CHAPTER 3 WASTE EXCHANGE APPROACH

This chapter will explain waste exchange approach that relevant to this thesis. There are three parts as follows:

- explanation the meaning, philosophy, and implementation of waste exchange;
- waste audit approach which explains the methods to identify waste management problems and the possibilities of waste management options to solve problems; and
- feasibility approach which describes how to justify the feasibility of waste exchange project by considering technology, economic and financial factors.

Waste Exchange

Waste treatment is one method to reduce quantity and toxicity of wastes before they are released to the environment. This is an end-of pipe solution. It means that this method will be used after wastes are generated. This method still have limitations since it will transfer wastes from one medium to the others even though levels of quantities and toxicity after leaving treatment facilities are acceptable. Actually this method may reduce only one of many harmful characteristics so that it may increase risk to human health and environmental in some cases. This method also look over opportunities of other methods in reducing wastes that might be better off.

Investigation of EPA in America revealed that even though a lot of effort and money are spent on pollution control but only moderate return on investment and pollution control grades are achieved. From this reason new method called waste minimisation or pollution prevention is developed.

Source reduction and recycling are considered as waste minimisation method as shown in Figure 3-1. But some people argue that waste treatment should also be waste minimisation method since it can reduce quantity and toxicity of wastes.

From Figure 3-1 it can be explained more in details of waste minimisation techniques as follows:

1. Source reduction involve eliminate or reduce wastes in production process by product changes, process modification, raw material changes, good operating practices such as inventory control or waste stream segregation.

2. Recycling is a process of recovering wastes for reuse. Reuse is recycling without any processing. It can be recycle of wastes in production process, recycle on-site, recycle off-site, or waste exchange.

EPA (**Paula A. Comella and Robert W. Rittmeyer, 1990**) also established hierarchy of waste management method as shown in Figure 3-2. Preferred technique which will be applied for waste management starts from tail to the head of the arrow.

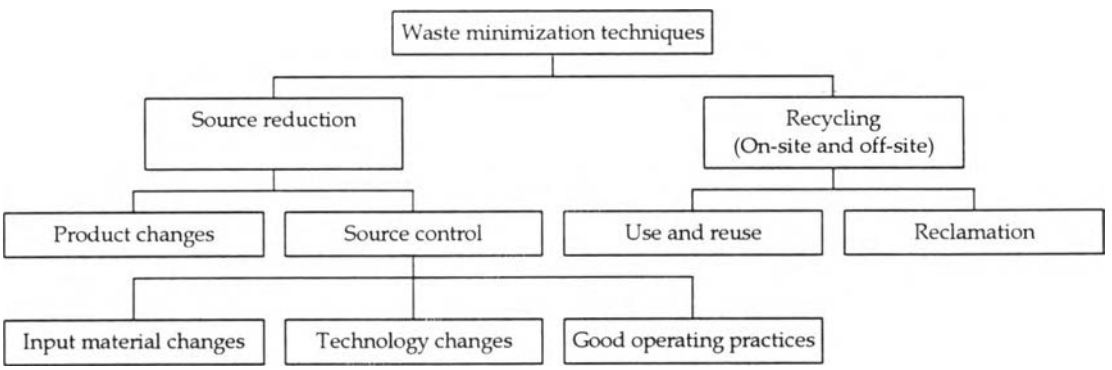

Figure 3-1 Waste minimisation techniques

Source : Paula A. Comella and Robert W. Rittmeyer (1990)

