site visits also helped him acquire a greater understanding of the environmental and social situations of the candidate countries so that the data for the intangible parameters could be entered with greater accuracy into the model.

In the following sections, descriptions of the test procedures for the plants in Malaysia, Thailand, Taiwan and Hong Kong respectively will be given.

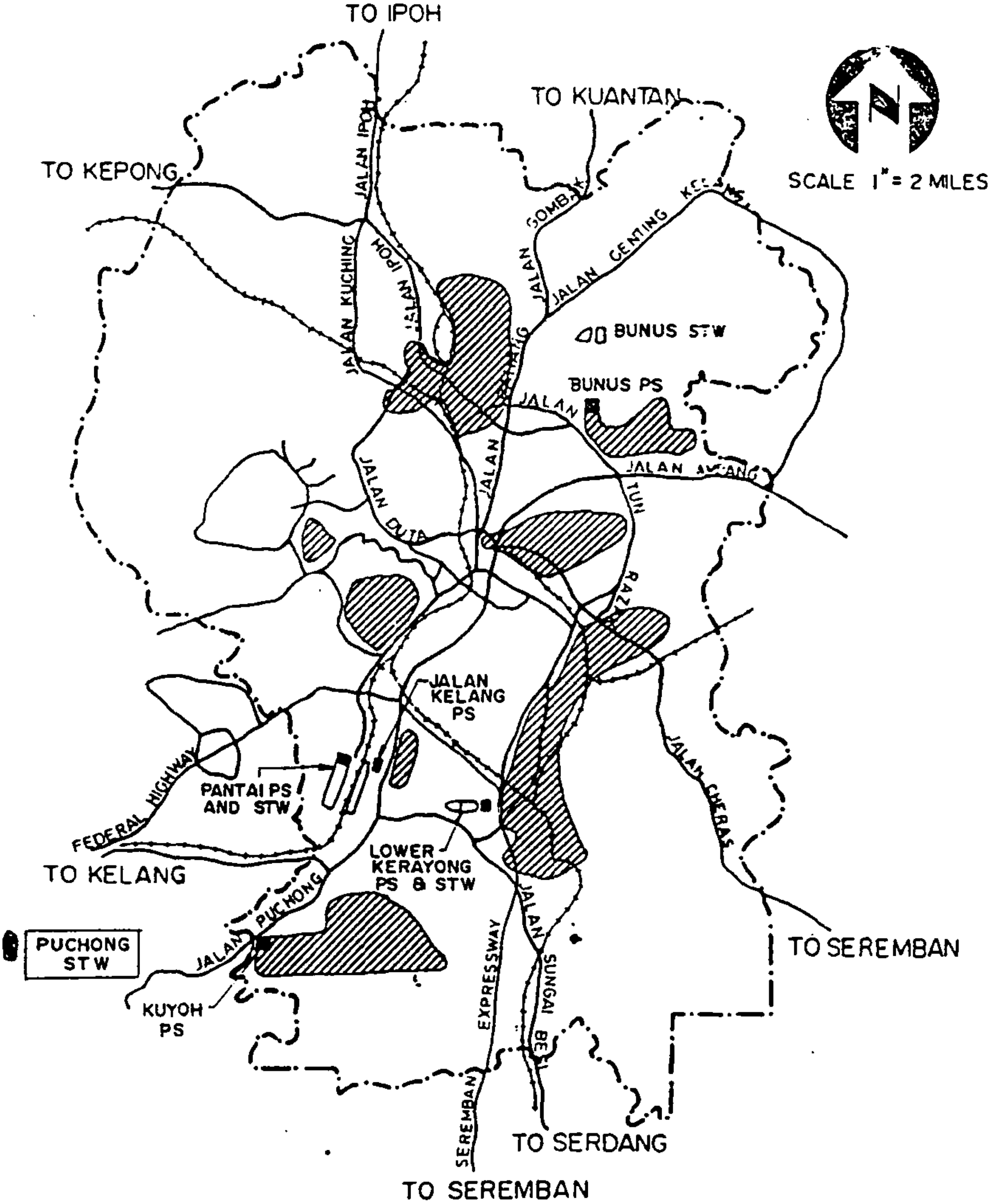
7.3 Puchong Sewage Treatment Plant (Malaysia)

The Puchong STP, built in 1984-85, is located at the south-west of Kualu Lumpur, the capital of Malaysia. The plant is situated outside the city boundary but not far away from Kuala Lumpur, and is therefore situated in a semi-rural area (see Fig. 7.1)[3]. The plant was designed to treat an average daily dry weather flow of 1800 m^3/day (ie. 8000 P.E.) and the designed influent BOD_5 was 220 mg/l[3]. However, due to ground water infiltration into the sewerage system, the actual mean BOD_5 figure was found to be only 108 mg/l when the plant was commissioned (see Appendix C.2.1). The treatment plant consists of two ponds, one facultative pond (3 Ha) and then one maturation pond (0.9 Ha). Land is available in Puchong area. The capacity of the plant can be increased in the future by the construction of additional stabilization ponds as land for extension has already been reserved. The effluent is discharged to a river named Sungai Kelang and has BOD_5 and s.s. standards of 29 mg/l and 2 mg/l respectively (result of weekly grab samples). The plant can be considered, in general, as working successfully.

Other details concerning Malaysia in broad terms -- as well as the Puchong STP itself -- can be seen in Appendices

AREAS SERVED AND PHASE I - FACILITIES

KEY PLAN



KEY

—·—·— FEDERAL TERRITORY BOUNDARY

Fig. 7.1: LOCATION OF PUCHONG STW

C.1.1, C.2.1 and C.3.1. Although not all questions were answered in the completed questionnaires, the information obtained was adequate for making up the twenty decision variable reciprocal matrices for entry into the model. Each decision variable matrices is of order 8x8. As mentioned on Page 65 (Chapter 4) and Sections 6.4 and 6.5.1 (Chapter 6), the 8 decision variables used were those in the first category (ie. A, B, ..., H) shown in the hierarchical structure in Fig. 4.1 of Chapter 4. They are reproduced hereunder for easy reference:

Decision Variable	Description
1	Stabilization ponds
2	Aerated lagoons
3	Biofiltration
4	Activated sludge processes
5	Primary Settlement
6	Land application
7	Small plants
8	Package activated sludge plants

The decision variable matrices for the 20 parameters are shown in Section 8.1 of Chapter 8 and their construction was based on the discussions contained in Section 6.5 of Chapter 6. These data were entered into the model according to the procedures given in the computer program users' manual (Appendix B.1.1). The result (ie. output of the model) is also shown at the end of Section 8.1.

The optimum treatment alternative given on Page 132 as selected by the model, which scores 100%, is stabilization pond (ie. Decision Variable 1). The second best alternative, which scores 87%, is aerated lagoon (ie. Decision Variable 2). The third, which scores 75%, is small plant (ie. Decision Variable 7). This is the result that had been anticipated from a less rigorous, general appreciation of the situation. It should be noted that, however, stabilization pond is the optimal alternative only for this very particular situation. If the site is relocated somewhere else in Malaysia with a different environment, or if the requirement on the standard of effluent is different, or if there are any changes that have taken place in terms of the social conditions, the result may well be a treatment alternative other than stabilization ponds.

7.4 Pattaya South Sewage Treatment Plant (Thailand)

Pattaya is one of Thailand's main local and international tourist attractions and is second only to Bangkok in foreign exchange earnings from tourism. The total town area of Pattaya is about 200 km^2 and the resident population is about 50,000. Most of the population is concentrated in the relatively small beach zone (see Fig. 7.2). Due to the continual growth of the town and the continual deterioration of the beach environment, it is a great concern on the part of the

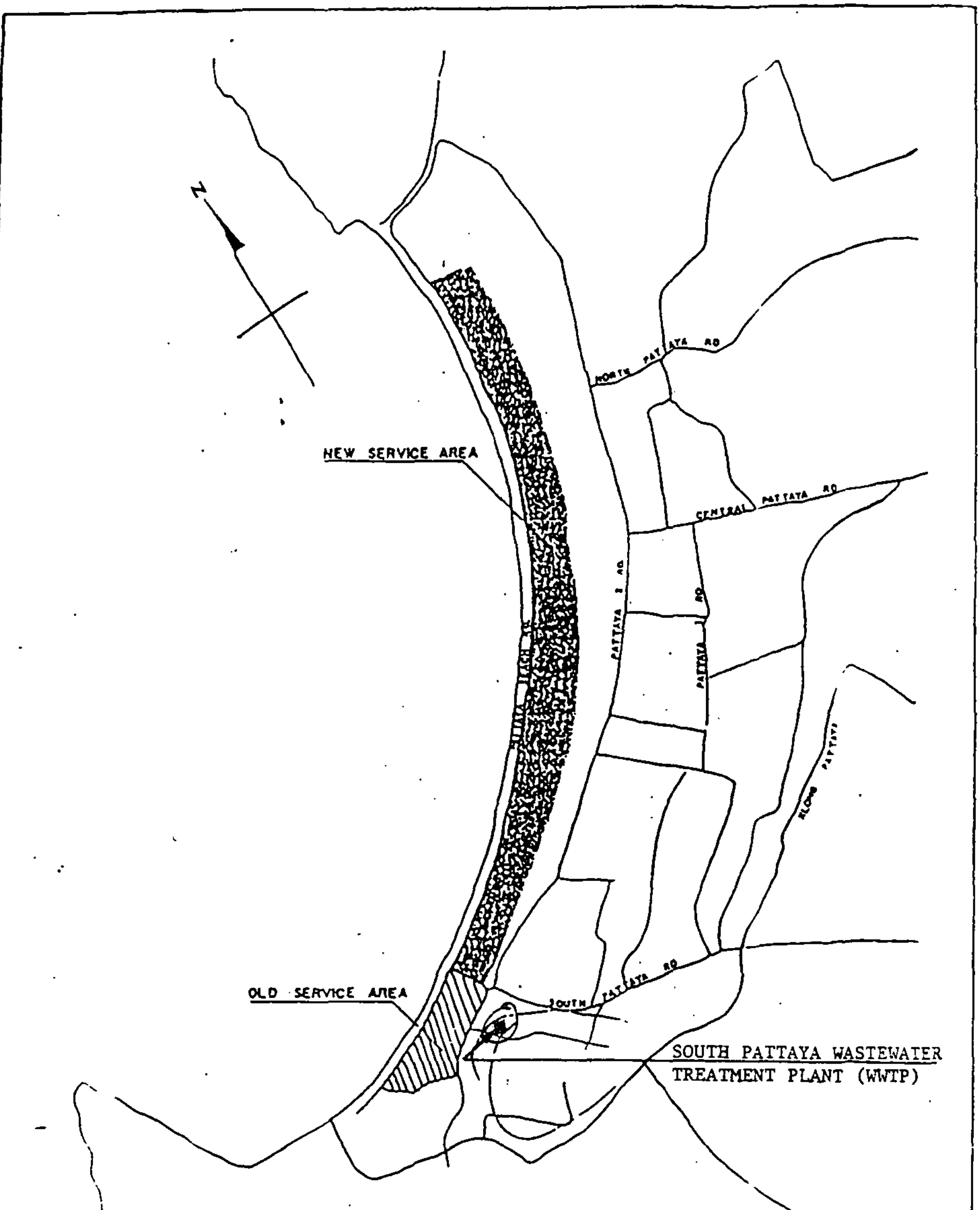


Fig. 7.2: MAP OF PATTAYA CITY AND SEWERAGE SERVICE AREA

Fig. 7.3

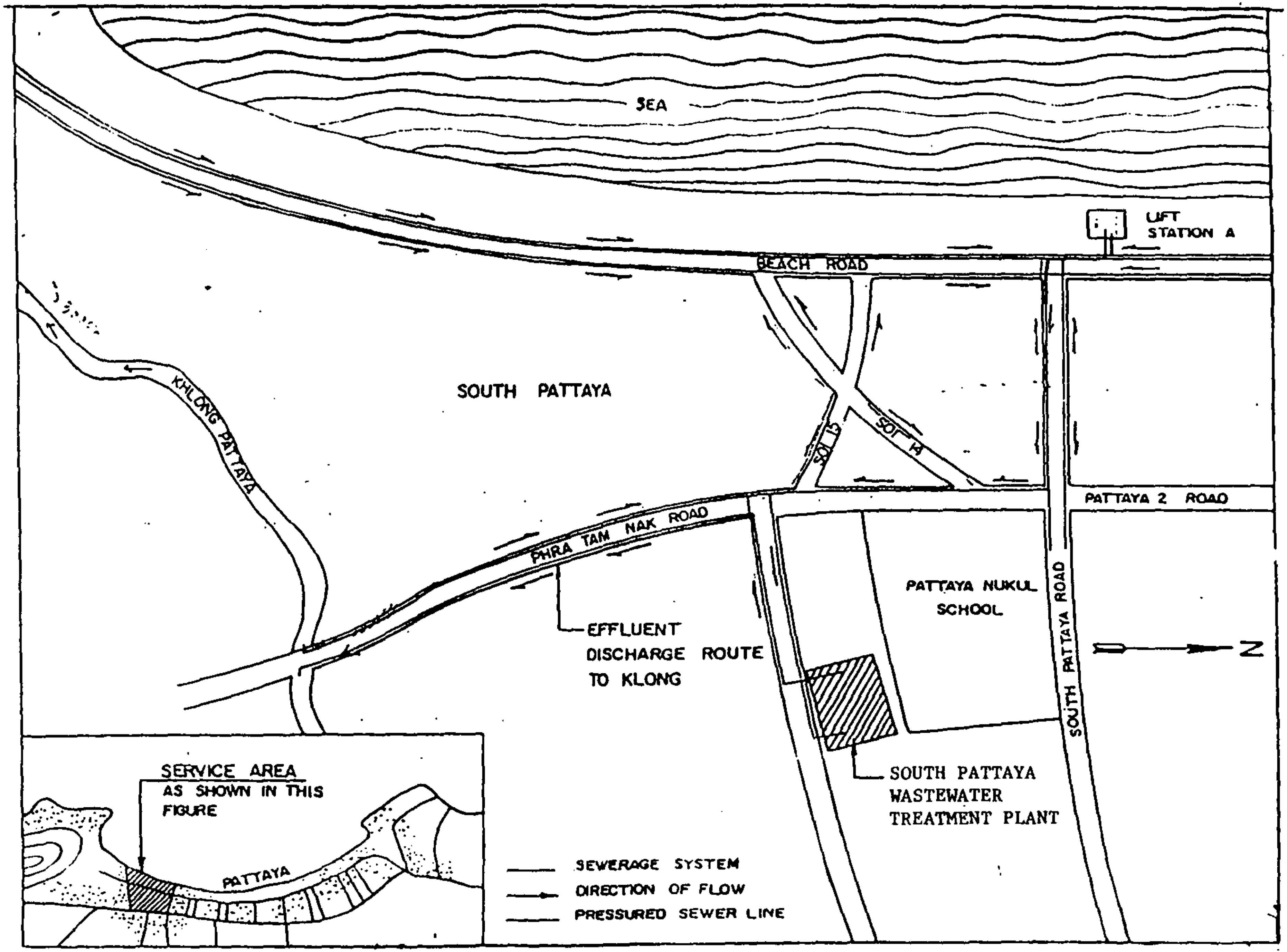


Fig. 7.3: OLD SERVICE AREA AND SEWERAGE SYSTEM

Pattaya government that the degradation of the beaches may cause a loss of tourist income. So, in 1982, a simple sewerage system and a wastewater treatment plant were built for servicing a densely populated but relatively small zone at south Pattaya as shown in Figs. 7.2 and 7.3[4].

As the treatment plant is located at a very densely populated zone, the site area available for the plant is very limited (about 0.2 Ha). The plant was designed to treat a daily average DWF of 1000 m^3/day (ie. 5000 P.E.) of municipal sewage and the effluent standard for BOD_5 was set to be not more than 15 mg/l[4]. Effluent would be discharged to a canal (Khlong Pattaya) and then to the beach. The treatment process employed is extended aeration activated sludge. Surface aerators are used in the aeration tank. Details of the treatment plant can be found in Appendix C.2.2 and other details concerning Thailand/Pattaya can be found in Appendices C.1.2 and C.3.2.

This plant is now not in operation. The author was informed during the visit that the plant had previously been working unsatisfactorily. This fact identifies the additional reason, which was not mentioned in Section 7.2, for selecting this plant for testing the model. The model should, if it works well, give an optimal treatment alternative which is not that of the activated sludge process. So, for this particular test, the result should be a negative one rather than a positive one, unlike the Puchong STP of Malaysia.

The decision variables used, as mentioned on Page 65, were those in the second category (ie. a, b, ..., l) shown in the hierarchical structure in Fig. 4.1 of Chapter 4. They are:

Decision Variable	Description
1	Stabilization ponds
2	Fully-aerated lagoons + Secondary settlement
3	Fully/Partially aerated lagoons
4	Simple percolating filtration
5	Modified percolating filtration
6	Conventional activated sludge process
7	Deep-shaft/High-purity oxygen process
8	Primary settlement
9	Land application
10	Rotating Biological contactors
11	Oxidation ditches
12	Package activated sludge plants

The twenty 12x12 decision variable matrices entered into the model are given in Section 8.2 of Chapter 8. They were again constructed based on Section 6.5. On Page 143, the optimal treatment alternative obtained, which scores

100%, is that of rotating biological contactors (ie. Decision Variable 10) and not the installed activated sludge process. The second best alternative, which scores 86%, is package activated sludge plants (ie. Decision Variable 12). The third, which scores 84%, is conventional activated sludge process (ie. Decision Variable 6). It is worthwhile to mention that there is a RBC plant built recently (in 1985) in Pattaya to serve the new service area (Fig. 7.2) and it was found to work very successfully when the author visited this plant in early 1987.

7.5 Min Shen Sewage Treatment Plant (Taiwan)

Min Shen Sewage Treatment Plant is at the north-east of Taipei city, the capital of Taiwan which has a population of two millions. The plant is not too far away from the city centre (see Fig. 7.4)[5], and is responsible for treating the wastewater from the Min Shen Housing Estate (the Minshen Community). It was built on quite a small site (about 0.8 Ha) which was assigned by the government of Taipei city for constructing sewage treatment facilities. The plant was designed to treat 15,500 m^3/day (daily average) of municipal wastewater (ie. 60,000 P.E.) and the designed influent BOD_5 and s.s. were both 200 mg/l. Two different treatment processes are used in the plant --- RBC and activated sludge. The settled sewage flows to a distribution chamber which leads about 20% of the flow to the RBC basin and 80% to the activated sludge aeration

第二期六年工程執行計畫(民國七十年至七十五年)

SECOND SIX-YEAR IMPLEMENTATION PLAN (1981-1986)

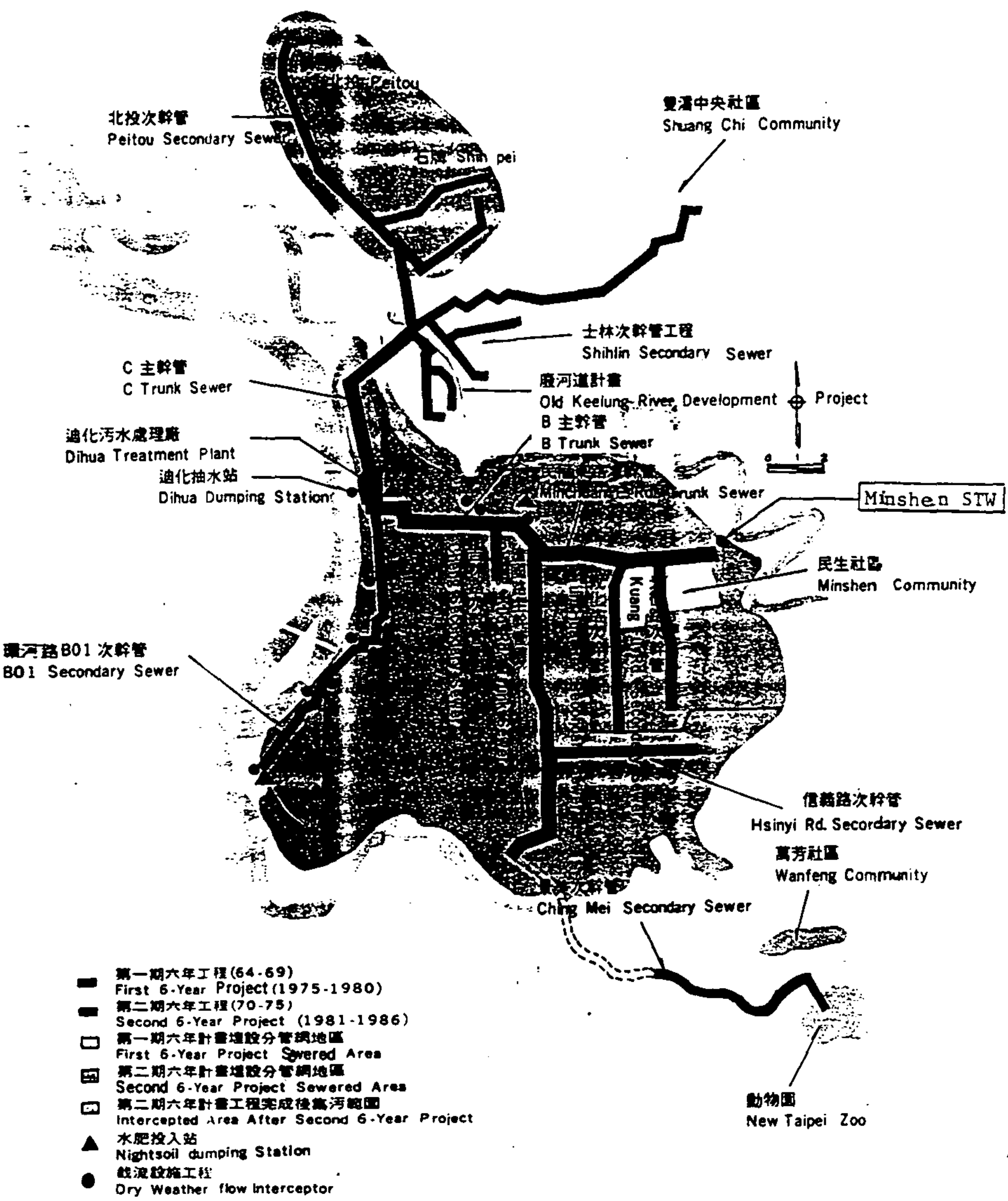


Fig. 7.4 : LOCATION OF MINSHEN STW

tank. The effluent after secondary treatment goes through tertiary treatment (rapid sand filtration) before it is discharged to the Keelung River which is adjacent to the plant. The effluent is required by the authority to be of a very high standard (BOD_5: 5-10 and s.s.: 5-10) for two reasons: (1) the Keelung River is already fairly polluted as a result of the rapid industrialization (the environmental protection programmes launched there recently have not been able to cope with the rapid industrial development), (2) the effluent is partly used in a scenic fountain in the San Min Park of the Min Shen Housing Estate, which is a pioneering project of wastewater reuse in Taiwan. The effluent from the RBC usually has a BOD_5 of 10 to 15 mg/l and that from the activated sludge process 20 to 30 mg/l. These figures reduce to about 8 mg/l and 18 mg/l respectively following tertiary treatment. Therefore, for most of the time, only the tertiary treated effluent from the RBC process is used in the wastewater reuse project. However, it is the desire of the authority to have more reusable effluent from the plant. Further details of this plant can be found in Appendix C.2.3 and that of Taiwan/Taipei in general can be found in Appendices C.1.3 and C.3.3.

The decision variables used on this occasion were those in the third category (ie. 1, 2, ..., 46) shown in the hierarchical structure in Fig. 4.1. Since there were too many decision variables in this category, they had to be reduced to a smaller number --- preferably not exceeding 15 (see Section 6.4 of Chapter 6) --- by the use of a screening exercise. In this test, the number of decision variables that remained after screening was 10. The screening exercise is simple and is described in the next paragraph.

Decision variables numbered 1 to 13 were not to be considered as the site area available could in no way permit their selection. Now, only 33 (ie. 45 - 13) decision variables remained for selection. Out of these 33 decision variables, only those with tertiary treatment were to be considered because the required effluent standard could only consistently be met with the use of tertiary treatment. Now there were only 10 decision variables remaining all of which include tertiary treatment and hence they were taken as the decision variables for the test.

Decision Variable	Description
1	Primary clarifier + Simple percolating filtration + Tertiary treatment
2	Primary clarifier + Percolating filtration with recirculation + Tertiary treatment
3	Primary clarifier + Alternating double filtration + Tertiary treatment
4	Primary clarifier + Conventional activated sludge process + Tertiary treatment
5	Primary clarifier + High-purity oxygen activated sludge process + Tertiary Treatment

6	Deep shaft + Nitrifying filter
7	Primary clarifier + Rotating biological contactor + Tertiary treatment
8	Oxidation ditch + Tertiary treatment
9	Package activated sludge plant + Tertiary treatment
10	Package high-purity oxygen plant + Tertiary treatment

The tertiary treatment in the above decision variables is assumed, except for Deep Shaft, to be rapid sand filtration, the existing tertiary treatment method used by the plant. Other tertiary treatment techniques (eg. microstraining) of course could have been used in this plant, but whether or not they are more appropriate than the existing rapid sand filtration is an irrelevant question in this selection exercise, as the objective here is to select the best alternative to be employed before the tertiary treatment. The twenty 10x10 decision variable matrices entered into the model are given in Section 8.3 of Chapter 8. The result of the computer run on Page 154 shows that the optimal treatment alternative, which scores 100%, is primary clarifier + RBC + tertiary treatment (ie. Decision Variable 7), which is, again, in agreement with the existing situation. The second best alternative, which scores 95%, is primary clarifier + high-purity oxygen activated sludge process + tertiary treatment (ie. Decision Variable 5). The third, which scores 91%, is primary clarifier + conventional activated sludge process + tertiary treatment (ie. Decision Variable 4).

7.6 Shatin Sewage Treatment Plant (Hong Kong)

Shatin STP is situated at the south-west end of Tolo Harbour (see Fig. 7.5)[6]. The effluent from the plant is discharged to the Harbour. Since Tolo Harbour is nearly an enclosed bay, there is a lack of natural currents in the sea water to dilute and disperse the discharged effluent. Hence, the standard of the effluent required is high in order to control the water quality in the harbour which has experienced a decline in environmental conditions as a result of rapid residential and industrial development in Shatin. The plant was built on a piece of reclaimed land created by filling a huge volume of earth onto the Tolo Harbour. The site is quite isolated. Land is always a problem in Hong Kong and the cost of land is extremely expensive. In this particular case, land for building the plant was not available unless it was reclaimed from the sea, thus making the land cost exceptionally costly.

The construction of Shatin STP began in late 1970's and the first phase of the plant started operation in 1981, treating an average daily dry weather flow of 100,000 m^3/day (about 240,000 P.E.). The second phase of the plant, treating also the same amount of flow, started operation in 1986, resulting in a total treatment capacity

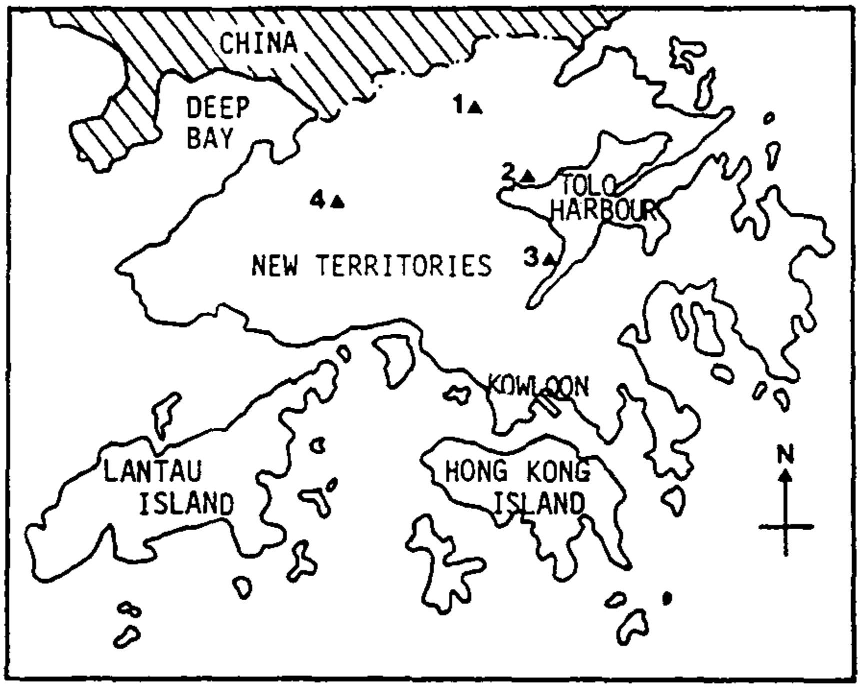


Fig. 7.5 : Map of Hong Kong and Location of Sewage Treatment Plants: 1 - Shek Wu Hui STP, 2 - Tai Po STP, 3 - Shatin STP and 4 - Yuen Long STP.

of 200,000 m^3/day for the plant. The treatment method employed is the activated sludge process. 60% of the influent is from the municipality of Shatin New Town and 40% from the industrial establishments in the vicinity. The mixed influent has an average BOD_5 of 250 mg/l and s.s. of 220 mg/l. No tertiary treatment (e.g. microstrainers or rapid sand filters) is provided in the plant. The effluent standard is of 10 to 15 mg/l BOD_5 and 15 to 25 mg/l s.s. in average. The plant is considered to be working quite satisfactorily. Other details concerning Hong Kong in broad terms and the Shatin STP itself can be found in Appendices C.1.4, C.2.4 and C.3.4.

The decision variables used in the test were those in the first category (ie. A, B, ..., H) shown in the hierarchical structure in Fig. 4.1 of Chapter 4. They are:

Decision Variable	**Description**
1	Stabilization ponds
2	Aerated lagoons
3	Biofiltration
4	Activated sludge process
5	Primary settlement
6	Land application
7	Small plants
8	Package activated sludge plants

The 8x8 decision variable matrices for the 20 parameters are shown in Section 8.4.1 of Chapter 8. The computer run shows that activated sludge process (ie. Decision Variable 4) is the optimal treatment alternative (see Page 165).

Then, the seven decision variables (numbered 23, 24, 25, 26, 27, 28 and 29) under Activated Sludge Process in the hierarchical structure shown in Fig. 4.1 were further ranked. These seven decision variables are:

Decision Variable	Description
1	Primary clarifier + Conventional activated sludge process
2	Septic tank + Conventional activated sludge process
3	Primary clarifier + Conventional activated sludge process + Tertiary treatment
4	Deep shaft
5	Deep shaft + Nitrifying filter
6	Primary clarifier + High-purity oxygen activated sludge process
7	Primary clarifier + High-purity oxygen activated sludge process + Tertiary treatment

The term tertiary treatment that appears in the decision variables should refer to either microstrainers or rapid sand filters as Shatin STP is a huge plant. The twenty 7x7 decision variable matrices are shown in Section 8.4.2 of Chapter 8. The model gives a result on Page 176 that primary clarifier + conventional activated sludge process + tertiary treatment (ie. Decision Variable 3) is the most appropriate treatment alternative. Although the existing Shatin plant is working quite successfully without the use of tertiary treatment, it is the opinion of the author that the latter (perhaps microstrainers) should be added to the plant in order that a even more satisfactory treatment result will be achieved.

CHAPTER 8 --- MODEL TESTING (II)

This chapter must be read in conjunction with Appendix B.1.1, the user's manual of the model. The user should also refer to the DOS manual of an IBM-PC[1] if he uses the PC at the first time. The following sections show a complete record of the dialogue between the user and the computer for ranking wastewater treatment alternatives in Malaysia, Thailand, Taiwan and Hong Kong respectively.

8.1 Computer Run for Puchong STP (Malaysia)

This section must be read in conjunction with Section 7.3 of Chapter 7. The following is a record of running the model.

```
RANKING OF LIQUID TREATMENT ALTERNATIVES

Order of decision variable matrix is n x n where n =  8

PARAMETER 1 : Flow
Do you want to use data from an existing file ?  Y or N ? Y
Name of the existing file is ? PARA1.LIQ
The decision variable matrix is :

1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000
0.333 0.333 0.333 1.000 0.333 0.333 0.333 0.333
1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N
```

Please wait .....

