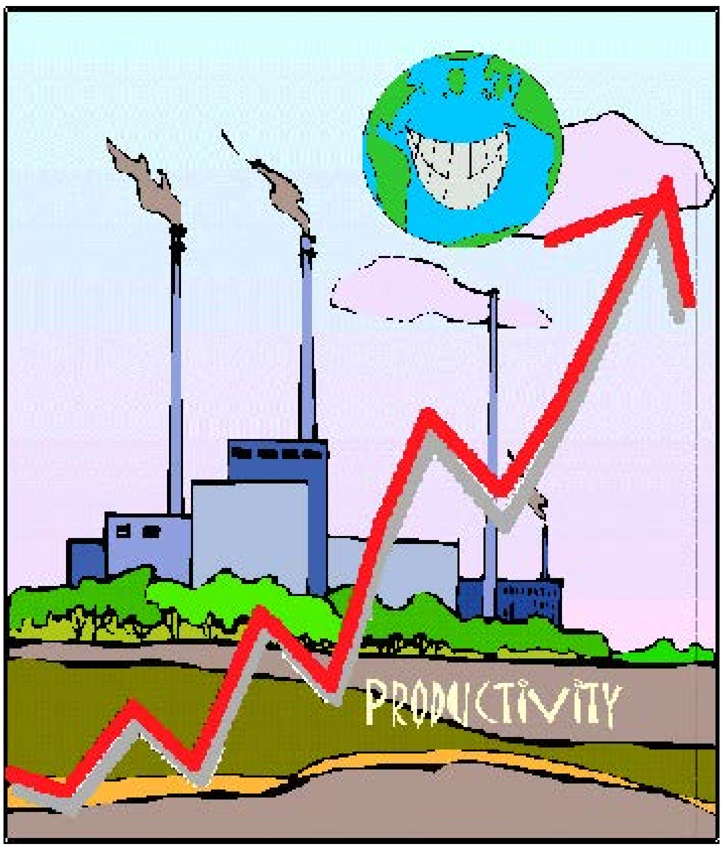
ACHIEVING HIGHER PRODUCTIVITY THROUGH GP



ASIAN PRODUCTIVITY ORGANIZATION

CONTENTS

ABSTRACT

Productivity has become a national priority for all economies. Whether you are a policy maker, businessman or worker, our sustainable prosperity depends on our ability to increase productivity. At the same time, environmental protection and sustainable development have also become vital for countries and enterprises.

A strategy to simultaneously enhance productivity and environmental performance to enable sustainable development is Green Productivity (GP). It is the application of appropriate productivity and environmental management tools, techniques and technologies to enhance productivity and protect the environment.

This booklet shows what Green Productivity is all about and how to implement it. It explains the Green Productivity Methodology, a step-by-step procedure developed by the APO for exploiting maximum GP opportunities. It provides a brief walk-through of the 6 steps of the GP Methodology: Getting Started; Planning; Generation, Screening, Evaluation and Prioritization of GP Options; Implementation of GP Options; Monitoring and Review; and Sustaining GP.

To support the GP Methodology, a set of GP tools and Technologies are used to draw quantitative and qualitative conclusions. This booklet summarizes 14 of the GP tools and Techniques that can be used. They are: Brainstorming; Flowchart; Plant Layout; Material and Energy Balance; Ishikawa Diagram; Pareto Diagram; Cost Benefit Analysis; Decision Matrix; Source Reduction; Recycle, Reuse and Recovery; End-of-Pipe Treatment Technologies; Designing Environmentally Compatible Products; 7 Wastes of Production; and 5S – Good Housekeeping Practices.

Finally, this booklet provides an interesting case study of a mushroom canning factory in Malaysia. Information on the factory is provided for managers to try out their understanding of the GP approach. Using this information, managers can apply the GP Methodology and obtain solutions to enhance productivity and environment performance of the factory, using GP tools and Techniques. A useful glossary of terms used in discussions on GP is provided at the end of the booklet.

1. UNDERSTANDING PRODUCTIVITY

1.1 Introduction

Productivity is not just confined to industries only. It is relevant to all organizations and business activities. Productivity consciousness is pertinent to all of us and should be a way of life. At home, doing a job without planning very often leads to a lot of unnecessary tasks and reworks that will result in a waste of our effort. In school, the wrong method of teaching will also lead to a waste of effort for all concerned. Water wastage from leaking taps is a waste of the earth's natural resources and in shows a lack of productivity consciousness. Wasting raw materials, utilities and manpower in the workplace will result in less profitability for shareholders of the company. Everyday, we consume the earth's natural resources like water, fuel, trees, food and so on. If we continue to do so in an unproductive manner, depletion of these natural resources might occur. In an extreme scenario, many unproductive and less environmental-friendly industries may continue to pollute the environment that create or regenerate much-needed natural resources.

The population of the world is about 6.3 billion in the year 2002 and is still growing at a projected declining rate of about 1.2% per annum. If the projected growth is true, will we have enough food to feed everyone in future? Will we have enough land to cultivate our food and build houses to live in? Will we have enough jobs or business opportunities for the younger generations? There are no definite answers to these questions. To ensure a better tomorrow, we must strive to make full use of all available natural, human, and man-made resources to speed up development. The solution is to increase productivity. Be it for a country, a company or an individual, we must be able to increase our output at a rate faster than the rate of growth of the world's population while maintaining the same or lesser amount of resources being consumed.