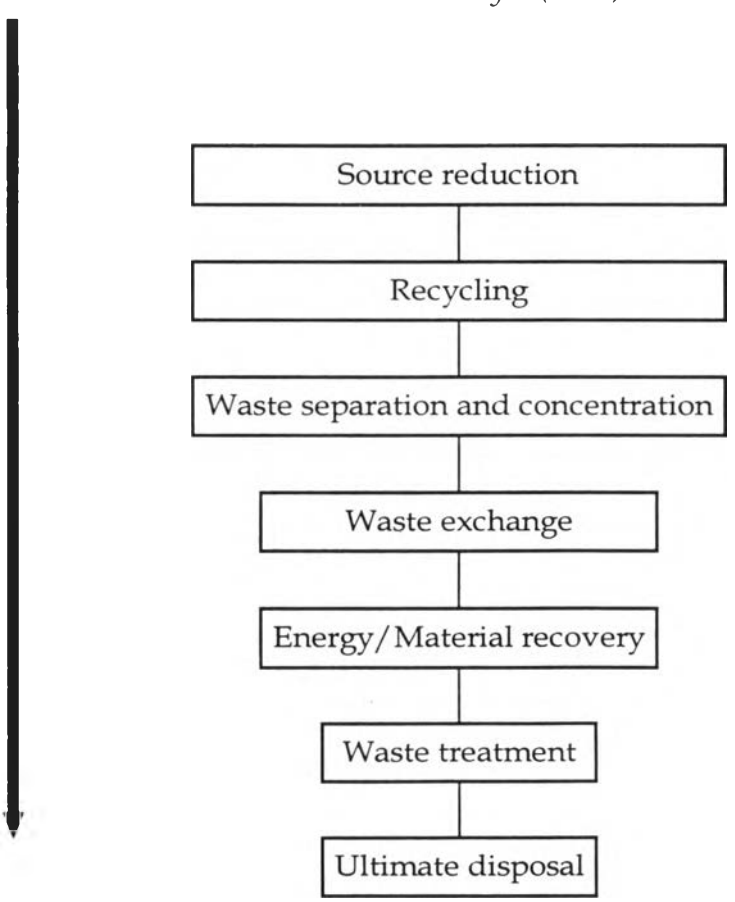

Figure 3-2 US EPA Waste management Priority Hierarchy

Source : U.S. Environmental Protection Agency (September, 1996)

From the above information it can be concluded that waste exchange is one methodology of waste minimisation that would be more accepted in the future. It also is more preferable method than waste treatment. The following will be described in more details of waste exchange.

Waste exchange system can be classified into two types as follows.

1. *Waste information exchange* This system will have the information centre that provide lists of waste available and waste required for waste generators and users of waste respectively. General activities of this system can be explained as follows:

1.1 *Investigate information of waste generators* Waste information exchange centre will survey types, quantities, and quality of available waste and keep this data in data base system.

1.2 *Investigate information of waste users* Waste information exchange centre will survey in the same way as section 1.1. but all data come from waste users.

1.3 *Distribute information* Waste information exchange centre will distribute all recorded information to any industry who is interested via bulletin regularly such as every quarter or every month. Some waste information centre they distribute in formation via computer system. Distributed information may include relevant laws and regulation, how to transport waste, technologies for reuse or recycle waste or waste management technologies.

Potential users of waste can find out the details of waste available such as type, quantity, characteristic from waste exchange centre. If he can find any interesting waste, he can contact directly to waste generator or contact waste exchange centre.

Role of waste exchange centre can be passive exchange centre or active exchange centre. Passive exchange will provide only lists of waste available and material wanted. Active exchange centre will provide the same service as passive exchange centre plus the duty to find potential users for wastes that are difficult to exchange, and contact them to find out how they can use that waste.

Waste information exchange centre will not involve in negotiation between waste generator and waste user for trading waste. But he will co-ordinate between two person to make trading waste happen. Most waste information centres will operate by government and they do not want profit from their services. Their income mostly come from fee of listing available waste or wanted waste, budget from government, or donation from industries.

Example of this system such as waste information exchange centre that operate in UK since 1974 by government. It distributed information every 3 month for five year. During that time anyone who received this service did

not pay money and has 5,000 members from the start. After it begun to charge the cost, number of members are reduced and now it does not exist.

Another example of country that use this system is Ontario in Canada. Ontario foundation research has distributed bulletin every six month since 1978. It had 3,700 members at beginning operation. Now it has cost of operation approximately 45,300 US$ per year. Twenty percent of operation cost has been supported from Environment Canada, twenty five percent of operation cost come from industries, and the rest come from local government body. Concept of operation is shown in Figure 3-3 and Figure 3-4.