The matrix just entered is stored in a file named 'PARA1.LIQ'

Press the RETURN key to continue

PARAMETER 2 : Influent / Effluent

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA2.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	5.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	5.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	5.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	5.000	1.000	1.000	1.000
0.200	0.200	0.200	0.200	1.000	0.200	0.200	0.200
1.000	1.000	1.000	1.000	5.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	5.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	5.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA2.LIQ

Press the RETURN key to continue

PARAMETER 3 : Size of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA3.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	4.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	5.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	5.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	6.000	1.000	1.000
0.333	0.250	0.200	0.200	0.167	1.000	0.200	0.200
1.000	1.000	1.000	1.000	1.000	5.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	5.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA3.LIQ

Press the RETURN key to continue

PARAMETER 4 : Nature of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA4.LIQ

The decision variable matrix is :

1.000	1.000	3.000	3.000	3.000	3.000	3.000	3.000
1.000	1.000	3.000	3.000	3.000	3.000	3.000	3.000
0.333	0.333	1.000	1.000	1.000	1.000	1.000	1.000
0.333	0.333	1.000	1.000	1.000	1.000	1.000	1.000
0.333	0.333	1.000	1.000	1.000	1.000	1.000	1.000
0.333	0.333	1.000	1.000	1.000	1.000	1.000	1.000
0.333	0.333	1.000	1.000	1.000	1.000	1.000	1.000
0.333	0.333	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA4.LIQ

Press the RETURN key to continue

PARAMETER 5 : Land cost

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA5.LIQ

The decision variable matrix is :

1.000	0.500	0.333	0.333	0.333	3.000	0.333	0.333
2.000	1.000	0.500	0.500	0.500	4.000	0.500	0.500
3.000	2.000	1.000	1.000	1.000	5.000	1.000	1.000
3.000	2.000	1.000	1.000	1.000	5.000	1.000	1.000
3.000	2.000	1.000	1.000	1.000	5.000	1.000	1.000
0.333	0.250	0.200	0.200	0.200	1.000	0.200	0.200
3.000	2.000	1.000	1.000	1.000	5.000	1.000	1.000
3.000	2.000	1.000	1.000	1.000	5.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA5.LIQ

Press the RETURN key to continue

PARAMETER 6 : Local money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA6.LIQ

The decision variable matrix is :

1.000	2.000	4.000	5.000	2.000	2.000	3.000	5.000
0.500	1.000	3.000	4.000	1.000	1.000	2.000	4.000
0.250	0.333	1.000	2.000	0.333	0.333	0.500	2.000
0.200	0.250	0.500	1.000	0.250	0.250	0.333	1.000
0.500	1.000	3.000	4.000	1.000	1.000	2.000	4.000
0.500	1.000	3.000	4.000	1.000	1.000	2.000	4.000
0.333	0.500	2.000	3.000	0.500	0.500	1.000	3.000
0.200	0.250	0.500	1.000	0.250	0.250	0.333	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA6.LIQ

Press the RETURN key to continue

PARAMETER 7 : Foreign money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA7.LIQ

The decision variable matrix is :

1.000	1.000	3.000	5.000	1.000	1.000	3.000	4.000
1.000	1.000	2.000	4.000	1.000	1.000	2.000	4.000
0.333	0.500	1.000	3.000	0.333	0.333	1.000	2.000
0.200	0.250	0.333	1.000	0.200	0.200	0.333	0.500
1.000	1.000	3.000	5.000	1.000	1.000	2.000	4.000
1.000	1.000	3.000	5.000	1.000	1.000	2.000	4.000
0.333	0.500	1.000	3.000	0.500	0.500	1.000	2.000
0.250	0.250	0.500	2.000	0.250	0.250	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA7.LIQ

Press the RETURN key to continue

PARAMETER 8 : Local skill for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA8.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
0.333 0.333 0.500 1.000 0.333 0.333 0.333 0.500
1.000 1.000 1.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 3.000 1.000 1.000 1.000 2.000
0.500 0.500 1.000 2.000 0.500 0.500 0.500 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA8.LIQ

Press the RETURN key to continue

PARAMETER 9 : Community support

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA9.LIQ

The decision variable matrix is :

```
1.000 1.000 2.000 3.000 1.000 0.333 2.000 3.000
1.000 1.000 2.000 3.000 1.000 0.333 1.000 3.000
0.500 0.500 1.000 2.000 0.500 0.250 1.000 1.000
0.333 0.333 0.500 1.000 3.000 0.200 2.000 1.000
1.000 1.000 2.000 0.333 1.000 0.333 2.000 3.000
3.000 3.000 4.000 5.000 3.000 1.000 4.000 5.000
0.500 1.000 1.000 0.500 0.500 0.250 1.000 1.000
0.333 0.333 1.000 1.000 0.333 0.200 0.500 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA9.LIQ

Press the RETURN key to continue

PARAMETER 10 : Power source

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA10.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA10.LIQ

Press the RETURN key to continue

PARAMETER 11 : Availability of local material

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA11.LIQ

The decision variable matrix is :

1.000	1.000	2.000	4.000	2.000	1.000	2.000	3.000
1.000	1.000	1.000	4.000	1.000	1.000	1.000	3.000
0.500	1.000	1.000	3.000	1.000	1.000	1.000	2.000
0.250	0.250	0.333	1.000	0.333	0.333	0.500	1.000
0.500	1.000	1.000	3.000	1.000	1.000	2.000	3.000
1.000	1.000	1.000	3.000	1.000	1.000	2.000	3.000
0.500	1.000	1.000	2.000	0.500	0.500	1.000	2.000
0.333	0.333	0.500	1.000	0.333	0.333	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA11.LIQ

Press the RETURN key to continue

PARAMETER 12 : Cost of operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA12.LIQ

The decision variable matrix is :

1.000	3.000	4.000	5.000	3.000	3.000	3.000	5.000
0.333	1.000	2.000	4.000	1.000	1.000	1.000	4.000
0.250	0.500	1.000	3.000	0.500	0.500	0.500	3.000
0.200	0.250	0.333	1.000	0.333	0.333	0.333	1.000
0.333	1.000	2.000	3.000	1.000	1.000	1.000	3.000
0.333	1.000	2.000	3.000	1.000	1.000	1.000	3.000
0.333	1.000	2.000	3.000	1.000	1.000	1.000	3.000
0.200	0.250	0.333	1.000	0.333	0.333	0.333	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA12.LIQ

Press the RETURN key to continue

PARAMETER 13 : Professional skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA13.LIQ

The decision variable matrix is :

1.000	1.000	2.000	5.000	1.000	3.000	2.000	3.000
1.000	1.000	2.000	4.000	1.000	2.000	2.000	2.000
0.500	0.500	1.000	3.000	0.333	1.000	0.500	1.000
0.200	0.250	0.333	1.000	0.200	0.333	0.250	0.333
1.000	1.000	3.000	5.000	1.000	3.000	2.000	3.000
0.333	0.500	1.000	3.000	0.333	1.000	0.500	1.000
0.500	0.500	2.000	4.000	0.500	2.000	1.000	2.000
0.333	0.500	1.000	3.000	0.333	1.000	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA13.LIQ

Press the RETURN key to continue

PARAMETER 14 : Local technical skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA14.LIQ

The decision variable matrix is :

1.000	2.000	3.000	6.000	2.000	4.000	3.000	4.000
0.500	1.000	3.000	5.000	2.000	3.000	3.000	3.000
0.333	0.333	1.000	3.000	0.333	1.000	0.500	1.000
0.167	0.200	0.333	1.000	0.200	0.333	0.250	0.333
0.500	0.500	3.000	5.000	1.000	3.000	2.000	3.000
0.250	0.333	1.000	3.000	0.333	1.000	0.500	1.000
0.333	0.333	2.000	4.000	0.500	2.000	1.000	2.000
0.250	0.333	1.000	3.000	0.333	1.000	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA14.LIQ

Press the RETURN key to continue

PARAMETER 15 : Administration set-up

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA15.LIQ

The decision variable matrix is :

1.000	1.000	2.000	4.000	1.000	3.000	2.000	2.000
1.000	1.000	2.000	4.000	1.000	3.000	2.000	2.000
0.500	0.500	1.000	3.000	0.500	2.000	1.000	1.000
0.250	0.250	0.333	1.000	0.250	0.500	0.333	0.333
1.000	1.000	2.000	4.000	1.000	3.000	2.000	2.000
0.333	0.333	0.500	2.000	0.333	1.000	0.500	0.500
0.500	0.500	1.000	3.000	0.500	2.000	1.000	1.000
0.500	0.500	1.000	3.000	0.500	2.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA15.LIQ

Press the RETURN key to continue

PARAMETER 16 : Training

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA16.LIQ

The decision variable matrix is :

1.000	3.000	5.000	9.000	3.000	5.000	3.000	7.000
0.333	1.000	3.000	7.000	1.000	3.000	1.000	5.000
0.200	0.333	1.000	5.000	0.333	1.000	0.500	3.000
0.111	0.143	0.200	1.000	0.143	0.200	0.143	0.333
0.333	1.000	3.000	7.000	1.000	3.000	1.000	5.000
0.200	0.333	1.000	5.000	0.333	1.000	0.333	3.000
0.333	1.000	2.000	7.000	1.000	3.000	1.000	5.000
0.143	0.200	0.333	3.000	0.200	0.333	0.200	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA16.LIQ

Press the RETURN key to continue

PARAMETER 17 : Professional ethics

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA17.LIQ

The decision variable matrix is :

1.000	2.000	4.000	7.000	2.000	4.000	2.000	5.000
0.500	1.000	3.000	6.000	1.000	3.000	1.000	4.000
0.250	0.333	1.000	4.000	0.500	1.000	0.500	2.000
0.143	0.167	0.250	1.000	0.200	0.333	0.200	0.500
0.500	1.000	2.000	5.000	1.000	3.000	1.000	4.000
0.250	0.333	1.000	3.000	0.333	1.000	0.500	1.000
0.500	1.000	2.000	5.000	1.000	2.000	1.000	3.000
0.200	0.250	0.500	2.000	0.250	1.000	0.333	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA17.LIQ

Press the RETURN key to continue

PARAMETER 18 : Climate

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA18.LIQ

The decision variable matrix is :

1.000	1.000	2.000	2.000	2.000	5.000	2.000	2.000
1.000	1.000	2.000	2.000	2.000	5.000	2.000	2.000
0.500	0.500	1.000	1.000	1.000	3.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	3.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	3.000	1.000	1.000
0.200	0.200	0.333	0.333	0.333	1.000	0.333	0.333
0.500	0.500	1.000	1.000	1.000	3.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	3.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA18.LIQ

Press the RETURN key to continue

PARAMETER 19 : Local water-borne diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA19.LIQ

The decision variable matrix is :

1.000	2.000	3.000	3.000	5.000	1.000	3.000	3.000
0.500	1.000	2.000	2.000	4.000	0.500	2.000	2.000
0.333	0.500	1.000	1.000	3.000	0.333	1.000	1.000
0.333	0.500	1.000	1.000	3.000	0.333	1.000	1.000
0.200	0.250	0.333	0.333	1.000	0.200	0.333	0.333
1.000	2.000	3.000	3.000	5.000	1.000	3.000	3.000
0.333	0.500	1.000	1.000	3.000	0.333	1.000	1.000
0.333	0.500	1.000	1.000	3.000	0.333	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA19.LIQ

Press the RETURN key to continue

PARAMETER 20 : Endemic vector-borne (water-related) diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA20.LIQ

The decision variable matrix is :

1.000	1.000	0.333	0.333	0.333	2.000	0.333	0.333
1.000	1.000	0.333	0.333	0.333	2.000	0.333	0.333
3.000	3.000	1.000	1.000	1.000	3.000	1.000	1.000
3.000	3.000	1.000	1.000	1.000	3.000	1.000	1.000
3.000	3.000	1.000	1.000	1.000	3.000	1.000	1.000
0.500	0.500	0.333	0.333	0.333	1.000	0.333	0.333
3.000	3.000	1.000	1.000	1.000	3.000	1.000	1.000
3.000	3.000	1.000	1.000	1.000	3.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA20.LIQ

You have already entered all the necessary data

Press the RETURN key to continue

Please wait. Calculation of the ranking of the alternatives is in process.

The ranking is :

	RANKING IN %
Alternative 1	100
Alternative 2	87.95443
Alternative 3	70.46707
Alternative 4	60.0522
Alternative 5	67.94486
Alternative 6	60.55442
Alternative 7	75.00223
Alternative 8	66.6338

8.2 Computer Run for Pattaya South STP (Thailand)

This section must be read in conjunction with Section 7.4 of Chapter 7. The following is a record of running the model.

RANKING OF LIQUID TREATMENT ALTERNATIVES

Order of decision variable matrix is n x n where n = 12

PARAMETER 1 : Flow

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA1.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 2.000 2.000 2.000 3.000 2.000 1.000 2.000 2.000 2.000
1.000 1.000 1.000 2.000 2.000 2.000 3.000 2.000 1.000 2.000 2.000 2.000
1.000 1.000 1.000 2.000 2.000 2.000 3.000 2.000 1.000 2.000 2.000 2.000
0.500 0.500 0.500 1.000 1.000 1.000 2.000 1.000 0.500 1.000 1.000 1.000
0.500 0.500 0.500 1.000 1.000 1.000 2.000 1.000 0.500 1.000 1.000 1.000
0.500 0.500 0.500 1.000 1.000 1.000 2.000 1.000 0.500 1.000 1.000 1.000
0.333 0.333 0.333 0.500 0.500 0.500 1.000 0.500 0.333 0.500 0.500 0.500
0.500 0.500 0.500 1.000 1.000 1.000 2.000 1.000 0.500 1.000 1.000 1.000
1.000 1.000 1.000 2.000 2.000 2.000 3.000 2.000 1.000 2.000 2.000 2.000
0.500 0.500 0.500 1.000 1.000 1.000 2.000 1.000 0.500 1.000 1.000 1.000
0.500 0.500 0.500 1.000 1.000 1.000 2.000 1.000 0.500 1.000 1.000 1.000
0.500 0.500 0.500 1.000 1.000 1.000 2.000 1.000 0.500 1.000 1.000 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named 'PARA1.LIQ'

Press the RETURN key to continue

PARAMETER 2 : Influent / Effluent

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA2.LIQ

The decision variable matrix is :

1.000	0.500	1.000	0.500	0.500	0.333	0.333	9.000	0.333	0.333	0.500	0.333
2.000	1.000	2.000	1.000	1.000	0.500	0.500	9.000	0.500	0.500	1.000	0.500
1.000	0.500	1.000	0.500	0.500	0.333	0.333	9.000	0.333	0.333	0.500	0.333
2.000	1.000	2.000	1.000	1.000	0.500	0.500	9.000	0.500	0.500	1.000	0.500
2.000	1.000	2.000	1.000	1.000	0.500	0.500	9.000	0.500	0.500	1.000	0.500
3.000	2.000	3.000	2.000	2.000	1.000	1.000	9.000	1.000	1.000	2.000	1.000
3.000	2.000	3.000	2.000	2.000	1.000	1.000	9.000	1.000	1.000	2.000	1.000
0.111	0.111	0.111	0.111	0.111	0.111	0.111	1.000	0.111	0.111	0.111	0.111
3.000	2.000	3.000	2.000	2.000	1.000	1.000	9.000	1.000	1.000	2.000	1.000
3.000	2.000	3.000	2.000	2.000	1.000	1.000	9.000	1.000	1.000	2.000	1.000
2.000	1.000	2.000	1.000	1.000	0.500	0.500	9.000	0.500	0.500	1.000	0.500
3.000	2.000	3.000	2.000	2.000	1.000	1.000	9.000	1.000	1.000	2.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA2.LIQ

Press the RETURN key to continue

PARAMETER 3 : Size of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA3.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	0.200	0.111	0.111	0.111	1.000	0.111	0.200	0.111
1.000	1.000	1.000	1.000	0.200	0.111	0.111	0.111	1.000	0.111	0.200	0.111
1.000	1.000	1.000	1.000	0.200	0.111	0.111	0.111	1.000	0.111	0.200	0.111
1.000	1.000	1.000	1.000	0.200	0.111	0.111	0.111	1.000	0.111	0.200	0.111
5.000	5.000	5.000	5.000	1.000	0.200	0.200	0.200	7.000	0.200	1.000	0.200
9.000	9.000	9.000	9.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
9.000	9.000	9.000	9.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
9.000	9.000	9.000	9.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
1.000	1.000	1.000	1.000	0.143	0.111	0.111	0.111	1.000	0.111	0.111	0.111
9.000	9.000	9.000	9.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
5.000	5.000	5.000	5.000	1.000	0.200	0.200	0.200	9.000	0.200	1.000	0.200
9.000	9.000	9.000	9.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA3.LIQ

Press the RETURN key to continue

PARAMETER 4 : Nature of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA4.LIQ

The decision variable matrix is :

1.000	1.000	1.000	0.200	0.200	0.111	0.111	0.111	3.000	0.111	0.200	0.111
1.000	1.000	1.000	0.200	0.200	0.111	0.111	0.111	3.000	0.111	0.200	0.111
1.000	1.000	1.000	0.200	0.200	0.111	0.111	0.111	3.000	0.111	0.200	0.111
5.000	5.000	5.000	1.000	1.000	0.200	0.200	0.200	7.000	0.200	1.000	0.200
5.000	5.000	5.000	1.000	1.000	0.200	0.200	0.200	7.000	0.200	1.000	0.200
9.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
9.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
9.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
0.333	0.333	0.333	0.143	0.143	0.111	0.111	0.111	1.000	0.111	0.143	0.111
9.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000
5.000	5.000	5.000	1.000	1.000	0.200	0.200	0.200	7.000	0.200	1.000	0.200
9.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	9.000	1.000	5.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA4.LIQ

Press the RETURN key to continue

PARAMETER 5 : Land cost

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA5.LIQ

The decision variable matrix is :

1.000	0.333	0.500	0.250	0.200	0.167	0.143	0.125	2.000	0.143	0.250	0.200
3.000	1.000	3.000	0.333	0.250	0.200	0.167	0.143	4.000	0.167	0.250	0.200
2.000	0.333	1.000	0.333	0.250	0.200	0.167	0.143	3.000	0.167	0.250	0.200
4.000	3.000	3.000	1.000	0.500	0.250	0.200	0.167	5.000	0.200	0.500	0.500
5.000	4.000	4.000	2.000	1.000	0.333	0.250	0.200	6.000	0.250	1.000	1.000
6.000	5.000	5.000	4.000	3.000	1.000	0.333	0.250	7.000	0.333	3.000	2.000
7.000	6.000	6.000	5.000	4.000	3.000	1.000	0.500	8.000	1.000	4.000	3.000
8.000	7.000	7.000	6.000	5.000	4.000	2.000	1.000	9.000	2.000	5.000	4.000
0.500	0.250	0.333	0.200	0.167	0.143	0.125	0.111	1.000	0.125	0.200	0.167
7.000	6.000	6.000	5.000	4.000	3.000	1.000	0.500	8.000	1.000	5.000	4.000
4.000	4.000	4.000	2.000	1.000	0.333	0.250	0.200	5.000	0.200	1.000	0.500
5.000	5.000	5.000	2.000	1.000	0.500	0.333	0.250	6.000	0.250	2.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA5.LIQ

Press the RETURN key to continue

PARAMETER 6 : Local money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA6.LIQ

The decision variable matrix is :

1.000	2.000	2.000	4.000	4.000	5.000	7.000	2.000	2.000	3.000	2.000	5.000
0.500	1.000	1.000	3.000	3.000	4.000	6.000	1.000	1.000	2.000	1.000	4.000
0.500	1.000	1.000	3.000	3.000	4.000	6.000	1.000	1.000	2.000	1.000	4.000
0.250	0.333	0.333	1.000	1.000	2.000	4.000	0.333	0.333	0.500	0.333	2.000
0.250	0.333	0.333	1.000	1.000	2.000	4.000	0.333	0.333	0.500	0.333	2.000
0.200	0.250	0.250	0.500	0.500	1.000	3.000	0.250	0.250	0.333	0.250	1.000
0.143	0.167	0.167	0.250	0.250	0.333	1.000	0.167	0.167	0.200	0.167	0.333
0.500	1.000	1.000	3.000	3.000	4.000	6.000	1.000	1.000	2.000	1.000	4.000
0.500	1.000	1.000	3.000	3.000	4.000	6.000	1.000	1.000	2.000	1.000	4.000
0.333	0.500	0.500	2.000	2.000	3.000	5.000	0.500	0.500	1.000	0.500	3.000
0.500	1.000	1.000	3.000	3.000	4.000	6.000	1.000	1.000	2.000	1.000	4.000
0.200	0.250	0.250	0.500	0.500	1.000	3.000	0.250	0.250	0.333	0.250	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA6.LIQ

Press the RETURN key to continue

PARAMETER 7 : Foreign money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA7.LIQ

The decision variable matrix is :

1.000	3.000	3.000	5.000	5.000	7.000	9.000	3.000	3.000	5.000	4.000	7.000
0.333	1.000	1.000	3.000	3.000	5.000	7.000	1.000	1.000	3.000	2.000	5.000
0.333	1.000	1.000	3.000	3.000	5.000	7.000	1.000	1.000	3.000	2.000	5.000
0.200	0.333	0.333	1.000	1.000	3.000	5.000	0.333	0.333	1.000	0.500	3.000
0.200	0.333	0.333	1.000	1.000	3.000	5.000	0.333	0.333	1.000	0.500	3.000
0.143	0.200	0.200	0.333	0.333	1.000	3.000	0.200	0.200	0.333	0.250	1.000
0.111	0.143	0.143	0.200	0.200	0.333	1.000	0.143	0.143	0.200	0.167	0.333
0.333	1.000	1.000	3.000	3.000	5.000	7.000	1.000	1.000	3.000	2.000	5.000
0.333	1.000	1.000	3.000	3.000	5.000	7.000	1.000	1.000	3.000	2.000	5.000
0.200	0.333	0.333	1.000	1.000	3.000	5.000	0.333	0.333	1.000	0.500	3.000
0.250	0.500	0.500	2.000	2.000	4.000	6.000	0.500	0.500	2.000	1.000	4.000
0.143	0.200	0.200	0.333	0.333	1.000	3.000	0.200	0.200	0.333	0.250	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA7.LIQ

Press the RETURN key to continue

```
PARAMETER 8 : Local skill for construction

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA8.LIQ

The decision variable matrix is :
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
0.333 0.333 0.333 0.333 0.333 1.000 3.000 0.333 0.333 0.333 0.333 1.000
0.200 0.200 0.200 0.200 0.200 0.333 1.000 0.200 0.200 0.200 0.200 0.333
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 1.000 1.000 3.000 5.000 1.000 1.000 1.000 1.000 3.000
0.333 0.333 0.333 0.333 0.333 1.000 3.000 0.333 0.333 0.333 0.333 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA8.LIQ

Press the RETURN key to continue


PARAMETER 9 : Community support

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA9.LIQ

The decision variable matrix is :
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000 1.000
0.333 0.333 0.333 0.333 0.333 0.500 1.000 0.333 0.333 0.333 0.333 0.333
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA9.LIQ

Press the RETURN key to continue
```

```
PARAMETER 10 : Power source

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA10.LIQ

The decision variable matrix is :
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA10.LIQ

Press the RETURN key to continue


PARAMETER 11 : Availability of local material

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA11.LIQ

The decision variable matrix is :
1.000 2.000 2.000 2.000 2.000 5.000 6.000 2.000 2.000 2.000 2.000 4.000
0.500 1.000 1.000 1.000 1.000 4.000 5.000 1.000 1.000 1.000 1.000 3.000
0.500 1.000 1.000 1.000 1.000 4.000 5.000 1.000 1.000 1.000 1.000 3.000
0.500 1.000 1.000 1.000 1.000 3.000 4.000 1.000 1.000 1.000 1.000 2.000
0.500 1.000 1.000 1.000 1.000 3.000 4.000 1.000 1.000 1.000 1.000 2.000
0.200 0.250 0.250 0.333 0.333 1.000 2.000 0.250 0.250 0.333 0.333 1.000
0.167 0.200 0.200 0.250 0.250 0.500 1.000 0.200 0.200 0.250 0.250 0.333
0.500 1.000 1.000 1.000 1.000 4.000 5.000 1.000 1.000 1.000 1.000 3.000
0.500 1.000 1.000 1.000 1.000 4.000 5.000 1.000 1.000 1.000 1.000 3.000
0.500 1.000 1.000 1.000 1.000 3.000 4.000 1.000 1.000 1.000 1.000 3.000
0.500 1.000 1.000 1.000 1.000 3.000 4.000 1.000 1.000 1.000 1.000 3.000
0.250 0.333 0.333 0.500 0.500 1.000 3.000 0.333 0.333 0.333 0.333 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA11.LIQ

Press the RETURN key to continue
```

```
PARAMETER 12 : Cost of operation & maintenance

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA12.LIQ

The decision variable matrix is :
1.000 3.000 2.000 3.000 3.000 6.000 8.000 2.000 2.000 3.000 3.000 6.000
0.333 1.000 0.500 1.000 1.000 4.000 6.000 0.500 0.500 1.000 1.000 4.000
0.500 2.000 1.000 2.000 2.000 5.000 7.000 1.000 1.000 2.000 2.000 5.000
0.333 1.000 0.500 1.000 1.000 4.000 6.000 0.500 0.500 1.000 1.000 4.000
0.333 1.000 0.500 1.000 1.000 4.000 6.000 0.500 0.500 1.000 1.000 4.000
0.167 0.250 0.200 0.250 0.250 1.000 3.000 0.200 0.200 0.250 0.250 1.000
0.125 0.167 0.143 0.167 0.167 0.333 1.000 0.143 0.143 0.167 0.167 0.333
0.500 2.000 1.000 2.000 2.000 5.000 7.000 1.000 1.000 2.000 2.000 5.000
0.500 2.000 1.000 2.000 2.000 5.000 7.000 1.000 1.000 2.000 2.000 5.000
0.333 1.000 0.500 1.000 1.000 4.000 6.000 0.500 0.500 1.000 1.000 4.000
0.333 1.000 0.500 1.000 1.000 4.000 6.000 0.500 0.500 1.000 1.000 4.000
0.167 0.250 0.200 0.250 0.250 1.000 3.000 0.200 0.200 0.250 0.250 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA12.LIQ

Press the RETURN key to continue


PARAMETER 13 : Professional skill available for operation & maintenance

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA13.LIQ

The decision variable matrix is :
1.000 1.000 1.000 2.000 3.000 5.000 7.000 2.000 3.000 2.000 2.000 3.000
1.000 1.000 1.000 2.000 3.000 5.000 7.000 2.000 3.000 2.000 2.000 3.000
1.000 1.000 1.000 2.000 3.000 5.000 7.000 2.000 3.000 2.000 2.000 3.000
0.500 0.500 0.500 1.000 2.000 4.000 6.000 1.000 2.000 1.000 1.000 2.000
0.333 0.333 0.333 0.500 1.000 3.000 5.000 0.500 1.000 0.500 0.500 1.000
0.200 0.200 0.200 0.250 0.333 1.000 3.000 0.250 0.333 0.250 0.250 0.333
0.143 0.143 0.143 0.167 0.200 0.333 1.000 0.167 0.200 0.167 0.167 0.200
0.500 0.500 0.500 1.000 2.000 4.000 6.000 1.000 2.000 1.000 1.000 2.000
0.333 0.333 0.333 0.500 1.000 3.000 5.000 0.500 1.000 0.500 0.500 1.000
0.500 0.500 0.500 1.000 2.000 4.000 6.000 1.000 2.000 1.000 1.000 2.000
0.500 0.500 0.500 1.000 2.000 4.000 6.000 1.000 2.000 1.000 1.000 2.000
0.333 0.333 0.333 0.500 1.000 3.000 5.000 0.500 1.000 0.500 0.500 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA13.LIQ

Press the RETURN key to continue
```

PARAMETER 14 : Local technical skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA14.LIQ

The decision variable matrix is :

1.000	2.000	2.000	3.000	4.000	6.000	8.000	3.000	4.000	3.000	3.000	4.000
0.500	1.000	1.000	2.000	3.000	5.000	7.000	2.000	3.000	2.000	2.000	3.000
0.500	1.000	1.000	2.000	3.000	5.000	7.000	2.000	3.000	2.000	2.000	3.000
0.333	0.500	0.500	1.000	2.000	4.000	6.000	1.000	2.000	1.000	1.000	2.000
0.250	0.333	0.333	0.500	1.000	3.000	5.000	0.500	1.000	0.500	0.500	1.000
0.167	0.200	0.200	0.250	0.333	1.000	3.000	0.250	0.333	0.250	0.250	0.333
0.125	0.143	0.143	0.167	0.200	0.333	1.000	0.167	0.200	0.167	0.167	0.200
0.333	0.500	0.500	1.000	2.000	4.000	6.000	1.000	2.000	1.000	1.000	2.000
0.250	0.333	0.333	0.500	1.000	3.000	5.000	0.500	1.000	0.500	0.500	1.000
0.333	0.500	0.500	1.000	2.000	4.000	6.000	1.000	2.000	1.000	1.000	2.000
0.333	0.500	0.500	1.000	2.000	4.000	6.000	1.000	2.000	1.000	1.000	2.000
0.250	0.333	0.333	0.500	1.000	3.000	5.000	0.500	1.000	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA14.LIQ

Press the RETURN key to continue

PARAMETER 15 : Administration set-up

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA15.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	2.000	5.000	7.000	2.000	4.000	2.000	2.000	3.000
1.000	1.000	1.000	2.000	2.000	5.000	7.000	2.000	4.000	2.000	2.000	3.000
1.000	1.000	1.000	2.000	2.000	5.000	7.000	2.000	4.000	2.000	2.000	3.000
0.500	0.500	0.500	1.000	2.000	4.000	6.000	1.000	3.000	1.000	1.000	2.000
0.500	0.500	0.500	0.500	1.000	4.000	6.000	1.000	3.000	1.000	1.000	2.000
0.200	0.200	0.200	0.250	0.250	1.000	3.000	0.250	0.500	0.250	0.250	0.333
0.143	0.143	0.143	0.167	0.167	0.333	1.000	0.167	0.250	0.167	0.167	0.200
0.500	0.500	0.500	1.000	1.000	4.000	6.000	1.000	3.000	1.000	1.000	2.000
0.250	0.250	0.250	0.333	0.333	2.000	4.000	0.333	1.000	0.333	0.333	0.500
0.500	0.500	0.500	1.000	1.000	4.000	6.000	1.000	3.000	1.000	1.000	2.000
0.500	0.500	0.500	1.000	1.000	4.000	6.000	1.000	3.000	1.000	1.000	2.000
0.333	0.333	0.333	0.500	0.500	3.000	5.000	0.500	2.000	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA15.LIQ

Press the RETURN key to continue

PARAMETER 16 : Training

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA16.LIQ

The decision variable matrix is :

1.000	2.000	2.000	2.000	2.000	4.000	6.000	2.000	3.000	2.000	2.000	3.000
0.500	1.000	1.000	1.000	1.000	3.000	5.000	1.000	2.000	1.000	1.000	2.000
0.500	1.000	1.000	1.000	1.000	3.000	5.000	1.000	2.000	1.000	1.000	2.000
0.500	1.000	1.000	1.000	1.000	3.000	5.000	1.000	2.000	1.000	1.000	2.000
0.500	1.000	1.000	1.000	1.000	3.000	5.000	1.000	2.000	1.000	1.000	2.000
0.250	0.333	0.333	0.333	0.333	1.000	3.000	0.333	0.500	0.333	0.333	0.500
0.167	0.200	0.200	0.200	0.200	0.333	1.000	0.200	0.250	0.200	0.200	0.250
0.500	1.000	1.000	1.000	1.000	3.000	5.000	1.000	3.000	1.000	1.000	3.000
0.333	0.500	0.500	0.500	0.500	2.000	4.000	0.333	1.000	0.500	0.500	1.000
0.500	1.000	1.000	1.000	1.000	3.000	5.000	1.000	2.000	1.000	1.000	2.000
0.500	1.000	1.000	1.000	1.000	3.000	5.000	1.000	2.000	1.000	1.000	2.000
0.333	0.500	0.500	0.500	0.500	2.000	4.000	0.333	1.000	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA16.LIQ

Press the RETURN key to continue

PARAMETER 17 : Professional ethics

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA17.LIQ

The decision variable matrix is :

1.000	2.000	2.000	4.000	4.000	7.000	9.000	2.000	4.000	2.000	2.000	5.000
0.500	1.000	1.000	3.000	3.000	6.000	8.000	1.000	3.000	1.000	1.000	4.000
0.500	1.000	1.000	3.000	3.000	6.000	8.000	1.000	3.000	1.000	1.000	4.000
0.250	0.333	0.333	1.000	1.000	4.000	6.000	0.500	1.000	0.500	0.500	2.000
0.250	0.333	0.333	1.000	1.000	4.000	6.000	0.333	1.000	0.333	0.333	3.000
0.143	0.167	0.167	0.250	0.250	1.000	3.000	0.167	0.250	0.167	0.167	0.333
0.111	0.125	0.125	0.167	0.167	0.333	1.000	0.125	0.167	0.125	0.125	0.200
0.500	1.000	1.000	2.000	3.000	6.000	8.000	1.000	3.000	1.000	1.000	4.000
0.250	0.333	0.333	1.000	1.000	4.000	6.000	0.333	1.000	0.333	0.333	1.000
0.500	1.000	1.000	2.000	3.000	6.000	8.000	1.000	3.000	1.000	1.000	4.000
0.500	1.000	1.000	2.000	3.000	6.000	8.000	1.000	3.000	1.000	1.000	4.000
0.200	0.250	0.250	0.500	0.333	3.000	5.000	0.250	1.000	0.250	0.250	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA17.LIQ

Press the RETURN key to continue

PARAMETER 18 : Climate

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA18.LIQ

The decision variable matrix is :

1.000	1.000	1.000	3.000	3.000	2.000	2.000	2.000	5.000	2.000	2.000	2.000
1.000	1.000	1.000	3.000	3.000	2.000	2.000	2.000	5.000	2.000	2.000	2.000
1.000	1.000	1.000	3.000	3.000	2.000	2.000	2.000	5.000	2.000	2.000	2.000
0.333	0.333	0.333	1.000	1.000	0.500	0.500	0.500	3.000	0.500	0.500	0.500
0.333	0.333	0.333	1.000	1.000	0.500	0.500	0.500	3.000	0.500	0.500	0.500
0.500	0.500	0.500	2.000	2.000	1.000	1.000	1.000	4.000	1.000	1.000	1.000
0.500	0.500	0.500	2.000	2.000	1.000	1.000	1.000	4.000	1.000	1.000	1.000
0.500	0.500	0.500	2.000	2.000	1.000	1.000	1.000	4.000	1.000	1.000	1.000
0.200	0.200	0.200	0.333	0.333	0.250	0.250	0.250	1.000	0.250	0.250	0.250
0.500	0.500	0.500	2.000	2.000	1.000	1.000	1.000	4.000	1.000	1.000	1.000
0.500	0.500	0.500	2.000	2.000	1.000	1.000	1.000	4.000	1.000	1.000	1.000
0.500	0.500	0.500	2.000	2.000	1.000	1.000	1.000	4.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA18.LIQ

Press the RETURN key to continue

PARAMETER 19 : Local water-borne diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA19.LIQ

The decision variable matrix is :

1.000	2.000	1.000	4.000	5.000	3.000	4.000	7.000	2.000	5.000	3.000	3.000
0.500	1.000	0.500	3.000	4.000	2.000	3.000	6.000	1.000	4.000	2.000	2.000
1.000	2.000	1.000	4.000	5.000	3.000	4.000	7.000	2.000	5.000	3.000	3.000
0.250	0.333	0.250	1.000	2.000	1.000	1.000	5.000	0.333	2.000	0.500	0.500
0.200	0.250	0.200	0.500	1.000	0.500	0.500	4.000	0.250	1.000	0.333	0.333
0.333	0.500	0.333	1.000	2.000	1.000	2.000	5.000	0.333	3.000	0.500	0.500
0.250	0.333	0.250	1.000	2.000	0.500	1.000	5.000	0.333	2.000	0.500	0.500
0.143	0.167	0.143	0.200	0.250	0.200	0.200	1.000	0.167	0.250	0.200	0.200
0.500	1.000	0.500	3.000	4.000	3.000	3.000	6.000	1.000	4.000	3.000	3.000
0.200	0.250	0.200	0.500	1.000	0.333	0.500	4.000	0.250	1.000	0.500	0.500
0.333	0.500	0.333	2.000	3.000	2.000	2.000	5.000	0.333	2.000	1.000	1.000
0.333	0.500	0.333	2.000	3.000	2.000	2.000	5.000	0.333	2.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....
The matrix just entered is stored in a file named PARA19.LIQ

Press the RETURN key to continue

PARAMETER 20 : Endemic vector-borne (water-related) diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA20.LIQ

The decision variable matrix is :

1.000	1.000	1.000	0.500	0.500	0.333	0.200	0.333	3.000	0.200	0.500	0.333
1.000	1.000	1.000	0.500	0.500	0.333	0.200	0.333	3.000	0.200	0.500	0.333
1.000	1.000	1.000	0.500	0.500	0.333	0.200	0.333	3.000	0.200	0.500	0.333
2.000	2.000	2.000	1.000	1.000	0.500	0.250	0.500	4.000	0.250	1.000	0.500
2.000	2.000	2.000	1.000	1.000	0.500	0.250	0.500	4.000	0.250	1.000	0.500
3.000	3.000	3.000	2.000	2.000	1.000	0.333	1.000	5.000	0.333	2.000	1.000
5.000	5.000	5.000	4.000	4.000	3.000	1.000	3.000	7.000	1.000	4.000	3.000
3.000	3.000	3.000	2.000	2.000	1.000	0.333	1.000	5.000	0.333	2.000	1.000
0.333	0.333	0.333	0.250	0.250	0.200	0.143	0.200	1.000	0.143	0.250	0.200
5.000	5.000	5.000	4.000	4.000	3.000	1.000	3.000	7.000	1.000	4.000	3.000
2.000	2.000	2.000	1.000	1.000	0.500	0.250	0.500	4.000	0.250	1.000	0.500
3.000	3.000	3.000	2.000	2.000	1.000	0.333	1.000	5.000	0.333	2.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named 'PARA20.LIQ'

You have already entered all the necessary data

Press the RETURN key to continue

Please wait. Calculation of the ranking of the alternatives is in process.

The ranking is :

	RANKING IN %
Alternative 1	77.32462
Alternative 2	66.4855
Alternative 3	65.83235
Alternative 4	50.38338
Alternative 5	55.20052
Alternative 6	84.51299
Alternative 7	84.36512
Alternative 8	82.55039
Alternative 9	63.00436
Alternative 10	100
Alternative 11	63.26463
Alternative 12	86.33479

8.3 Computer Run for Min Shen STP (Taiwan)

This section must be read in conjunction with Section 7.5 of Chapter 7. The following is a record of running the model.

RANKING OF LIQUID TREATMENT ALTERNATIVES

Order of decision variable matrix is n x n where n = 10

PARAMETER 1 : Flow

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA1.LIQ

The decision variable matrix is :

1.000	0.500	0.500	0.500	0.500	3.000	0.500	0.500	3.000	3.000
2.000	1.000	1.000	1.000	1.000	4.000	1.000	1.000	4.000	4.000
2.000	1.000	1.000	1.000	1.000	4.000	1.000	1.000	4.000	4.000
2.000	1.000	1.000	1.000	1.000	4.000	1.000	1.000	4.000	4.000
2.000	1.000	1.000	1.000	1.000	4.000	1.000	1.000	4.000	4.000
0.333	0.250	0.250	0.250	0.250	1.000	0.250	0.250	1.000	1.000
2.000	1.000	1.000	1.000	1.000	4.000	1.000	2.000	4.000	4.000
2.000	1.000	1.000	1.000	1.000	4.000	0.500	1.000	3.000	3.000
0.333	0.250	0.250	0.250	0.250	1.000	0.250	0.333	1.000	1.000
0.333	0.250	0.250	0.250	0.250	1.000	0.250	0.333	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named 'PARA1.LIQ'

Press the RETURN key to continue

PARAMETER 2 : Influent / Effluent

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA2.LIQ

The decision variable matrix is :

1.000	1.000	1.000	0.500	0.500	0.500	0.500	1.000	0.500	0.500
1.000	1.000	1.000	0.500	0.500	0.500	0.500	1.000	0.500	0.500
1.000	1.000	1.000	0.500	0.500	0.500	0.500	1.000	0.500	0.500
2.000	2.000	2.000	1.000	1.000	1.000	1.000	2.000	1.000	1.000
2.000	2.000	2.000	1.000	1.000	1.000	1.000	2.000	1.000	1.000
2.000	2.000	2.000	1.000	1.000	1.000	1.000	2.000	1.000	1.000
2.000	2.000	2.000	1.000	1.000	1.000	1.000	2.000	1.000	1.000
1.000	1.000	1.000	0.500	0.500	0.500	0.500	1.000	0.500	0.500
2.000	2.000	2.000	1.000	1.000	1.000	1.000	2.000	1.000	1.000
2.000	2.000	2.000	1.000	1.000	1.000	1.000	2.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA2.LIQ

Press the RETURN key to continue

PARAMETER 3 : Size of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA3.LIQ

The decision variable matrix is :

1.000	0.200	0.200	0.111	0.111	0.111	0.111	0.333	0.111	0.111
5.000	1.000	1.000	0.200	0.200	0.200	0.200	3.000	0.200	0.200
5.000	1.000	1.000	0.200	0.200	0.200	0.200	3.000	0.200	0.200
9.000	5.000	5.000	1.000	1.000	1.000	1.000	7.000	1.000	1.000
9.000	5.000	5.000	1.000	1.000	1.000	1.000	7.000	1.000	1.000
9.000	5.000	5.000	1.000	1.000	1.000	1.000	7.000	1.000	1.000
9.000	5.000	5.000	1.000	1.000	1.000	1.000	7.000	1.000	1.000
3.000	0.333	0.333	0.143	0.143	0.143	0.143	1.000	0.167	0.167
9.000	5.000	5.000	1.000	1.000	1.000	1.000	5.000	1.000	1.000
9.000	5.000	5.000	1.000	1.000	1.000	1.000	6.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA3.LIQ

Press the RETURN key to continue

PARAMETER 4 : Nature of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA4.LIQ

The decision variable matrix is :

1.000	1.000	1.000	0.333	0.200	0.200	0.250	1.000	0.250	0.200
1.000	1.000	1.000	0.333	0.200	0.200	0.250	1.000	0.250	0.200
1.000	1.000	1.000	0.333	0.200	0.200	0.250	1.000	0.250	0.200
3.000	3.000	3.000	1.000	0.333	1.000	0.500	3.000	0.500	0.333
5.000	5.000	5.000	3.000	1.000	1.000	2.000	5.000	4.000	1.000
5.000	5.000	5.000	1.000	1.000	1.000	2.000	5.000	4.000	1.000
4.000	4.000	4.000	2.000	0.500	0.500	1.000	4.000	1.000	0.500
1.000	1.000	1.000	0.333	0.200	0.200	0.250	1.000	0.250	0.200
4.000	4.000	4.000	2.000	0.250	0.250	1.000	4.000	1.000	0.500
5.000	5.000	5.000	3.000	1.000	1.000	2.000	5.000	2.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA4.LIQ

Press the RETURN key to continue

PARAMETER 5 : Land cost

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA5.LIQ

The decision variable matrix is :

1.000	0.333	0.333	0.200	0.111	0.111	0.143	0.500	0.250	0.143
3.000	1.000	1.000	0.333	0.143	0.143	0.200	2.000	0.500	0.200
3.000	1.000	1.000	0.333	0.143	0.143	0.200	2.000	0.500	0.200
5.000	3.000	3.000	1.000	0.200	0.200	0.333	4.000	2.000	0.333
9.000	7.000	7.000	5.000	1.000	1.000	3.000	7.000	5.000	3.000
9.000	7.000	7.000	5.000	1.000	1.000	3.000	7.000	5.000	3.000
7.000	5.000	5.000	3.000	0.333	0.333	1.000	5.000	4.000	1.000
2.000	0.500	0.500	0.250	0.143	0.143	0.200	1.000	0.333	0.167
4.000	2.000	2.000	0.500	0.200	0.200	0.250	3.000	1.000	0.250
7.000	5.000	5.000	3.000	0.333	0.333	1.000	6.000	4.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA5.LIQ

Press the RETURN key to continue

PARAMETER 6 : Local money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA6.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	3.000	5.000	1.000	1.000	2.000	3.000
1.000	1.000	1.000	3.000	4.000	5.000	1.000	1.000	3.000	4.000
1.000	1.000	1.000	3.000	4.000	5.000	1.000	1.000	3.000	4.000
0.500	0.333	0.333	1.000	2.000	4.000	0.333	0.333	1.000	2.000
0.333	0.250	0.250	0.500	1.000	3.000	0.250	0.250	0.500	1.000
0.200	0.200	0.200	0.250	0.333	1.000	0.200	0.200	0.250	0.500
1.000	1.000	1.000	3.000	4.000	5.000	1.000	1.000	3.000	4.000
1.000	1.000	1.000	3.000	4.000	5.000	1.000	1.000	3.000	4.000
0.500	0.333	0.333	1.000	2.000	4.000	0.333	0.333	1.000	2.000
0.333	0.250	0.250	0.500	1.000	2.000	0.250	0.250	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA6.LIQ

Press the RETURN key to continue

PARAMETER 7 : Foreign money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA7.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	0.500	1.000	2.000	0.500	0.500	0.500	1.000
0.500	0.500	0.500	0.500	0.500	1.000	0.500	0.500	0.500	1.000
1.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	0.500	1.000	1.000	0.500	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA7.LIQ

Press the RETURN key to continue