Over the last decade, the word "productivity" has become a common phrase among governments, policy makers, economists, industrialists, environmentalists and workers. In fact, productivity has become a national priority for all economies, be they developed or emerging. This is because the sustainable prosperity of most countries depends on the countries' ability to continuously produce more output per unit resource used. Furthermore, productivity improvement fuels economic growth, keeps a lid on inflation and enables a higher standard of living. At a micro-level, productivity improvement means increased competitiveness for a company, and higher wages and better quality of worklife for an individual.

1.2 Definition of Productivity

The technical definition of productivity is a relationship between the quantity of output and the quantity of input used to produce the output.

Productivity = Output[1] */ Input*[2]

[1] Output includes products and services that can be represented by sales, value added or physical quantities.
[2] Input includes labour, raw materials, machinery, energy, capital and so on.

In other words, productivity tells us the number of units of output that can be obtained from a unit of input. A strict mathematical interpretation of the productivity equation shows that productivity can be improved by increasing output or decreasing input. However, it is important to note that productivity is not a mere pursuit of efficiency and there are instances where an increase in productivity may not be desirable. For example, higher productivity should not be achieved at the expense of quality requirements. Quality requirements by the customers may include the quality of the product or service itself, timely delivery, reasonable pricing and work processes that do not cause problems to the environment. An organization cannot be considered productive if it produces the highest number of goods in the shortest length of time, but has the goods rejected because of shoddy quality or causes environmental pollution during the life cycle of the product/service.

Productivity is qualitatively defined differently in different parts of the world but essentially the meanings are largely similar. In fact, productivity is really an "attitude of the mind[3]". It is about people adding value to a work process by their skills, team spirit, efficiency, pride in work and customer orientation, aided by machines and systems. Thus, productivity is not just about getting maximum efficiency by "doing things right" but also achieving maximum effectiveness by "doing the right things". It is necessary to go beyond the basic input-output relationship to understand the determinants of productivity improvement. This means that productivity should perhaps be defined as:

Productivity = *Efficiency + Effectiveness*

= *Doing things right + Doing the Right Things*

1.3 Measuring Productivity

Productivity is usually measured by ratios that are obtained by dividing an output by an input. However, there are several measures of output and input. Output can be measured in gross terms such as sales, or after deducting purchased inputs to derive value added or wealth created. For specific operations, it is possible to measure output in physical terms such as number of computers produced or number of customers served. At the national level, the measure used is gross domestic product (GDP). As for inputs, measures include workers, capital, materials and energy, among many others.

There is a multitude of productivity indicators differing not only in computation but also in concept. This can be advantageous because different measures can be used depending on the purpose of measurement and the availability of data. The types of measures vary with the number of inputs. If output is related to only one input, we obtain a partial productivity measure. For example,

Labour Productivity = Output / Labour
Material Productivity = Output / Raw Materials
Energy Productivity = Output / Energy
Capital Productivity = Output / Capital

[3] Based on the definition by The European Productivity Agency's Report of the Rome Conference, "The Concept of Productivity and Aims of the National Centres" in 1958. See the glossary for definition.

On the other hand, if output is related to several inputs, we obtain a total productivity measure. In practice, owing to data limitations, most measures of Total Factor Productivity only take into account labour and capital. For example,

Total Factor Productivity = Output / (Labour + Capital)

For those who are particular in measurements, the term "Multi-Factory Productivity" is sometimes preferred. In this case, the denominator of the ratio includes all inputs that are being taken into account.

Additionally, the Value Added method is another method that is used to measure productivity. This method has become increasingly popular in recent times. It basically involves using output to measure the additional wealth created by a company through its production or service operations. It is derived by subtracting the inputs, like brought in materials and services, from the output, which can be revenue or sales. For example, a company buys materials and adds value to it through their production processes to create products that command a higher value than the original raw materials. This wealth created by the company is distributed back to the people who have contributed to its creation. In most cases, value added is distributed as wages to employees, distribution for investment in machineries and facilities, profits to the enterprise, taxes to the government and interest to lenders of money. As such, value added can also be computed using the Subtraction Method or the Addition Method.

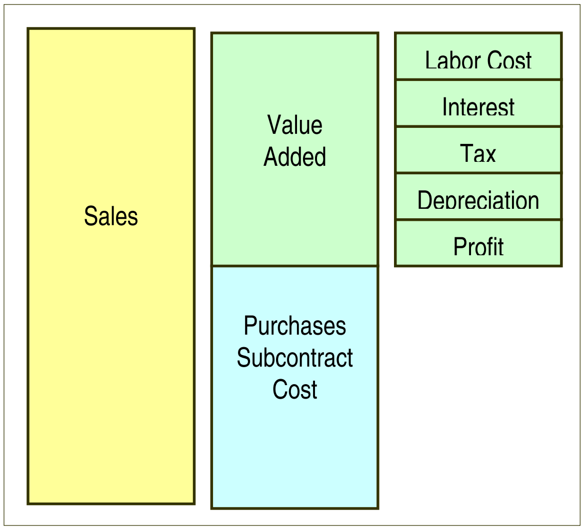


Figure 1 : Concept of Value Added

Value added = Total Sales - Brought-in materials and Services[4]

= Labour Cost + Interest + Taxation + Depreciation + Profit

1.4 Some Practical Measures of Productivity

There are many types of productivity measurement indicators being used at the enterprise level. As the process of measurement and monitoring consumes resources, the selected indicators must be simple, useful, easy to understand and the data must be easily available in the enterprise.