2. *Waste material exchange* Waste material exchange centre will buy valuable waste from waste generators or anyone who own usable waste and may be purify it before selling to waste users. This organisation is not non-profit centres so that there will have some certain types of waste for reuse or recycle.

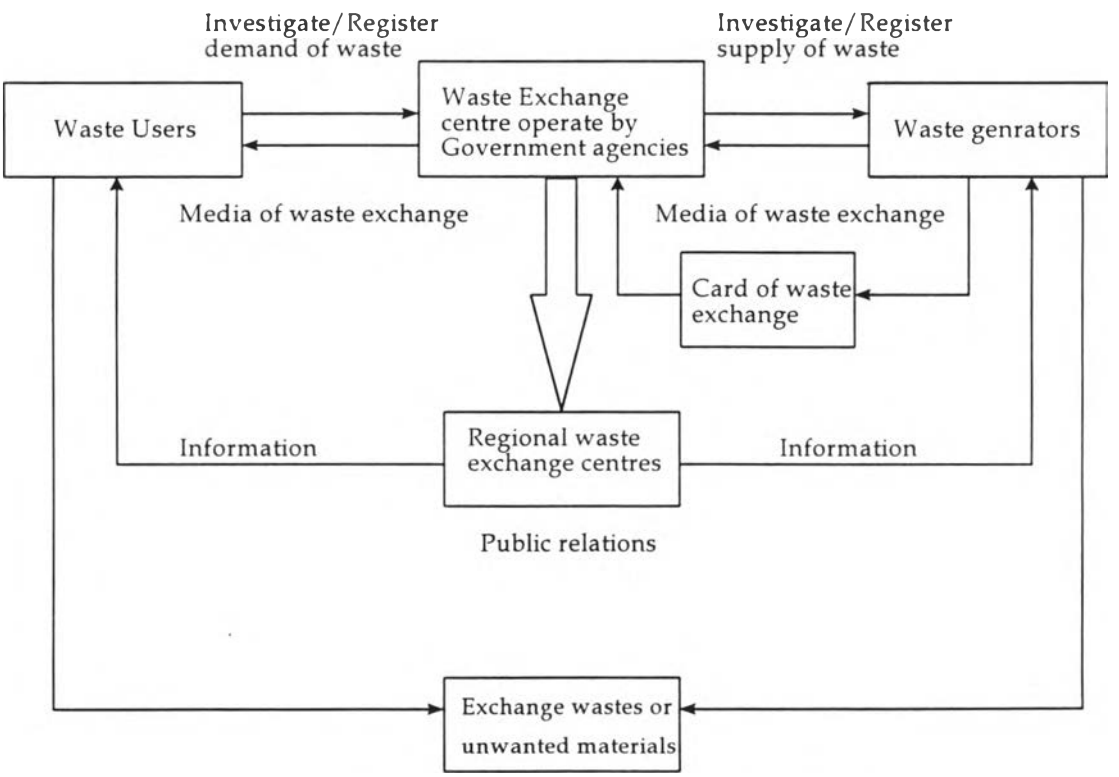

Figure 3-3 Concept of operation for waste exchange by government sector

Source : Rangsan Pinthong (1994)