```
PARAMETER 8 : Local skill for construction

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA8.LIQ

The decision variable matrix is :

1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
0.500 0.500 0.500 0.500 0.500 1.000 0.500 0.500 0.500 0.500
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 2.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA8.LIQ

Press the RETURN key to continue


PARAMETER 9 : Community support

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA9.LIQ

The decision variable matrix is :

1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA9.LIQ

Press the RETURN key to continue
```

PARAMETER 10 : Power source

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA10.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA10.LIQ

Press the RETURN key to continue

PARAMETER 11 : Availability of local material

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA11.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA11.LIQ

Press the RETURN key to continue

PARAMETER 12 : Cost of operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA12.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	3.000	4.000	1.000	2.000	3.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	2.000	3.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	2.000	3.000	3.000
0.500	0.500	0.500	1.000	2.000	3.000	0.500	1.000	2.000	2.000
0.333	0.333	0.333	0.500	1.000	2.000	0.333	0.500	1.000	1.000
0.250	0.250	0.250	0.333	0.500	1.000	0.250	0.333	0.500	0.500
1.000	1.000	1.000	2.000	3.000	4.000	1.000	2.000	3.000	3.000
0.500	0.500	0.500	1.000	2.000	3.000	0.500	1.000	2.000	2.000
0.333	0.333	0.333	0.500	1.000	2.000	0.333	0.500	1.000	1.000
0.333	0.333	0.333	0.500	1.000	2.000	0.333	0.500	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA12.LIQ

Press the RETURN key to continue

PARAMETER 13 : Professional skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA13.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	0.500	1.000	2.000	0.500	0.500	0.500	1.000
0.333	0.333	0.333	0.333	0.500	1.000	0.333	0.333	0.333	0.500
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	0.500	1.000	2.000	0.500	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA13.LIQ

Press the RETURN key to continue

PARAMETER 14 : Local technical skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA14.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	2.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	2.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	2.000	3.000
0.500	0.500	0.500	1.000	2.000	3.000	0.500	0.500	1.000	2.000
0.333	0.333	0.333	0.500	1.000	2.000	0.333	0.333	0.500	1.000
0.250	0.250	0.250	0.333	0.500	1.000	0.250	0.250	0.333	0.500
1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	2.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	2.000	3.000
0.500	0.500	0.500	1.000	2.000	3.000	0.500	0.500	1.000	2.000
0.333	0.333	0.333	0.500	1.000	2.000	0.333	0.333	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA14.LIQ

Press the RETURN key to continue

PARAMETER 15 : Administration set-up

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA15.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	0.500	1.000	2.000	0.500	0.500	0.500	1.000
0.333	0.333	0.333	0.333	0.500	1.000	0.333	0.333	0.333	0.500
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	1.000	2.000	3.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	0.500	1.000	2.000	0.500	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA15.LIQ

Press the RETURN key to continue

PARAMETER 16 : Training

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA16.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
0.333	0.333	0.333	0.333	0.333	1.000	0.333	0.333	0.333	0.333
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA16.LIQ

Press the RETURN key to continue

PARAMETER 17 : Professional ethics

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA17.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	3.000	5.000	1.000	1.000	1.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	1.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	1.000	3.000
0.500	0.500	0.500	1.000	2.000	3.000	0.500	0.500	0.500	2.000
0.333	0.333	0.333	0.500	1.000	2.000	0.333	0.333	0.333	1.000
0.200	0.250	0.250	0.333	0.500	1.000	0.200	0.200	0.250	0.500
1.000	1.000	1.000	2.000	3.000	5.000	1.000	1.000	1.000	3.000
1.000	1.000	1.000	2.000	3.000	5.000	1.000	1.000	1.000	3.000
1.000	1.000	1.000	2.000	3.000	4.000	1.000	1.000	1.000	3.000
0.333	0.333	0.333	0.500	1.000	2.000	0.333	0.333	0.333	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA17.LIQ

Press the RETURN key to continue

PARAMETER 18 : Climate

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA18.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA18.LIQ

Press the RETURN key to continue

PARAMETER 19 : Local water-borne diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA19.LIQ

The decision variable matrix is :

1.000	1.000	1.000	0.500	0.500	0.500	1.000	0.333	0.333	0.500
1.000	1.000	1.000	0.500	0.500	0.500	1.000	0.333	0.333	0.500
1.000	1.000	1.000	0.500	0.500	0.500	1.000	0.333	0.333	0.500
2.000	2.000	2.000	1.000	1.000	1.000	2.000	0.500	0.500	1.000
2.000	2.000	2.000	1.000	1.000	1.000	2.000	0.500	0.500	1.000
2.000	2.000	2.000	1.000	1.000	1.000	2.000	0.500	0.500	1.000
1.000	1.000	1.000	0.500	0.500	0.500	1.000	0.333	0.333	0.500
3.000	3.000	3.000	2.000	2.000	2.000	3.000	1.000	1.000	2.000
3.000	3.000	3.000	2.000	2.000	2.000	3.000	1.000	1.000	2.000
2.000	2.000	2.000	1.000	1.000	1.000	2.000	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA19.LIQ

Press the RETURN key to continue

PARAMETER 20 : Endemic vector-borne (water-related) diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA20.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA20.LIQ

You have already entered all the necessary data

Press the RETURN key to continue

Please wait. Calculation of the ranking of the alternatives is in process.

The ranking is :

	RANKING IN %
Alternative 1	59.66283
Alternative 2	67.58635
Alternative 3	67.58635
Alternative 4	91.93332
Alternative 5	95.66285
Alternative 6	84.11186
Alternative 7	100
Alternative 8	65.81622
Alternative 9	88.19032
Alternative 10	85.22399

8.4 Computer Run for Shatin STP (Hong Kong)

8.4.1 General Selection

This section must be read in conjunction with Section 7.6 of Chapter 7. The following is a record of running the model.

```
RANKING OF LIQUID TREATMENT ALTERNATIVES

Order of decision variable matrix is n x n where n =  8

PARAMETER 1 : Flow

Do you want to use data from an existing file ?  Y or N ? Y
Name of the existing file is ? PARA1.LIQ

The decision variable matrix is :

1.000 0.333 0.167 0.111 0.111 3.000 0.250 0.250
3.000 1.000 0.200 0.125 0.125 5.000 0.333 0.333
6.000 5.000 1.000 0.333 0.333 7.000 0.500 0.500
9.000 8.000 3.000 1.000 1.000 9.000 5.000 5.000
9.000 8.000 3.000 1.000 1.000 9.000 5.000 5.000
0.333 0.200 0.143 0.111 0.111 1.000 0.143 0.143
4.000 3.000 2.000 0.200 0.200 7.000 1.000 1.000
4.000 3.000 2.000 0.200 0.200 7.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named 'PARA1.LIQ'

Press the RETURN key to continue
```

PARAMETER 2 : Influent / Effluent

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA2.LIQ

The decision variable matrix is :

1.000	1.000	0.500	0.333	9.000	0.333	0.333	0.333
1.000	1.000	0.500	0.333	9.000	0.333	0.333	0.333
2.000	2.000	1.000	0.500	9.000	0.500	0.500	0.500
3.000	3.000	2.000	1.000	9.000	1.000	1.000	1.000
0.111	0.111	0.111	0.111	1.000	0.111	0.111	0.111
3.000	3.000	2.000	1.000	9.000	1.000	1.000	1.000
3.000	3.000	2.000	1.000	9.000	1.000	1.000	1.000
3.000	3.000	2.000	1.000	9.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA2.LIQ

Press the RETURN key to continue

PARAMETER 3 : Size of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA3.LIQ

The decision variable matrix is :

1.000	1.000	0.200	0.111	0.111	1.000	0.111	0.111
1.000	1.000	0.200	0.111	0.111	1.000	0.111	0.111
5.000	5.000	1.000	0.200	0.200	7.000	0.200	0.200
9.000	9.000	5.000	1.000	1.000	9.000	1.000	1.000
9.000	9.000	5.000	1.000	1.000	9.000	1.000	1.000
1.000	1.000	0.143	0.111	0.111	1.000	0.111	0.111
9.000	9.000	5.000	1.000	1.000	9.000	1.000	1.000
9.000	9.000	5.000	1.000	1.000	9.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA3.LIQ

Press the RETURN key to continue

PARAMETER 4 : Nature of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA4.LIQ

The decision variable matrix is :

1.000	1.000	2.000	2.000	2.000	7.000	2.000	2.000
1.000	1.000	2.000	2.000	2.000	7.000	2.000	2.000
0.500	0.500	1.000	1.000	1.000	7.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	7.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	7.000	1.000	1.000
0.143	0.143	0.143	0.143	0.143	1.000	0.143	0.143
0.500	0.500	1.000	1.000	1.000	7.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	7.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA4.LIQ

Press the RETURN key to continue

PARAMETER 5 : Land cost

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA5.LIQ

The decision variable matrix is :

1.000	0.500	0.250	0.143	0.111	3.000	0.143	0.143
2.000	1.000	0.333	0.167	0.125	5.000	0.167	0.167
4.000	3.000	1.000	0.250	0.167	6.000	0.250	0.250
7.000	6.000	4.000	1.000	0.200	7.000	1.000	1.000
9.000	8.000	6.000	5.000	1.000	9.000	3.000	3.000
0.333	0.200	0.167	0.143	0.111	1.000	0.143	0.143
7.000	6.000	4.000	1.000	0.333	7.000	1.000	1.000
7.000	6.000	4.000	1.000	0.333	7.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA5.LIQ

Press the RETURN key to continue

PARAMETER 6 : Local money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA6.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	1.000	0.500	0.500	0.500	1.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	1.000	0.500	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA6.LIQ

Press the RETURN key to continue

PARAMETER 7 : Foreign money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA7.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	1.000	0.500	0.500	0.500	1.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	1.000	0.500	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA7.LIQ

Press the RETURN key to continue

PARAMETER 8 : Local skill for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA8.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA8.LIQ

Press the RETURN key to continue

PARAMETER 9 : Community support

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA9.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA9.LIQ

Press the RETURN key to continue

PARAMETER 10 : Power source

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA10.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA10.LIQ

Press the RETURN key to continue

PARAMETER 11 : Availability of local material

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA11.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA11.LIQ

Press the RETURN key to continue

PARAMETER 12 : Cost of operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA12.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	1.000	0.500	0.500	0.500	1.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
1.000	1.000	1.000	2.000	1.000	1.000	1.000	2.000
0.500	0.500	0.500	1.000	0.500	0.500	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA12.LIQ

Press the RETURN key to continue

PARAMETER 13 : Professional skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA13.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA13.LIQ

Press the RETURN key to continue

PARAMETER 14 : Local technical skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA14.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA14.LIQ

Press the RETURN key to continue

PARAMETER 15 : Administration set-up

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA15.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA15.LIQ

Press the RETURN key to continue

PARAMETER 16 : Training

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA16.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA16.LIQ

Press the RETURN key to continue

PARAMETER 17 : Professional ethics

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA17.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA17.LIQ

Press the RETURN key to continue

PARAMETER 18 : Climate

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA18.LIQ

The decision variable matrix is :

1.000	1.000	2.000	2.000	2.000	7.000	2.000	2.000
1.000	1.000	2.000	2.000	2.000	7.000	2.000	2.000
0.500	0.500	1.000	1.000	1.000	5.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	5.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	5.000	1.000	1.000
0.143	0.143	0.200	0.200	0.200	1.000	0.200	0.200
0.500	0.500	1.000	1.000	1.000	5.000	1.000	1.000
0.500	0.500	1.000	1.000	1.000	5.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA18.LIQ

Press the RETURN key to continue

PARAMETER 19 : Local water-borne diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA19.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000
0.333	0.333	0.333	0.333	1.000	0.333	0.333	0.333
1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA19.LIQ

Press the RETURN key to continue

PARAMETER 20 : Endemic vector-borne (water-related) diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA20.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA20.LIQ

You have already entered all the necessary data

Press the RETURN key to continue

Please wait. Calculation of the ranking of the alternatives
is in process.

The ranking is :

	RANKING IN %
Alternative 1	59.72916
Alternative 2	60.72353
Alternative 3	67.37144
Alternative 4	100
Alternative 5	85.68993
Alternative 6	58.68803
Alternative 7	93.35902
Alternative 8	89.88984

8.4.2 Refined Selection

This section must be read in conjunction with Section 7.6 of Chapter 7. The following is a record of running the model.

```
RANKING OF LIQUID TREATMENT ALTERNATIVES

Order of decision variable matrix is n x n where n =  7



PARAMETER 1 : Flow

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA1.LIQ

The decision variable matrix is :

1.000 3.000 1.000 2.000 2.000 3.000 3.000
0.333 1.000 0.333 0.500 0.500 1.000 1.000
1.000 3.000 1.000 2.000 2.000 3.000 3.000
0.500 2.000 0.500 1.000 1.000 2.000 2.000
0.500 2.000 0.500 1.000 1.000 2.000 2.000
0.333 1.000 0.333 0.500 0.500 1.000 1.000
0.333 1.000 0.333 0.500 0.500 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named 'PARA1.LIQ'

Press the RETURN key to continue
```

```
PARAMETER 2 : Influent / Effluent

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA2.LIQ


The decision variable matrix is :

1.000 1.000 0.500 1.000 0.500 1.000 0.500
1.000 1.000 0.500 1.000 0.500 1.000 0.500
2.000 2.000 1.000 2.000 1.000 2.000 1.000
1.000 1.000 0.500 1.000 0.500 1.000 0.500
2.000 2.000 1.000 2.000 1.000 2.000 1.000
1.000 1.000 0.500 1.000 0.500 1.000 0.500
2.000 2.000 1.000 2.000 1.000 2.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA2.LIQ

Press the RETURN key to continue




PARAMETER 3 : Size of site


Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA3.LIQ


The decision variable matrix is :

1.000 3.000 1.000 1.000 1.000 1.000 1.000
0.333 1.000 0.333 0.333 0.333 0.333 0.333
1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 3.000 1.000 1.000 1.000 1.000 1.000
1.000 3.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA3.LIQ

Press the RETURN key to continue
```

PARAMETER 4 : Nature of site

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA4.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA4.LIQ

Press the RETURN key to continue

PARAMETER 5 : Land cost

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA5.LIQ

The decision variable matrix is :

1.000	3.000	2.000	0.143	0.500	0.200	0.250
0.333	1.000	0.500	0.111	0.250	0.143	0.167
0.500	2.000	1.000	0.125	0.333	0.167	0.200
7.000	9.000	8.000	1.000	7.000	3.000	4.000
2.000	4.000	3.000	0.143	1.000	0.200	0.250
5.000	7.000	6.000	0.333	5.000	1.000	2.000
4.000	6.000	5.000	0.250	4.000	0.500	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA5.LIQ

Press the RETURN key to continue

PARAMETER 6 : Local money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA6.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	3.000	2.000	2.000
1.000	1.000	1.000	2.000	3.000	2.000	2.000
1.000	1.000	1.000	2.000	3.000	2.000	2.000
0.500	0.500	0.500	1.000	2.000	1.000	1.000
0.333	0.333	0.333	0.500	1.000	0.500	0.500
0.500	0.500	0.500	1.000	2.000	1.000	1.000
0.500	0.500	0.500	1.000	2.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA6.LIQ

Press the RETURN key to continue

PARAMETER 7 : Foreign money for construction

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA7.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	3.000	3.000
1.000	1.000	1.000	1.000	1.000	3.000	3.000
1.000	1.000	1.000	1.000	1.000	3.000	3.000
1.000	1.000	1.000	1.000	1.000	3.000	3.000
1.000	1.000	1.000	1.000	1.000	3.000	3.000
0.333	0.333	0.333	0.333	0.333	1.000	1.000
0.333	0.333	0.333	0.333	0.333	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA7.LIQ

Press the RETURN key to continue

```
PARAMETER 8 : Local skill for construction

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA8.LIQ


The decision variable matrix is :

1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA8.LIQ

Press the RETURN key to continue



PARAMETER 9 : Community support

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA9.LIQ


The decision variable matrix is :

1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA9.LIQ

Press the RETURN key to continue
```

```
PARAMETER 10 : Power source

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA10.LIQ


The decision variable matrix is :

1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA10.LIQ

Press the RETURN key to continue
```

```
PARAMETER 11 : Availability of local material

Do you want to use data from an existing file ?  Y or N ? Y

Name of the existing file is ? PARA11.LIQ


The decision variable matrix is :

1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix ?  Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA11.LIQ

Press the RETURN key to continue
```

PARAMETER 12 : Cost of operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA12.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	3.000	3.000	3.000
1.000	1.000	1.000	2.000	3.000	3.000	3.000
1.000	1.000	1.000	2.000	3.000	3.000	3.000
0.500	0.500	0.500	1.000	2.000	2.000	2.000
0.333	0.333	0.333	0.500	1.000	1.000	1.000
0.333	0.333	0.333	0.500	1.000	1.000	1.000
0.333	0.333	0.333	0.500	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA12.LIQ

Press the RETURN key to continue

PARAMETER 13 : Professional skill available for operation & maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA13.LIQ

The decision variable matrix is :

1.000	1.000	1.000	3.000	3.000	1.000	1.000
1.000	1.000	1.000	3.000	3.000	1.000	1.000
1.000	1.000	1.000	3.000	3.000	1.000	1.000
0.333	0.333	0.333	1.000	1.000	0.333	0.333
0.333	0.333	0.333	1.000	1.000	0.333	0.333
1.000	1.000	1.000	3.000	3.000	1.000	1.000
1.000	1.000	1.000	3.000	3.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA13.LIQ

Press the RETURN key to continue

PARAMETER 14 : Local technical skill available for operation
& maintenance

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA14.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 2.000 2.000 1.000 1.000
1.000 1.000 1.000 2.000 2.000 1.000 1.000
1.000 1.000 1.000 2.000 2.000 1.000 1.000
0.500 0.500 0.500 1.000 1.000 0.500 0.500
0.500 0.500 0.500 1.000 1.000 0.500 0.500
1.000 1.000 1.000 2.000 2.000 1.000 1.000
1.000 1.000 1.000 2.000 2.000 1.000 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA14.LIQ

Press the RETURN key to continue

PARAMETER 15 : Administration set-up

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA15.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA15.LIQ

Press the RETURN key to continue

PARAMETER 16 : Training

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA16.LIQ

The decision variable matrix is :

1.000	1.000	1.000	2.000	2.000	1.000	1.000
1.000	1.000	1.000	2.000	2.000	1.000	1.000
1.000	1.000	1.000	2.000	2.000	1.000	1.000
0.500	0.500	0.500	1.000	1.000	0.500	0.500
0.500	0.500	0.500	1.000	1.000	0.500	0.500
1.000	1.000	1.000	2.000	2.000	1.000	1.000
1.000	1.000	1.000	2.000	2.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA16.LIQ

Press the RETURN key to continue

PARAMETER 17 : Professional ethics

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA17.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA17.LIQ

Press the RETURN key to continue

PARAMETER 18 : Climate

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA18.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA18.LIQ

Press the RETURN key to continue

PARAMETER 19 : Local water-borne diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA19.LIQ

The decision variable matrix is :

1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA19.LIQ

Press the RETURN key to continue

PARAMETER 20 : Endemic vector-borne (water-related) diseases

Do you want to use data from an existing file ? Y or N ? Y

Name of the existing file is ? PARA20.LIQ

The decision variable matrix is :

```
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

Do you want to change data in the above matrix ? Y or N ? N

Please wait .....

The matrix just entered is stored in a file named PARA20.LIQ

You have already entered all the necessary data

Press the RETURN key to continue

Please wait. Calculation of the ranking of the alternatives is in process.

The ranking is :

	RANKING IN %
Alternative 1	89.36844
Alternative 2	69.29602
Alternative 3	100
Alternative 4	83.26269
Alternative 5	87.32095
Alternative 6	77.60319
Alternative 7	87.51058

PART 4

FURTHER DEVELOPMENT AND CONCLUSION

CHAPTER 9 --- FORECASTING CHANGES ON APPROPRIATE TECHNOLOGY WITH TIME

9.1 Sensitivity Analysis

The model has been tested in Chapters 7 and 8 and the results obtained are found to be satisfactory. The next question, now, is : how will the appropriate technology change as social and environmental conditions in a given situation change with time, or in other words, how sensitive is the model developed? Sensitivity analysis is concerned with investigating the sensitivity of the response of the model to changes in data input. In the context of this research, sensitivity analysis means the investigation of the change of optimal treatment alternative resulting from a change of decision variable matrices of certain parameters.

It must be pointed out that a detailed and thorough sensitivity analysis of the technique of eigenvector prioritization requires a profound mathematical knowledge background. It is an area in which, perhaps, only mathematicians should carry out the investigation. A limited approach to the topic was initiated by Vargas in 1983[3]. His work was confined to 3 x 3 reciprocal matrices only and he concluded that higher-dimension reciprocal matrices do not have a generalized property and the sensitivity analysis of the latter is very complex[3].

To the knowledge of the author, no further work has so far been done by others after Vargas. Therefore, there is a large amount of work in this area left to be explored by mathematicians, and it is beyond the scope of the present research to enter deeply into the theory of sensitivity analysis of the mathematical technique applied in the model. The intention of the author, however, is to, before ending the thesis, throw out an idea by which the technique of sensitivity analysis may be applied in order that the model developed in this research can be extended to be able to forecast a change of the appropriate technology required as conditions described by certain parameters alter with time.

9.2 Application of Sensitivity Analysis to The Model

There are certain parameters (e.g. Parameter 18: climate) which will not alter with time. The parameters which are most vulnerable to changes are the subjective / intangible factors (see Section 4.2.2 of Chapter 4). Professional skill for O & M (ie. Parameter 13), for instance, in a given situation may improve with time. In the perfect case, the decision variable matrix will become an all-one matrix (ie. matrix with all its elements equal to 1). The Taiwan Min Shen STP is used as an example. The original decision variable matrix of Parameter 13 is reproduced in Fig. 9.1. If the professional skill is forecast to improve in fifteen years time, say, then the

Alt No.	Simple bio-filter 1	Bio-filter (recir) 2	Bio-filter (ADF) 3	A.S. 4	O_2 5	Deep shaft 6	RBC 7	Oxi-dation ditch 8	Pack-age Plant 9	Pack-age O_2 10
1	1	1	1	1	2	3	1	1	1	2
2		1	1	1	2	3	1	1	1	2
3			1	1	2	3	1	1	1	2
4				1	2	3	1	1	1	2
5					1	2	½	½	½	1
6						1	⅓	⅓	⅓	½
7							1	1	1	2
8								1	1	2
9									1	2
10										1

All lower triangular elements $= a_{ji} = \frac{1}{a_{ij}}$

Fig. 9.1: Original Decision Variable Matrix for Para 13 (Taiwan)

Alt No.	Simple bio-filter 1	Bio-filter (recir) 2	Bio-filter (ADF) 3	A.S. 4	O_2 5	Deep shaft 6	RBC 7	Oxi-dation ditch 8	Pack-age Plant 9	Pack-age O_2 10
1	1	1	1	1	1	1	1	1	1	1
2		1	1	1	1	1	1	1	1	1
3			1	1	1	1	1	1	1	1
4				1	1	1	1	1	1	1
5					1	1	1	1	1	1
6						1	1	1	1	1
7							1	1	1	1
8								1	1	1
9									1	1
10										1

All lower triangular elements $= a_{ji} = \frac{1}{a_{ij}} = 1$

Fig. 9.2: New Decision Variable Matrix for Para 13 (Taiwan)

decision variable matrix of this parameter will become an all-one matrix as shown in Fig. 9.2 after fifteen years. This means that the professional skill at that time will be capable of handling all types of treatment alternatives without finding one more difficult than another.

Decision variable matrices of other parameters may change in the same manner with time. Some of them will, of course, remain the same, depending on the situation in question. The new ranking of the alternatives will be calculated using the same mathematical technique as described in Chapter 5 by a computer program named SENSIANA with the amended set of decision variable matrices as inputting data. A full example of the forecasting exercise will be given in Section 9.4. The computer program SENSIANA is to be described in the following section.

9.3 The Computer Program

A new computer program is written for carrying out the sensitivity analysis (or forecasting exercise). The name of the program is, as mentioned above, called SENSIANA. It is again written in IBM BASIC language(2) and can be run on an IBM personal computer (or any XT or AT) after compilation(1).

The parameter matrix, similar to the one used in MODEL, is again a built-in feature of SENSIANA. Users do not have to know what are the values inside the parameter matrix when they use the program. They only have to input new values of the decision variable matrices of the parameters which they forecast will change. A user's manual of SENSIANA is given in Appendix B.2.1. A flow chart of the program and a listing of it are given in Appendices B.2.2 and B.2.3 respectively.

It should be borne in mind that values of the decision variable matrices should be entered in six decimal places, but they will be shown on the screen in three decimal places. This, however, will not affect the accuracy of the calculation in which data of six decimal places will be used throughout.

After running SENSIANA, k new files will be created where k is the total number of parameters whose decision variable matrices are amended. The names of these k new files are "PARA*.LIQ" where * represents the parameter number. The k old files of the original decision variable matrices will be erased automatically. In addition, a new COMPOMAT.LIQ file, storing the data of the new composite matrix, and another file named SENSIRUN.LIQ, storing the record of the dialogue between the user and the computer when the program was in use, will be formed. One can view the contents of these two files by using the "TYPE" command.

9.4 Example --- Min Shen STP of Taiwan

9.4.1 Forecasting Changes

The computer program MODEL was run in Section 8.3 of Chapter 8 and the background was described in Section 7.5 of Chapter 7 for Min Shen STP of Taiwan. In this Section, SENSIANA will be run for the same plant.

Assuming that the training of professionals and technicians (ie. Parameter 16) in Taiwan is already good, it is then forecast that in fifteen years both the professional skill and the local technical skill available for operation and maintenance (ie. Parameters 13 and 14) will become very much better. In addition, after fifteen years of good training, professional ethics (ie. Parameter 17) of the personnel involved with the STP will also be excellent. In such a situation, it is assumed that the decision variable matrices of Parameters 13, 14, 16 and 17 will become all-one matrices (see Fig. 9.2).

Based on the above assumptions, the decision variable matrices of Parameters 13, 14, 16 and 17 are to be amended and their elements are all re-entered as 1 when the computer program SENSIANA is run. A complete record of the dialogue between the user and the computer is shown in Section 9.4.2. The computer run gives a result on P.189 that primary clarifier + high-purity oxygen activated sludge process + tertiary treatment (ie. Decision Variable 5) is the most appropriate treatment alternative instead of primary clarifier + RBC + tertiary treatment (ie. Decision Variable 7) as obtained previously (see Section 7.5 of Chapter 7).

9.4.2 Running The Computer Program

This section must be read in conjunction with Appendix B.2.1, the user's manual of SENSIANA. The ten decision variables to be ranked as given on Page 116 (Section 7.5) should also be referred to. The following is record of running the program.

```
Order of decision variable matrix is n x n where n =  10

Enter the parameter number whose matrix is to be reviewed.
The number (ie. the Kth parameter, K = 1 to 20) is ?  13
The decision variable matrix is:

1.000 1.000 1.000 1.000 2.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 1.000 2.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 1.000 2.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 1.000 2.000 3.000 1.000 1.000 1.000 2.000
0.500 0.500 0.500 0.500 1.000 2.000 0.500 0.500 0.500 1.000
0.333 0.333 0.333 0.333 0.500 1.000 0.333 0.333 0.333 0.500
1.000 1.000 1.000 1.000 2.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 1.000 2.000 3.000 1.000 1.000 1.000 2.000
1.000 1.000 1.000 1.000 2.000 3.000 1.000 1.000 1.000 2.000
0.500 0.500 0.500 0.500 1.000 2.000 0.500 0.500 0.500 1.000

Do you want to change data in the above matrix? Y or N ? Y

You only have to enter the upper triangular elements

A( 1 , 1 ) =  1
A( 1 , 2 ) =  1
A( 1 , 3 ) =  1
```

```
A( 1 , 4 ) =  1
A( 1 , 5 ) =  1
A( 1 , 6 ) =  1
A( 1 , 7 ) =  1
A( 1 , 8 ) =  1
A( 1 , 9 ) =  1
A( 1 , 10 ) =  1
A( 2 , 2 ) =  1
A( 2 , 3 ) =  1
A( 2 , 4 ) =  1
A( 2 , 5 ) =  1
A( 2 , 6 ) =  1
A( 2 , 7 ) =  1
A( 2 , 8 ) =  1
A( 2 , 9 ) =  1
A( 2 , 10 ) =  1
A( 3 , 3 ) =  1
A( 3 , 4 ) =  1
A( 3 , 5 ) =  1
A( 3 , 6 ) =  1
A( 3 , 7 ) =  1
A( 3 , 8 ) =  1
A( 3 , 9 ) =  1
A( 3 , 10 ) =  1
A( 4 , 4 ) =  1
A( 4 , 5 ) =  1
A( 4 , 6 ) =  1
A( 4 , 7 ) =  1
A( 4 , 8 ) =  1
A( 4 , 9 ) =  1
A( 4 , 10 ) =  1
A( 5 , 5 ) =  1
A( 5 , 6 ) =  1
A( 5 , 7 ) =  1
A( 5 , 8 ) =  1
A( 5 , 9 ) =  1
A( 5 , 10 ) =  1
A( 6 , 6 ) =  1
A( 6 , 7 ) =  1
A( 6 , 8 ) =  1
A( 6 , 9 ) =  1
A( 6 , 10 ) =  1
A( 7 , 7 ) =  1
A( 7 , 8 ) =  1
A( 7 , 9 ) =  1
A( 7 , 10 ) =  1
A( 8 , 8 ) =  1
A( 8 , 9 ) =  1
A( 8 , 10 ) =  1
A( 9 , 9 ) =  1
A( 9 , 10 ) =  1
A( 10 , 10 ) =  1
```

The decision variable matrix is:

```
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
```

Do you want to change data in the above matrix? Y or N ? N

Do you want to change another decision variable matrix ? Y

Enter the parameter number whose matrix is to be reviewed.

The number (ie. the Kth parameter, K = 1 to 20) is ? 14

The decision variable matrix is:

```
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 2.000 3.000
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 2.000 3.000
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 2.000 3.000
0.500 0.500 0.500 1.000 2.000 3.000 0.500 0.500 1.000 2.000
0.333 0.333 0.333 0.500 1.000 2.000 0.333 0.333 0.500 1.000
0.250 0.250 0.250 0.333 0.500 1.000 0.250 0.250 0.333 0.500
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 2.000 3.000
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 2.000 3.000
0.500 0.500 0.500 1.000 2.000 3.000 0.500 0.500 1.000 2.000
0.333 0.333 0.333 0.500 1.000 2.000 0.333 0.333 0.500 1.000
```

Do you want to change data in the above matrix? Y or N ? Y

You only have to enter the upper triangular elements

```
A( 1 , 1 ) =  1
A( 1 , 2 ) =  1
A( 1 , 3 ) =  1
A( 1 , 4 ) =  1
A( 1 , 5 ) =  1
A( 1 , 6 ) =  1
A( 1 , 7 ) =  1
A( 1 , 8 ) =  1
A( 1 , 9 ) =  1
A( 1 , 10 ) =  1
```

```
A( 2 , 2 ) =  1
A( 2 , 3 ) =  1
A( 2 , 4 ) =  1
A( 2 , 5 ) =  1
A( 2 , 6 ) =  1
          .
          .
          .
          .
A( 9 , 9 ) = 1
A( 9 , 10 ) =  1
A( 10 , 10 ) =  1
```

The decision variable matrix is:

1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Do you want to change data in the above matrix? Y or N ? N

Do you want to change another decision variable matrix ? Y

Enter the parameter number whose matrix is to be reviewed.