Labour Productivity

Labour Productivity is a ratio that determines the value added per employee and its mathematical formula is given by:

Labour Productivity = Value added / No. of employees

[4] Brought-in materials and services usually included raw materials, brought-in components, subcontract cost, packing materials, fuel cost, transport and freight cost, consumable stores, loose tools, maintenance cost and so on.

However, it can be further decomposed as follows:

Labour Productivity = Value added per dollar of sales x Sales per employee
(Value added / Sales) x (Sales / No. of employees)

The value added to sales ratio and the sales per employee ratio work together to determine the value added per employee.

Labour Cost Competitiveness

Labour Cost Competitiveness is a ratio that determines the value added per dollar of labour cost and its mathematical formula is given by:

Labour Cost Competitiveness = Value added / Labour Cost

However, it can be further decomposed as follows:

Labour Cost Competitiveness = Value added per employee / Labour cost per employee
(Value added / No. of employees) / (Labour cost / No. of employees)

The value added per employee ratio and the average labour cost ratio work together to determine the labour cost competitiveness.

Fixed Assets Productivity

Fixed Assets Productivity is a ratio that determines the value added per dollar of fixed assets and its mathematical formula is given by:

Fixed Assets Productivity = Value added / Fixed Assets

However, it can be further decomposed as follows:

Fixed Assets Productivity = Value added per employee / Fixed assets per employee
(Value added / No. of employee) / (Fixed assets / No. of employees)

The value added per employee ratio and the fixed assets per employee ratio work together to determine the fixed assets productivity.

Performance Ratios

In relation with the key productivity ratios, various performance ratios can be generated to complement the productivity measurement system of an enterprise. For example:

- Cost of materials / Sales
- Sales / Average merchandise inventory
- Cost of goods for resale / Sales
- Materials used in product / Total materials consumed
- Number of rejects / Total number of products produced
- Electricity used / Unit of product produced
- Sales / Floor area of facilities

- Number of complaints / Total number of customers served

1.5 Approaches to Achieve Higher Productivity

There are many different approaches in which productivity can be improved. However, the choice of tools varies with the needs of the enterprise. The needs can be customer focused where enterprises introduce Total Quality Management (TQM) techniques and tools or it can be the approach of Total Productive Maintenance (TPM) where enterprises make heavy investments in machineries. For those enterprises in the assembly industry where inventory management is a major concern, the Just-In-Time (JIT) approach is usually adopted. The development of ISO 9000 Quality Management System has helped enterprises to standardize their improvements and incorporate them as part of the company's standard operating procedures.

Over the years, apart from rapid industrialization in many developed and emerging economies, there has been also a lot of concern about environmental degradation. As such, governments all over the world have since started to enforce environmental protection laws. In order to comply with the environmental laws, enterprises have resorted to techniques like dilution, treatment, prevention and the modern technique of eco-efficiency to deal with the waste generated in their business operations.

In fact, environmental protection and sustainable development have become the main motivation behind national and enterprise-level development strategies. For example, enterprises are driven by their customers and local authorities to comply with environmental protection standards by implementing Environmental Management Systems like the ISO 14000. This has led to the integration of environmental protection activities in the productivity systems of many enterprises. The evidence of this phenomenon can be found when we examine the mechanics of business operations outlined in the next section.

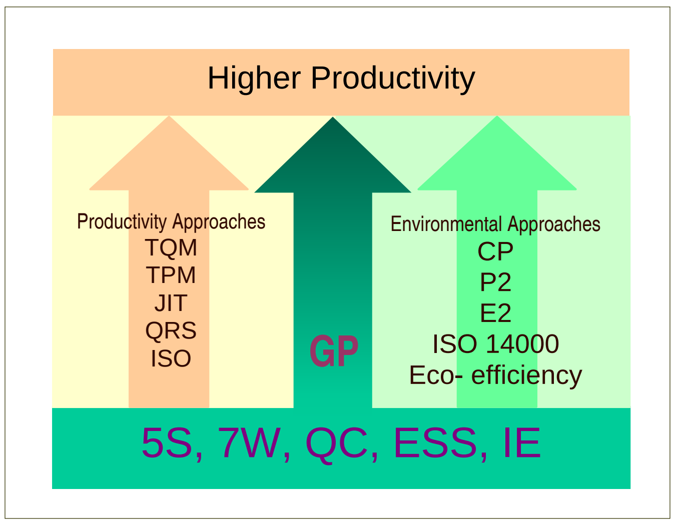


Figure 2 : Approaches to Achieve Higher Productivity

1.6 The Mechanics of Business Operations

At the enterprise level, in order to achieve optimum results in the day-to-day running of business operations (other than funding issues), the management will usually have to physically deal with the 4M's of operations so that all resources can continuously operate in a balanced condition. The 4Ms being referred to are manpower, materials, machines and method.