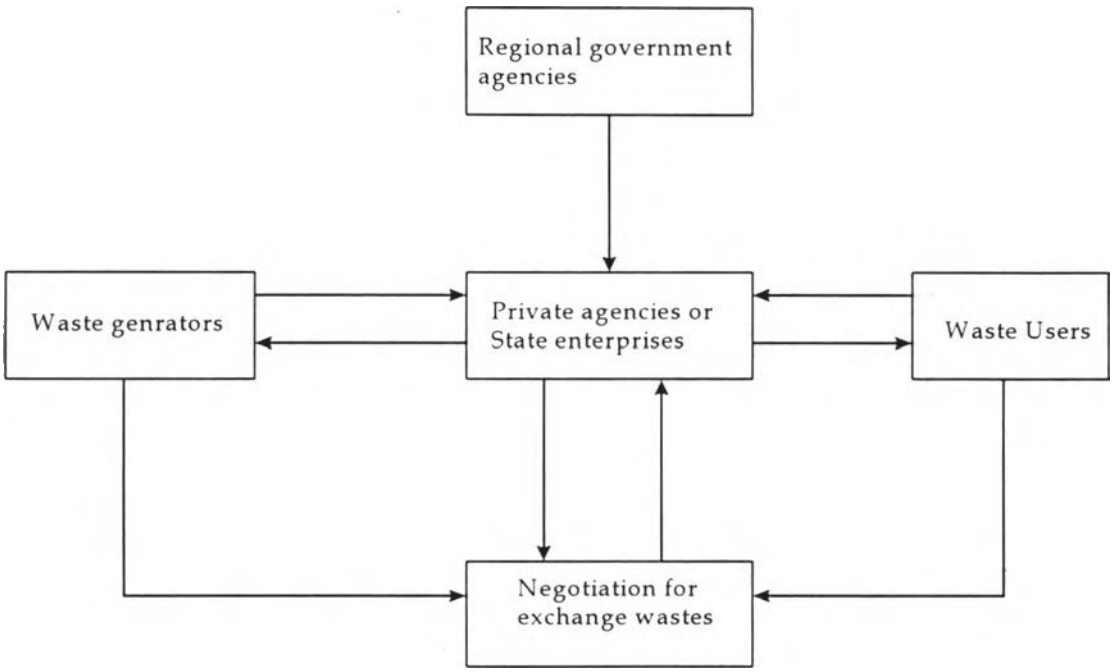

Figure 3-4 Concept of operation for waste exchange in corporation of government and private sector

Source : Rangsan Pinthong (1994)

Waste Audit

In order to identify the possibilities of sustainable waste management, industries should conduct waste audit. The effective methods to conduct waste audit should consist of : (**CIET, 1997**)

- an appropriate techniques and analysis to satisfy and identify an organisation's waste management goals;
- accurate collection waste management data; and
- a logical sequence of steps to create a plan to reduce wastes.

Normally, there are six steps for undertaking waste audit. The detail of each step are explained as follows : (**CIET, 1997**)

1. *Review operation* This step will help us to understand the background information of industries by considering operation characteristics of facilities and current waste management practices. For instance, information concerning operation characteristics of the facility is type of operation, capacity of facility, number of employees and operating days etc.

For a large facilities, information of each department has to be conducted in more details. For example, what is major function or product of each department, how many employees in each departments are, and how

much area that each departments occupy, and what operation time of each departments is.

To consider current waste management, auditor has to examine waste disposal and handling, size of waste containers, and frequency and timing to dispose waste, current recycle or reuse, quantities of waste for recycling or reuse, disposal costs, and recycling or reuse costs.

2. *Identify Wastes* Auditor has to find out what types of wastes are generated and from where, and these wastes are mixed or separated. Specified types of wastes should comply with laws and regulation, if possible.

3. *Plan Your Audit* This step will identify methodology, sample of waste for analysing, and resource requirements. Methodology which auditor will select depends on available data and level of accuracy. Normally, there are three methodologies for waste audit.

- *The visual assessment* This method is simple and take little time but low accuracy. This method is useful if waste is homogeneous. Auditor can perform this method by walking through all area of facility to estimate volume and composition of generated waste in different area.

- *Waste Sampling and Sorting* This method will sample waste to find composition of wastes and sort types and estimate quantities of wastes in each area. It is suitable for mixed waste or large volume. It also requires more detail and accurate than the visual assessment.

- *The Input/Output Assessment (Mass balance method)* This method is best appropriate for production process. It use material balance method of input and output to define types and quantities of waste. It give the insight of all processes in facility. Accuracy of this method is highest but it requires highest resources and time.