The number (ie. the Kth parameter, K = 1 to 20) is ? 16

The decision variable matrix is:

1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
0.333	0.333	0.333	0.333	0.333	1.000	0.333	0.333	0.333	0.333
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	3.000	1.000	1.000	1.000	1.000

```
Do you want to change data in the above matrix? Y or N ? Y
You only have to enter the upper triangular elements


A( 1 , 1 ) =  1
A( 1 , 2 ) =  1
A( 1 , 3 ) =  1
A( 1 , 4 ) =  1
A( 1 , 5 ) =  1
A( 1 , 6 ) =  1
A( 1 , 7 ) =  1
A( 1 , 8 ) =  1
A( 1 , 9 ) =  1
A( 1 , 10 ) =  1
A( 2 , 2 ) =  1
A( 2 , 3 ) =  1
A( 2 , 4 ) =  1
A( 2 , 5 ) =  1
          .
          .
          .
          .

A( 9 , 9 ) =  1
A( 9 , 10 ) =  1
A( 10 , 10 ) =  1


The decision variable matrix is:

1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000


Do you want to change data in the above matrix? Y or N ? N



Do you want to change another decision variable matrix ? Y



Enter the parameter number whose matrix is to be reviewed.

The number (ie. the Kth parameter, K = 1 to 20) is ?  17
```

```
The decision variable matrix is:

1.000 1.000 1.000 2.000 3.000 5.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 1.000 3.000
0.500 0.500 0.500 1.000 2.000 3.000 0.500 0.500 0.500 2.000
0.333 0.333 0.333 0.500 1.000 2.000 0.333 0.333 0.333 1.000
0.200 0.250 0.250 0.333 0.500 1.000 0.200 0.200 0.250 0.500
1.000 1.000 1.000 2.000 3.000 5.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 2.000 3.000 5.000 1.000 1.000 1.000 3.000
1.000 1.000 1.000 2.000 3.000 4.000 1.000 1.000 1.000 3.000
0.333 0.333 0.333 0.500 1.000 2.000 0.333 0.333 0.333 1.000

Do you want to change data in the above matrix? Y or N ? Y


You only have to enter the upper triangular elements

A( 1 , 1 ) =  1
A( 1 , 2 ) =  1
A( 1 , 3 ) =  1
A( 1 , 4 ) =  1
A( 1 , 5 ) =  1
A( 1 , 6 ) =  1
A( 1 , 7 ) =  1
A( 1 , 8 ) =  1
A( 1 , 9 ) =  1
A( 1 , 10 ) =  1
A( 2 , 2 ) =  1
A( 2 , 3 ) =  1
        .
        .
        .
        .

A( 9 , 9 ) =  1
A( 9 , 10 ) =  1
A( 10 , 10 ) =  1


The decision variable matrix is:

1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000

Do you want to change data in the above matrix? Y or N ? N
```

Do you want to change another decision variable matrix ? N

Please wait. Calculation of ranking of the alternatives is in process.

The ranking is:

RANKING IN %

Alternative 1	58.60932
Alternative 2	66.74297
Alternative 3	66.74297
Alternative 4	94.03391
Alternative 5	100
Alternative 6	90.31671
Alternative 7	99.60104
Alternative 8	64.86311
Alternative 9	88.51567
Alternative 10	89.39321

9.5 Observation

It can be seen from Section 9.4 that there will be a change of appropriate technology for Min Shen STP if certain social and environmental conditions change with time. The author has also tried to run SENSIANA to carry out forecasting exercises for wastewater treatment plants other than Min Shen, but these were not successful in obtaining different rankings compared to those obtained previously shown in Chapters 7 and 8. The reason may probably be this : if in the original ranking (ie. result obtained by running MODEL) the difference in % between the first best and the second best alternatives is 10% or more then the first alternative will not easily become the second or lower in the sensitivity analysis. The best alternatives for situations of Malaysia, Thailand and Hong Kong do not change in the forecasting exercise, because they are all higher by more than 10% than their respective second best alternatives. The above statement is merely an informed guess of the author from the limited trials on the exercise and is suggested without a sound support of mathematical theories. However, this issue can be an interesting area which mathematicians and engineers should be able to find a lot more to explore.

9.6 A Further Illustration

It is a bit unfortunate that the wastewater treatment plants under test except the Min Shen STP in Taiwan have results which are so overwhelmingly in one direction that the forecasting function (sensitivity analysis) of the model cannot be easily demonstrated. An imaginary treatment plant, therefore, is employed here to further illustrate this particular function of the model.

The imaginary plant is situated just outside Tun Mun (a newly developed and modern town quite far away from the city) of Hong Kong. As it is a relatively remote area the land there at present is not very costly. The plant has to serve a population of about 3,000 persons (an average flow of about 1,000 m^3/day), who live in a low density residential housing estate near Tun Mun. The site given for the plant is located at a corner of the estate. It is not a large site and treatment methods requiring large area are therefore not suitable. Effluent standard of "Royal Commission Recommendation" is required. As the residents would like to see only minimal exposed sewage, the management of the housing estate has decided that only package sewage treatment plants should be used.

It should be noted that in a vigorous selection the decision of using package plants should be obtained from an initial ranking of the alternatives in category A, B, ...
..., H or category a, b, ..., 1 of Fig. 4.1 of Chapter 4. The initial ranking is neglected here because the purpose of this section is only to give a further illustration of how the sensitivity analysis can be practically applied. Now, the problem is to select the best alternative out of four, namely, decision variables 43, 44, 45 and 46 as described in Section 4.3 of Chapter 4. They are reproduced hereunder for easy reference.

Treatment Alternative	Description
1	Package activated sludge plant
2	Package activated sludge plant + Tertiary treatment
3	Package high-purity oxygen plant
4	Package high-purity oxygen plant + Tertiary treatment

The 20 decision variable matrices for the parameters are as follows:

PARAMETER 1 : Flow

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 2 : Influent / Effluent

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 3 : Size of site

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 4 : Nature of site

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 5 : Land cost

1.000	2.000	0.333	0.333
0.500	1.000	0.333	0.333
3.000	3.000	1.000	2.000
3.000	3.000	0.500	1.000

PARAMETER 6 : Local money for construction

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 7 : Foreign money for construction

1.000	1.000	2.000	2.000
1.000	1.000	2.000	2.000
0.500	0.500	1.000	1.000
0.500	0.500	1.000	1.000

PARAMETER 8 : Local skill for construction

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 9 : Community support

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 10 : Power source

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 11 : Availability of local material

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 12 : Cost of operation & maintenance

1.000	1.000	2.000	2.000
1.000	1.000	2.000	2.000
0.500	0.500	1.000	1.000
0.500	0.500	1.000	1.000

PARAMETER 13 : Professional skill for operation & maintenance

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 14 : Local technical skill for operation & maintenance

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 15 : Administration set-up

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 16 : Training

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 17 : Professional ethics

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 18 : Climate

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 19 : Local water-borne diseases

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

PARAMETER 20 : Endemic vector-borne (water related) diseases

1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000

The above twenty decision variable matrices are input into the MODEL and the ranking calculated is:

RANKING IN %

Alternative	1	100
Alternative	2	99.59249
Alternative	3	98.8111
Alternative	4	97.58864

The best alternative obtained is Package activated sludge plant (ie. Alternative 1). As can be seen from the result, the final decision is not so overwhelmingly in one direction as compared to previous cases. It may be possible that the final decision will be changed by altering one of the parameters.

If the management would like to use the effluent for watering grass lawns surrounding the housing estate, a higher effluent standard would be needed. Hence, the decision variable matrix of Parameter 2 (ie. effluent standard) would need to be amended. This could be done by running SENSIANA. The following shows a record of running the program.

Order of decision variable matrix is n x n where n = 4

Enter the parameter number whose matrix is to be reviewed.
The number (ie. the kth parameter, k = 1 to 20) is ? 2

```
The original decision variable matrix is:

1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000


Do you want to change data in the above matrix? Y or N ? y

You only have to enter the upper triangular elements


A( 1 , 1 ) =  1
A( 1 , 2 ) =  .333333
A( 1 , 3 ) =  1
A( 1 , 4 ) =  .333333
A( 2 , 2 ) =  1
A( 2 , 3 ) =  3
A( 2 , 4 ) =  1
A( 3 , 3 ) =  1
A( 3 , 4 ) =  .333333
A( 4 , 4 ) =  1


The new decision variable matrix is:

1.000 0.333 1.000 0.333
3.000 1.000 3.000 1.000
1.000 0.333 1.000 0.333
3.000 1.000 3.000 1.000


Do you want to change data in the above matrix? Y or N ? n


Do you want to change another decision variable matrix ? n


Please wait.  Calculation of ranking of the alternatives
 is in process.


The ranking is:


                    RANKING IN %
                    ____________

        Alternative  1            83.71777
        Alternative  2            100
        Alternative  3            82.62343
        Alternative  4            98.15552
```

It can be seen that the best alternative has now changed to Package activated sludge plant + Tertiary treatment (ie. Alternative 2).

Some years later, as development has been taking place rapidly in this part of Hong Kong, more people are coming to live in Tun Mun and its surrounding areas. There are a great demand of new houses in the housing estate. The management has an idea of expanding the estate and is thinking of building new houses on the surrounding grass lawns. As such, reuse of effluent is no more required. The current land cost, however, is much higher than in those earlier years and the management may have to expand the housing project at the expense of the curtailment of the site for sewage treatment. Now, the decision variable matrix of Parameter 5 (ie. land cost) should be amended. The program SENSIANA is run again as follows.

```
Order of decision variable matrix is n x n where n =  4

Enter the parameter number whose matrix is to be reviewed.
The number (ie. the kth parameter, k = 1 to 20) is ?  5

The original decision variable matrix is:

1.000 2.000 0.333 0.333
0.500 1.000 0.333 0.333
3.000 3.000 1.000 2.000
3.000 3.000 0.500 1.000
```

Do you want to change data in the above matrix? Y or N ? y

You only have to enter the upper triangular elements

```
A( 1 , 1 ) =  1
A( 1 , 2 ) =  3
A( 1 , 3 ) =  .142857
A( 1 , 4 ) =  .166666
A( 2 , 2 ) =  1
A( 2 , 3 ) =  .125
A(2 , 4 ) =  .142857
A( 3 , 3 ) =  1
A( 3 , 4 ) =  3
A( 4 , 4 ) =  1
```

The new decision variable matrix is:

```
1.000 3.000 0.143 0.167
0.333 1.000 0.125 0.143
7.000 8.000 1.000 3.000
6.000 7.000 0.333 1.000
```

Do you want to change data in the above matrix? Y or N ? n

Do you want to change another decision variable matrix ? n

Please wait. Calculation of ranking of the alternatives is in process.

The ranking is:

RANKING IN %

Alternative 1	99.34187
Alternative 2	98.98346
Alternative 3	100
Alternative 4	97.49687

It can be seen that the best alternative has changed again to Package high-purity oxygen plant (ie. Alternative 3).

The above is an imaginary situation by which the application of sensitivity analysis / SENSIANA is illustrated. It is the author's hope that readers could have appreciated it better after going through this section.

CHAPTER 10 --- DISCUSSIONS AND ACKNOWLEDGMENT

10.1 Suggestion for Further Works

This research has proposed a new approach to select the most appropriate technology in wastewater treatment alternatives. The major advantages of this approach have been described in Section 5.3 of Chapter 5 and will not be repeated here. It is a macro-level approach as opposed to detailed micro-level analysis given by the existing optimization techniques as described in Chapter 3. There are limitations, however, in the model developed in this research. The following will give an account of the limitations and the author's suggestion for possible further work which can be done to improve the model.

A major drawback is that sludge treatment alternatives are not considered in the model. Sludge treatment is an inseparable part of wastewater treatment and should be planned and designed together with liquid treatment. It is suggested that further works should be done on developing as well as integrating a sludge treatment alternative selection model to the one developed in this research. It is envisaged that many of the parameters used in this liquid treatment selection model will also be used in the sludge treatment selection model. Only a few parameters might need to be deleted and a few added. The first 3 best alternatives from running the liquid treatment model and the first 3 best ones from the sludge treatment model will be combined to form a total of 9 (ie. 3 x 3) decision variables. They will then be ranked by using a similar approach so that the best liquid-cum-sludge treatment alternative can be obtained. It may be possible that a computer program be written such that this whole process will be done internally and automatically by the computer and require no input of extra data.

Another drawback to this model lies in the difficulty in constructing decision variable matrices. At present it is a very tedious and time consuming task. The author has spent weeks in constructing the matrices as shown in Chapter 8. In order that the model will be of a practical value in engineering application an easier and a less time consuming method in this respect should be investigated. A method to improve this drawback is to identify an order of preference for the decision variables with respect to each parameter. Once the order of preference is identified a decision variable matrix can be formed automatically by incorporating an additional sub-routine in the computer program. The matrices constructed in this way, however, will be totally consistent. Therefore, this suggested method will have the advantage of shortening the time of construction but will also have the disadvantage of ignoring the inconsistency usually existing in real situations which can only be reflected when individual pair-wise comparisons are made. Secondly, a more systematic procedure in considering the indicators as described by the parameters should also be developed so that the construction of decision variable matrices can be carried out in a more scientific manner. It may be possible that some subjective parameters be quantified and measured systematically by using certain measurable indicators which describe the subjective parameters. This systematic procedure should be looked into along side with the problem associated with matrix construction discussed in the earlier part of this paragraph.

As mentioned in Section 9.5 of Chapter 9, further works should be done on the sensitivity analysis (or forecasting exercise), both in theory and in systematic application. The author has only thrown out an idea in the chapter and a large amount of possible development will need to be explored.

Although it is the author's belief that the parameter matrix proposed in this thesis is a sound one, yet it does not mean that no further improvement will be necessary in the future. It is self-evident that "two heads are better than one", and in this case, several heads will be even better. The use of expert opinion, the Delphi technique[1,2], may be applied to improve the parameter matrix. The technique involves the findings of the most reliable consensus of opinion of a group of experts, and this is achieved by means of a series of intensive questionnaires interspersed with summarized information and opinion feedback derived from earlier responses. The details involved in the Delphi technique can be found in References 1 and 2. The application of the technique is outside the scope of this thesis.

In the Delphi method, each expert selected responds anonymously to the series of questionnaires to avoid disproportionate influence of strong personalities. Another method, differing appreciably from the Delphi approach, is to gather the experts together for open discussion. In attempting to present their arguments openly, the experts provide judgements by mutual agreement and revision of views. This second method is a simpler and quicker procedure than Delphi and its results can be highly effective. Its only disadvantage is that some strong personalities in the group may influence the views of the others in face to face discussion. Nevertheless, both methods of analysing the problem will improve the quality of judgements. The author believes that the accuracy of the model will be improved if either one of the methods be employed in judging the parameter matrix.

Furthermore, the 46 decision variables listed in Section 4.3 of Chapter 4 are in no way a complete list of wastewater treatment alternatives. Other treatment alternatives may be added to the list and by doing so the hierarchical structure of the decision variables may probably need some adjustments. The existing list of decision variables, however, is believed by the author to be adequate in normal engineering applications.

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--- END ---

PART 5

APPENDICES

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CHAPTER 9

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APPENDIX B.1.1 --- USERS' MANUAL (MODEL)

B.1.1.1

Type "Model" against the "A>" prompt (or "C>" prompt if a hard-disc of XT or AT is used) and then press <ENTER>. The following will be shown on the screen:

```
***********************************************************
*                                                         *
* RANKING OF LIQUID TREATMENT ALTERNATIVES                *
*                                                         *
* Order of decision variable matrix is n x n where n =    *
*                                                         *
***********************************************************
```

Then, type the number of decision variables to be ranked and press <ENTER>. The computer will respond as follows:

```
***********************************************************
*                                                         *
* PARAMETER 1:  Flow                                      *
*                                                         *
* Do you want to use data from an existing file?  Y or N? *
*                                                         *
***********************************************************
```

The answer can either be (i) No or (ii) Yes

If the answer is No then see (i) hereunder. If the answer is Yes then see (ii) in Section B.1.1.2.

(i) No: Respond by typing "N" and then pressing <ENTER> if the data are not already stored in an existing data file. The computer will then respond as follows:

```
**************************************************************
*                                                            *
* You only have to enter the upper triangular elements       *
*                                                            *
* A (1,1) =                                                  *
*                                                            *
* ?                                                          *
*                                                            *
**************************************************************
```

So, input a_{11} (up to six decimal places) against the "?" prompt and press <ENTER>. The computer will then continue to ask one to enter a_{12}, a_{13} and so on until all the upper triangular elements (ie a_{ij} for $1 \leqslant i < j \leqslant n$) are entered. After the last element, a_{nn}, has been entered, the following will appear on the screen:

```
**************************************************************
*                                                            *
* The n x n matrix just entered is:                          *
*                                                            *
*      (                                         )           *
*      |       (all elements are shown here up   |           *
*      |        to three decimal places although |           *
*      |        they have been entered in six    |           *
*      |        decimal places)                  |           *
*      (                                         )           *
*                                                            *
* Do you want to change data in the above matrix? Y or N?    *
*                                                            *
**************************************************************
```

If the answer is yes, type "Y" and press <ENTER>. The user will then be asked to enter data again in the same manner as just described. If the answer is no, type "N" and press <ENTER>. The computer will tell one to wait for a short while, and will then show on the screen that this matrix is stored in a file named "PARA1.LIQ" After that, the user will be told by the computer to press <ENTER> to continue. So press <ENTER>, and the screen will respond as follows:

```
**************************************************************
*                                                            *
* PARAMETER 2:  Influent / Effluent                          *
*                                                            *
* Do you want to use data from an existing file? Y or N?    *
*                                                            *
**************************************************************
```

Now, the user is asked to input data for parameter 2. So, repeat responding to the computer in a similar manner as previously described until data for all the 20 parameters are entered.

B.1.1.2

(ii) Yes: If data are already stored in an existing file, type "Y" and then press <ENTER>. One will see the following on the screen:

```
**************************************************************
*                                                            *
* Name of the existing file is?                              *
*                                                            *
**************************************************************
```

Type the name of the existing data file "PARA1.LIQ" (data files are named as PARA1.LIQ2, PARA2.LIQ, ..., PARA20.LIQ) and then press <ENTER>. The computer will respond as follows:

```
****************************************************************
*                                                              *
* The decision variable matrix is :                            *
*                                                              *
*        ┌                                  ┐                  *
*        │                                  │                  *
*        │     (all elements of             │                  *
*        │      the matrix are              │                  *
*        │      shown here)                 │                  *
*        │                                  │                  *
*        └                                  ┘                  *
*                                                              *
* Do you want to change data in the above matrix? Y or N?      *
*                                                              *
****************************************************************
```

If the answer is no, then continue to interact with the computer as previously described. If the answer is yes, then the compute will ask the user to re-enter a_{11}, a_{12}, ..., a_{nn}.

B.1.1.3

Another feature of the program is that it automatically tests the consistency of the data entered. It allows them to have a certain degree of inconsistency but not too much (see Section 5.3.3). If the data entered are too inconsistent, the computer will inform the user of it and ask if he wants to revise the data.

B.1.1.4

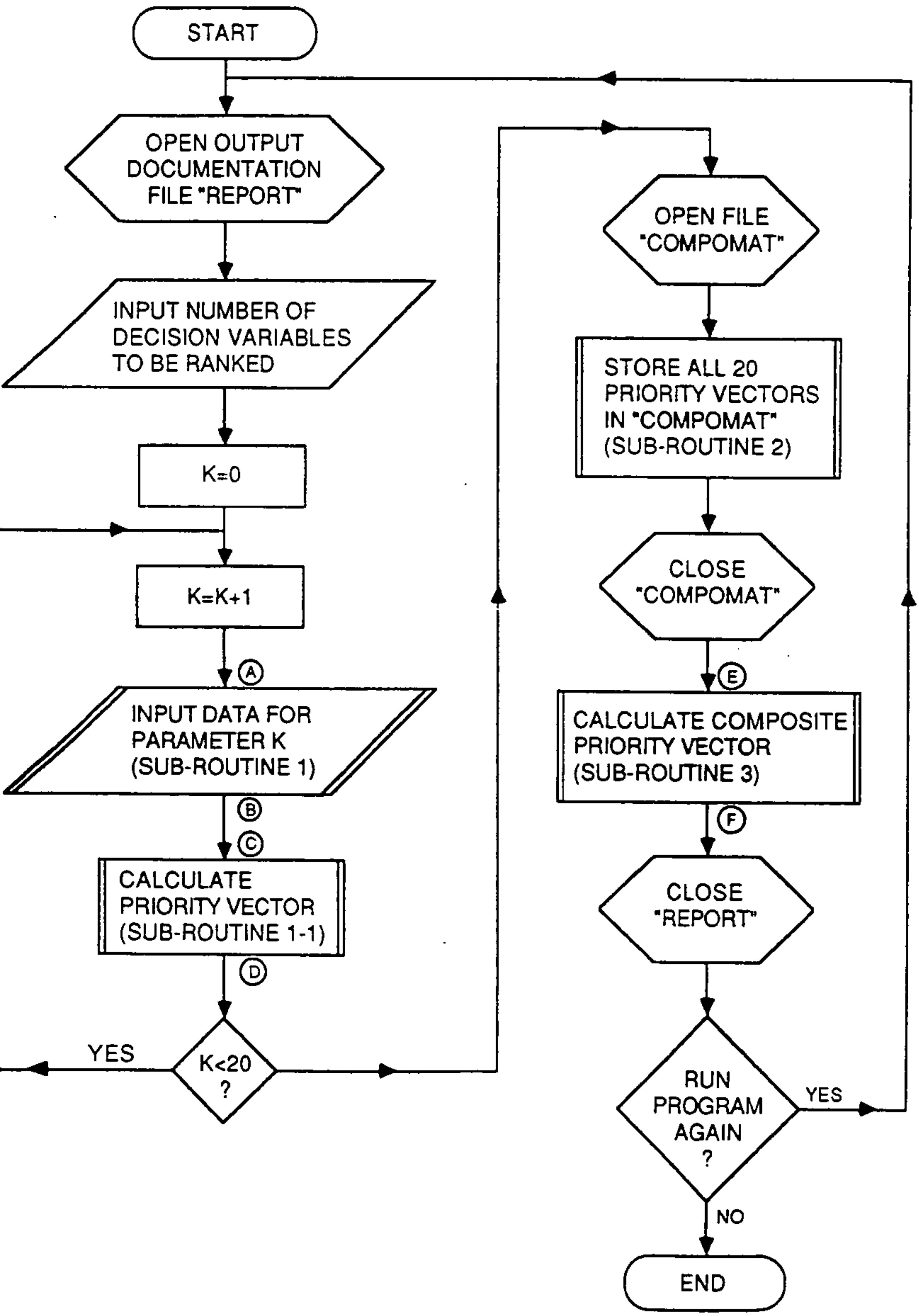
Keep on responding to the computer until all data are entered into the model. After the data for Parameter 20 have been entered, one will see the following on the screen:

```
****************************************************************
*                                                              *
* You have already entered all the necessary data              *
*                                                              *
* Press the RETURN key to continue                             *
*                                                              *
****************************************************************
```

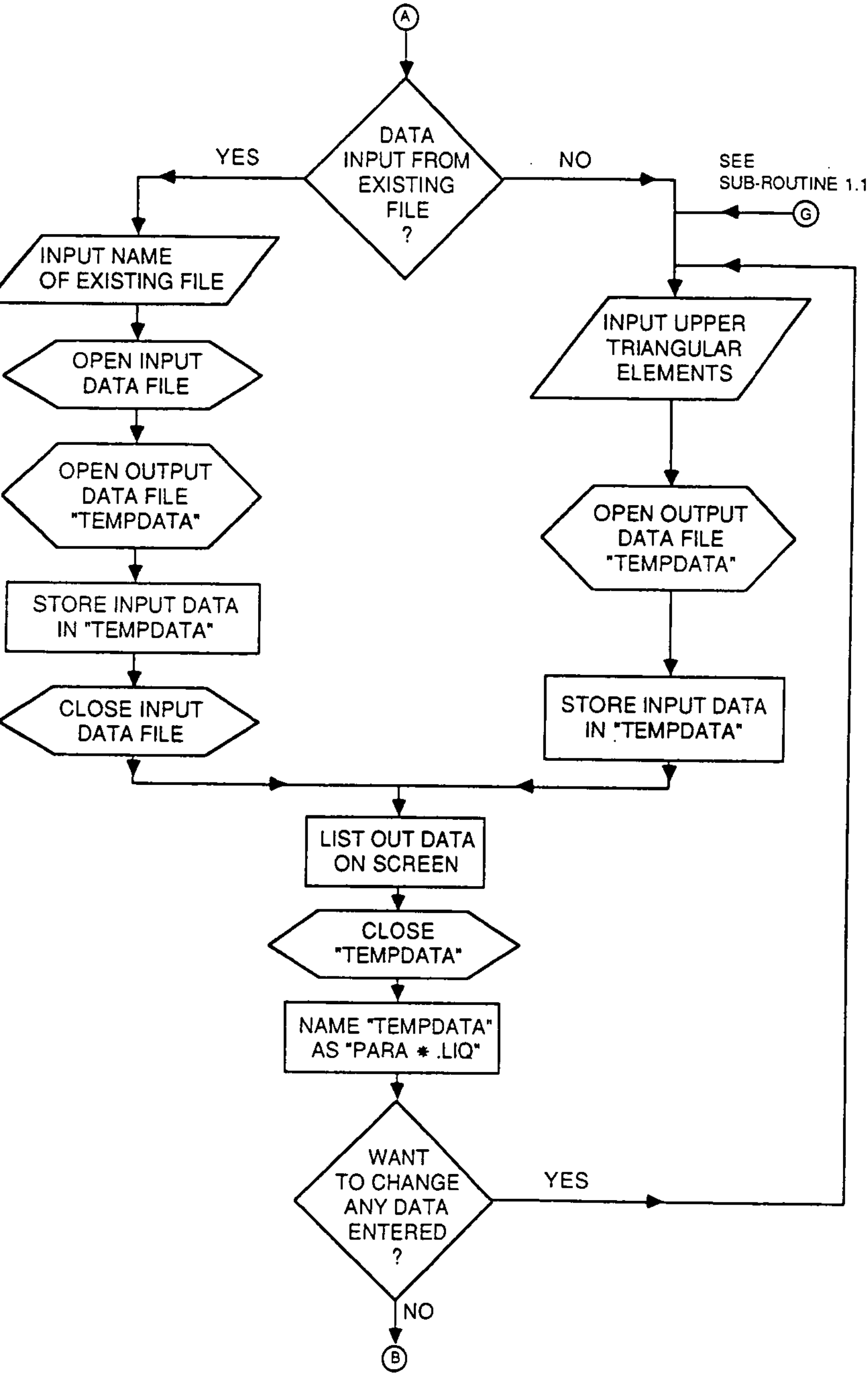
If the user presses <ENTER>, he will be told to wait as the calculation of the ranking of the treatment alternatives is in progress. After a short while, the result of the final ranking will appear on the screen. The user will then be asked whether to run the program again. If your answer is yes, the whole program will be run again, and if no, the program will end.

APPENDIX B.1.2 --- FLOW CHART (MODEL)