Manpower

In most of the developed or emerging economies, labour cost usually makes up a large proportion of the total expenses in enterprises and it usually increases with time. As such, in order to stay competitive, enterprises strive to keep their labour force lean and trim through techniques like mechanization, automation and computerization. Productivity of the output generated also depends on the skills of the workers. As such, sufficient training and a conducive work environment is essential in order to develop and retain skilled workers. For examples, enterprises must ensure that their facilities fulfill occupational health and safety requirements. This is to ensure that accidents would be unlikely to occur, and local authorities would not intervene to shut down the factory for a long period of time. This means that there will be potential savings in lost of operation time that will affect the morale of workers. Similarly, environmental pollution caused by discharging pollutants into the environment may also affect the environmental quality and health of the people working and living in and near the premises.

Materials

Enterprises should dispose their material wastes in a proper manner that would not cause pollution to the environment. Additionally, enterprises must also utilize their resources efficiently so as to prevent wastage of natural resources. From the productivity perspective, reducing material waste will lead to a reduction in the cost of the products and services produced. On the other hand, from the environmental perspective, reducing wastes means less environmental pollution.

Machines

Utilisation of proper and efficient machines is important for an enterprise to remain competitive. The machines must help the enterprise produce defect-free produces or services in a shorter time while consuming lesser manpower in the process. The machines must also be maintained such that the incidence of breakdowns is kept to a minimum as these will cause enterprises to incur loss in overheads, labour cost and material cost. In cases where defects occur, materials used in manufacturing of the defective products will be wasted. Thus, this consumes unnecessary raw materials or natural resources. Other areas concerning machines are industrial safety, industrial health and noise pollution. Enterprises are required by local authorities to comply with the requirements on occupational health and safety. Hence, improving productivity implies less environmental pollution.

Method

The method of processing raw materials into finished products is important as poor and outdated processing methods will lead to a waste in labour cost and material cost. Some processes do generate unnecessary pollutants like smoke and trade-effluent. Therefore, end-of-pipe treatment of these pollutants must be done before discharging them into the environment. The treatment of using scrubbers to clean the polluted air emitted or the use of wastewater treatment facilities will increase the overall cost of operation. Such expense will become a production waste that will ultimately affect the productivity of the factory.

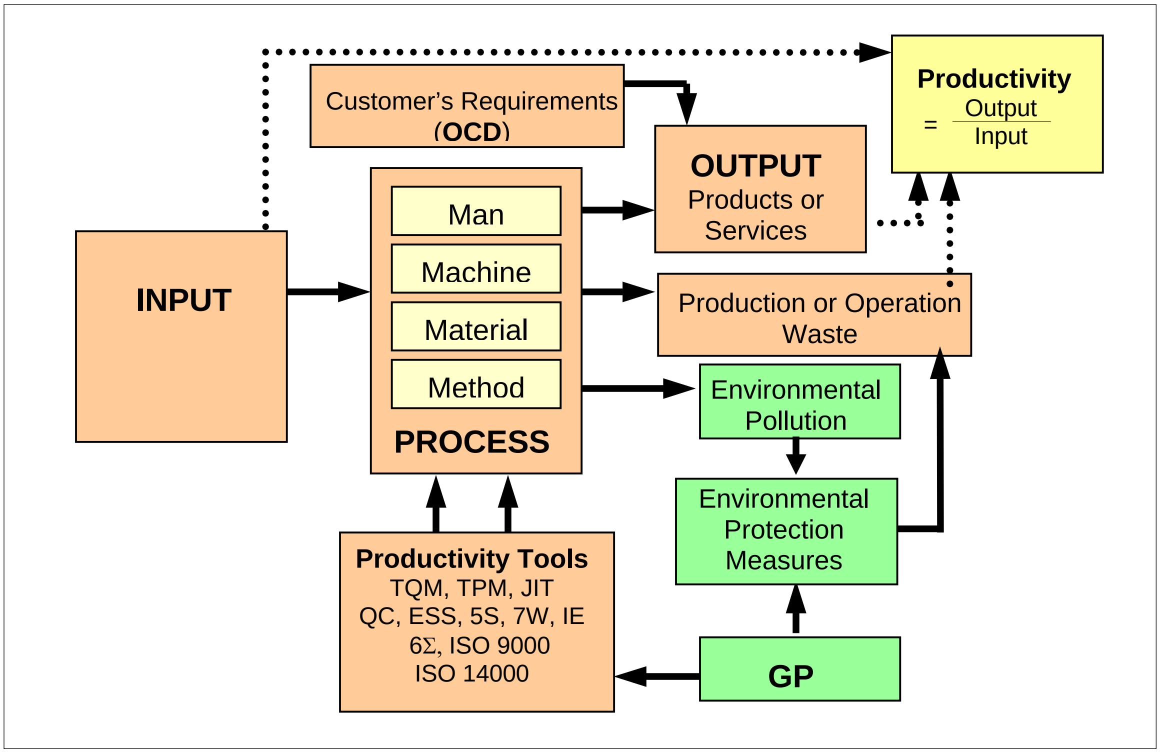


Figure 3: The Mechanics of Business Operation

1.7 Quality, Cost and Delivery (QCD)

Other than managing the 4Ms of Operations, enterprises must also focus on the requirements of customers. After all, they are the ones who decide to buy from the Enterprise. Usually, other factors being equal, customers would base their decisions on 3 main requirements; Quality, Cost and Delivery (QCD). As such, improving productivity can also mean meeting requirements of customers and improving each element of the requirements. We can improve productivity through improving quality. However, quality is not about the quality of products and services per se, but it is also about the quality of resources and production processes used to produce those goods and services. This is because any problems in the production process will lead to poor quality in the final products and services produced. As a result, this will lead to customer dissatisfaction.