Criteria to select the suitable waste audit methodology are :

- level of accuracy;
- available of manpower, time, money, and equipment;
- nature of operation and size of facility; and
- season of operation/operational changes.

After methodology is chosen, auditor has to define the way to sample waste and prepare of resources to conduct waste audit. Available options for waste sample are either sample at each significant location or sample at end of pipe. Sampling at each significant location such as major activity is suitable for more different wastes. And sampling at the end of pipe or disposal point is suitable for consistent composition of waste throughout all areas of facility. When area in facility for conducting waste audit is small, it is recommended to estimate composition of wastes by sampling total amount of waste. But if area is large, it is recommended to use representative sample from that area to estimate waste composition.

4. *Conduct the Waste Audit* Auditor will conduct waste audit according to selected methodology to identify types and quantities of wastes.

5. *Analyse Waste Audit Data* Collected data will be analysed i.e. to calculate waste generation rate (normally annual basis is used) which may help industries understand problems or inefficiency of processes, and disclose opportunities of sustainable waste management practices i.e. reduce, recycling and reuse of wastes.

6. *Prepare Waste Audit Report* Information of quantities and types of wastes generation will be combined into a report for further using.

Another thorough procedure of waste audit (**UNEP/UNIDO, 1991**) comprises three phases.

1. Phase one is pre-assessment phase for audit preparation. This phase has three steps; preparation and organisation audit team and resources; dividing process into unit operations; and construction process flow diagrams linking unit operations.
2. Phase 2 is data collection phase for deriving material balance. There are ten steps in this phase. First three steps involve identification of process input by determining inputs, recording water usage, and measuring current levels of waste reuse or recycling. Four steps are concerned finding process output by quantifying products/by-products, accounting for wastewater, gaseous emissions and off-site wastes. The last three steps are related to deriving a material balance by assembling input and output information, deriving a preliminary material balance, and evaluation and refinement material balance.
3. Phase 3 is synthesis phase which will translate results from material balance into waste reduction plan by identifying major sources of waste, operation and process efficiency, and unexplained losses. This phase can be divided into three majors steps; identification of waste reduction options which include long term and short term plan; evaluation of waste reduction options,; and designing and implementation waste reduction plan.

Detailed procedure of all steps in each phase are described in below.

Phase 1 Preassessment

Step 1 Preparation and organisation audit team and resources This step will prepare all necessary information and resources for waste audit and also set up waste audit team before next steps will be proceeded.

It is necessary to get support from top management level for waste and implementation results otherwise successful of this activities cannot be gained.

Member of waste audit team which depend on the size and complexity of audited process or plant and external resources requirements such as laboratory analytical facilities or sampling equipment will be identified.

Objectives and scope of work shall be defined in this step. Waste audit team should review all existing information and documentation concerning interesting process or plant to get familiar. If necessary, site survey should be undertaken.

Plant employees shall be informed about waste audit and encourage to take part since they are one important key factor to make waste audit success.

Step 2 Dividing process into unit operations In this step, unit operations of process or plant will be listed and identified their function, area of process, equipment, input, and output. Waste audit team should walk around process or plant to get more insight how interrelationships they are. They have to understand the function and process variables of each unit operations. Any obvious problems should be addressed.

Step 3 Construction process flow diagram linking unit operations After waste audit team understands functions of each unit operations and how they are connected. Process flow diagram of them has to be drawn to represent flow line of inputs and outputs from each unit operations and how each unit operations are connected. Waste audit team has to decide level of detail in investigation process or plant. Important area especially obvious problems should be examined in the early stage.

Phase 2 Data collection for deriving material balance

Step 4 Determining inputs Net inputs to process or plant and inputs to each unit operations shall be identified. These can be done by examining purchasing records. If some figures are not available, calculation from number of storage tanks or sacks and asking from plant operators can give the reliable information.