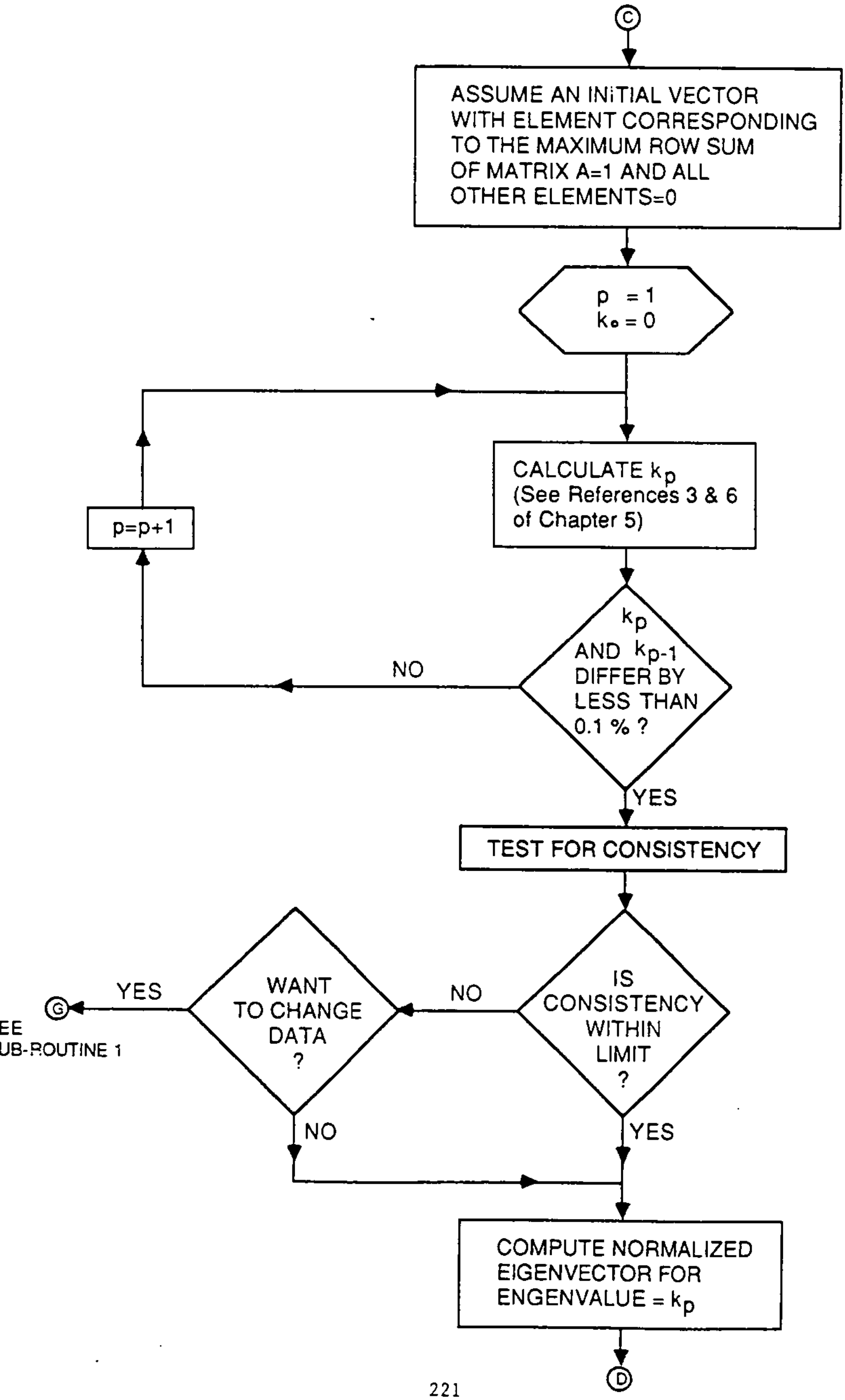
MAIN CHART



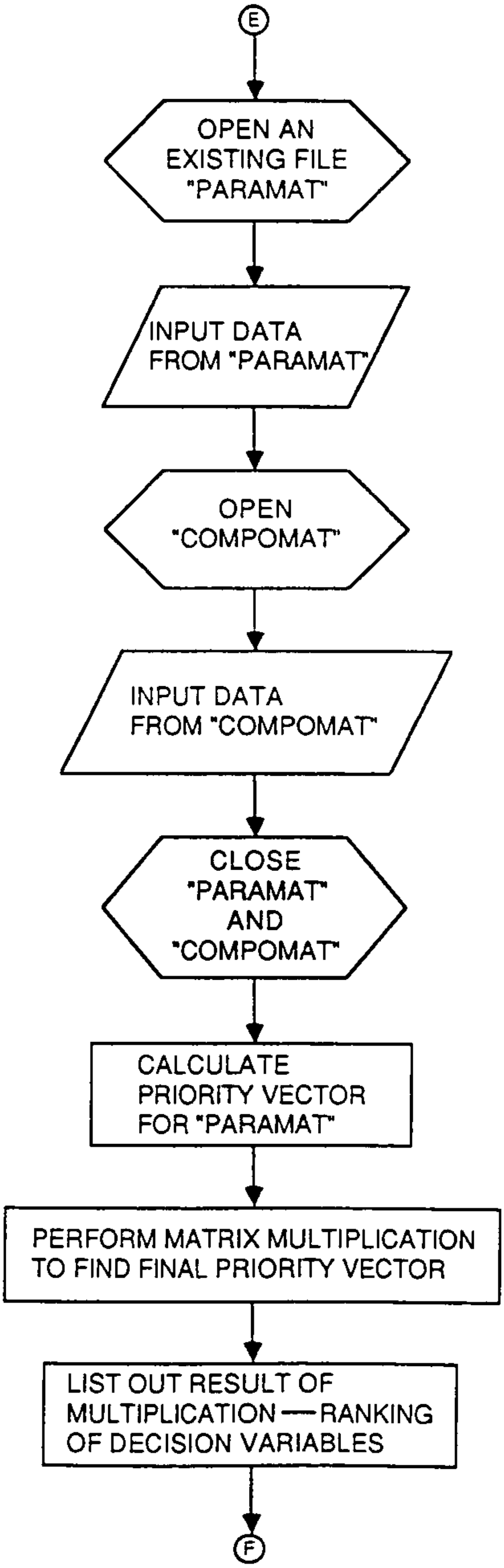
SUB-ROUTINE 1



SUBROUTINE 1.1



<u>SUB-ROUTINE 3</u>



APPENDIX B.1.3 --- PROGRAM LISTING (MODEL)

```
100 REM ********************************************************************
110 REM
120 REM
130 REM       PROGRAM NAME : MODEL
140 REM             AUTHOR : S.L. TANG
150 REM       DATE WRITTEN : 1986
160 REM
170 REM
180 REM ********************************************************************
190 REM
200 REM
210 REM       PROGRAM DISCRIPTION:
220 REM            THIS IS A PROGRAM FOR FINDING THE RANKING OF DIFFERENT
230 REM            WASTEWATER TREATMENT ALTERNATIVES
240 REM
250 REM
260 REM ********************************************************************
270 REM
280 REM
290 REM      DATA DICTIONARY:
300 REM
310 REM
320 REM      INPUT VARIABLES:
330 REM
340 REM                 N = ORDER OF DECISION VARIABLE MATRIX
350 REM         EX.FILE$ = ANSWER FOR WHETHER TO USE AN EXISTING FILE
360 REM             NAM$ = NAME FOR AN EXISTING FILE
370 REM             CON$ = PRESS RETURN KEY TO CONTINUE
380 REM                A = ARRAY FOR DATA INPUT INTO DECISION VARIABLE MATRIX
390 REM         CH.DATA$ = ANSWER FOR WHETHER TO CHANGE DATA IN A MATRIX
400 REM             REV$ = ANSWER FOR WHETHER TO REVISE DATA IN A MATRIX
410 REM         PARA.MAT = ARRAY FOR PARAMETER MATRIX FILE NAMED "PARAMAT"
420 REM              MAT = ARRAY FOR COMPOSITE MATRIX FILE NAMED "COMPOMAT"
430 REM           RERUN$ = ANSWER FOR WHETHER TO RERUN THE PROGRAM
440 REM
450 REM
460 REM      INPUT/OUTPUT VARIABLES:
470 REM
480 REM         DECIVAR.MAT = ARRAY FOR DECISION VARIABLE MATRIX
490 REM           COMPO.MAT = ARRAY FOR COMPOSITE MATRIX
500 REM
510 REM
520 REM      OUTPUT VARIABLES:
530 REM
540 REM            PERCENT = ARRAY FOR COMPOSITE PROIRITY VECTOR EXPRESS IN
550 REM                      TERMS OF PERCENTAGE
560 REM
570 REM
```

```
580 REM      OUTPUT FILES:
590 REM
600 REM         REPORT.LIQ = REPORT SHOWING THE DIALOGUE OF THE USER
610 REM                      AND THE COMPUTER WHEN RUNNING THE MODEL
620 REM       COMPOMAT.LIQ = THE COMPOSITE MATRIX
630 REM          PARA#.LIQ = DECISION VARIABLE MATRIX OF PARAMETER # (#=1-20)
640 REM
650 REM
660 REM      WORKING VARIABLES:
670 REM                  K = THE Kth PARAMETER
680 REM              PARA$ = NAME OF PARAMETER
690 REM               LIQ$ = FILE NAME OF DECISION VARIABLE MATRIX
700 REM           TEMPDATA = TEMPORARY FILE FOR STORING DECISION VARIABLE MATRIX
710 REM               I, J = LOOP CONTROL
720 REM            ROW.SUM = ARRAY FOR SUM OF ELEMENTS IN EACH ROW OF A MATRIX
730 REM                ROW = ROW NUMBER OF MAXIMUM ELGENVALUE
740 REM             VECTOR = ARRAY FOR INITIAL VECTOR AND SUBSEQUENT VECTORS
750 REM                  C = ARRAY FOR TEMPORARY EIGENVECTOR DURING ITERATIONS
760 REM                MAX = MOST RECENT MAX ELEMENT IN VECTOR DURING ITERATIONS
770 REM            PRE.MAX = MAXIMUM ELEMENT IN VECTOR AT THE PREVIOUS ITERATION
780 REM               DIFF = DIFFERENCE OF MAX AND PRE.MAX
790 REM              EIGEN = ARRAY FOR ELGENVECTOR
800 REM          NOR.EIGEN = ARRAY FOR NORMALIZED EIGENVECTOR
810 REM          EIGEN.SUM = SUM OF ELEMENTS IN EIGENVECTOR
820 REM        CONSIS.IDX = CONSISTENCY INDEX
830 REM               MAXI = LIMIT OF CONSISTENCY INDEX
840 REM                  Q = THE Kth COLUMN OF COMPOSITE MATRIX
850 REM        NOR.PARAVEC = ARRAY FOR NORMALIZED EIGENVECTOR OF PARAMETER MATRIX
860 REM          COMPO.VEC = ARRAY FOR COMPOSITE PRIORITY VECTOR
870 REM          COMPO.MAX = MAXIMUM ELEMENT OF COMPOSITE PRIORITY VECTOR
880 REM
890 REM
900 REM
910 REM
920 REM ####################################################################
930 REM
940 REM
950 REM                        MAIN CONTROL MODULE
960 REM
970 REM
980 REM ####################################################################
990 REM
1000 REM
1010 GOSUB 1130          : REM   INITIALIZE
1020 GOSUB 1470          : REM   PERFORM SUB-ROUTINE 1
1030 GOSUB 5230          : REM   PERFORM SUB-ROUTINE 2
1040 GOSUB 5470          : REM   PERFORM SUB-ROUTINE 3
1050 END
1060 REM
1070 REM
1080 REM
1090 REM
1100 REM ####################################################################
1110 REM
1120 REM
```

```
1130 REM                              INITIALIZE
1140 REM
1150 REM
1160 REM ***************************************************************
1170 REM
1180 REM
1190 DIM A(20,20), DECIVAR.MAT(20,20), PARA.MAT(20,20), ROW.SUM(20)
1200 DIM VECTOR(20), C(20), EIGEN(20), NOR.EIGEN(20), NOR.PARAVEC(20)
1210 DIM COMPO.MAT(20,20), MAT(20,20), COMPO.VEC(20), PERCENT(20)
1220 REM
1230 REM
1240 OPEN "O", #1, "REPORT.LIQ"
1250 REM
1260 REM
1270 PRINT "RANKING OF LIQUID TREATMENT ALTERNATIVES"
1280 PRINT #1, "RANKING OF LIQUID TREATMENT ALTERNATIVES"
1290 PRINT  :  PRINT #1, " "
1300 PRINT  :  PRINT #1, " "
1310 PRINT  :  PRINT #1, " "
1320 PRINT  :  PRINT #1, " "
1330 PRINT  :  PRINT #1, " "
1340 PRINT  :  PRINT #1, " "
1350 INPUT "Order of decision variable matrix is n x n where n = ", N
1360 PRINT #1, "Order of decision variable matrix is n x n where n = "; N
1370 PRINT  :  PRINT #1, " "
1380 PRINT  :  PRINT #1, " "
1390 RETURN
1400 REM
1410 REM
1420 REM
1430 REM
1440 REM ***************************************************************
1450 REM
1460 REM
1470 REM      SUB-ROUTINE 1:
1480 REM           THIS IS A SUB-ROUTINE FOR INPUTING DATA (ie. DECISION
1490 REM           VARIABLE MATRICES) TO THE MODEL, STORING THEM IN SEPARATE
1500 REM           FILES AND CALCULATING BY SUB-ROUTINE 2 THE PRIORITY VECTORS
1510 REM
1520 REM
1530 REM ***************************************************************
1540 REM
1550 REM
1560 REM                   SUB-ROUTINE 1 CONTROL MODULE
1570 REM
1580 REM
1590 FOR K = 1 TO 20
1600      READ PARA$
1610      READ LIQ$
1620      PRINT PARA$
1630      PRINT #1, PARA$
1640      PRINT  :  PRINT #1, " "
1650      PRINT  :  PRINT #1, " "
```

```
1660      GOSUB 2020    : REM    INPUT DATA FOR DECISION VARIABLE MATRIX
1670      PRINT  :  PRINT #1, " "
1680      PRINT  :  PRINT #1, " "
1690      PRINT  :  PRINT #1, " "
1700      PRINT  :  PRINT #1, " "
1710      PRINT "Please wait ..... "
1720      PRINT #1, "Please wait ....."
1730      GOSUB 3480    : REM    PERFORM SUB-ROUTINE 1.1
1740      PRINT  :  PRINT #1, " "
1750      PRINT  :  PRINT #1, " "
1760      PRINT "The matrix just entered is stored in a file named ";LI$
1770      PRINT #1, "The matrix just entered is stored in a file named ";LI$
1780      PRINT  :  PRINT #1, " "
1790      PRINT  :  PRINT #1, " "
1800      INPUT "Press the RETURN key to continue",CON$
1810      PRINT #1, "Press the RETURN key to continue"
1820      PRINT  :  PRINT #1, " "
1830      PRINT  :  PRINT #1, " "
1840      PRINT  :  PRINT #1, " "
1850      PRINT  :  PRINT #1, " "
1860      PRINT  :  PRINT #1, " "
1870      PRINT  :  PRINT #1, " "
1880 NEXT K
1890 REM
1900 PRINT "You have already entered all the necessary data"
1910 PRINT #1, "You have already entered all the necessary data"
1920 PRINT  :  PRINT #1, " "
1930 PRINT  :  PRINT #1, " "
1940 PRINT  :  PRINT #1, " "
1950 PRINT  :  PRINT #1, " "
1960 RETURN
1970 REM
1980 REM
1990 REM ********************************************************************
2000 REM
2010 REM
2020 REM       INPUT DATA FOR DECISION VARIABLE MATRIX
2030 REM
2040 REM
2050 INPUT "Do you want to use data from an existing file? Y or N ? ",EX.FILE$
2060 PRINT #1,"Do you want to use data from an existing file? Y or N ? ";EX.FILE$
2070 IF EX.FILE$ = "Y"  THEN  2140
2080 IF EX.FILE$ = "y"  THEN  2140
2090 IF EX.FILE$ = "N"  THEN  2760
2100 IF EX.FILE$ = "n"  THEN  2760
2110 GOTO 2050
2120 REM
2130 REM
2140 REM       INPUT DATA FROM EXISTING FILE
2150 REM
2160 REM
2170 PRINT : PRINT #1, " "
2180 PRINT : PRINT #1, " "
2190 INPUT "Name of the existing file is ? ", NAM$
2200 PRINT #1, "Name of the existing file is ? "; NAM$
```

```
2210 REM
2220 REM
2230 REM      STORE THE FILE DATA IN A TEMPORARY FILE NAMED "TEMPDATA"
2240 REM
2250 REM
2260 OPEN "I", #2, NAM$
2270 OPEN "O", #3, "TEMPDATA"
2280 FOR I = 1 TO N
2290      FOR J = 1 TO N
2300           INPUT #2, A(I,J)
2310           PRINT #3, A(I,J);
2320      NEXT J
2330      PRINT #3, " "
2340 NEXT I
2350 CLOSE #2
2360 CLOSE #3
2370 REM
2380 REM
2390 REM      LIST OUT THE DECISION VARIABLE MATRIX (FROM EXISTING FILE)
2400 REM
2410 REM
2420 PRINT  :  PRINT #1, " "
2430 PRINT  :  PRINT #1, " "
2440 PRINT "The decision variable matrix is: "
2450 PRINT #1, "The decision variable matrix is: "
2460 PRINT  :  PRINT #1, " "
2470 OPEN "I", #2, "TEMPDATA"
2480 FOR I = 1 TO N
2490      FOR J = 1 TO N
2500           INPUT #2, DECIVAR.MAT(I,J)
2510           PRINT USING "#.### "; DECIVAR.MAT(I,J);
2520           PRINT #1, USING "#.### "; DECIVAR.MAT(I,J);
2530      NEXT J
2540      PRINT : PRINT #1, " "
2550 NEXT I
2560 CLOSE #2
2570 PRINT  :  PRINT #1, " "
2580 PRINT  :  PRINT #1, " "
2590 KILL LI9$
2600 INPUT "Do you want to change data in the above matrix? Y or N ? ";CH.DATA$
2610 PRINT #1,"Do you want to change data in the above matrix? Y or N ? ";CH.DATA$
2620 IF CH.DATA$ = "Y"  THEN  2760
2630 IF CH.DATA$ = "y"  THEN  2760
2640 IF CH.DATA$ = "N"  THEN  2690
2650 IF CH.DATA$ = "n"  THEN  2690
2660 GOTO 2600
2670 REM
2680 REM
2690 REM      RENAME "TEMPDATA"
2700 REM
2710 REM
2720 NAME "TEMPDATA" AS LI9$
2730 GOTO 3400
2740 REM
2750 REM
```

```
2760 REM      MANUAL DATA INPUT
2770 REM
2780 REM
2790 PRINT : PRINT #1, " "
2800 PRINT : PRINT #1, " "
2810 PRINT "You only have to enter the upper triangular elements"
2820 PRINT #1, "You only have to enter the upper triangular elements"
2830 PRINT  :  PRINT #1, " "
2840 PRINT  :  PRINT #1, " "
2850 FOR I = 1 TO N
2860      FOR J = I TO N
2870            PRINT "A(";I;",";J") = " : INPUT A(I,J)
2880            PRINT #1, "A(";I;",";J") = " ; A(I,J)
2890            A(J,I) = 1/A(I,J)
2900      NEXT J
2910 NEXT I
2920 REM
2930 REM
2940 REM      STORE THE DATA JUST ENTERED IN A DATA FILE NAMED "TEMPDATA"
2950 REM
2960 REM
2970 OPEN "O", #2, "TEMPDATA"
2980 FOR I = 1 TO N
2990      FOR J = 1 TO N
3000            PRINT #2, A(I,J);
3010      NEXT J
3020      PRINT #2, " "
3030 NEXT I
3040 CLOSE #2
3050 REM
3060 REM
3070 REM      LIST OUT THE DECISION VARIABLE MATRIX (FROM MANUAL INPUT)
3080 REM
3090 REM
3100 PRINT  :  PRINT #1, " "
3110 PRINT  :  PRINT #1, " "
3120 PRINT "The decision variable matrix is:"
3130 PRINT #1, "The decision variable matrix is:"
3140 PRINT  :  PRINT #1, " "
3150 OPEN "I", #2, "TEMPDATA"
3160 FOR I = 1 TO N
3170      FOR J = 1 TO N
3180            INPUT #2, DECIVAR.MAT(I,J)
3190            PRINT USING "#.### "; DECIVAR.MAT(I,J);
3200            PRINT #1, USING "#.### "; DECIVAR.MAT(I,J);
3210      NEXT J
3220      PRINT : PRINT #1, " "
3230 NEXT I
3240 CLOSE #2
3250 PRINT  :  PRINT #1, " "
3260 PRINT  :  PRINT #1, " "
3270 INPUT "Do you want to change data in the above matrix? Y or N ? ",CH.DATA$
3280 PRINT #1,"Do you want to change data in the above matrix? Y or N ? ";CH.DATA$
```

```
3290 IF CH.DATA$ = "Y"  THEN  2760
3300 IF CH.DATA$ = "y"  THEN  2760
3310 IF CH.DATA$ = "N"  THEN  3360
3320 IF CH.DATA$ = "n"  THEN  3360
3330 GOTO 3270
3340 REM
3350 REM
3360 REM      RENAME "TEMPDATA"
3370 REM
3380 REM
3390 NAME "TEMPDATA" AS LI9$
3400 RETURN
3410 REM
3420 REM
3430 REM
3440 REM
3450 REM ******************************************************************
3460 REM
3470 REM
3480 REM      SUB-ROUTINE 1.1:
3490 REM          THIS IS A SUB-ROUTINE FOR FINDING MAXIMUM EIGENVALUE AND ITS
3500 REM          CORRESPONDING PRIORITY VECTOR OF A SQUARE MATRIX OF ORDER N
3510 REM
3520 REM
3530 REM ******************************************************************
3540 REM
3550 REM
3560 REM                     SUB-ROUTINE 1.1 CONTROL MODULE
3570 REM
3580 REM
3590 GOSUB 3730     : REM FIND THE SUM OF ELEMENTS IN EACH ROW OF MATRIX
3600 GOSUB 3850     : REM FIND THE MAXIMUM OF ROW-SUMS
3610 GOSUB 3960     : REM ASSUME AN INITIAL VECTOR
3620 GOSUB 4070     : REM PERFORM THE ITERATIONS
3630 GOSUB 4500     : REM CALCULATE THE EIGENVECTOR
3640 GOSUB 4590     : REM CALCULATE THE NORMALIZED ELGENVECTOR
3650 GOSUB 4720     : REM TEST FOR CONSISTENCY
3660 GOSUB 5080     : REM STORE THE NORMALIZED EIGENVECTOR
3670 RETURN
3680 REM
3690 REM
3700 REM ******************************************************************
3710 REM
3720 REM
3730 REM      FIND THE SUM OF ELEMENTS IN EACH ROW OF MATRIX
3740 REM
3750 REM
3760 FOR I = 1 TO N
3770      ROW.SUM(I) = 0
3780      FOR J = 1 TO N
3790           ROW.SUM(I) = ROW.SUM(I) + DECIVAR.MAT(I,J)
3800      NEXT J
3810 NEXT I
3820 RETURN
3830 REM
```

```
3840 REM
3850 REM      FIND THE MAXIMUM OF ROW-SUMS
3860 REM
3870 REM
3880 MAX = ROW.SUM(1) : ROW = 1
3890 FOR I = 2 TO N STEP 1
3900      IF MAX > ROW.SUM(I)   THEN   3920
3910         MAX = ROW.SUM(I)  :  ROW = I
3920 NEXT I
3930 RETURN
3940 REM
3950 REM
3960 REM      ASSUME AN INITIAL VECTOR
3970 REM
3980 REM
3990 FOR J = 1 TO N
4000      IF J = ROW   THEN   4020
4010      VECTOR(J) = 0  :  GOTO 4030
4020      VECTOR(J) = 1
4030 NEXT J
4040 RETURN
4050 REM
4060 REM
4070 REM      PERFORM THE ITERATIONS
4080 REM
4090 REM
4100 PRE.MAX = 0
4110 FOR I = 1 TO N
4120      C(I) = 0
4130      FOR J = 1 TO N
4140         C(I) = C(I) + DECIVAR.MAT(I,J) * VECTOR(J)
4150      NEXT J
4160 NEXT I
4170 MAX = C(1)  :  ROW = 1
4180 FOR I = 2 TO N STEP 1
4190      IF MAX > C(I)   THEN   4210
4200         MAX = C(I)  :  ROW = I
4210 NEXT I
4220 REM
4230 REM
4240 REM      TEST FOR THE NEED OF FURTHER ITERATION
4250 REM
4260 REM
4270 IF  N =   3  THEN  DIFF = .003
4280 IF  N =   4  THEN  DIFF = .004
4290 IF  N =   5  THEN  DIFF = .005
4300 IF  N =   6  THEN  DIFF = .006
4310 IF  N =   7  THEN  DIFF = .007
4320 IF  N =   8  THEN  DIFF = 8.000001E-03
4330 IF  N =   9  THEN  DIFF = 9.000001E-03
4340 IF  N =  10  THEN  DIFF = .01
4350 IF  N =  11  THEN  DIFF = .011
4360 IF  N =  12  THEN  DIFF = .012
4370 IF  N =  13  THEN  DIFF = .013
4380 IF  N =  14  THEN  DIFF = .014
```

```
4390 IF  N =  15  THEN  DIFF = .015
4400 IF  N => 16  THEN  DIFF = .02
4410 IF  ABS(MAX - PRE.MAX) < DIFF   THEN  4470  ELSE  4420
4420 FOR J = 1 TO N
4430      VECTOR(J) = C(J)/MAX
4440 NEXT J
4450 PRE.MAX = MAX
4460 GOTO 4110
4470 RETURN
4480 REM
4490 REM
4500 REM      CALCULATE THE EIGENVECTOR
4510 REM
4520 REM
4530 FOR I = 1 TO N
4540      EIGEN(I) = C(I)/MAX
4550 NEXT I
4560 RETURN
4570 REM
4580 REM
4590 REM      CALCULATE THE NORMALIZED EIGENVECTOR
4600 REM
4610 REM
4620 EIGEN.SUM = 0
4630 FOR I = 1 TO N
4640      EIGEN.SUM = EIGEN.SUM + EIGEN(I)
4650 NEXT I
4660 FOR I = 1 TO N
4670      NOR.EIGEN(I) = EIGEN(I)/EIGEN.SUM
4680 NEXT I
4690 RETURN
4700 REM
4710 REM
4720 REM      TEST FOR CONSISTENCY
4730 REM
4740 REM
4750 CONSIS.IDX = (MAX - N)/(N - 1)
4760 IF  N =   3  THEN  MAXI =    3.09
4770 IF  N =   4  THEN  MAXI =    4.24
4780 IF  N =   5  THEN  MAXI =    5.41
4790 IF  N =   6  THEN  MAXI =    6.59
4800 IF  N =   7  THEN  MAXI =    7.75
4810 IF  N =   8  THEN  MAXI =    8.95
4820 IF  N =   9  THEN  MAXI =   10.11
4830 IF  N =  10  THEN  MAXI =   11.3
4840 IF  N =  11  THEN  MAXI =   12.5
4850 IF  N =  12  THEN  MAXI =   13.7
4860 IF  N =  13  THEN  MAXI =   14.9
4870 IF  N =  14  THEN  MAXI =   16.2
4880 IF  N =  15  THEN  MAXI =   17.5
4890 IF  N => 16  THEN  MAXI = 1000
4900 IF  MAX > MAXI  THEN  4910  ELSE  5050
4910 PRINT  :  PRINT #1, " "
4920 PRINT  :  PRINT #1, " "
```

```
4930 PRINT "The decision variable matrix is not very consistent"
4940 PRINT #1, "The decision variable matrix is not very consistent"
4950 PRINT "The consistency index is "; CONSIS.IDX
4960 PRINT #1, "The consistency index is "; CONSIS.IDX
4970 PRINT  :  PRINT #1, " "
4980 INPUT "Do you want to revise the data in this matrix? Y or N ? ",REV$
4990 PRINT #1, "Do you want to revise the data in this matrix? Y or N ? ";REV$
5000 IF  REV$ = "Y"  THEN  KILL LI9$  :  GOTO 2760
5010 IF  REV$ = "y"  THEN  KILL LI9$  :  GOTO 2760
5020 IF  REV$ = "N"  THEN  5050
5030 IF  REV$ = "n"  THEN  5050
5040 GOTO  4980
5050 RETURN
5060 REM
5070 REM
5080 REM      STORE THE NORMALIZED EIGENVECTOR
5090 REM
5100 REM
5110 Q = X
5120 FOR I = 1 TO N
5130      COMPO.MAT(I,Q) = NOR.EIGEN(I)
5140 NEXT I
5150 RETURN
5160 REM
5170 REM
5180 REM
5190 REM
5200 REM ***********************************************************************
5210 REM
5220 REM
5230 REM      SUB-ROUTINE 2:
5240 REM           THIS IS A SUB-ROUTINE FOR CONSTRUCTING THE
5250 REM           COMPOSITE MATRIX "COMPOMAT.LI9"
5260 REM
5270 REM
5280 REM ***********************************************************************
5290 REM
5300 REM
5310 OPEN "O", #2, "COMPOMAT.LI9"
5320 FOR I = 1 TO N
5330      FOR J = 1 TO 9
5340           PRINT #2, COMPO.MAT(I,J);
5350      NEXT J
5360      PRINT #2, " "
5370 NEXT I
5380 CLOSE #2
5390 RETURN
5400 REM
5410 REM
5420 REM
5430 REM
5440 REM ***********************************************************************
5450 REM
5460 REM
```

```
5470 REM      SUB-ROUTINE 3:
5480 REM           THIS IS A SUB-ROUTINE FOR CALCULATING COMPOSITE
5490 REM           PRIORITY VECTOR
5500 REM
5510 REM
5520 REM ******************************************************************
5530 REM
5540 REM
5550 REM                     SUB-ROUTINE 3 CONTROL MODULE
5560 REM
5570 REM
5580 PRINT "Please wait.  Calculation of ranking of the alternatives"
5590 PRINT "is in process."
5600 PRINT #1, "Please wait.  Calculation of ranking of the alternatives"
5610 PRINT #1, "is in process."
5620 OPEN "I", #2, "PARAMAT"
5630 K=20
5640 GOSUB 5930     : REM   INPUT DATA FROM PARAMETER MATRIX
5650 CLOSE #2
5660 GOSUB 6040     : REM   CALCULATE THE EIGENVECTOR OF "PARAMAT"
5670 OPEN "I", #3, "COMPOMAT.LIQ"
5680 GOSUB 6890     : REM   INPUT DATA FROM COMPOSITE MATRIX
5690 CLOSE #3
5700 GOSUB 7000     : REM   PERFORM THE MULTIPLICATION
5710 GOSUB 7120     : REM   EXPRESS COMPO.VEC(I) IN TERMS OF %
5720 GOSUB 7260     : REM   PRINT THE RESULT OF RANKING
5730 CLOSE #1
5740 PRINT
5750 PRINT
5760 INPUT "PRESS the RETURN key to continue", CON$
5770 PRINT
5780 PRINT
5790 PRINT "You have finished ranking the liquid treatment alternatives."
5800 PRINT "Do you wish to re-run the program to rank liquid treatment?"
5810 PRINT
5820 INPUT "Input Y or N ? ", RERUN$
5830 PRINT
5840 PRINT
5850 IF  RERUN$ = "Y"  THEN  950
5860 IF  RERUN$ = "y"  THEN  950
5870 RETURN
5880 REM
5890 REM
5900 REM ******************************************************************
5910 REM
5920 REM
5930 REM      INPUT DATA FROM THE PARAMETER MATRIX
5940 REM
5950 REM
5960 FOR I = 1 TO K
5970      FOR J = 1 TO K
5980           INPUT #2, PARA.MAT(I,J)
5990      NEXT J
6000 NEXT I
6010 RETURN
```

```
6020 REM
6030 REM
6040 REM      CALCULATE THE EIGENVVECTOR OF "PARAMAT"
6050 REM
6060 REM
6070 REM
6080 REM
6090 REM      FIND THE SUM OF ELEMENTS IN EACH ROW OF MATRIX
6100 REM
6110 REM
6120 FOR I = 1 TO K
6130       ROW.SUM(I) = 0
6140       FOR J = 1 TO K
6150           ROW.SUM(I) = ROW.SUM(I) + PARA.MAT(I,J)
6160       NEXT J
6170 NEXT I
6180 REM
6190 REM
6200 REM      FIND THE MAXIMUM OF ROW-SUMS
6210 REM
6220 REM
6230 MAX = ROW.SUM(1)  :  ROW = 1
6240 FOR I = 2 TO K
6250       IF MAX > ROW.SUM(I)  THEN  6270
6260          MAX = ROW.SUM(I)  :  ROW = I
6270 NEXT I
6280 REM
6290 REM
6300 REM      ASSUME AN INITAIL VECTOR
6310 REM
6320 REM
6330 FOR J = 1 TO K
6340       IF J = ROW  THEN  6360
6350       VECTOR(J) = 0  :  GOTO 6370
6360       VECTOR(J) = 1
6370 NEXT J
6380 REM
6390 REM
6400 REM      PERFORM THE ITERATIONS
6410 REM
6420 REM
6430 PRE.MAX = 0
6440 FOR I = 1 TO K
6450       C(I) = 0
6460       FOR J = 1 TO K
6470          C(I) = C(I) + PARA.MAT(I,J) * VECTOR(J)
6480       NEXT J
6490 NEXT I
6500 MAX = C(1)  :  ROW = 1
6510 FOR I = 2 TO K STEP 1
6520       IF MAX > C(I)  THEN  6540
6530          MAX = C(I)  :  ROW = I
6540 NEXT I
6550 REM
6560 REM
```

```
6570 REM      TEST FOR THE NEED OF FURTHER ITERATION
6580 REM
6590 REM
6600 IF  ABS(MAX - PRE.MAX) < .02  THEN  6680  ELSE  6610
6610 FOR J = 1 TO K
6620      VECTOR(J) = C(J)/MAX
6630 NEXT J
6640 PRE.MAX = MAX
6650 GOTO 6440
6660 REM
6670 REM
6680 REM      CALCULATE THE EIGENVECTOR OF "PARAMAT"
6690 REM
6700 REM
6710 FOR I = 1 TO K
6720      EIGEN(I) = C(I)/MAX
6730 NEXT I
6740 REM
6750 REM
6760 REM      CALCULATE THE NORMALIZED EIGENVECTOR OF "PARAMAT"
6770 REM
6780 REM
6790 EIGEN.SUM = 0
6800 FOR I = 1 TO K
6810      EIGEN.SUM = EIGEN.SUM + EIGEN(I)
6820 NEXT I
6830 FOR I = 1 TO K
6840      NOR.PARAVEC(I) = EIGEN(I)/EIGEN.SUM
6850 NEXT I
6860 RETURN
6870 REM
6880 REM
6890 REM      INPUT DATA FROM THE COMPOSITE MATRIX
6900 REM
6910 REM
6920 FOR I = 1 TO N
6930      FOR J = 1 TO K
6940           INPUT #3, MAT(I,J)
6950      NEXT J
6960 NEXT I
6970 RETURN
6980 REM
6990 REM
7000 REM      PERFORM THE MULITIPLICATION
7010 REM
7020 REM
7030 FOR I = 1 TO N
7040      COMPO.VEC(I) = 0
7050      FOR J = 1 TO K
7060           COMPO.VEC(I) = COMPO.VEC(I) + MAT(I,J) * NOR.PARAVEC(J)
7070 NEXT J
7080 NEXT I
7090 RETURN
7100 REM
7110 REM
```

```
7120 REM      EXPRESS COMPOSITE PRIORITY VECTOR IN TERMS OF %
7130 REM
7140 REM
7150 COMPO.MAX = COMPO.VEC(1)
7160 FOR I = 2 TO N STEP 1
7170      IF COMPO.MAX > COMPO.VEC(I)  THEN  7190
7180         COMPO.MAX = COMPO.VEC(I)
7190 NEXT I
7200 FOR I = 1 TO N
7210      PERCENT(I) = (COMPO.VEC(I)/COMPO.MAX) * 100
7220 NEXT I
7230 RETURN
7240 REM
7250 REM
7260 REM      PRINT THE RESULT OF RANKING
7270 REM
7280 REM
7290 PRINT  :  PRINT #1, " "
7300 PRINT  :  PRINT #1, " "
7310 PRINT "The ranking is: "
7320 PRINT #1, "The ranking is: "
7330 PRINT  :  PRINT #1, " "
7340 PRINT  :  PRINT #1, " "
7350 PRINT " ", "RANKING IN %"
7360 PRINT #1, " ", "RANKING IN %"
7370 PRINT " ", "____________"
7380 PRINT #1, " ", "____________"
7390 PRINT  :  PRINT #1, " "
7400 FOR I = 1 TO N
7410      PRINT "Alternative "; I, PERCENT(I)
7420      PRINT #1, "Alternative "; I,PERCENT(I)
7430 NEXT I
7440 RETURN
7450 REM
7460 REM
7470 REM
7480 REM
7490 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
7500 REM
7510 REM
7520 REM                              DATA
7530 REM
7540 REM
7550 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
7560 REM
7570 REM
7580 DATA "PARAMETER 1 : Flow"
7590 DATA "PARA1.LIQ"
7600 DATA "PARAMETER 2 : Influent / Effluent"
7610 DATA "PARA2.LIQ"
7620 DATA "PARAMETER 3 : Size of site"
7630 DATA "PARA3.LIQ"
7640 DATA "PARAMETER 4 : Nature of site"
7650 DATA "PARA4.LIQ"
```

```
7660 DATA "PARAMETER 5 : Land cost"
7670 DATA "PARA5.LIQ"
7680 DATA "PARAMETER 6 : Local money for construction"
7690 DATA "PARA6.LIQ"
7700 DATA "PARAMETER 7 : Foreign money for construction"
7710 DATA "PARA7.LIQ"
7720 DATA "PARAMETER 8 : Local skill for construction"
7730 DATA "PARA8.LIQ"
7740 DATA "PARAMETER 9 : Community support"
7750 DATA "PARA9.LIQ"
7760 DATA "PARAMETER 10 : Power source"
7770 DATA "PARA10.LIQ"
7780 DATA "PARAMETER 11 : Availability of local material"
7790 DATA "PARA11.LIQ"
7800 DATA "PARAMETER 12 : Cost of operation & maintenance"
7810 DATA "PARA12.LIQ"
7820 DATA "PARAMETER 13 : Professional skill for operation & maintenance"
7830 DATA "PARA13.LIQ"
7840 DATA "PARAMETER 14 : Local technical skill for operation & maintenance"
7850 DATA "PARA14.LIQ"
7860 DATA "PARAMETER 15 : Administration set-up"
7870 DATA "PARA15.LIQ"
7880 DATA "PARAMETER 16 : Training"
7890 DATA "PARA16.LIQ"
7900 DATA "PARAMETER 17 : Professional ethics"
7910 DATA "PARA17.LIQ"
7920 DATA "PARAMETER 18 : Climate"
7930 DATA "PARA18.LIQ"
7940 DATA "PARAMETER 19 : Local water-borne diseases"
7950 DATA "PARA19.LIQ"
7960 DATA "PARAMETER 20 : Endemic vector-borne (water related) diseases"
7970 DATA "PARA20.LIQ"
7980 REM
7990 REM
8000 REM ***********************************************************************
```

APPENDIX B.2.1. --- USER'S MANUAL (SENSIANA)

Type "SENSIANA" against the "A>" prompt (or "C>" prompt if a hard-disc of XT or AT is used) and then press <ENTER>. The following will be shown on the screen:

```
*************************************************************
*                                                           *
* Order of decision variable matrix is n x n where n =      *
*                                                           *
*************************************************************
```

Then, type the number of decision variables to be ranked and press <ENTER>. The computer will respond as follows:

```
***************************************************************
*                                                             *
* Enter the parameter number whose matrix is to be reviewed.*
*                                                             *
*  The number (ie. the kth parameter, k = 1 to 20) is?        *
*                                                             *
***************************************************************
```

So, type the number next to the "?" prompt and press <ENTER>. The computer will show the original matrix on the screen and ask if the matrix should be revised as follows:

```
*************************************************************
*                                                           *
* The decision variable matrix is:                          *
*      _                                  _                 *
*     |   (the elements shown are those of |                *
*     |    the original matrix)            |                *
*     |                                    |                *
*     |_                                  _|                *
*                                                           *
* Do you want to change data in the above matrix? Y or N?  *
*                                                           *
*************************************************************
```

Usually the answer should be Yes because this is a sensitivity analysis program. (The answer would be No only if the user has entered a wrong parameter number and in such a case the computer will ask him to re-enter the parameter number.) So type "Y" and then press <ENTER>. The computer will respond as follows:

```
*************************************************************
*                                                           *
* You only have to enter the upper triangular elements      *
*                                                           *
* A(1,1) =                                                  *
*                                                           *
* ?                                                         *
*                                                           *
*************************************************************
```

So, input a_{11} (up to six decimal places) against the "?" prompt and press <ENTER>. The computer will then continue to ask the user to enter a_{12}, a_{13} and so on until all the upper triangular elements (ie. a_{ij} for $1 \leq i < j \leq n$) are entered. After the last element, a_{nn}, has been entered, the following will appear on the screen:

```
*************************************************************
*                                                           *
* The decision variable matrix is:                          *
*     ┌                                      ┐              *
*     │   (the elements shown are those      │              *
*     │    newly entered)                    │              *
*     │                                      │              *
*     │                                      │              *
*     └                                      ┘              *
*                                                           *
* Do you want to change data in the above matrix? Y or N?   *
*                                                           *
*************************************************************
```

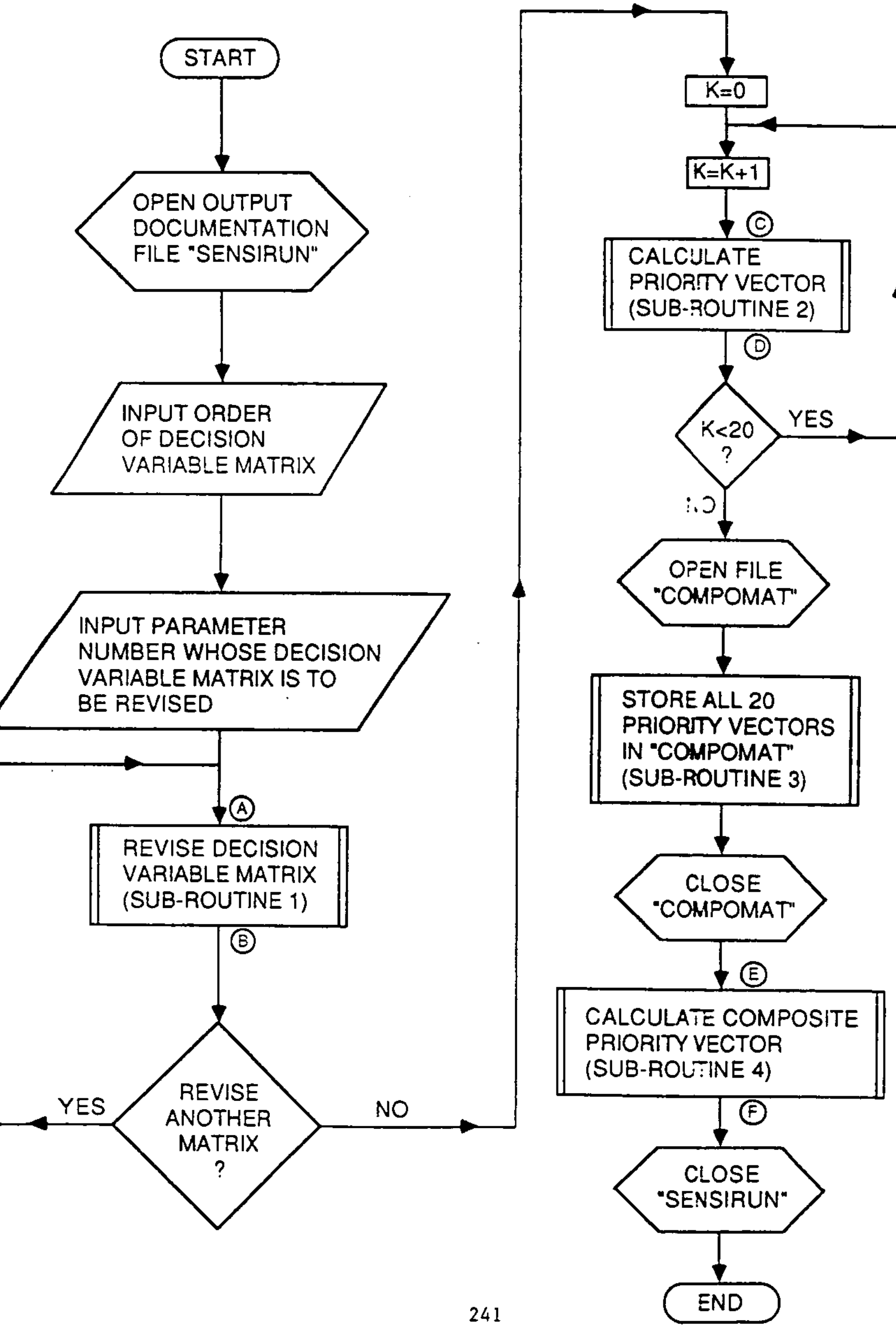
If the user has entered wrong data, then answer "Y" and the computer will allow him to input the data once again. If the answer is "N", the computer will ask you another question:

```
*************************************************************
*                                                           *
* Do you want to change another decision variable matrix? *
*                                                           *
*************************************************************
```

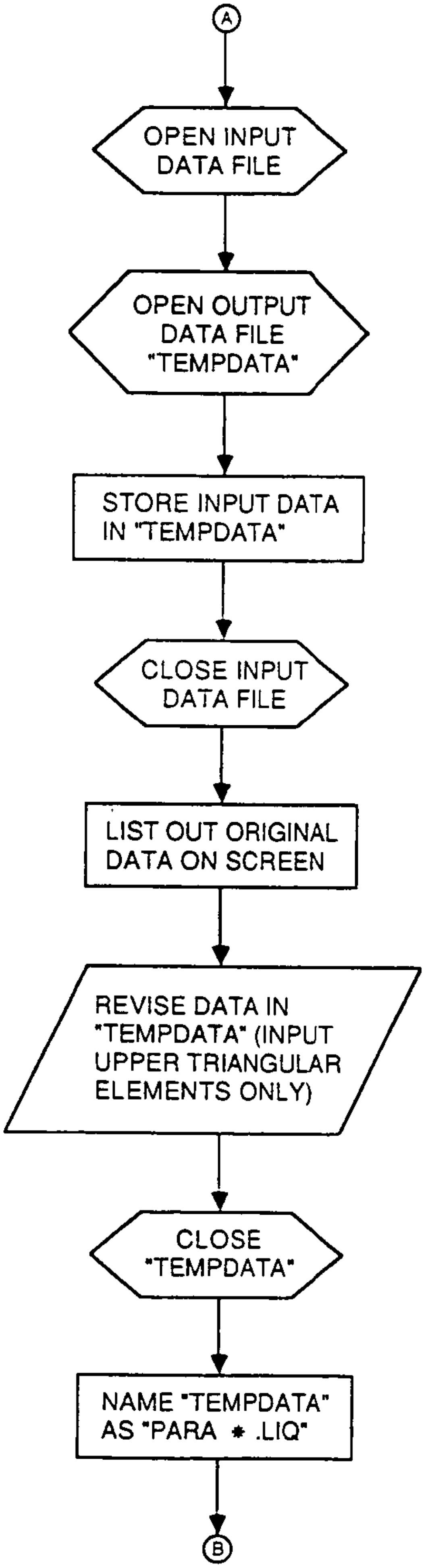
If the user has decision variable matrices of other parameters needed to be revised, then type "Y" and press <ENTER>. The computer will repeat to ask the whole set of questions as described in the previous paragraphs of this manual and the users will have to respond to them accordingly. If the user has finished revising the decision variable matrices, then type "N" and press <ENTER>. The computer will tell the user to wait as the calculation of the ranking of the treatment alternatives is in progress. After a short while, the result of the final ranking will appear on the screen and the program will end.