We can reduce the cost of the product through improving the production processes. This is because productivity is after all measured by the number of units of output produced by a unit of input. Therefore, production management must take into account the importance of reducing costs while increasing the value-added element of production.

By focusing on delivery requirements, we can ensure that the thru-put time and lead-time of production be improved to its optimum level. This is because whether the item is a finished product, a part or a basic material, the customer has plans for its use. If the item is not delivered on schedule, the customer's plans will be disrupted. The customer will thus lose confidence in the producer and is most likely not going to make any more orders from that producer. In other words, if enterprises can satisfy their customers with high-quality (Q) products and services, at a lower cost (C), and with shorter and timelier delivery (D) than their competitors, they would be able to remain competitive and eventually perform well. All in all, the key word is again, sustainable development.

1.8 The Approach of Green Productivity

Unlike most of the known techniques adopted by enterprises for improvement, the approach of Green Productivity does not just focus on environmental issues alone; it also addresses issues pertaining to productivity. In fact when Green Productivity is implemented, enterprises would experience productivity improvement through reduction in expenditure on environmental protection through source reduction, waste minimization, pollution prevention and cleaner production. Hence, companies can now achieve higher productivity while protecting the environment that will enable sustainable development. Green Productivity (GP) is defined as a strategy for simultaneously enhancing productivity and environmental performance for overall socio-economic development. This strategy is executed through the application of appropriate techniques, technologies and management systems to produce environmentally compatible goods and services.

Green Productivity (GP) is a strategy for enhancing productivity and environmental performance for overall socio-economic development. It is the application of appropriate productivity and environmental management tools, techniques and technologies to reduce the environmental impact of an organization's activities, goods and services.

Definition by the Asian Productivity Organization (APO)

This concept was coined by the Asian Productivity Organization (APO) in 1994[5] to raise public awareness on the environmental problems[6] faced by the world today. APO's main objective is to demonstrate that environmental protection and productivity improvement can be profitably harmonized, even in small and medium enterprises. This is because more often than not, the production processes of the small and medium enterprises are inefficient. Their production processes often lead to wastage of resources like raw materials and energy, which generate a heavy burden to the environment. Therefore, APO implemented a series of Green Productivity Programs for National Productivity Organizations (NPOs) to put into practice the concept of GP. Essentially, the implementation of Green Productivity is to achieve higher productivity and at the same time provide *sustainable*

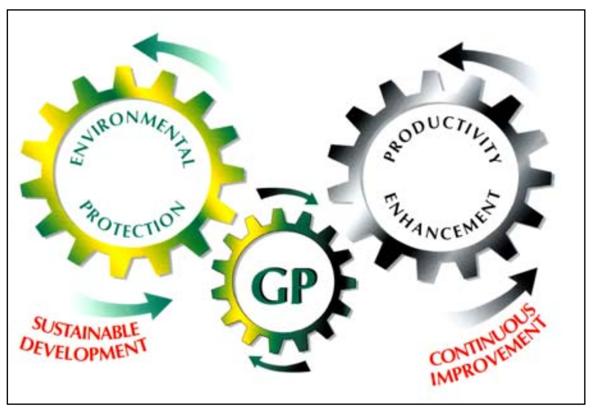


Figure 4 : Meaning of Green Productivity

[5] A declaration was signed on 6 December 1996 at Manila, Philippines at the APO World Conference on Green Productivity. The Conference declared that environmental protection should be promoted without sacrificing productivity.

[6] The environmental issues in the region can be categorized as: Pollution, Environmental Degradation, Resource Depletion and Biodiversity.

development[7]. Sustainable development is defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. This includes the use of services and products which meet our basic needs and improve the quality of life. The entire life cycle of these products and services must be based on minimizing the use of natural resources and toxic substances that result in emissions.

1.9 Benefits of Implementing Green Productivity

The implementation of Green Productivity will bring about immediate as well as long-term benefits to different stakeholders.

For enterprises:

- *Reduction of waste through efficient resource utilization*
- *Lower operational and environmental compliance costs*
- *Reduction or elimination of long-term liabilities and clean-up costs*
- *Increase in productivity*
- *Compliance with government regulations*
- *Better public image*
- *Increase in competitive advantage*
- *Increase in market share and profitability*

For employees:

- *Greater workers' participation*
- *Potential increase in employees' share of value-added*
- *Improvement in health and safety in the workplace*
- *Better quality of work life*

For consumers:

- *High quality products and services*
- *Reasonable pricing*
- *On time delivery*

In essence, policy makers, economists and environmentalists will continue to foster this form of growth that will accelerate economic expansion in a sustainable manner. Green Productivity thus forms an integral part of the broader sustainable development agenda and moves society towards sustainable production and consumption that makes business sense. Finally, to translate the guiding principles of GP into practice, companies can adopt a systematic implementation framework. This framework encompasses the GP Methodology, and supporting Tools and Techniques. They will be explained in the following chapters.