Step 5 Recording water usage Since all or some portion of water usage will be wastewater after it can no longer use or spill off. If water usage can be reduced, wastewater will be reduced which means water cost and treatment costs are reduced. From this reason, water usage is included in waste audit procedure to see how effectively uses of it. Source of water supply and points of supply shall be investigated. Waste audit team has to examine how many unit operations use water and how much using rate is. They may have to monitor water usage of each unit operations by using some measuring devices.

Step 6 Examination current reuse and recycling Current reuse or recycling of any material or water has to be defined otherwise double counting quantities will be occurred. If it happen, calculation of material balance will be wrong and it causes improper planning and decision making in next steps.

Step 7 Quantifying products/by-products Waste audit team has to quantify quantities of outputs in form of solid, liquid, and gas which leave from each unit operators and process as a whole. Outputs can be products, by-products, wastewater, or gas emissions. In case where outputs from any unit operations are difficult to quantify, waste audit team should use production rate which measured over a period of time for calculation outputs.

Step 8 Accounting for wastewater In this step, strength and quantities of wastewater from all unit operations and process as a whole has to be measured by sampling and analysing it. Types of contamination and their concentration have to be identified.

Step 9 Accounting for gas emissions As wastewater, gaseous emissions have to be accounted. In this case, it can be difficult to measure because gaseous emissions are not always obvious. Waste audit team can estimate quantities by using stoichiometric information.

Step 10 Accounting for off-site wastes Quantities and types of off-site wastes has to be accounted. Information of how and how long they are stored prior to dispatch shall be collected. Investigation of whether storage of these wastes cause any additional environmental problems shall be done.

Step 11 Assembling input and output information Information from step 8-10 should be combined and put it to the block diagram which represents unit operation. At this step, waste audit team has to decide which inputs and outputs should be included in material balance. Units of measurement should be standardised by using weight per day, per year or per batch basis.

Step 12 Deriving preliminary material balance material balance will be derived in this step by using weight units. Normally when we derive material balance, volume units will not be used since they are not always conserved. It may be necessary to repeat procedure for each concerned contaminant.

Step 13 Evaluating material balance This step will examine gap or imbalance of results from deriving material balance. If there are significant difference between inputs and outputs, further investigation is required. Review of material balance for each unit operations should be done to ensure that there is no overlooked or unnoticed losses.

Step 14 Refining material balance After a significant difference between inputs and outputs is found, adjustment of material balance by adding necessary factors or estimation of unaccountable losses should be done. For high strength or hazardous waste, accurate measurements are required to design waste reduction options. Be in mind that in theory inputs have to be equal outputs. But in real life it is rarely happen.

Phase 3 Synthesis

Step 15 Identifying obvious waste reduction measures Waste audit team should identify are which can be reduced waste by simple adjustments

in procedure. Significant waste reduction can often be met by improved operation, better handling and storage, and taking more care.

Step 16 Targeting and characterising problem wastes At this step, causes of waste generation and factors that lead to these cause are considered. Waste audit team should characterise each waste generation and give priority to reduce waste.

Step 17 Examination the possibilities of waste segregation Waste audit team should examine whether there is any possibility to segregate wastes. Since this method can enhance opportunity of reuse and recycling, waste treatment costs can be reduced.

Step 18 Identifying long term waste reduction measures Long term waste reduction plan and possibilities of it for example changes in production process, process control, or raw materials uses should be considered.

Step 19 Evaluating waste reduction options by considering environmental and economic terms Economic and environmental evaluation of each waste reduction options shall be conducted. The results of each options shall be compared to support decision making.

Step 20 Designing and implementing waste reduction action plan Action plan shall be set up for short term waste reduction which reveals from step 15 and long term waste reduction which reveals from step 18-19. Monitoring plan shall also set up to check how the progress of implementation plan is. This results should be published to let all employees know how effective of this plan is. Record keeping system for supporting waste audit and material balance shall be adopted. Incentive or disincentive systems to promote waste reduction plan should be design and implemented.

All these steps of waste audit should be done regularly. Employees especially for person who work in the process should be trained to undertake waste audit. This will help to improve their awareness of their operations and how they can contribute to reduce wastes.