APPENDIX B.2.2- - -FLOW CHART (SENSIANA)

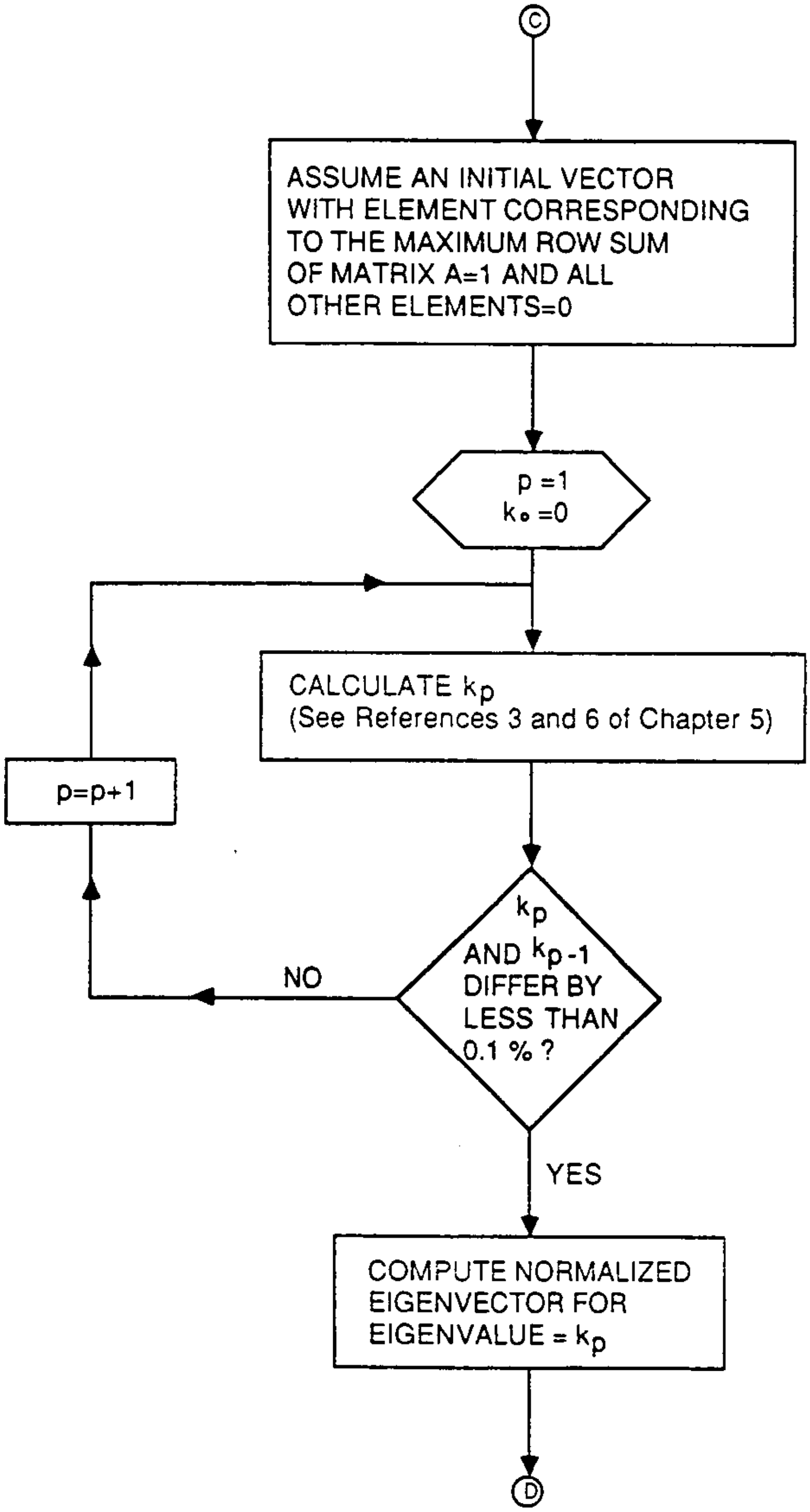
MAIN CHART



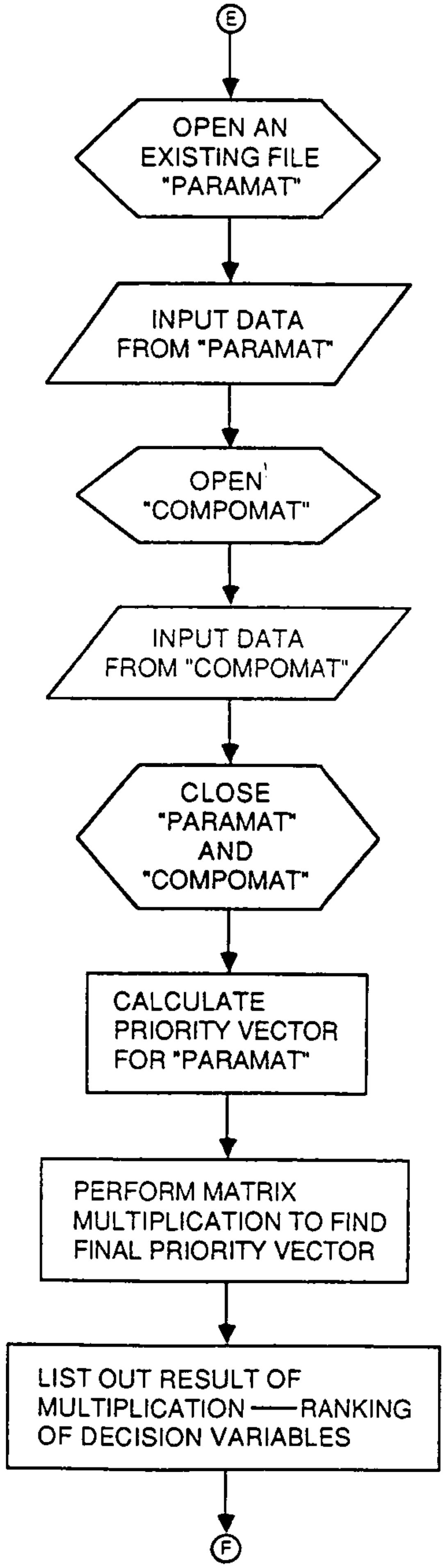
SUB-ROUTINE 1



SUB-ROUTINE 2



<u>SUB-ROUTINE 4</u>



APPENDIX B.2.3 --- PROGRAM LISTING (SENSIANA)

```
100 REM ************************************************************************
110 REM
120 REM
130 REM       PROGRAM NAME : SENSIANA
140 REM             AUTHOR : S.L. TANG
150 REM       DATE WRITTEN : 1988
160 REM
170 REM
180 REM ************************************************************************
190 REM
200 REM
210 REM       PROGRAM DISCRIPTION:
220 REM            THIS IS A PROGRAM FOR SENSITIVITY ANALYSIS OF RANKING
230 REM            WASTEWATER TREATMENT ALTERNATIVES
240 REM
250 REM
260 REM ************************************************************************
270 REM
280 REM
290 REM      DATA DICTIONARY:
300 REM
310 REM
320 REM      INPUT VARIABLES:
330 REM
340 REM               N = ORDER OF DECISION VARIABLE MATRIX
350 REM               A = ARRAY FOR DATA INPUT INTO DECISION VARIABLE MATRIX
360 REM       CH.DATA$ = ANSWER FOR WHETHER TO CHANGE DATA IN A MATRIX
370 REM       PARA.MAT = ARRAY FOR PARAMETER MATRIX FILE NAMED "PARAMAT"
380 REM            MAT = ARRAY FOR COMPOSITE MATRIX FILE NAMED "COMPOMAT"
390 REM
400 REM
410 REM      INPUT/OUTPUT VARIABLES:
420 REM
430 REM       DECIVAR.MAT = ARRAY FOR DECISION VARIABLE MATRIX
440 REM         COMPO.MAT = ARRAY FOR COMPOSITE MATRIX
450 REM
460 REM
470 REM      OUTPUT VARIABLES:
480 REM
490 REM           PERCENT = ARRAY FOR COMPOSITE PRIORITY VECTOR EXPRESS IN
500 REM                          TERMS OF PERCENTAGE
510 REM
520 REM
530 REM      OUTPUT FILES:
540 REM
550 REM       SENSIRUN.LIB = REPORT SHOWING THE DIALOGUE OF THE USER
560 REM                      AND THE COMPUTER WHEN RUNNING THE MODEL
570 REM       COMPOMAT.LIB = THE COMPOSITE MATRIX
580 REM          PARA#.LIB = DECISION VARIABLE MATRIX OF PARAMETER # (#=1-2
590 REM
600 REM
```

```
610 REM      WORKING VARIABLES:
620 REM                  K = THE Kth PARAMETER
630 REM               LIO$ = FILE NAME OF DECISION VARIABLE MATRIX
640 REM           TEMPDATA = TEMPORARY FILE FOR STORING DECISION VARIABLE MATRIX
650 REM               I, J = LOOP CONTROL
660 REM            ROW.SUM = ARRAY FOR SUM OF ELEMENTS IN EACH ROW OF A MATRIX
670 REM                ROW = ROW NUMBER OF MAXIMUM ELGENVALUE
680 REM             VECTOR = ARRAY FOR INITIAL VECTOR AND SUBSEQUENT VECTORS
690 REM                  C = ARRAY FOR TEMPORARY EIGENVECTOR DURING ITERATIONS
700 REM                MAX = MOST RECENT MAX ELEMENT IN VECTOR DURING ITERATIONS
710 REM            PRE.MAX = MAXIMUM ELEMENT IN VECTOR AT THE PREVIOUS ITERATION
720 REM               DIFF = DIFFERENCE OF MAX AND PRE.MAX
730 REM              EIGEN = ARRAY FOR ELGENVECTOR
740 REM          NOR.EIGEN = ARRAY FOR NORMALIZED EIGENVECTOR
750 REM          EIGEN.SUM = SUM OF ELEMENTS IN EIGENVECTOR
760 REM         CONSIS.IDX = CONSISTENCY INDEX
770 REM               MAXI = LIMIT OF CONSISTENCY INDEX
780 REM                  Q = THE Kth COLUMN OF COMPOSITE MATRIX
790 REM        NOR.PARAVEC = ARRAY FOR NORMALIZED EIGENVECTOR OF PARAMETER MATRIX
800 REM          COMPO.VEC = ARRAY FOR COMPOSITE PRIORITY VECTOR
810 REM          COMPO.MAX = MAXIMUM ELEMENT OF COMPOSITE PRIORITY VECTOR
820 REM
830 REM
840 REM
850 REM
860 REM ********************************************************************
870 REM
880 REM
890 REM                        MAIN CONTROL MODULE
900 REM
910 REM
920 REM ********************************************************************
930 REM
940 REM
950 GOSUB 1080     : REM     INITIALIZE
960 GOSUB 1360     : REM     SUB-ROUTINE 1
970 GOSUB 3130     : REM     SUB-ROUTINE 2
980 GOSUB 4980     : REM     SUB-ROUTINE 3
990 GOSUB 5220     : REM     SUB-ROUTINE 4
1000 END
1010 REM
1020 REM
1030 REM
1040 REM
1050 REM ********************************************************************
1060 REM
1070 REM
1080 REM                        INITIALIZE
1090 REM
1100 REM
1110 REM ********************************************************************
1120 REM
1130 REM
1140 DIM A(20,20), DECIVAR.MAT(20,20), PARA.MAT(20,20), ROW.SUM(20)
1150 DIM VECTOR (20), C(20), EIGEN(20), NOR.EIGEN(20), NOR.PARAVEC(20)
```

```
1160 DIM COMPO.MAT(20,20), MAT(20,20), COMPO.VEC(20), PERCENT(20)
1170 REM
1180 REM
1190 OPEN "O", #1, "SENSIRUN.LIQ"
1200 REM
1210 REM
1220 INPUT "Order of decision variable matrix is n x n where n = ", N
1230 PRINT #1, "Order of decision variable matrix is n x n where n = "; N
1240 PRINT  :  PRINT #1, " "
1250 PRINT  :  PRINT #1, " "
1260 PRINT  :  PRINT #1, " "
1270 PRINT  :  PRINT #1, " "
1280 RETURN
1290 REM
1300 REM
1310 REM
1320 REM
1330 REM ****************************************************************
1340 REM
1350 REM
1360 REM      SUB-ROUTINE 1:
1370 REM           THIS IS A SUB-ROUTINE FOR INPUTTING THE DECISION
1380 REM           VARIABLE MATRIX OF PARAMETER K
1390 REM
1400 REM
1410 REM ****************************************************************
1420 REM
1430 REM
1440 REM                      SUB-ROUTINE 1 CONTROL MODULE
1450 REM
1460 REM
1470 PRINT "Enter the parameter number whose matrix is to be reviewed."
1480 PRINT #1, "Enter the parameter number whose matrix is to be reviewed."
1490 PRINT  :  PRINT #1," "
1500 INPUT "The number (ie. the Kth parameter, K = 1 to 20) is ? ", K
1510 PRINT #1, "The number (ie. the Kth parameter, K = 1 to 20) is ? "; K
1520 IF K = 1  THEN  LIQ$ = "PARA1.LIQ"
1530 IF K = 2  THEN  LIQ$ = "PARA2.LIQ"
1540 IF K = 3  THEN  LIQ$ = "PARA3.LIQ"
1550 IF K = 4  THEN  LIQ$ = "PARA4.LIQ"
1560 IF K = 5  THEN  LIQ$ = "PARA5.LIQ"
1570 IF K = 6  THEN  LIQ$ = "PARA6.LIQ"
1580 IF K = 7  THEN  LIQ$ = "PARA7.LIQ"
1590 IF K = 8  THEN  LIQ$ = "PARA8.LIQ"
1600 IF K = 9  THEN  LIQ$ = "PARA9.LIQ"
1610 IF K = 10  THEN  LIQ$ = "PARA10.LIQ"
1620 IF K = 11  THEN  LIQ$ = "PARA11.LIQ"
1630 IF K = 12  THEN  LIQ$ = "PARA12.LIQ"
1640 IF K = 13  THEN  LIQ$ = "PARA13.LIQ"
1650 IF K = 14  THEN  LIQ$ = "PARA14.LIQ"
1660 IF K = 15  THEN  LIQ$ = "PARA15.LIQ"
1670 IF K = 16  THEN  LIQ$ = "PARA16.LIQ"
1680 IF K = 17  THEN  LIQ$ = "PARA17.LIQ"
1690 IF K = 18  THEN  LIQ$ = "PARA18.LIQ"
1700 IF K = 19  THEN  LIQ$ = "PARA19.LIQ"
```

```
1710 IF K = 20  THEN  LIQ$ = "PARA20.LIQ"
1720 OPEN "I", #2, LIQ$
1730 OPEN "O", #3, "TEMPDATA"
1740 FOR I = 1 TO N
1750      FOR J = 1 TO N
1760           INPUT #2, A(I,J)
1770           PRINT #3, A(I,J);
1780      NEXT J
1790      PRINT #3, " "
1800 NEXT I
1810 CLOSE #2
1820 CLOSE #3
1830 REM
1840 REM
1850 REM      LIST OUT THE DECISION VARIABLE MATRIX (FROM EXISTING FILE)
1860 REM
1870 REM
1880 PRINT  :  PRINT #1, " "
1890 PRINT  :  PRINT #1, " "
1900 PRINT "The decision variable matrix is: "
1910 PRINT #1, "The decision variable matrix is: "
1920 PRINT  :  PRINT #1, " "
1930 OPEN "I", #2, "TEMPDATA"
1940 FOR I = 1 TO N
1950      FOR J = 1 TO N
1960           INPUT #2, DECIVAR.MAT(I,J)
1970           PRINT USING "#.### "; DECIVAR.MAT(I,J);
1980           PRINT #1, USING "#.### "; DECIVAR.MAT(I,J);
1990      NEXT J
2000      PRINT : PRINT #1, " "
2010 NEXT I
2020 CLOSE #2
2030 PRINT  :  PRINT #1, " "
2040 PRINT  :  PRINT #1, " "
2050 KILL LIQ$
2060 INPUT "Do you want to change data in the above matrix? Y or N ? ",CH.DATA$
2070 PRINT #1,"Do you want to change data in the above matrix? Y or N ? ";CH.DATA$
2080 IF CH.DATA$ = "Y"  THEN  2260
2090 IF CH.DATA$ = "y"  THEN  2260
2100 IF CH.DATA$ = "N"  THEN  2150
2110 IF CH.DATA$ = "n"  THEN  2150
2120 GOTO 2060
2130 REM
2140 REM
2150 REM      RENAME "TEMPDATA"
2160 REM
2170 REM
2180 NAME "TEMPDATA" AS LIQ$
2190 PRINT  :  PRINT #1, " "
2200 PRINT  :  PRINT #1, " "
2210 PRINT  :  PRINT #1, " "
2220 PRINT  :  PRINT #1, " "
2230 GOTO 2940
2240 REM
2250 REM
```

```
2260 REM      MANUAL DATA INPUT
2270 REM
2280 REM
2290 PRINT : PRINT #1, " "
2300 PRINT : PRINT #1, " "
2310 PRINT "You only have to enter the upper triangular elements"
2320 PRINT #1, "You only have to enter the upper triangular elements"
2330 PRINT  :  PRINT #1, " "
2340 PRINT  :  PRINT #1, " "
2350 FOR I = 1 TO N
2360      FOR J = I TO N
2370           PRINT "A(";I;",";J") = " : INPUT A(I,J)
2380           PRINT #1, "A(";I;",";J") = " ; A(I,J)
2390           A(J,I) = 1/A(I,J)
2400      NEXT J
2410 NEXT I
2420 REM
2430 REM
2440 REM      STORE THE DATA JUST ENTERED IN A DATA FILE NAMED "TEMPDATA"
2450 REM
2460 REM
2470 OPEN "O", #2, "TEMPDATA"
2480 FOR I = 1 TO N
2490      FOR J = 1 TO N
2500           PRINT #2, A(I,J);
2510      NEXT J
2520      PRINT #2, " "
2530 NEXT I
2540 CLOSE #2
2550 REM
2560 REM
2570 REM      LIST OUT THE DECISION VARIABLE MATRIX (FROM MANUAL INPUT)
2580 REM
2590 REM
2600 PRINT  :  PRINT #1, " "
2610 PRINT  :  PRINT #1, " "
2620 PRINT "The decision variable matrix is:"
2630 PRINT #1, "The decision variable matrix is:"
2640 PRINT  :  PRINT #1, " "
2650 OPEN "I", #2, "TEMPDATA"
2660 FOR I = 1 TO N
2670      FOR J = 1 TO N
2680           INPUT #2, DECIVAR.MAT(I,J)
2690           PRINT USING "#.### "; DECIVAR.MAT(I,J);
2700           PRINT #1, USING "#.### "; DECIVAR.MAT(I,J);
2710      NEXT J
2720      PRINT : PRINT #1, " "
2730 NEXT I
2740 CLOSE #2
2750 PRINT  :  PRINT #1, " "
2760 PRINT  :  PRINT #1, " "
2770 INPUT "Do you want to change data in the above matrix? Y or N ? ",CH.DATA$
2780 PRINT #1,"Do you want to change data in the above matrix? Y or N ? ";CH.DATA$
2790 IF CH.DATA$ = "Y"  THEN  2260
2800 IF CH.DATA$ = "y"  THEN  2260
```

```
2810 IF CH.DATA$ = "N"  THEN  2860
2820 IF CH.DATA$ = "n"  THEN  2860
2830 GOTO 2770
2840 REM
2850 REM
2860 REM      RENAME "TEMPDATA"
2870 REM
2880 REM
2890 NAME "TEMPDATA" AS LIQ$
2900 PRINT  :  PRINT #1, " "
2910 PRINT  :  PRINT #1, " "
2920 PRINT  :  PRINT #1, " "
2930 PRINT  :  PRINT #1, " "
2940 INPUT "Do you vant to change another decision variable matrix ? ",CH.DATA$
2950 PRINT #1, "Do you vant to change another decision variable matrix ? ";CH.DATA$
2960 PRINT  :  PRINT #1, " "
2970 PRINT  :  PRINT #1, " "
2980 PRINT  :  PRINT #1, " "
2990 PRINT  :  PRINT #1, " "
3000 IF CH.DATA$ = "Y"  THEN  1470
3010 IF CH.DATA$ = "y"  THEN  1470
3020 IF CH.DATA$ = "N"  THEN  3050
3030 IF CH.DATA$ = "n"  THEN  3050
3040 GOTO 2940
3050 RETURN
3060 REM
3070 REM
3080 REM
3090 REM
3100 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
3110 REM
3120 REM
3130 REM      SUB-ROUTINE 2:
3140 REM           THIS IS A SUB-ROUTINE TO CALCULATE THE 20 PRIORITY VECTORS
3150 REM
3160 REM
3170 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
3180 REM
3190 REM
3200 PRINT "Please vait.  Calculation of ranking of the alternatives"
3210 PRINT "is in process."
3220 PRINT #1, "Please vait.  Calculation of ranking of the alternatives"
3230 PRINT #1, "is in process."
3240 FOR K = 1 TO 20
3250      GOSUB 3290
3260 NEXT K
3270 RETURN
3280 IF K = 1  THEN  LIQ$ = "PARA1.LIQ"
3290 IF K = 2  THEN  LIQ$ = "PARA2.LIQ"
3300 IF K = 3  THEN  LIQ$ = "PARA3.LIQ"
3310 IF K = 4  THEN  LIQ$ = "PARA4.LIQ"
3320 IF K = 5  THEN  LIQ$ = "PARA5.LIQ"
3330 IF K = 6  THEN  LIQ$ = "PARA6.LIQ"
3340 IF K = 7  THEN  LIQ$ = "PARA7.LIQ"
3350 IF K = 8  THEN  LIQ$ = "PARA8.LIQ"
```

```
3360 IF K = 9  THEN  LIQ$ = "PARA9.LIQ"
3370 IF K = 10  THEN  LIQ$ = "PARA10.LIQ"
3380 IF K = 11  THEN  LIQ$ = "PARA11.LIQ"
3390 IF K = 12  THEN  LIQ$ = "PARA12.LIQ"
3400 IF K = 13  THEN  LIQ$ = "PARA13.LIQ"
3410 IF K = 14  THEN  LIQ$ = "PARA14.LIQ"
3420 IF K = 15  THEN  LIQ$ = "PARA15.LIQ"
3430 IF K = 16  THEN  LIQ$ = "PARA16.LIQ"
3440 IF K = 17  THEN  LIQ$ = "PARA17.LIQ"
3450 IF K = 18  THEN  LIQ$ = "PARA18.LIQ"
3460 IF K = 19  THEN  LIQ$ = "PARA19.LIQ"
3470 IF K = 20  THEN  LIQ$ = "PARA20.LIQ"
3480 OPEN "I", #2, LIQ$
3490 FOR I = 1 TO N
3500      FOR J = 1 TO N
3510           INPUT #2, DECIVAR.MAT(I,J)
3520      NEXT J
3530 NEXT I
3540 CLOSE #2
3550 REM
3560 REM
3570 REM ******************************************************************
3580 REM
3590 REM
3600 REM      SUB-ROUTINE 2.1:
3610 REM           THIS IS A SUB-ROUTINE FOR FINDING MAXIMUM EIGENVALUE AND ITS
3620 REM           CORRESPONDING PRIORITY VECTOR OF A SQUARE MATRIX OF ORDER N
3630 REM
3640 REM
3650 REM ******************************************************************
3660 REM
3670 REM
3680 REM                     SUB-ROUTINE 2.1 CONTROL MODULE
3690 REM
3700 REM
3710 GOSUB 3840    : REM FIND THE SUM OF ELEMENTS IN EACH ROW OF MATRIX
3720 GOSUB 3960    : REM FIND THE MAXIMUM OF ROW-SUMS
3730 GOSUB 4070    : REM ASSUME AN INITIAL VECTOR
3740 GOSUB 4180    : REM PERFORM THE ITERATIONS
3750 GOSUB 4610    : REM CALCULATE THE EIGENVECTOR
3760 GOSUB 4700    : REM CALCULATE THE NORMALIZED EIGENVECTOR
3770 GOSUB 4830    : REM STORE THE NORMALIZED EIGENVECTOR
3780 RETURN
3790 REM
3800 REM
3810 REM ******************************************************************
3820 REM
3830 REM
3840 REM      FIND THE SUM OF ELEMENTS IN EACH ROW OF MATRIX
3850 REM
3860 REM
```

```
3870 FOR I = 1 TO N
3880      ROW.SUM(I) = 0
3890      FOR J = 1 TO N
3900           ROW.SUM(I) = ROW.SUM(I) + DECIVAR.MAT(I,J)
3910      NEXT J
3920 NEXT I
3930 RETURN
3940 REM
3950 REM
3960 REM      FIND THE MAXIMUM OF ROW-SUMS
3970 REM
3980 REM
3990 MAX = ROW.SUM(1) : ROW = 1
4000 FOR I = 2 TO N STEP 1
4010      IF MAX > ROW.SUM(I)   THEN   4030
4020         MAX = ROW.SUM(I)  :  ROW = I
4030 NEXT I
4040 RETURN
4050 REM
4060 REM
4070 REM      ASSUME AN INITIAL VECTOR
4080 REM
4090 REM
4100 FOR J = 1 TO N
4110      IF J = ROW   THEN   4130
4120      VECTOR(J) = 0  :  GOTO 4140
4130      VECTOR(J) = 1
4140 NEXT J
4150 RETURN
4160 REM
4170 REM
4180 REM      PERFORM THE ITERATIONS
4190 REM
4200 REM
4210 PRE.MAX = 0
4220 FOR I = 1 TO N
4230      C(I) = 0
4240      FOR J = 1 TO N
4250           C(I) = C(I) + DECIVAR.MAT(I,J) * VECTOR(J)
4260      NEXT J
4270 NEXT I
4280 MAX = C(1)  :  ROW = 1
4290 FOR I = 2 TO N STEP 1
4300      IF MAX > C(I)   THEN   4320
4310         MAX = C(I)  :  ROW = I
4320 NEXT I
4330 REM
4340 REM
4350 REM      TEST FOR THE NEED OF FURTHER ITERATION
4360 REM
4370 REM
4380 IF  N =   3  THEN  DIFF = .003
4390 IF  N =   4  THEN  DIFF = .004
4400 IF  N =   5  THEN  DIFF = .005
4410 IF  N =   6  THEN  DIFF = .006
```

```
4420 IF  N =   7  THEN  DIFF = .007
4430 IF  N =   8  THEN  DIFF = 8.000001E-03
4440 IF  N =   9  THEN  DIFF = 9.000001E-03
4450 IF  N =  10  THEN  DIFF = .01
4460 IF  N =  11  THEN  DIFF = .011
4470 IF  N =  12  THEN  DIFF = .012
4480 IF  N =  13  THEN  DIFF = .013
4490 IF  N =  14  THEN  DIFF = .014
4500 IF  N =  15  THEN  DIFF = .015
4510 IF  N => 16  THEN  DIFF = .02
4520 IF  ABS(MAX - PRE.MAX) < DIFF   THEN  4580  ELSE  4530
4530 FOR J = 1 TO N
4540       VECTOR(J) = C(J)/MAX
4550 NEXT J
4560 PRE.MAX = MAX
4570 GOTO 4220
4580 RETURN
4590 REM
4600 REM
4610 REM      CALCULATE THE EIGENVECTOR
4620 REM
4630 REM
4640 FOR I = 1 TO N
4650       EIGEN(I) = C(I)/MAX
4660 NEXT I
4670 RETURN
4680 REM
4690 REM
4700 REM      CALCULATE THE NORMALIZED EIGENVECTOR
4710 REM
4720 REM
4730 EIGEN.SUM = 0
4740 FOR I = 1 TO N
4750       EIGEN.SUM = EIGEN.SUM + EIGEN(I)
4760 NEXT I
4770 FOR I = 1 TO N
4780       NOR.EIGEN(I) = EIGEN(I)/EIGEN.SUM
4790 NEXT I
4800 RETURN
4810 REM
4820 REM
4830 REM      STORE THE NORMALIZED EIGENVECTOR
4840 REM
4850 REM
4860 Q = K
4870 FOR I = 1 TO N
4880       COMPO.MAT(I,Q) = NOR.EIGEN(I)
4890 NEXT I
4900 RETURN
4910 REM
4920 REM
4930 REM
4940 REM
```

```
4950 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
4960 REM
4970 REM
4980 REM      SUB-ROUTINE 3:
4990 REM           THIS IS A SUB-ROUTINE FOR CONSTRUCTING THE
5000 REM           COMPOSITE MATRIX "COMPOMAT.LIQ"
5010 REM
5020 REM
5030 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
5040 REM
5050 REM
5060 OPEN "O", #2, "COMPOMAT.LIQ"
5070 FOR I = 1 TO N
5080      FOR J = 1 TO Q
5090           PRINT #2, COMPO.MAT(I,J);
5100      NEXT J
5110      PRINT #2, " "
5120 NEXT I
5130 CLOSE #2
5140 RETURN
5150 REM
5160 REM
5170 REM
5180 REM
5190 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
5200 REM
5210 REM
5220 REM      SUB-ROUTINE 4:
5230 REM           THIS IS A SUB-ROUTINE FOR CALCULATING COMPOSITE
5240 REM           PRIORITY VECTOR
5250 REM
5260 REM
5270 REM ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
5280 REM
5290 REM
5300 REM                    SUB-ROUTINE 4 CONTROL MODULE
5310 REM
5320 REM
5330 OPEN "I", #2, "PARAMAT"
5340 K=20
5350 GOSUB 5510     : REM   INPUT DATA FROM PARAMETER MATRIX
5360 CLOSE #2
5370 GOSUB 5620     : REM   CALCULATE THE EIGENVECTOR OF "PARAMAT"
5380 OPEN "I", #3, "COMPOMAT.LIQ"
5390 GOSUB 6470     : REM   INPUT DATA FROM COMPOSITE MATRIX
5400 CLOSE #3
5410 GOSUB 6580     : REM   PERFORM THE MULTIPLICATION
5420 GOSUB 6700     : REM   EXPRESS COMPO.VEC(I) IN TERMS OF %
5430 GOSUB 6840     : REM   PRINT THE RESULT OF RANKING
5440 CLOSE #1
5450 RETURN
5460 REM
5470 REM
```

```
5480 REM ************************************************************************
5490 REM
5500 REM
5510 REM       INPUT DATA FROM THE PARAMETER MATRIX
5520 REM
5530 REM
5540 FOR I = 1 TO K
5550       FOR J = 1 TO K
5560            INPUT #2, PARA.MAT(I,J)
5570       NEXT J
5580 NEXT I
5590 RETURN
5600 REM
5610 REM
5620 REM       CALCULATE THE EIGENVECTOR OF "PARAMAT"
5630 REM
5640 REM
5650 REM
5660 REM
5670 REM       FIND THE SUM OF ELEMENTS IN EACH ROW OF MATRIX
5680 REM
5690 REM
5700 FOR I = 1 TO K
5710       ROW.SUM(I) = 0
5720       FOR J = 1 TO K
5730            ROW.SUM(I) = ROW.SUM(I) + PARA.MAT(I,J)
5740       NEXT J
5750 NEXT I
5760 REM
5770 REM
5780 REM       FIND THE MAXIMUM OF ROW-SUMS
5790 REM
5800 REM
5810 MAX = ROW.SUM(1)  :  ROW = 1
5820 FOR I = 2 TO K
5830       IF MAX > ROW.SUM(I)  THEN  5850
5840          MAX = ROW.SUM(I)  :  ROW = I
5850 NEXT I
5860 REM
5870 REM
5880 REM       ASSUME AN INITAIL VECTOR
5890 REM
5900 REM
5910 FOR J = 1 TO K
5920       IF J = ROW  THEN  5940
5930       VECTOR(J) = 0  :  GOTO 5950
5940       VECTOR(J) = 1
5950 NEXT J
5960 REM
5970 REM
5980 REM       PERFORM THE ITERATIONS
5990 REM
6000 REM
```

```
6010 PRE.MAX = 0
6020 FOR I = 1 TO K
6030      C(I) = 0
6040      FOR J = 1 TO K
6050           C(I) = C(I) + PARA.MAT(I,J) * VECTOR(J)
6060      NEXT J
6070 NEXT I
6080 MAX = C(1)  :  ROW = 1
6090 FOR I = 2 TO K STEP 1
6100      IF MAX > C(I)  THEN  6120
6110         MAX = C(I)  :  ROW = I
6120 NEXT I
6130 REM
6140 REM
6150 REM      TEST FOR THE NEED OF FURTHER ITERATION
6160 REM
6170 REM
6180 IF  ABS(MAX - PRE.MAX) < .02  THEN  6260  ELSE  6190
6190 FOR J = 1 TO K
6200      VECTOR(J) = C(J)/MAX
6210 NEXT J
6220 PRE.MAX = MAX
6230 GOTO 6020
6240 REM
6250 REM
6260 REM      CALCULATE THE EIGENVECTOR OF "PARAMAT"
6270 REM
6280 REM
6290 FOR I = 1 TO K
6300      EIGEN(I) = C(I)/MAX
6310 NEXT I
6320 REM
6330 REM
6340 REM      CALCULATE THE NORMALIZED EIGENVECTOR OF "PARAMAT"
6350 REM
6360 REM
6370 EIGEN.SUM = 0
6380 FOR I = 1 TO K
6390      EIGEN.SUM = EIGEN.SUM + EIGEN(I)
6400 NEXT I
6410 FOR I = 1 TO K
6420      NOR.PARAVEC(I) = EIGEN(I)/EIGEN.SUM
6430 NEXT I
6440 RETURN
6450 REM
6460 REM
6470 REM      INPUT DATA FROM THE COMPOSITE MATRIX
6480 REM
6490 REM
6500 FOR I = 1 TO N
6510      FOR J = 1 TO K
6520           INPUT #3, MAT(I,J)
6530      NEXT J
6540 NEXT I
6550 RETURN
```

```
6560 REM
6570 REM
6580 REM      PERFORM THE MULITIPLICATION
6590 REM
6600 REM
6610 FOR I = 1 TO N
6620      COMPO.VEC(I) = 0
6630      FOR J = 1 TO K
6640            COMPO.VEC(I) = COMPO.VEC(I) + MAT(I,J) * NOR.PARAVEC(J)
6650 NEXT J
6660 NEXT I
6670 RETURN
6680 REM
6690 REM
6700 REM      EXPRESS COMPOSITE PRIORITY VECTOR IN TERMS OF %
6710 REM
6720 REM
6730 COMPO.MAX = COMPO.VEC(1)
6740 FOR I = 2 TO N STEP 1
6750      IF COMPO.MAX > COMPO.VEC(I)  THEN  6770
6760         COMPO.MAX = COMPO.VEC(I)
6770 NEXT I
6780 FOR I = 1 TO N
6790      PERCENT(I) = (COMPO.VEC(I)/COMPO.MAX) * 100
6800 NEXT I
6810 RETURN
6820 REM
6830 REM
6840 REM      PRINT THE RESULT OF RANKING
6850 REM
6860 REM
6870 PRINT  :  PRINT #1, " "
6880 PRINT  :  PRINT #1, " "
6890 PRINT "The ranking is: "
6900 PRINT #1, "The ranking is: "
6910 PRINT  :  PRINT #1, " "
6920 PRINT  :  PRINT #1, " "
6930 PRINT " ", "RANKING IN %"
6940 PRINT #1, " ", "RANKING IN %"
6950 PRINT " ", "____________"
6960 PRINT #1, " ", "____________"
6970 PRINT  :  PRINT #1, " "
6980 FOR I = 1 TO N
6990      PRINT "Alternative "; I, PERCENT(I)
7000      PRINT #1, "Alternative "; I,PERCENT(I)
7010 NEXT I
7020 RETURN
```

QUESTIONNAIRE

(A) Sewerage

1. Total population 14,000,000 (including East Malaysia)

   a) % in urban areas 35 %
   b) % in rural areas 65 %
   } Total 100%

2. Percentage of population served by public sewers :

   a) % in urban areas 13 %
   b) % in rural areas negligible
   c) % overall of (a) (b) : 4.5 %

3. The sewerage systems used in (2) above are mainly :

   a) Combined sewers : [Yes] or [No] ✓
   b) separate sewers : [Yes] ✓ or [No]
   c) both combined & separate sewers : [Yes] or [No] ✓

   If the answer is (c), please give details : ______

4. Names of 3 largest cities :

   a) Kuala Lumpur (population 1,000,000) (ie. K.L. + Petaling Jaya + Shah Alam + Kelang) = 1.5 million Greater K.L.
   b) Ipoh (population 300,000)
   c) Georgetown (population 250,000)

5. Total length of sewers : *Only 3 cities have sewerage systems*

a) in City *K.L./Shah Alam* is *Not known* km

b) in City *George Town* is *"* km

c) in City *Kota Kinabalu* is *"* km

d) Overall total length of sewers in the whole country is ______ km. *Butterworth, Ipoh, Johor Bahru etc. are under planning stage.*

6. a) Largest diameter of sewers used :

450 mm ø (City ______)

______ mm ø (City ______)

______ mm ø (City ______)

b) Smalles diameter of sewers use :

150 mm ø (City ______)

______ mm ø (City ______)

______ mm ø (City ______)

c) Average depth *Not known*

______ m (City ______)

______ m (City ______)

______ m (City ______)

d) Materials of pipes mainly used in the country :

- [ ] steel
- [x] concrete ✓
- [ ] other : *Vitrified clay pipes* (please specify)

7. Average cost of sewers $ ______ per km.

[including] / [excluding] pumping stations

(B) Treatment Plants

8. How many wastewater treatment plants altogether, whether large or small, industrial or municipal, are there in the country?

a) Not possible to give the exact number (public)

b) ______ (private) e.g. in-house plants in factories, etc.