[7] More details can be obtained from a 300-page book, "Agenda 21" developed for achieving sustainable development in the 21st century. It was adopted in the first international Earth Summit, at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, on 14 June 1992.

2. THE GREEN PRODUCTIVITY METHODOLOGY

In order for a Green Productivity Program to be effective, it is important to bring all the stakeholders together to ensure identification of maximum opportunities. The program should be flexible enough to adapt itself to suit unexpected circumstances. The Green Productivity Methodology is basically a step-by-step procedure that was developed by the APO for ensuring exploitation of maximum Green Productivity opportunities. The Green Productivity Methodology or the GP Methodology was developed based on KAIZEN[8] principles and the PDCA[9] cycle. The GP Methodology has been tried out in the APO's Green Productivity Demonstration Program (GPDP) and it has been proven to be effective in achieving higher productivity. The GP Methodology consists of six major steps that are made up of thirteen tasks. The description of each of the steps and tasks is outlined in Table 1.

Step I :	**Getting Started**
Task 1: GP Team formation Task 2: Walk-through survey and information collection	
Step II :	**Planning**
Task 3: Identification of problems and causes Task 4: Setting objectives and targets	
Step III :	**Generation, Evaluation and Prioritization of GP Options**
Task 5: Generation of GP Options Task 6: Screening, Evaluation and Prioritization of GP Options	
Step IV :	**Implementation of GP Options**
Task 7: Formulation of GP implementation plan Task 8: Implementation of selected options Task 9: Training, awareness building and developing competence	
Step V :	**Monitoring and Review**
Task 10: Monitoring and Evaluation of results Task 11: Management review	
Step VI :	**Sustaining GP**
Task 12: Incorporate changes into the organization's system of management Task 13: Identify new/additional problem areas for continual improvement	

Table 1: The Green Productivity Methodology

[8] Kaizen is a Japanese word for small incremental continuous process improvement.
[9] PDCA cycle stands for Plan, Do, Check, Act cycle. This cycle was developed by Dr. Edward Deming and is used mainly by managers and Quality Circles for planning and problem solving activities.

2.1 Step I : Getting Started

Task 1 - Green Productivity Team Formation

The first task in a Green Productivity program is to form a GP team. The GP team is responsible for managing and coordinating the entire program, identifying and implementing the appropriate GP measures. The GP team should be made up of representatives that have interest in the results of the program. In other words, all the stakeholders should be present in the team. The composition of the team would ultimately depend on the organizational structure and the requirements of the program. In addition, external experts may be included in the team to aid in the identification of maximum GP opportunities. The GP team should be capable of identifying potential areas, developing solutions and facilitating their implementation. To ensure continuity and sustainability of the GP program, an in-house team is more desirable than a fully external team

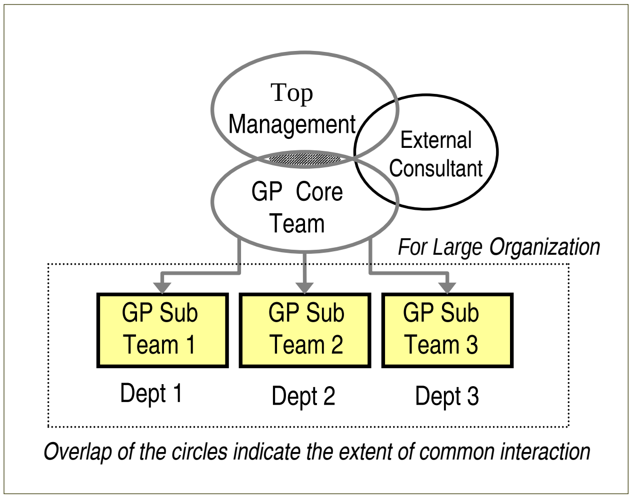


Figure 5 : Organization for implementation of GP

Task 2 - Walk-through Survey and Information Collection

The GP team should familiarize itself with the manufacturing or service process including utilities, waste treatment and disposal facilities. A walk-through survey would allow the team to identify and list all the process steps. Following that, a **flowchart, process flow diagram, initial layout**, drainage system, vents and other material/energy loss areas should be identified and produced. Generally, a **Material Balance** or **Energy Balance** should be done at this point to account inputs, outputs and losses in the manufacturing system. It is important to note that special attention must to be paid to periodic and intermittent waste generating steps as these often tend to be overlooked. In addition, housekeeping practices should be evaluated. Next, the GP Team should prepare a preliminary list of waste generating operations, including a gross estimation of waste generated from different process steps. The possibility of waste prevention and control should also be noted. Additionally, special attention should be paid to steps that generate toxic and hazardous wastes. If the facilitator of the GP exercise is not familiar with the operations of the organization, he should gather general information about the organization like the number of employees and the physical size of the factory or farm by reviewing existing documents or conducting one-to-one meetings to find out about the latest updates.

The two tasks above would aid in the selection of the first focus area for Green Productivity. For organizations with large premises, it would be more desirable for the GP team to focus on a smaller area so that the assessment can be completed fast and the results can also be shown at an early date. This helps in generating and sustaining interest in the enterprise.