Feasibility Study

The objective of feasibility study is to provide the basic information for deciding whether to begin and continue project or not. It also help decision makers to select the most desirable alternatives among the others.

The objective of feasibility study is not to find out whether the project is good enough to be financed but to determine the best alternative under specified conditioned.

Feasibility study must contain technical, economic, and commercial analysis of critical elements that involve production or operation of products or services. Each elements is evaluated not only separately but also in relation to all the others. It means that selection of the right technical aspect will depend on the scope of the market or demand and supply of products or

services, capacity of agency, and attitude and behaviour of consumers and producers.

Feasibility should define production capacity at selected location, technologies, materials and inputs to be used, investment and production costs, sales revenue, and return on investment.

Most feasibility studies have the same or similar areas of study even though each project has different magnitude, complexity and nature. Regardless these factors, feasibility study have to answer the following basic questions. (**Baum, Warren C., Tolbert, and Stoke M, 1985**)

- Does the project act accordance with development objectives and priorities of country?
- Is the relevant policy framework compatible with achievement of project's objectives?
- Is the project technically sound and is it the best available technical options?
- Can the project administrative be done?
- Is there enough demand for the output of project?
- Is the project economically justified and financially successful in operation?
- Is the project environmentally sound?
- Is the project compatible with the traditions and customs of the beneficiaries?

It should bear in mind that the large project will be required more information than the small project. Iterative process with feedback loops and interlinkages should be launched in order to achieve all above objectives.

When technical aspect in feasibility study is evaluated, it should be done only in preliminary engineering considerations. Since detailed engineering is time consuming and cost a lot of money, it should be done after project is selected to proceed.

Economic analysis of benefits and costs should be conducted to the point that economic rate of return can be calculated with a reasonable recommended degree of accuracy. The analysis should discover whether the demand of project will make the output to be sold at prices that are pay.

Financial analysis should discover the financial attractiveness to investors, intended participants, and beneficiaries. It should give general outline of a financial plan to make sure that there are available funds to operate the project. Feasibility study may define further actions that should be done otherwise objectives of project and successful in operation may not be achieved.

Other aspects such as institutional, environment, and managerial should be conducted in feasibility analysis since they have an important effect on successful of project.

Feasibility study can base on market oriented or material inputs. That means initiative of feasibility study come from an assumed or existing demand or form available material inputs.

Feasibility study is not the end process but it arrive at an decision on investment that is not necessary to have the same conclusion as in this study. It is rarely find that decision of investors is fully conform the results of feasibility study.

The following will explain project selection criteria that normally use for economic analysis.

1. *Net Present Value* It is defined as the present value of the total benefits minus total costs then convert the result into present value. The formula for this method is

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \text{ or } \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t}$$

Where
- NPV = Net Present Value
- B_t = Benefits in year t
- C_t = Costs in year t
- i = Discount rate
- n = final year of consideration

Project should be selected when net present value is positive. It should be rejected, if net present value is negative. In case of zero net present value, project mat be accept. When many projects are compared, project that give highest positive value should be selected.

2. *Benefits-Costs ratio (B/C)* It is the ratio of total benefits to total costs of project. The formula for this method is

$$B/C = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}}$$

Project should be accepted if Benefits-Costs ratio is higher than unity. If not, project will be rejected. When alternatives are compare, the project that give highest Benefits-Costs ratio should be selected.

3. *Internal Rate of Return (IRR)* It is the discount rate that give net present value equal to zero or net present value of total benefits equal to net present value of total costs. The formula of this method is

$$\sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} = 0 \quad \text{or} \quad \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$$

Decision rule for this method is to accept the project when internal rate of return is higher than specified value. When many projects are compared, project that give highest value higher than specified value should be selected.

A critical point of net present value and benefits-costs ratio is selection of discount rate. An appropriate discount rate should be selected. The higher discount rate, the lower net present value and benefits-costs ratio, and vice versa.