9. Whether or not a name list of the plants in (8) can be provided.

10. Quantities of wastewater produced per day :

a) Industrial estates ; 80 m^3/Ha/day (average)

b) Municipal : 200 l/capita/day (average)

11. How is the charge collected from the users :

a) through "sanitation fee'? [Yes ✓] or [No] fitment charges: $ per fitment

b) through water consumption fee? [Yes ✓] or [No]

If yes, 30 % of water fee is for wastewater treatment.

c) through general tax revenue? [Yes] or [No ✓]

Mainly → d) through property tax? [Yes ✓] or [No]

e) through other means? Connection charge from households to public sewers (please specify)

12. Average charge : $ ______ per m^3.

13. The charges recovers :

[Sewerage systems only]

[treatment plants only]

[both ✓]

14. Whether or not equitable? [Yes] or [No] Not known. Nobody ever calculated it.

15. Names of 3 larges wastewater treatment plants :

a) Pantai STP (location : Pantai. Kulua Lumpur)

i) treating { [industrial] [municipal] ✓ [both] } wastewaters

ii) method of treatment : Aerated lagoons

iii) size : 250,000 population equivalent.

b) Lower Kerayong STP (location : Sungai Besi, Kulua Lumpur)

i) treating { [industrial] [municipal] ✓ [both] } wastewaters

ii) method of treatment : Stabilization ponds

iii) size : 22,000 population equivalent.

c) Wardieburn STP (location : Setapak, Kulua Lumpur)

i) treating { [industrial] [municipal] ✓ [both] } wastewaters

ii) method of treatment : Stabilization ponds

iii) size : 12,000 population equivalent.

(d) Puchong S.T.P. at Puchong. size : 8,000 P.E.

16. Future development in treatment plants :

a) Centralization or decentralization : ✓

i) One plant for a few nearby towns/cities?

[Yes] or [No] ✓

ii) Each town/city has several plants?

[Yes] ✓ or [No]

b) Size :

i) tends to be larger? [Yes] or [No]

ii) tends to be smaller? [Yes] or [No]

iii) No change? [Yes] or [No]

Questions cannot be answered. Depending on situations.

17. Is there or will there be any provision for effluent reuse?

[Yes] or [No] ✓

If yes, in what way? ______________________________

____

____

____

(C) Legislation and Management

18. The authorties dealing with fresh water and wastewater are :

[the same]

[separate] ✓

19. Names of the authorities which formulates policies concerning wastewaters are :

a) On national basis : 1. Ministry of Science, Technology & Environment; 2. Ministry of Health; 3. Ministry of Housing & Local Government

b) On regional basis : Nil

c) On city basis : Municipal Council / District Council

d) Others : ____________

The relationship of a, b, c and d above is : No formal relationship. No authority is submissive to another.

20. Are the authorities mentioned in (19) responsible for setting effluent standards?

[Yes ✓] or [No]

If no, what authorities? But only (a) in 19.

21. The division of region (see 19.b above) is bas on :

a) the existing administrative boundaries.

[Yes ✓] or [No]

b) another set of boundaries divided according to the water courses.

[Yes] or [No ✓]

22. Names of the authorities responsible for enforcing the legislation and controlling the industrial discharges are :

a) On national basis : Department of Environment (Ministry of Science, Technology & Environment)

b) On regional basis : Nil

c) On city basis : Local authorities (i.e. Municipal Council/ District Council)

d) Others : ______

The relationship of a, b, c and d is : ______

No rigid relationship between (a) and (c).

23. Names of the authorities responsible for the planning, design and construction of wastewater facilities are :

a) On national basis : Ministry of Housing & Local Government

b) On regional basis : Nil

c) On city basis : Local authorities

d) Others : ______

The relationship of a, b, c and d is : ______

(a) plays a coordinating role.

(c) plays the actual implementation role.

24. Names of authorities responsible for the operation and maintenance of the sewer and treatment plants are :

a) On national basis : Nil

b) On regional basis : Nil

c) On city basis : Local authorities

d) Others : ______

The relationship of a, b, c and d is : ______

28. Have the following points in general been provided for in the legislations for industrial wastewater discharges?

a) Staged implementation (geographically)

[Yes] or [No ✓]

b) Different effluent standards for different zones.

[Yes ✓] or [No] two different standards : Standards A & B

c) Standards expressed quantitatively [Yes ✓] or [No]

d) Are there existing discharge exemptions [Yes ✓] or [No]

29. Expenditure spent in (i) sewerage and (ii) treatment plants :

		National	
Before 1980	--	$	Not known
1981	--	$	
1982	--	$	
1983	--	$	
1984	--	$	M$ 2,980 (based on 1983 price level)
1985 to ultimate	--	$	
		$	

30. Please outline some difficulties faced in the implementation of these schemes, technically or managerially.

1. Lack of fund.
2. Shortage of trained manpower.
3. No central authority to be wholly responsible for the matter.

Aug. 1984

QUESTIONNAIRE

(A) Sewerage

1. Total population 55,000,000
   a) % in urban areas 6 million in Bangkok 7.2 million in 72 cities 22%
   b) % in rural areas 78%

   } Total 100% There are 72 provincial cities

2. Percentage of population served by public sewers :
   a) % in urban areas 100,000 persons are served by public sewers
   b) % in rural areas 0%
   c) % overall of (a) (b) : practically 0%

3. The sewerage systems used in (2) above are mainly :
   a) Combined sewers : [Yes] or [No]
   b) separate sewers : [Yes ✓] or [No] for these 100,000 persons
   c) both combined & separate sewers : [Yes ✓] or [No]

   If the answer is (c), please give details : Combined sewers are used to cater for storm water originally.

4. Names of 3 largest cities :
   a) Bangkok (population 6 million)
   b) Chiangmai (population 0.1 million)
   c) Pattaya (population 50,000)

(B) Treatment Plants

8. How many wastewater treatment plants altogether, whether large or small, industrial or municipal, are there in the country?

a) 16 (municipal) (public) 14 (Bangkok) + 2 (Pattaya) = 16

b) 700 (industrial) (private) e.g. in-house plants in factories, etc.

9. Whether or not a name list of the plants in (8) can be provided.

10. Quantities of wastewater produced per day :

a) Industrial estates ; not known m^3/Ha/day (average)

b) Municipal : 150 l/capita/day (average)
future target : 250

11. How is the charge collected from the users :

a) through "sanitation fee'? [Yes] or [No] ✓

b) through water consumption fee? [Yes] or [No] ✓

If yes, ________ % of water fee is for wastewater treatment.

c) through general tax revenue? [Yes] or [No] ✓

d) through property tax? [Yes] or [No] ✓

e) through other means? No charge. No such a system at present. (please specify) There is a plan to charge industrialists who discharge wastewaters but the plan is not yet implemented.

12. Average charge : $ ________ per m^3.

13. The charges recovers :

[Sewerage systems only]

[treatment plants only]

[both]

14. Whether or not equitable? [Yes] or [No]

15. Names of 3 larges wastewater treatment plants :

a) Huay Khwang STP (location : Huay Khwang, Bangkok)

i) treating { [industrial] [municipal] ✓ [both] } wastewaters

ii) method of treatment : Activated sludge

iii) size : 20,000 population equivalent.

b) Khlong Chan STP (location : Khlong Chan, Bangkok)

i) treating { [industrial] [municipal] [both] } wastewaters

ii) method of treatment : Activated sludge

iii) size : 38,000 population equivalent.

c) Pattaya New STP (location : Pattaya)

i) treating { [industrial] [municipal] ✓ [both] } wastewaters

ii) method of treatment : RBC

iii) size : 25,000 population equivalent.

16. Future development in treatment plants :

a) Centralization or decentralization :

i) One plant for a few nearby towns/cities?

[Yes] or [No ✓]

ii) Each town/city has several plants?

[Yes ✓] or [No]

b) Size : Difficult to answer. Depends on situations.

i) tends to be larger? [Yes] or [No]

ii) tends to be smaller? [Yes] or [No]

iii) No change? [Yes] or [No]

17. Is there or will there be any provision for effluent reuse?

[Yes] or [No ✓]

If yes, in what way? ______________________________

____

____

____

(C) <u>Legislation and Management</u>

18. The authorties dealing with fresh water and wastewater are :

{ [the same]
  [separate ✓]

19. Names of the authorities which formulates policies concerning wastewaters are :

a) On national basis : "National Environment Board" — municipal; "Industrial Works Department" — industrial

b) On regional basis : Same as (a)

c) On city basis : "Bangkok Metropolitan Administration" in Bangkok

d) Others : Other cities: Local/City Council

The relationship of a, b, c and d above is :

(c)/(d) follows the principles set by (a).

20. Are the authorities mentioned in (19) responsible for setting effluent standards?

[Yes ✓] or [No]

If no, what authorities?

21. The division of region (see 19.b above) is based on :

a) the existing administrative boundaries.

[Yes ✓] or [No]

b) another set of boundaries divided according to the water courses.

[Yes] or [No ✓]

But the government is thinking of doing so.

22. Names of the authorities responsible for enforcing the legislation and controlling the industrial discharges are :

a) On national basis : Industrial Works Department (i.e. IWD)

b) On regional basis : Branches of IWD

c) On city basis : ____________

d) Others : ____________

The relationship of a, b, c and d is : ____________

23. Names of the authorities responsible for the planning, design and construction of wastewater facilities are :

a) On national basis : No such an establishment on national basis.

b) On regional basis : PWD (e.g. Pattaya STP)

c) On city basis : National Housing Authority

d) Others : Department of Health — STPs for hospitals all over Thailand.

The relationship of a, b, c and d is :

No proper relationship.

Division of responsibilities is very confused.

24. Names of authorities responsible for the operation and maintenance of the sewer and treatment plants are :

a) On national basis :
b) On regional basis :
c) On city basis :
d) Others :

Similar to (23). Each authorities take care of their own STPs.

~~The relationship of a, b, c and d is :~~

Not yet materialized: There is a policy that in the future all plants in Bangkok will be under "Bangkok Metropolitan Administration" and all other plants (in other municipalities) will be under PWD.

25. The authorities responsible for monitoring wastewater discharges are same as the ones mentioned in (24).

[Yes] or [No] ✓

If no, what authroities? Industrial wastewaters — IWD

Municipal wastewater — No authority is controlling it.

26. Briefly describe the methods used in monitoring wastewater discharges. (e.g. the number of times in a month taking wastewater samples from a factory, etc.)

IWD takes samples once a month to 4 times a year.

27. How many legislations currently are there concerning with water polution control?

1. Bangkok Metropolitan Administration Act (Date : 1975)
2. National Environmental Quality Act (Date : 1978)
3. Building Control Act (Date : 1979)
4. Domestic Effluent Standards (Date : 1984 (draft only))

The approximate time of enforcement after the publication of legislation :

[1 year] [2 year] [3 year]

[others] Immediate
(please specify)

28. Have the following points in general been provided for in the legislations for industrial wastewater discharges?

a) Staged implementation (geographically)

Yes or No ✓

b) Different effluent standards for different zones.

Yes ✓ or No   4 standards: A, B, C and D.

c) Standards expressed quantitatively   Yes ✓ or No

d) Are there existing discharge exemptions   Yes or No ✓

Not in the law, but relaxation is normally given to old factories.

29. Expenditure spent in (i) sewerage and (ii) treatment plants:

		National
Before 1980	--	$
1981	--	$
1982	--	$
1983	--	$
1984	--	$
1985 to ultimate	--	$
		$

No planning.

Figures cannot be easily known as several authorities are involved.

30. Please outline some difficulties faced in the implementation of these schemes, technically or managerially.

1. Lack of fund; costs are too high in the politicians' eyes.
2. Lack of enthusiasm on the part of general public.
3. Lack of training in both technical and professional levels.
4. Management problems — problems occur during operation usually due to management difficulties.

January 1987.

APPENDIX C.1.3 --- TAIWAN

QUESTIONNAIRE

(A) Sewerage

1. Total population approx. 18 million

   a) % in urban areas 20 } Total 100%

   b) % in rural areas 80

2. Percentage of population served by public sewers :

		STORM SEWER (used currently to convey wastewater) 1983	1991	SEPERATE SEWER 1983	1991
a) % in urban areas	Taipei	82%	90%	6%	50%
	Kaohsiung	50%	75%	0%	48%
b) % in rural areas					
c) % overall of (a) (b) :		13%	42%	1%	23.65%

3. The sewerage systems used in (2) above are mainly :

   a) Combined sewers : [Yes] or [No]

   b) separate sewers : [Yes] or [No]

   c) both combined & separate sewers : [Yes] or [No]

   If the answer is (c), please give details :

   seperate sewerage system constructed since 1970 in several urban area or large cities.

4. Names of 3 largest cities :

   a) Taipei (population 2,250,000)

   b) Kaohsiung (population 1,250,000)

   c) Tai chung (population 600,000)

(B) Treatment Plants

8. How many wastewater treatment plants altogether, whether large or small, industrial or municipal, are there in the country?

a) 17 (public)

b) 200 (Kaohsiung) (private) e.g. in-house plants in factories, etc.

9. Whether or not a name list of the plants in (8) can be provided.

10. Quantities of wastewater produced per day :

a) Industrial estates ; 50 - 200 m^3/Ha/day (average)

b) Municipal : 250 - 320 l/capita/day (average)

11. How is the charge collected from the users :

a) through "sanitation fee'? [Yes] or [No] ✓

b) through water consumption fee? [Yes] ✓ or [No]

If yes, ______ % of water fee is for wastewater treatment.

c) through general tax revenue? [Yes] ✓ or [No]

d) through property tax? [Yes] or [No] ✓

e) through other means? ______ (please specify)

12. Average charge : $ 1.5 per m^3. (for municipal sewerage and treatment plants, not industrial.)

13. The charges recovers :

[Sewerage systems only]

[treatment plants only]

[both] ✓

16. Future development in treatment plants :

a) Centralization or decentralization :

i) One plant for a few nearby towns/cities?

[Yes] ✓ or [No]

ii) Each town/city has several plants?

[Yes] or [No]

b) Size :

i) tends to be larger? [Yes] ✓ or [No]

ii) tends to be smaller? [Yes] or [No] ✓

iii) No change? [Yes] or [No] ✓

17. Is there or will there be any provision for effluent reuse?

[Yes] or [No]

If yes, in what way? ______________________

Yes, but very little paper mill industries (not pulp)

Min Shen effluent - irrigation of glasses.

(C) Legislation and Management

18. The authorties dealing with fresh water and wastewater are :

[the same]

[separate] ✓

19. Names of the authorities which formulates policies concerning wastewaters are :

a) On national basis : ______________________

b) On regional basis : (省環境保護局) National Bearue of env. protection.

c) On city basis : 市環境保護局) Bearue of Env. Pro. City based e.g. Taipei, Kaohsiung.

d) Others : ______________________

The relationship of a, b, c and d above is : ______________________

____

____

____

____

20. Are the authorities mentioned in (19) responsible for setting effluent standards?

[Yes] ✓ or [No]

If no, what authorities? ______________________

By National Bearue only

____

21. The division of region (see 19.b above) is based on :

a) the existing administrative boundaries.

[Yes] ✓ or [No]

b) another set of boundaries divided according to the water courses.

[Yes] or [No]

under consideration, during planning stage.

22. Names of the authorities responsible for enforcing the legislation and controlling the industrial discharges are :

a) On national basis : ______________________

b) On regional basis : ______________________

c) On city basis : ______________________

d) Others : ______________________________________

The relationship of a, b, c and d is : ______________________

Municipal wastewater : same as 19

Industrial district wastewater : industrial district Management Centre

工業區管理中心

23. Names of the authorities responsible for the planning, design and construction of wastewater facilities are :

a) On national basis : 行政院之內政部

b) On regional basis : 省建設廳之住都局

c) On city basis : 縣市政府之工務局 下水道工程處

d) Others : ______________________________________

The relationship of a, b, c and d is : ______________________

24. Names of authorities responsible for the operation and maintenance of the sewer and treatment plants are :

a) On national basis : ______________________

b) On regional basis : ______________________

c) On city basis : ______________________

d) Others : ______________________________________

The relationship of a, b, c and d is : ______________________

same as 23.

25. The authorities responsible for monitoring wastewater discharges are same as the ones mentioned in (24).

[Yes] ✓ or [No]

If no, what authroities? ______________________

____

____

26. Briefly describe the methods used in monitoring wastewater discharges. (e.g. the number of times in a month taking wastewater samples from a factory, etc.)

Taking samples from the factory several times in a month by each sewerage treatment plant or pollution control division.

____

27. How many legislations currently are there concerning with water polution control?

1. 水污染防治法 (Date : 1974/ 7/11)
2. 水污染防治法 (revised) (Date : 1983/ 5/ 27)
3. 下水道法 (Date : 1984/ 1985)
4. ______________________ (Date : ______________)

The approximate time of enforcement after the publication of legislation :

[1 year] [2 year] [3 year]

[others] immediate
(please specify)

1974年7月11日之前已用行政命令

Standard : Entering public sewers

BOD_5 not exceeding 600 mg/l

s.s. " " " 600 mg/l

28. Have the following points in general been provided for in the legislations for industrial wastewater discharges?

a) Staged implementation (geographically)

[Yes] or [No] /

b) Different effluent standards for different zones.

[Yes] / or [No]

c) Standards expressed quantitatively [Yes] / or [No]

d) Are there existing discharge exemptions [Yes] or [No] /

29. Expenditure spent in (i) sewerage and (ii) treatment plants :

		National	City : Kaohsiung
Before 1980	--	$	
1981	--	$	
1982	--	$	
1983	--	$	
1984	--	$	
1985 to ultimate	--	NT $ 305 00 m	3640 m
		$	

30. Please outline some difficulties faced in the implementation of these schemes, technically or managerially.

1. financial problem
2. land available "
3. technical problem
4. traditional idea "

1984.

APPENDIX C.1.4 --- HONG KONG

QUESTIONNAIRE

(A) Sewerage

1. Total population nearly 6 million

   a) % in urban areas 90 } Total 100%

   b) % in rural areas 10

2. Percentage of population served by public sewers :

   a) % in urban areas 98

   b) % in rural areas 16

   c) % overall of (a) (b) : 90

3. The sewerage systems used in (2) above are mainly :

   a) Combined sewers : [Yes] or [No]

   b) separate sewers : [Yes] or [No]

   c) both combined & separate sewers : [Yes] ✓ or [No]

   If the answer is (c), please give details : ______

   Urban area have seperate sewerage system

   ______

   ______

4. Names of 3 largest cities :

   a) ______ (population ______)

   b) ______ (population ______)

   c) ______ (population ______)

5. Total length of sewers :

a) in City ____________ is ____________ km

b) in City ____________ is ____________ km

c) in City ____________ is ____________ km

d) Overall total length of sewers in the whole country is ____________ km.

6. a) Largest diameter of sewers used :

2100 mm ø (City ____________)

____________ mm ø (City ____________)

____________ mm ø (City ____________)

b) Smalles diameter of sewers use :

300 mm ø (City ____________)

____________ mm ø (City ____________)

____________ mm ø (City ____________)

c) Average depth

____________ m (City ____________)

____________ m (City ____________)

____________ m (City ____________)

d) Materials of pipes mainly used in the country :

[steel]

[concrete] ✓

[other] : ____________ (please specify)

7. Average cost of sewers HK$ 6000 per ~~km.~~ m (for 2100 mm ø)

[including]
[excluding] ✓
pumping stations

(B) Treatment Plants

8. How many wastewater treatment plants altogether, whether large or small, industrial or municipal, are there in the country?

a) ____31____ (public)

b) ________ (private) e.g. in-house plants in factories, etc.

9. Whether or not a name list of the plants in (8) can be provided.

10. Quantities of wastewater produced per day :

a) Industrial estates ; 550,000-1000,000 m^3/Ha/day (average)

b) Municipal : 210-450 l/capita/day (average)

11. How is the charge collected from the users :

a) through "sanitation fee'? [Yes] or [No] ✓

b) through water consumption fee? [Yes] or [No] ✓

If yes, ________ % of water fee is for wastewater treatment.

c) through general tax revenue? [Yes] ✓ or [No]

d) through property tax? [Yes] or [No] ✓

e) through other means? ________________ (please specify)

12. Average charge : $ ________ per m^3.

13. The charges recovers :

[Sewerage systems only]
[treatment plants only]
[both]

Not applicable

14. ~~Whether or not~~ equitable? [Yes] or [No]

15. Names of 3 larges wastewater treatment plants :

a) Shek Wu Hui (location : Sheung Shui)

i) treating { [industrial] [municipal] [both] ✓ } wastewaters

ii) method of treatment : secondary treatment

iii) size : 293000 population equivalent.

b) Shatin STP (location : Shatin)

i) treating { [industrial] [municipal] [both] ✓ } wastewaters

ii) method of treatment : secondary treatment

iii) size : 376800 population equivalent.

c) Tai Po STP (location : Tai Po)

i) treating { [industrial] [municipal] [both] ✓ } wastewaters

ii) method of treatment : secondary treatment

iii) size : 140,000 population equivalent.

16. Future development in treatment plants :

a) Centralization or decentralization :

i) One plant for a few nearby towns/cities?

[Yes] ✓ or [No]

ii) Each town/city has several plants?

[Yes] or [No] ✓

b) Size :

i) tends to be larger? [Yes] ✓ or [No]

ii) tends to be smaller? [Yes] or [No] ✓

iii) No change? [Yes] or [No] ✓

17. Is there or will there be any provision for effluent reuse?

[Yes] ✓ or [No]

If yes, in what way? being considered; working party set up recently (early 1984). No specific proposal yet.

(C) Legislation and Management

18. The authorties dealing with fresh water and wastewater are :

[the same]

[separate] ✓

22. Names of the authorities responsible for enforcing the legislation and controlling the industrial discharges are :

a) On national basis : ______________________

b) On regional basis : ______________________

c) On city basis : ______________________

d) Others : ______________________

The relationship of a, b, c and d is : ______________________

Liquid & solid wastes of Engineering Development Dept. (ie. EDD)

____

23. Names of the authorities responsible for the planning, design and construction of wastewater facilities are :

a) On national basis : ______________________

b) On regional basis : ______________________

c) On city basis : ______________________

d) Others : ______________________

The relationship of a, b, c and d is : ______________________

CEO of EDD

____

24. Names of authorities responsible for the operation and maintenance of the sewer and treatment plants are :

a) On national basis : ______________________

b) On regional basis : ______________________

c) On city basis : ______________________

d) Others : ______________________

The relationship of a, b, c and d is : ______________________

Electrical & Mechanical Services Dept.

____

25. The authorities responsible for monitoring wastewater discharges are same as the ones mentioned in (24).

[Yes] or [No] ✓

If no, what authroities? ______

POllution Control Dept. of Liquid & Solid Waste Division, EDD

26. Briefly describe the methods used in monitoring wastewater discharges. (e.g. the number of times in a month taking wastewater samples from a factory, etc.)

fortnightly to once a year

27. How many legislations currently are there concerning with water polution control?

1. Engineering Development Dept. (Date : Not ordinance)
2. Agriculture & Fisheries Dept. (Date : but merely)
3. Marine Dept. (Date : regulations)
4. Water Pollution Control Ordinance (EPA) (Date : 1980)

The approximate time of enforcement after the publication of legislation :

[1 year] [2 year] [3 year]

[others] 4 year
(please specify)

28. Have the following points in general been provided for in the legislations for industrial wastewater discharges?

a) Staged implementation (geographically)

[Yes ✓] or [No]

b) Different effluent standards for different zones.

[Yes ✓] or [No]

c) Standards expressed quantitatively [Yes] or [No ✓]

d) Are there existing discharge exemptions [Yes ✓] or [No]

29. Expenditure spent in (i) sewerage and (ii) treatment plants:

		National
Before 1980	--	$
1981	--	$
1982	--	$
1983	--	$
1984	--	$
1985 to ultimate	-- 1995	$ 2,000 m (1983 money)
		$

30. Please outline some difficulties faced in the implementation of these schemes, technically or managerially.

too early to say

1. space limited

2. discharge to storm drain.

April 1984.

APPENDIX C.2.1 --- MALAYSIA

Name of Wastewater Plant : Puchong STP

Location : Puchong, K.L., Malaysia Precinct (Selangor)

Detail address : ....

.... Tel : ....

Name of the person responsible : Mr. K. Asairinachan / Mr. Ahmad Thani

Date of filling this form : 1986

---

1. Name of the Consulting Engineer designing this plant : Engineering Science Inc. / Malaysia International Consultant Sdn. Bhd.

   Address : No. 14 Jalan 20/16A, Paramount Gardens, Petaling Jaya, Selangor, Malaysia. Tel : 7765233

2. Treatment methods used in this plant :

   a) Preliminary treatment : Screening ....(e.g. screening, grit removal etc)

   b) Primary treatment : } Stabilization pond + Maturation pond ...... (e.g. sedimentation etc)

   c) Secondary treatment : .... (e.g. trickling filter, oxidation ditch, ect)

   d) Tertiary treatment : ——— (e.g. sand filtration, microstrainer, grass plots etc)

3. Sludge treatment method(s) : Nil .... (e.g. aerobic/anaerobic digestion, thickening etc)

4. Sludge dewatering method(s) : Nil .... (e.g. drying beds, filter press, centrifuge, etc)

5. Existing total area of the plant : 4 Ha

6. Wastewaters from what industries ?

   mainly : All municipal wastewater

   others : ....

Construction cost (excluding land cost) : $ M$ 2,780,000 ....

(based on the value of money in 19 83.)

a. Civil works :

road works .... 5 .. %

~~foundation/engineering~~ pond works .... 77 .... %

buildings (excluding staff quarters) ... 2 ... %

staff quarters .... %

~~others~~ pipes + sewers + MHs .... 12 .... %

Sub-total 96 .... %

b. Equipment .... 4 ... %

total 100%

Capacity of the plant based on the capital cost in (7) above :

a) .... 8000 .... population equivalent

and

d) .... 1800 .... m^3/day (average)

in which

.... % is industrial wastewater

.... 100 .... % is municipal wastewater

Total 100%

Ultimate capacity of the plant : .... population equivalent in Year 19 ....., i.e. .... m^3/day (average).

Not yet known but ultimate capacity will be larger as

Estimated ultimate total construction cost, including capital cost in (7) :

$ .... (based on value of money in 19 .....)

Ultimate Total area : .... Ha

. Cost that the users of the treatment facilities have to pay : mainly

~~$ .... per m^3 (average)~~ through rates / property tax

a. The total income can cover :

(i) [ ] - operation/maintenance cost of the plant

(ii) [ ] - construction cost of the plant

(iii) [✓] - both operation/maintenance and construction costs

(iv) [ ] - the total incomes is even more than what is required in (iii)

b. If the answer of (a) above is (iv), whether or not it includes cost of sewers construction ? [including] or [excluding] ✓

11. Operation and maintenance costs (based on 19 ..... value of money) :

Chemical : $ .... per month

Energy : $ .... per month

Personnel : $ .... per month

(including staff, chemist & labourers etc.)

Repair & unkeeping $ .... per month

Others : (......... $ .... per month

...................)

please specify

Total = ... Information not released

12. Number of persons associated with the operation on the plant :

Number of executive staff : not stationing in the plant, share with other plants

Number of staff in laboratory : ....

Number of technical/operational : 3 (1 x 3 shifts)

Number of supporting staff : ....

(e.g. general clerk, accounts clerks, typist etc) share with other plants

Number of labourers : ....

Others : (....................) : ....

please specify

Total = ...

13. Average degree of pollution of incoming wastewaters :

BOD_5 = 108 mg/l

S.S. = 82 mg/l

COD = 680 mg/l

pH = 7.0

Major chemicals : NH_3-N (24.3 ppm)

Org-N (45.7 ppm)

.... (.................. ppm)

14. Average degree of pollution of wastewater aft4er primary treatment but before secondary treatment. (i.e. Between the 1st & the 2nd ponds)

BOD_5 = 17 mg/l

S.S. = 7 mg/l

COD = 220 mg/l

pH = 7.3

Major chemicals : NH_3-N (13.7 ppm)

Org-N (4.4 ppm)

.... (.................. ppm)

15. Average effluent standard after secondary treatment but before tertiary treatment :

BOD_5 = ...29............. mg/l

S.S. = ...2............. mg/l

COD = ...80............. mg/l

pH = ...7.7............

Major chemicals : ......NH_3-N..... (.........12.4........ ppm)

......Org-N..... (.........0.8........ ppm)

.... (.................. ppm)

16. Average effluent standard when it is discharged out of the plant :

BOD_5 = ...29............. mg/l

S.S. = ...2............. mg/l

COD = ...80............. mg/l

pH = ...

Major chemicals : ......NH_3-N..... (.........12.4........ ppm)

......Org-N..... (.........0.8........ ppm)

.... (.................. ppm)

17. Distribution of the total plant cost :

a. Preliminary and primary treatment : .... % of total cost

b. Secondary treatment : .... % of total costs

c. Tertiary treatment : .... % of total costs

Note : total cost is the cost shown in Item 7.

18. Average volume of the sludge produced per day :

untreated : ......Nil...... m^3/day, treated .... m^3/day

Average percentage of water content of sludge : .... % moisture (treated)

.... % moisture (untreated)

How is the treated sludge disposed ?

.............Not applicable...

....

....

....

19. Whether or not the gas produced in sludge treatment is used to produce energy for use in the plant ?

[Yes] or [No] ✓

If yes,

a. The percentage of the total energy required in the plant from the source, x = ... %

b. Whether the energy cost quoted in (11) expresses this (100 - x)% ?

[Yes] or [No]

If no, how the gas is used or disposed ? ....
....
....

20. Equipments used in the plant [see Question 7(b)] :

(a) .... % is imported (in terms of value)

(b) ..100.. % is locally manufactured (in terms of value)

21. Is there or will there be any provision for effluent reuse ?

[Yes] or [No] ✓

If yes, in what way ? ....
....
....

If no, how is the effluent discharged ?

To :
- [sea] — [with] / [without] — submarine outfall, length of outfall .... km
- [river] ✓
- [other] : .... (please specify)

22. Briefly discribe the methods used in monitoring wastewater discharging <u>to</u> this plant. (e.g. the number of times in a month taking wastewater samples from a factory, etc.)

....
............No control.
....
....

23. In your opinion, do you think that this plant is running successfully ?

Very ✓ Successful	Fairly Successful	Not Successful

24. What difficulties do you find in operating the treatment plant?

Financial problem : [Yes] or [No] ✓

Economical problem : [Yes] or [No] ✓

Social-cultural problem : [Yes] or [No] ✓

Operational/technical problem : [Yes] or [No] ✓

Environmental problem : [Yes] or [No] ✓

Legislational problem : [Yes] or [No] ✓

Administrational/organisational problem : [Yes] or [No] ✓

Other problem : [Yes] or [No] ✓ ....

(please briefly describe)

....

25. Please elaborate on the problems found in (24) above :

....

....

....

....

(Thank you very much for your cooperation)

By the way, could you please supply me with a flow diagram of the plant and an introductory brochure/pamphlet of it, if any.

Name of Wastewater Plant : South Pattaya STP

Location : South Pattaya ...... Precinct (Pattaya)

Detail address : Phra Tam Nak Road, South Pattaya, Thailand

...... Tel (038) 429375

Name of the person responsible : Tharna Srichar

Date of filling this form : Jan. 1987

---

1. Name of the Consulting Engineer designing this plant : Public Works Department, Pattaya, Thailand
   Address : City Hall, Soi 6, Pattaya, Thailand
   ...... Tel : (038) 429125

2. Treatment methods used in this plant :
   a) Preliminary treatment : Nil
      ......(e.g. screening, grit removal etc)
   b) Primary treatment : Nil
      ...... (e.g. sedimentation etc)
   c) Secondary treatment : Activated sludge (extended aeration)
      ...... (e.g. trickling filter, oxidation ditch, ect)
   d) Tertiary treatment : Chlorination
      ......
      (e.g. sand filtration, microstrainer, grass plots etc)

3. Sludge treatment method(s) : Sludge drying bed
   ...... (e.g. aerobic/anaerobic digestion, thickening etc)

4. Sludge dewatering method(s) : Sludge drying bed
   ...... (e.g. drying beds, filter press, centrifuge, etc)

5. Existing total area of the plant : 0.2 Ha

6. Wastewaters from what industries ?
   mainly : municipal sewage
   others : ......

. Construction cost (excluding land cost) : $ ..$2.7 millions..................
(based on the value of money in 1982.)

a. Civil works :

road works .... %
foundation engineering works .... %
buildings (excluding staff quarters) .... %
staff quarters .... %
others .... %

Sub-total ...... % (of a.)

b. Equipment .... %

total (a. + b.) 100%

. Capacity of the plant based on the capital cost in (7) above :

a) ....5,000........... population equivalent

and

d) ....1,000........... m^3/day (average)

in which

.... % is industrial wastewater
.........100.............. % is municipal wastewater

Total 100%

. Ultimate capacity of the plant : ....5,000.......... population equivalent in Year 19 ....., i.e. ....1,000... m^3/day (average).

Same as (8).

Estimated ultimate total construction cost, including capital cost in (7) :
$ .... (based on value of money in 19 .....)

Ultimate Total area : .... Ha

0. Cost that the users of the treatment facilities have to pay :
$ ....0.... per m^3 (average)

a. The total income can cover :

(i) [ ] - operation/maintenance cost of the plant
(ii) [ ] - construction cost of the plant
(iii) [ ] - both operation/maintenance and construction costs
(iv) [ ] - the total incomes is even more than what is required in (iii)

b. If the answer of (a) above is (iv), whether or not it includes cost of sewers construction ? [including] or [excluding]

11. Operation and maintenance costs (based on 19 .83.. value of money) :

Chemical : $ .... per month
Energy : $ ....฿.30,000.... per month
Personnel : $ .... per month
(including staff, chemist & labourers etc.)
Repair & unkeeping $ .... per month
Others : (......... $ .... per month
...................)
please specify

Total = ... Not Known

12. Number of persons associated with the operation on the plant :

Number of executive staff : ....1........
Number of staff in laboratory Tests not done in the plant but in Bangkok.
Number of technical/operational : ....2........
Number of supporting staff : ....
(e.g. general clerk, accounts clerks, typist etc)
Number of labourers : ....3........
Others : (....................) : ....
please specify

Total = ...6...
All shared with the new STP.

13. Average degree of pollution of incoming wastewaters :

BOD_5 = ... mg/l
S.S. = ... mg/l
COD = ... mg/l
pH = ...
Major chemicals : .... (.................. ppm)
.... (.................. ppm)
.... (.................. ppm)

The plant is not operating

14. Average degree of pollution of wastewater aft4er primary treatment but before secondary treatment.

BOD_5 = ... mg/l
S.S. = ... mg/l
COD = ... mg/l
pH = ...
Major chemicals : .... (.................. ppm)
.... (.................. ppm)
.... (.................. ppm)

15. Average effluent standard after secondary treatment but before tertiary treatment :

BOD$_5$ = ... mg/l

S.S. = ... mg/l

COD = ... mg/l

pH = ...