2.2 Step II : Planning

Task 3 - Identification of Problems and Their Causes

The findings made in the walk-through survey will be used to identify problems and their causes. Tools like **Eco-Maps, Benchmarking, Flow Diagram** and **Process Flow Diagram**[10] will be used to identify problems and their causes. In general, problems could be with the process, water, chemicals, energy, labour, costs, waste generated, production, capacity utilization, product quality, market demand and so on. Subsequently, a **Cause-and-Effect Diagram** can be used to give a complete picture on the relationship of the problems and their causes or potential causes. In order to achieve a thorough analysis, **brainstorming** sessions should be held. These brainstorming sessions should not be limited only to the people belonging to the area of concern. This is because we can get a third-party assessment and also because there is a possibility that some causes may be from beyond the area of concern. The principles of good brainstorming should also be followed.

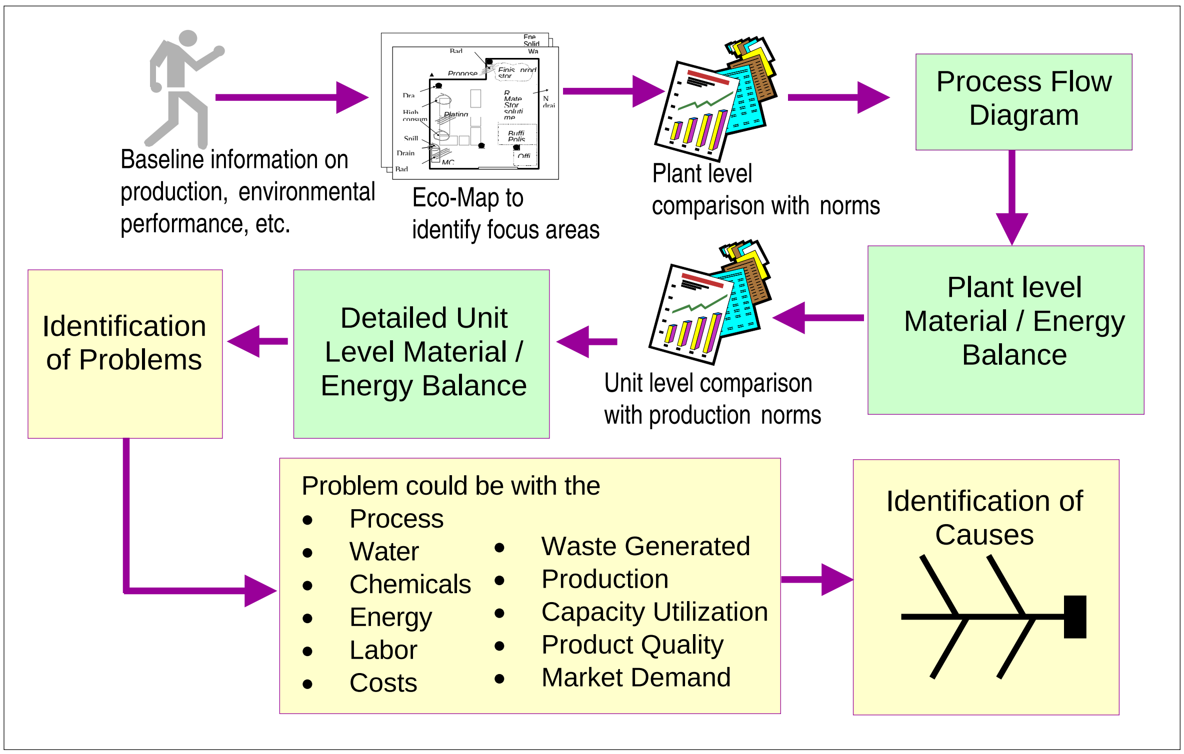


Figure 6 : Identification of Problems and Causes

Task 4 – Set Objectives and Targets

After achieving a comprehensive understanding of the problems and their causes, objectives and targets should be set. This is critical because firstly, objectives provide guidance to the GP team in choosing the appropriate options for eliminating causes of the problems. Secondly, targets act as performance indicators to prevent the GP team from deviating from the objectives. Targets should be decided with an anticipatory perspective and "SMART" (Specific, Measurable, Attainable, Relevant, and Trackable).

[10] Details of the available tools can be found in Chapter 3.

For example, if a certain objective is to be sought within 2 years, it should be investigated whether the objective can be completely achieved within that time frame. This is because allowance must be given for unforeseeable circumstances that may arise. Most important of all, measurement indicator(s) should be established. The purpose of the measurement indicator(s) is to evaluate and monitor the performance of the GP options implemented and to ensure that the set objectives and targets are achieved.

Objective	Attain the present applicable industry norm of 120 litres/kg water consumption		
Targets	**Targeted Achievement**	**Time Frame**	**Initial GP Options**
Target 1	Move from the present level of 180 litres/kg of water to 160 litres/kg	By March 2000	Practice housekeeping, strict process supervision, elimination of unnecessary washes, practice reuse of first washes
Target 2	Reach level of 140 litres/kg	By January 2001	Change dyes and chemicals that reduce wash-offs in the dyeing
Target 3	Achieve 120 litres/kg	By April 2002	Change two winches to one soft-flow machine in the dyeing department

Table 2 : Examples of Objectives and Targets

Step II should end with a list of identified problems and their causes, objectives and targets.