Major chemicals : .... (.................. ppm)

.... (.................. ppm)

.... (.................. ppm)

16. Average effluent standard when it is discharged out of the plant :

BOD$_5$ = ... mg/l

S.S. = ... mg/l

COD = ... mg/l

pH = ...

Major chemicals : .... (.................. ppm)

.... (.................. ppm)

.... (.................. ppm)

17. Distribution of the total plant cost : Figures not available

a. Preliminary and primary treatment : .... % of total cost

b. Secondary treatment : .... % of total costs

c. Tertiary treatment : .... % of total costs

Note : total cost is the cost shown in Item 7.

18. Average volume of the sludge produced per day : The plant is not operating.

untreated : .... m^3/day; treated .... m^3/day

Average percentage of water content of sludge : .... % moisture (treated)

.... % moisture (untreated)

How is the treated sludge disposed ?

....

....

....

....

19. Whether or not the gas produced in sludge treatment is used to produce energy for use in the plant ?

[Yes] or [No] ✓

If yes,

a. The percentage of the total energy required in the plant from the source, x = ... %

b. Whether the energy cost quoted in (11) expresses this (100 - x)% ?

[Yes] or [No]

If no, how the gas is used or disposed ? ....

.....Sludge drying beds do not produce gas..........

....

20. Equipments used in the plant [see Question 7(b)] :

(a) .... % is imported (in terms of value)

(b) ...100.. % is locally manufactured (in terms of value)

21. Is there or will there be any provision for effluent reuse ?

[Yes] or [No] ✓

If yes, in what way ? ....

....

....

If no, how is the effluent discharged ?

To :
- [sea] — [with] / [without] — submarine outfall, length of outfall .... km
- [river] ✓ To Khlong Pattaya and then to beach.
- [other] : .... (please specify)

22. Briefly discribe the methods used in monitoring wastewater discharging <u>to</u> this plant. (e.g. the number of times in a month taking wastewater samples from a factory, etc.)

....

............No control.......................................

....

....

23. In your opinion, do you think that this plant is running successfully ?

Very Successful	Fairly Successful	Not Successful ✓

24. What difficulties do you find in operating the treatment plant?

Financial problem : [Yes] ✓ or [No]

Economical problem : [Yes] ✓ or [No]

Social-cultural problem : [Yes] or [No] ✓

Operational/technical problem : [Yes] ✓ or [No]

Environmental problem : [Yes] or [No] ✓

Legislational problem : [Yes] or [No] ✓

Administrational/organisational problem : [Yes] ✓ or [No]

Other problem : [Yes] or [No] ....

(please briefly describe)

....

25. Please elaborate on the problems found in (24) above :

...Operation and maintenance funds are not easily obtained......

...No way can be found to charge the users.....................

....

....

(Thank you very much for your cooperation)

By the way, could you please supply me with a flow diagram of the plant and an introductory brochure/pamphlet of it, if any.

APPENDIX C.2.3 --- TAIWAN

Name of Wastewater Plant : ....Min Shen STP (民生污水處理廠)

Location : ..Min Shen Community......... Precinct (Taipei)

Detail address : 1159 Min-Chuen E. Road, Taipei City (By the side of Keelung River................ Tel : (02) 7628273..

Name of the person responsible : Mr. F. S. Shi (石[illegible])............

Date of filling this form : ...1985.................................

---

1. Name of the Consulting Engineer designing this plant : .... Sewerage Engineering Department, Public Works Bureau, Taipei

 Address : 台北市[illegible]路[illegible]段200號........................

 .... Tel : ....

2. Treatment methods used in this plant :

 a) Preliminary treatment : ..Bar screen, Grit channel, Comminutor.................(e.g. screening, grit removal etc)

 b) Primary treatment : ...Sedimentation tank.................. (e.g. sedimentation etc)

 c) Secondary treatment : ..Activated sludge / RBC + Sedimentation .... (e.g. trickling filter, oxidation ditch, ect)

 d) Tertiary treatment : ....Rapid Sand Filtration..................

 (e.g. sand filtration, microstrainer, grass plots etc)

3. Sludge treatment method(s) : Aerobic Digestion, Thickening, Mechanical Dewatering..... (e.g. aerobic/anaerobic digestion, thickening etc)

4. Sludge dewatering method(s) : ...Centrifuge.......................... (e.g. drying beds, filter press, centrifuge, etc)

5. Existing total area of the plant : ......0.76.................. Ha

6. Wastewaters from what industries ?

 mainly : ..Municipal Wastewater..........................

 others : ..—..

Construction cost (excluding land cost) : $ NT$ 100,000,000 (approx)

(based on the value of money in 1982) (NT$ 10,000,000 for RBC only including final clarifier for RBC effluent)

a. Civil works :

road works .... %
foundation engineering works .... %
buildings (excluding staff quarters) .... %
staff quarters .... %
others .... %

} Sub-total ...... %

b. Equipment .... %

} total 100%

Capacity of the plant based on the capital cost in (7) above :

a) .... population equivalent

and

d) 15,500 m³/day (average) Activated sludge : 13,000 m³/d. RBC : 2,500 m³/d.

in which

.... % is industrial wastewater
100 % is municipal wastewater
} Total 100%

Ultimate capacity of the plant : same as (8) population equivalent in Year 19 ....., i.e. .... m³/day (average).

Estimated ultimate total construction cost, including capital cost in (7) :
$ .... (based on value of money in 19 .....)

Ultimate Total area : .... Ha

Cost that the users of the treatment facilities have to pay :
$ .... per m³ (average)

a. The total income can cover :

(i) [✓] - operation/maintenance cost of the plant partly covered
(ii) [ ] - construction cost of the plant
(iii) [ ] - both operation/maintenance and construction costs
(iv) [ ] - the total incomes is even more than what is required in (iii)

b. If the answer of (a) above is (iv), whether or not it includes cost of sewers construction ? [including] or [excluding] ✓

11. Operation and maintenance costs (based on 19 85.. value of money) :

Chemical : $ .... per month

Energy : $ .... per month

~~Personnel : $ .... per month~~

(including staff, chemist & labourers etc.)

Repair & unkeeping $ .... per month

~~Others : (.......... $ .... per month~~
~~..............)~~

please specify

Total = NT$ 8,000,000 per year excluding salaries.

Whole plant

RBC alone NT$ 1,000,000 per year excluding salaries

12. Number of persons associated with the operation on the plant :

Number of executive staff : ....1.........

Number of staff in laboratory : ....1.........

Number of technical/operational : ......9..(3 x 3 shifts)

Number of supporting staff : ......5...........

(e.g. general clerk, accounts clerks, typist etc)

Number of labourers : ....

Others : (....................) : ....

please specify

Total = 16

13. Average degree of pollution of incoming wastewaters :

BOD_5 = ...200.............. mg/l

S.S. = ...200.............. mg/l

COD = ... mg/l

pH = ...

Major chemicals : .... (.................. ppm)

.... (.................. ppm)

.... (.................. ppm)

14. Average degree of pollution of wastewater aft4er primary treatment but before secondary treatment.

BOD_5 = ...140.............. mg/l

S.S. = ...120.............. mg/l

COD = ... mg/l

pH = ...

Insufficient primary sedimentation design

Major chemicals : .... (.................. ppm)

.... (.................. ppm)

.... (.................. ppm)

15. Average effluent standard after secondary treatment but before tertiary treatment :

BOD_5 = 10 to 15 (RBC), 20 to 30 (A.S.) mg/1 18 mg/l (combined effluent)

S.S. = 30 (combined effluent) mg/1

COD = ... mg/1

pH = ...

Major chemicals : .... (.................... ppm)

.... (.................... ppm)

.... (.................... ppm)

16. Average effluent standard when it is discharged out of the plant :

BOD_5 = 18 mg/1

S.S. = 30 mg/1

COD = ... mg/1

pH = ...

} figures for combined effluent
RBC effluent : 5 to 10 BOD_5
5 to 10 S.S.
(only RBC effluent is going through rapid sand filtration)

Major chemicals : .... (.................... ppm)

.... (.................... ppm)

.... (.................... ppm)

17. Distribution of the total plant cost :

a. Preliminary and primary treatment : .... % of total cost ?

b. Secondary treatment : .... % of total costs

c. Tertiary treatment : .... % of total costs

Note : total cost is the cost shown in Item 7.

18. Average volume of the sludge produced per day :

untreated : 100 m^3/day, treated 4 m^3/day

Average percentage of water content of sludge : 75 % moisture (treated)

97 ~ 98 % moisture (untreated)

How is the treated sludge disposed ?

by trucks to sanitary landfill

19. Whether or not the gas produced in sludge treatment is used to produce energy for use in the plant ?

[Yes] or [No ✓]

If yes,

a. The percentage of the total energy required in the plant from the source, x = ... %

b. Whether the energy cost quoted in (11) expresses this (100 - x)% ?

[Yes] or [No]

If no, how the gas is used or disposed ? ....

....

....

20. Equipments used in the plant [see Question 7(b)] :

(a) .... % is imported (in terms of value)

(b) ..100.. % is locally manufactured (in terms of value)

21. Is there or will there be any provision for effluent reuse ?

[Yes ✓] or [No]

If yes, in what way ? ...effluent from RBC after tertiary treatment (rapid sand filtration) is used in a scenic fountain in the San Min Park.........................

If no, how is the effluent discharged ?

To :
- [sea]
  - [with] / [without] submarine outfall, length of outfall .... km
- [river ✓] effluent from activated sludge process
- [other] : .... (please specify)

22. Briefly discribe the methods used in monitoring wastewater discharging <u>to</u> this plant. (e.g. the number of times in a month taking wastewater samples from a factory, etc.)

....

......No monitoring. No industrial wastewater. ......

....

....

23. In your opinion, do you think that this plant is running successfully ?

[Very Successful] ✓ RBC [Fairly Successful] ✓ Activated sludge [Not Successful]

24. What difficulties do you find in operating the treatment plant?

Financial problem : [Yes] or [No] ✓

Economical problem : [Yes] or [No] ✓

Social-cultural problem : [Yes] or [No] ✓

Operational/technical problem : [Yes] ✓ or [No]

Environmental problem : [Yes] or [No] ✓

Legislational problem : [Yes] ✓ or [No]

Administrational/organisational problem : [Yes] or [No]

Other problem : [Yes] or [No] ....

(please briefly describe)

....

25. Please elaborate on the problems found in (24) above :

....Insufficient primary treatment design : should have 2...
.....primary sedimentation tanks instead of one..................
....Insufficient design in aeration tank (for A.S.)..........
.....Legislational problem is directly relevant to industrial wastewater treatment plants but not to this plant.

(Thank you very much for your cooperation)

By the way, could you please supply me with a flow diagram of the plant and an introductory brochure/pamphlet of it, if any.

Construction cost (excluding land cost) HK$ 365 million (Stage 1 only)

(based on the value of money in 19.80.) Stage 2 : HK$ 280 million (1984 money)

a. Civil works :

- road works .... %
- foundation engineering works .... %
- buildings (excluding staff quarters) .... %
- staff quarters .... %
- others .... %

Sub-total ..58.. % (a)

b. Equipment .....42..... %

total 100%

Capacity of the plant based on the capital cost in (7) above :

a) ..Stage 1 : 240,000........ population equivalent Stage 1+2 : 505,000 P.E.

and

d) ..Stage 1 : 103,000........ m^3/day (average) Stage 1+2 : 206,000 m^3/day

in which

..........40...... % is industrial wastewater

..........60...... % is municipal wastewater

Total 100%

Ultimate capacity of the plant : ....670,000..... population equivalent in Year 1999..., i.e. ...275,000.... m^3/day (average).

Estimated ultimate total construction cos[...] ıding capital cost in (7) :

$ .... (based on value of [...] in 19 .....)

Ultimate Total area : ....[...] Ha

0. Cost that the users of the treatment fac[...] have to pay :

$ .... per m^3 (average)

a. The total income can cover :

- (i) [ ] - operation/maintenanc[...] of the plant
- (ii) [ ] - construction cost o[...]lant
- (iii) [ ] - both operation/main[...] and construction costs
- (iv) [ ] - the total incomes [...] even more than what is required in (iii)

b. If the answer of (a) above is (iv)[...]ıer or not it includes cost of sewers construction ? [inc...] or [excluding]

Page 312

Construction cost (excluding land cost) HK$ .365 million (Stage 1 only)
(based on the value of money in 19.80.) Stage 2 : HK$ 280 million (1984 money)

a. Civil works :

road works .... %
foundation engineering works .... %
buildings (excluding staff quarters) .... %
staff quarters .... %
others .... %

Sub-total ..58.. % (civil works)

b. Equipment ....42...... %

total 100%

Capacity of the plant based on the capital cost in (7) above :

a) ..Stage 1 : 240,000.......... population equivalent Stage 1+2 : 505,000 P.E.
and
d) ..Stage 1 : 103,000.......... m^3/day (average) Stage 1+2 : 206,000 m^3/day
in which
..........40...... % is industrial wastewater
..........60..... % is municipal wastewater
Total 100%

Ultimate capacity of the plant : ......670,000..... population equivalent in Year 1999..., i.e. ...275,000.... m^3/day (average).

Estimated ultimate total construction cost, including capital cost in (7) :
$ .... (based on value of money in 19 .....)

Ultimate Total area : .... Ha

0. Cost that the users of the treatment facilities have to pay :
$ .... per m^3 (average)

a. The total income can cover :
(i) [ ] - operation/maintenance cost of the plant
(ii) [ ] - construction cost of the plant
(iii) [ ] - both operation/maintenance and construction costs
(iv) [ ] - the total incomes is even more than what is required in (iii)

b. If the answer of (a) above is (iv), whether or not it includes cost of sewers construction ? [including] or [excluding]

11. Operation and maintenance costs (based on 19 84.. value of money) :

Chemical : $ ..51,967...... per month

Energy : $ ..315,417...... per month

Personnel : $ ..397,151...... per month

(including staff, chemist & labourers etc.)

Repair & unkeeping $ ..146,294.... per month

Others : (......... $ .... per month

..................)

please specify

Total = HK$ 910,829 per month (Stage 1 capacity only)

12. Number of persons associated with the operation on the plant :

Number of executive staff : ......11.........

Number of staff in laboratory : ......5.........

Number of technical/operational : ......61.........

Number of supporting staff : ......4.........

(e.g. general clerk, accounts clerks, typist etc)

Number of labourers : ......17.........

Others : (....................) : ....

please specify

Total = 96 (Stage 1 capacity only)

13. Average degree of pollution of incoming wastewaters :

BOD_5 = ...250............ mg/1

S.S. = ...220............ mg/1

COD = ... mg/1

pH = ...7.1.............

Major chemicals : ....NH_3 - N....... (.......30 mg/l... ppm)

....Org - N......... (.......10 mg/l.... ppm)

....Chloride......... (....340 mg/l.... ppm)

14. Average degree of pollution of wastewater aft4er primary treatment but before secondary treatment.

BOD_5 = ...160............ mg/1

S.S. = ...82............ mg/1

COD = ... mg/1

pH = ...7.0.............

Major chemicals : .....NH_3 - N...... (.........29 mg/l.. ppm)

....Org - N....... (......6.4 mg/l.. ppm)

....Chloride......... (.....310 mg/l.. ppm)

15. Average effluent standard after secondary treatment but before tertiary treatment :

BOD_5 = ...10 to 15.......... mg/l

S.S. = ...15 to 25.......... mg/l

COD = ... mg/l

pH = ...6.8..........

Major chemicals : ....NH_3 - N........ (....1.5 mg/l.... ppm)

....Org - N........ (....0.7 mg/l.... ppm)

....Chloride........ (....320 mg/l.... ppm)

16. Average effluent standard when it is discharged out of the plant :

BOD_5 = ...10 to 15.......... mg/l

S.S. = ...15 to 25.......... mg/l

COD = ... mg/l

pH = ...6.8..........

Major chemicals : ....NH_3 - N........ (....1.5 mg/l.... ppm)

....Org - N........ (....0.7 mg/l.... ppm)

....Chloride........ (....320 mg/l.... ppm)

17. Distribution of the total plant cost :

a. Preliminary and primary treatment : .... % of total cost

b. Secondary treatment : .... % of total costs

c. Tertiary treatment : .... % of total costs

Note : total cost is the cost shown in Item 7.

18. Average volume of the sludge produced per day :

untreated : Before digestion : 980 After digestion : 363 .. m^3/day, treated ....200...... m^3/day

Average percentage of water content of sludge : ...80... % moisture (treated)

...95... % moisture (untreated)

How is the treated sludge disposed ?

....Delivered by trucks to To Shuen Wan, Taipo, N.T.......

....

....

....

19. Whether or not the gas produced in sludge treatment is used to produce energy for use in the plant ?

[Yes] ✓ or [No]

If yes,

a. The percentage of the total energy required in the plant from the source, x = ...50... %

b. Whether the energy cost quoted in (11) expresses this (100 - x)% ?

[Yes] ✓ or [No]

If no, how the gas is used or disposed ? ....

....

....

20. Equipments used in the plant [see Question 7(b)] :

(a) ...100.. % is imported (in terms of value)

(b) .... % is locally manufactured (in terms of value)

21. Is there or will there be any provision for effluent reuse ?

[Yes] or [No] ✓

If yes, in what way ? ....

....

....

If no, how is the effluent discharged ?

To :
- [sea] ✓ — [with] ✓ / [without] — submarine outfall, length of outfall ....1.... km
- [river]
- [other] : .... (please specify)

22. Briefly discribe the methods used in monitoring wastewater discharging <u>to</u> this plant. (e.g. the number of times in a month taking wastewater samples from a factory, etc.)

....

........No control at source currently.......................

....

....

23. In your opinion, do you think that this plant is running successfully ?

Very Successful ✓	Fairly Successful	Not Successful

24. What difficulties do you find in operating the treatment plant?

Financial problem : Yes or No ✓

Economical problem : Yes or No ✓

Social-cultural problem : Yes or No ✓

Operational/technical problem : Yes ✓ or No

Environmental problem : Yes or No ✓

Legislational problem : Yes or No ✓

Administrational/organisational problem : Yes or No ✓

Other problem : Yes ✓ or No ....

(please briefly describe)

..Construction faults affecting operation e.g. flow meters, gas holders etc.

25. Please elaborate on the problems found in (24) above :

....

.........Pumps blocked by grit.................................

....

....

(Thank you very much for your cooperation)

By the way, could you please supply me with a flow diagram of the plant and an introductory brochure/pamphlet of it, if any.

APPENDIX C.3.1 --- MALAYSIA

Interviewing Questionnaire

Name of Wastewater Treatment Plant : Puchong STP

Detail address : Puchong, K.L., Malaysia Tel :

Name of responsible person : Mr. K. Asairinachan Rank : Plant Manager
Mr. Ahmad Thani Chemist

1. Name and address of the Consulting Engineer designing this plant :
Engineering Science Inc./ Malaysia International Consultant Sdn. Bhd.

   Is it a local or a foreign firm? Foreign / Local

2. Treatment methods used in this plant
   a. Preliminary treatment : Screening
   b. Primary treatment : } Two stabilization ponds in series
   c. Secondary treatment :
   d. Tertiary treatment :
   e. Sludge treatment :
   f. Vol. of dry sludge produced : .... m^3 per day
   g. Sludge disposal :

3. Site area of the plant
   a. Present ...4... Ha
   b. Ultimate ...Unknown... Ha

4. Nature of site
   a. Topography : Flat land, very little earth work is involved in construction
   b. Proximity to sludge disposal facility : No such facility is required

5. Strength of Influent
   a. BOD_5 ...108... mg/l
   b. S.S. ...82... mg/l
   c. pH ...7.0...

   Major chemicals ...NH_3 - N... (...24.3... ppm)
   ...Org. - N... (...45.7... ppm)
   .... (........ ppm)
   .... (........ ppm)

6. Effluent quality
   a. BoD_5 ...29... mg/l
   b. S.S. ...2... mg/l
   c. pH ...7.7...

   Major chemicals ...NH_3 - N... (...12.4... ppm)
   ...Org. - N... (...0.8... ppm)
   .... (........ ppm)
   .... (........ ppm)

   Is the effluent quality up to the required standard ? ...Yes...

7. How frequent and by what method (grab or composite etc) were the samples of (5) & (6) above collected ?
Grab samples taken once or twice weekly, usually in the morning.

8. Capacity of treatment of the plant : 8000 population equivalent (present) 1800 m³/day
.... population equivalent (ultimate)

9. Name and address of the Contractor who constructed this plant : Sarikon Group, 97, Wisma Sari, Jalan Bangsar, 59200, K.L., Malaysia
Tel : 2744922
Is it a local or a foreign contractor ? Local

10. Cost of construction (excluding land cost)
a. In local currency — Civil works : M$ 2,780,000
M & E works : (very small portion for M & E)

b. In foreign currency — Civil works : ....
M & E works : ....

11. What is your opinion on the local skill for construction ? Competent and highly skilled under the right supervision. Certain Malaysian construction companies have reached international standard.

12. Cost of operation and maintenance
a. In local currency : ....
b. In foreign currency : ....

13. What is your opinion on the local skill for operation and maintenance ?
a. professional level : We trained and qualified professionals trained in leading international tertiary institutions are available.
b. technical level : Technicians with the required qualifications and experience, can be sourced from polytechnics. They need greater management exposure, however!

14. Are materials and components readily available locally for operation and maintenance ? Yes

15. Name(s) of the local administration which support(s) the treatment plants' operation : City Hall (Federal Authority of K.L.)

16. Do you consider the set-ups in (15) above are appropriate and efficient ? So far so good, but there seems to be a bit confused since several government authorities are involved (e.g. design, planning).

17. Power source for operating the plant
a. Capacity of power req'd : ....
It is readily available ? Yes
b. Is the power supply reliable ? Yes

18. Training of local people
a. How is the situation of training professionals in the country ?
Still insufficient emphasis to establish specialist courses related to environmental engineering. Gaps are being filled by overseas education.

b. How is the situation of training technicians in the country ?
..Several polytechnics are under construction at present, but the quality of training is unknown.

c. How is the situation of training supporting professions in the country ?
........Not in a position to give comments.

19. Soical cultural factors

a. Is there any religious factors that affect the hygiene practices and technology choice in the country ? ....
..Islam is the official religion but it does not have anything to do with wastewater treatment.

b. Are the people willing and enthusiastic to improve the existing hygienic facilities ? ....
..Yes, people want improved hygienic facilities.

20. Soical ethics

a. What is the general attitude of social responsibility of the people ? Still needs to be more widely promoted. Attitude can be better if more education given to public.

b. How are the professionals committed to their jobs ? ....
..Commitment to jobs is undergoing changes. Due to retrenchment, salary freeze, etc., people not more realistic.

c. How are the technical staff and supporting staff committed to their jobs ? ..Same as above. Commitment to jobs depends on reward and punishment. If jobs are not renumerative and stagnant, staff will have no incentive to contribute...

21. Climate

a. Average monthly maximum temperature : ....32.... °C
Month(s) having such temperature : ....June to November......
Average humidity : ....98.4....%

b. Average monthly minimum temperature : ....22.5.... °C
Month(s) having such temperature : ....Jan. to April.........
Average humidity : ....56.0....%

c. Length of dry season : ....2.......... months,

from ....June..... to ....July........

d. Intensity and duration of sunshine in a year : ....
...Average daily sunshine hours 6 ~ 7 hours/day

22. Endemic local diseases

a. Malaria, filariasis, yellow fever : ..Under control..........
b. Human round worm and hook worm, fish-borne parasities : Under control
c. Infectious hepatitis, diarrhoeal diseases ...Occasional.........
d. Cholera, typhoid, bilharzia ..Under control.................

8. Capacity of treatment of the plant : ..5,000.... population equivalent (present)
..5,000.. population equivalent (ultimate)

9. Name and address of the Contractor who constructed this plant : ....
....
Name cannot be traced.
Is it a local or a foreign contractor ? ...Local..................

10. Cost of construction (excluding land cost)
a. In local currency   Civil works : } ฿ 2.7 million ......
                        M & E works : }..................
b. In foreign currency Civil works : ....
                        M & E works : ....

11. What is your opinion on the local skill for construction ? ....
....Local skill can be good... Quality of work largely depends on.....
....the construction supervisor and on the construction costs.........
....

12. Cost of operation and maintenance
a. In local currency : .... The plant is not in operation.
b. In foreign currency : ....

13. What is your opinion on the local skill for operation and maintenance ?
a. professional level : .In general not too good.. Some of them are good but many are careless.. Does not appreciate the importance of maintenance.
b. technical level : .Lack of comprehensive knowledge. Salary too low and lack of incentive.. Never bother to look at the "manual" or "operation guide".

14. Are materials and components readily available locally for operation and maintenance ? ..Yes...except for spare parts of sophisticated equipment.

15. Name(s) of the local administration which support(s) the treatment plants' operation :..
.....Public Health Division, ..City Hall, ..Pattaya...................
....
....

16. Do you consider the set-ups in (15) above are appropriate and efficient ? ....
.....It is different from the one who design and construct the plant (PWD).
.....The latter does not know a lot of operation details..............

17. Power source for operating the plant
a. Capacity of power req'd : ....
It is readily available ? .....Yes..................................
b. Is the power supply reliable ? ...Yes..............................

18. Training of local people
a. How is the situation of training professionals in the country ?
...Usually good academic training is provided, but practical.....
...experience is inadequate in designing or operating STPs.........
....

b. How is the situation of training technicians in the country ?
...Even worse than the professionals. Poor writing/feedback/reporting ability. Usually only a 3 to 5 days course is provided to technicians and this is definitely not enough.

c. How is the situation of training supporting professions in the country ? Poor. No initiative. No evaluation or comparison of different treatment processes. A chemist can carry out BOD/COD etc. for 10 years without improvement.

19. Soical cultural factors

a. Is there any religious factors that affect the hygiene practices and technology choice in the country ? No

b. Are the people willing and enthusiastic to improve the existing hygienic facilities ? Only a small group of better-off people are enthusiastic. The general public does not.

20. Soical ethics

a. What is the general attitude of social responsibility of the people ? People are not ignorant of it but sometimes they pretend not to know about it and do not practise it.

b. How are the professionals committed to their jobs ? Some are good and some are not. If they are not good anyway, it is the financial reason which prevents them to good.

c. How are the technical staff and supporting staff committed to their jobs ? Same as (b).

21. Climate

a. Average monthly maximum temperature : 35 °C
Month(s) having such temperature : March and April
Average humidity : ....%

b. Average monthly minimum temperature : 25 °C
Month(s) having such temperature : December and January
Average humidity : ....%

c. Length of dry season : 6 months,

from Nov. to April

d. Intensity and duration of sunshine in a year : quite high

22. Endemic local diseases

a. Malaria, filariasis, yellow fever : under control
b. Human round worm and hook worm, fish-borne parasities : moderately serious
c. Infectious hepatitis, diarrhoeal diseases ... widely spread, dysentery also.
d. Cholera, typhoid, bilharzia ... under control

Interviewing Questionnaire

Name of Wastewater Treatment Plant : Min Shen STP (民生污水廠)

Detail address : 1159 Min-Chuen East Road, Taipei
Tel : (02) 7628273

Name of responsible person : Mr. F. S. Shi Rank : Engineer

1. Name and address of the Consulting Engineer designing this plant : Sewerage Engineering Department, Public Works Bureau, Taipei

   Is it a local or a foreign firm? local government

2. Treatment methods used in this plant
   a. Preliminary treatment : Bar screen, grit channel, comminutor
   b. Primary treatment : Sedimentation tank
   c. Secondary treatment : Activated sludge / RBC, final sedimentation
   d. Tertiary treatment : Rapid sand filtration
   e. Sludge treatment : Aerobic digestion, thickening, mechanical dewatering
   f. Vol. of dry sludge produced : 4 m^3 per day
   g. Sludge disposal : by trucks to sanitary landfill

3. Site area of the plant
   a. Present 0.76 Ha
   b. Ultimate 0.76 Ha

   For (RBC, final clarifier, rapid sand filtration alone) : 500 m^2, excluding common facilities.

4. Nature of site
   a. Topography : flat, near Keelung River where effluent is discharged to.
   b. Proximity to sludge disposal facility : 15 km from plant, destination: 木柵

5. Strength of Influent
   a. BOD_5 200 mg/l
   b. S.S. 200 mg/l
   c. pH 7 to 8

   Major chemicals Negligible (ppm)
   (ppm)
   (ppm)
   (ppm)

6. Effluent quality (RBC only)
   a. BoD_5 10 to 15 mg/l
   b. S.S. 10 to 15 mg/l
   c. pH 7

   } before tertiary treatment. 5 to 10 mg/l after tertiary treatment

   Major chemicals (ppm)
   (ppm)
   (ppm)
   (ppm)

   Is the effluent quality up to the required standard ? Yes

7. How frequent and by what method (grab or composite etc) were the samples of (5) & (6) above collected ? Once everyday at 9 am. Grab samples at influent point, intermediate point and effluent point.
   (Composite samples at various points were taken in the first year of operation but is not done now.)

8. Capacity of treatment of the plant : ..15500 m³/day.. ~~population equivalent~~ (present)
Activated sludge : 13000 m³/day
RBC : 2,500 m³/day
.... ~~population equivalent~~ (ultimate)

9. Name and address of the Contractor who constructed this plant : ....
..Activated sludge : 台湾淨水工程公司..........
RBC : 華商實業有限股份公司
Is it a local or a foreign contractor ? all local..................

10. Cost of construction (excluding land cost)
a. In local currency Civil works : NT$ 100,000,000....
M & E works : ....
b. In foreign currency Civil works : ...Nil...............
M & E works : ....

11. What is your opinion on the local skill for construction ? ....
.......Very good..
....
....

12. Cost of operation and maintenance
a. In local currency : N.T.$ 8,000,000 per year excluding salaries
b. In foreign currency : ....Nil..........................

13. What is your opinion on the local skill for operation and maintenance ?
a. professional level : ...good.................................
....
b. technical level : ..fairly good, ...sometimes have emotional
...problems..

14. Are materials and components readily available locally for operation and maintenance ? ....Yes...............................

15. Name(s) of the local administration which support(s) the treatment plants' operation : ....
....Same as Answer to Question 1..........................
....
....

16. Do you consider the set-ups in (15) above are appropriate and efficient ? ....
.....Appropriate. However, government servants have lower....
..morale than people working in private sectors...............

17. Power source for operating the plant
a. Capacity of power req'd : ..160,000 kW-h/month in total (45,000 kW-h for RBC + Tertiary treatment)
It is readily available ? ..Yes.........................
b. Is the power supply reliable ? ..Yes.........................

18. Training of local people
a. How is the situation of training professionals in the country ?
....
..........Adequate...
....

b. How is the situation of training technicians in the country ?
....
...Less good than professionals but still adequate.......
....

c. How is the situation of training supporting professions in the country ? ....
..........Good.......................................
....
....

19. Soical cultural factors

a. Is there any religious factors that affect the hygiene practices and technology choice in the country ? ....
....
..................Not in Taipei.........................
....

b. Are the people willing and enthusiastic to improve the existing hygienic facilities ? ....
....
......Very much so.......................................
....

20. Soical ethics

a. What is the general attitude of social responsibility of the people ? ....
........Becoming better in the past two years...............
....

b. How are the professionals committed to their jobs ? ...Good...
....
....

c. How are the technical staff and supporting staff committed to their jobs ? ....
.............Fairly good.................................
....

21. Climate

a. Average monthly maximum temperature : ....27..... °C
Month(s) having such temperature : ......July - August.........
Average humidity : ....90.....%

b. Average monthly minimum temperature : ....15..... °C
Month(s) having such temperature : .....January...February....
Average humidity : .....50......%

c. Length of ~~dry~~ sunny season : ....6......... months,

from ....May... to ....October.....

d. Intensity and duration of sunshine in a year : ..May to October
....

22. Endemic local diseases

a. Malaria, filariasis, yellow fever : ....No..................
b. Human round worm and hook worm, fish-borne parasities : unknown
c. Infectious hepatitis, diarrhoeal diseases ...occasional..........
d. Cholera, typhoid, bilharzia ....No.........................

APPENDIX C.3.4 --- HONG KONG

Interviewing Questionnaire

Name of Wastewater Treatment Plant : Shatin STP

Detail address : Mei Sha Road, Shatin, N.T., Hong Kong
Tel : 0-6053375

Name of responsible person : Mr. David K.C. Wu Rank : Plant Manager

1. Name and address of the Consulting Engineer designing this plant : Watson Hawsley Asia, 56 Dundas Street, Kowloon, Hong Kong

   Is it a local or a foreign firm? foreign (U.K.)

2. Treatment methods used in this plant
   a. Preliminary treatment : Screening, Grit removal
   b. Primary treatment : Primary sedimentation tanks
   c. Secondary treatment : Activated sludge
   d. Tertiary treatment : —
   e. Sludge treatment : Anaerobic digestion + Mechanical dewatering
   f. Vol. of dry sludge produced : 200 m^3 per day
   g. Sludge disposal : Delivered by truck to sanitary landfill.

3. Site area of the plant
   a. Present 16 Ha
   b. Ultimate .... Ha

4. Nature of site
   a. Topography : Reclaimed land, flat
   b. Proximity to sludge disposal facility : 12 km from the plant

5. Strength of Influent
   a. BOD_5 250 mg/ℓ
   b. S.S. 220 mg/ℓ
   c. pH 7.1

   Major chemicals Ammonia nitrogen (30 ppm)
   Organic nitrogen (10 ppm)
   Chloride (340 ppm)
   .... (........ ppm)

6. Effluent quality
   a. BoD_5 10 ~ 15 mg/ℓ
   b. S.S. 10 ~ 15 mg/ℓ
   c. pH 6.8

   Major chemicals Ammonia nitrogen (1.5 ppm)
   Organic nitrogen (0.7 ppm)
   Chloride (320 ppm)
   .... (........ ppm)

   Is the effluent quality up to the required standard ? Yes

7. How frequent and by what method (grab or composite etc) were the samples of (5) & (6) above collected ? Composite sample, three times a day.

8. Capacity of treatment of the plant : 505,000 population equivalent (present)
670,000 population equivalent (ultimate)

9. Name and address of the Contractor who constructed this plant : Aoki Construction Co. Ltd.

Is it a local or a foreign contractor ? foreign (Japan)

10. Cost of construction (excluding land cost)
a. In local currency Civil works : HK$ 400 million (approx.)
M & E works : —

b. In foreign currency Civil works : —
M & E works : HK$ 300 million (approx.)

11. What is your opinion on the local skill for construction ?
Very good

12. Cost of operation and maintenance
a. In local currency : HK$ 910,000 per month
b. In foreign currency : —

13. What is your opinion on the local skill for operation and maintenance ?
a. professional level : Very good

b. technical level : Very good

14. Are materials and components readily available locally for operation and maintenance ? Yes

15. Name(s) of the local administration which support(s) the treatment plants' operation :
Electrical & Mechanical Services Department

16. Do you consider the set-ups in (15) above are appropriate and efficient ?
It is efficient but not appropriate. The administration should be under Environmental Protection Agency instead of E&M Dept.

17. Power source for operating the plant
a. Capacity of power req'd :
It is readily available ? Yes
b. Is the power supply reliable ? Yes

18. Training of local people
a. How is the situation of training professionals in the country ?
Very good

b. How is the situation of training technicians in the country ?
......Very good

c. How is the situation of training supporting professions in the country ?
......Very good

19. Soical cultural factors

a. Is there any religious factors that affect the hygiene practices and technology choice in the country ?
No

b. Are the people willing and enthusiastic to improve the existing hygienic facilities ?
......Yes

20. Soical ethics

a. What is the general attitude of social responsibility of the people ?
........Fairly good.... Some industrialists discharge illegal industrial wastewater to public sewers.

b. How are the professionals committed to their jobs ?
......Very good

c. How are the technical staff and supporting staff committed to their jobs ?
......Very good at higher technician level.
......Fairly good at labourer level.

21. Climate

a. Average monthly maximum temperature : ....28.... °C
Month(s) having such temperature : ...July — Sept....
Average humidity : ......90......%

b. Average monthly minimum temperature : ....15.... °C
Month(s) having such temperature : ...Dec — Feb....
Average humidity : ......40......%

c. Length of dry season : ......4...... months,

from ......Nov...... to ......Feb......

d. Intensity and duration of sunshine in a year : ...8 months.....
......May to December......

22. Endemic local diseases

a. Malaria, filariasis, yellow fever : ....Nil....
b. Human round worm and hook worm, fish-borne parasities : Occasional but under control
c. Infectious hepatitis, diarrhoeal diseases ...Occasional......
d. Cholera, typhoid, bilharzia ...Nil......