2.3 Step III : Generation, Screening, Evaluation and Prioritization of GP Options

Task 5 – Generation of GP Options

The most significant task in the entire GP methodology relates to the development of GP options. These options emerge directly from the various analyses conducted earlier. This is the most creative part of the GP Assessment Process because the GP team is now prepared to look for possible methods of improving productivity. The ability in identifying GP options depends on the members' knowledge gained from their education and previous work experience. Similarly, the availability of facilitating resources would also affect the members' ability. Facilitating resources can be obtained from personnel located in the same plant or other similar plants, trade associations, specialist organizations including R & D institutions, equipment suppliers, consultants, published literature, books and the Internet. The process of finding GP options should take place in an environment that stimulates creativity and independent thinking. Therefore, using techniques like **brainstorming** and group discussions are especially helpful in generating creative ideas.

Task 6 – Screening, Evaluation and Prioritization of GP Options

After identifying a list of possible GP options, the GP team would now select and prioritize the relevant and feasible options. Screening is a process to eliminate obviously unsuitable options so that more time can be allocated in evaluating options with greater potential. The **Sieve Method** can be used to effectively screen options by setting up cut-off values for certain critical parameters such as cost, time, manpower, etc. All GP options that exceed this cutoff value are directly eliminated. Through this method, options are then categorized as "options ready for implementation", "options selected for evaluation" and "rejected options". Options that can be directly implemented should be implemented immediately, while potential options would be selected for further assessment of their feasibility.

Additionally or alternatively, the **Weighted Sum Method** makes use of a **Decision Matrix** to rank the available options according to their importance based on certain criteria. In this method the criteria are first ranked according to significance by giving weights. The options are then ranked by assigning weights for each criterion. The product of the criteria weight and the individual weight of an option for that criterion forms the score of that option. The scores of an option for each criterion are then summed to get a total score. The total scores of all options are then compared and the option with the highest total score is selected as the most suitable option for the given criteria.

The **Pareto Diagram** can also be used here to prioritize the options based on their impacts or benefits accrued. From the diagram, we can identify the vital few from the trivial many based on real data that makes this approach easily acceptable.

The criteria for assessment of feasibility of each option can be categorized into the following three categories:

Assessment on Technical Feasibility

Assessing the technical feasibility of the options determines whether the options are technically workable. A typical checklist on technical evaluation should consist of:

- Availability of hardware/technology
- Availability of operating skills
- Availability of space
- Effect on production
- Effect on product quality
- Safety aspects
- Maintenance requirements
- Effect on operational flexibility
- Shut down requirements for implementation

Assessment on Economic Viability

Economic viability is the most important factor in evaluating if an option should be implemented. To ensure a smooth take-off and sustain interest in the entire GP program, it is essential that the first few options are economically very attractive. This is because this approach will generate more interest and commitment. Options requiring a small investment but involving more procedural changes like housekeeping measures, operational improvements, process control measures etc, do not require intensive economic analysis. Therefore, simple methods like **Pay Back Period** could be used. However, as the options become more capital intensive, methods like the **Internal Rate of Return (IRR)** and **Net Present Value (NPV)** should be used to assess the economic viability of those options.

Evaluation of the Environmental Impacts

The productivity improvement or waste prevention options need to be analyzed with respect to their impacts on the environment. Some positive impacts are reduction in toxicity and/or quantity of waste, improved treat-ability of waste, changes in applicability of environmental regulations and applicability of simple End-of Pipe pollution control systems.

Last but not least, an anticipatory or proactive approach of evaluation should also be adopted while evaluating the options. It is worthwhile to look beyond the implementation of the options and to make an attempt to predict the probability of success of each option. Step III should result in a prioritized list of GP options.

2.4 Step IV: Implementation of the GP options

Task 7 – Formulation of GP Implementation Plan

A GP Implementation Plan must be formulated to ensure a smooth implementation process. The implementation plan is basically a detailed activity plan that states the necessary preparation work, the time frame and the personnel involved in implementing the options. Examples of the preparation work are arranging finances and establishing linkages with other departments to facilitate effective communication. It is also imperative to garner support and cooperation from the affected personnel. Furthermore, it is also good to prepare checklists on the tasks and the relevant agencies/ departments involved. Before implementing any GP option, the following areas must be ascertained:

S/N	Task	By Whom	By When	Actual Date
1	Design machine modifications	John	End Jun	30 Jun
2	Modify machine	Wada	Mid Jul	12 Jul
3	Develop work instructions	Kim	Mid Jul	15 Jul
4	Training & Briefing of workers	Kelvin	16 Jul	17 Jul
5	Pilot Implementation	ALL	16 Jul	17 Jul
6	Review of pilot implementation results	ALL	16 Aug	20 Aug
7	Make recommendations for standardization to management	Lee	16 Sep	15 Sep

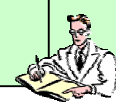


Table 3 : An example of GP Implementation Plan

- Location / point of application of the option
- Nature of the option
- Resources required
- Personnel required
- Whether production or activity at or near the point of application of the option is to be stopped, altered or relocated
- Responsibility matrix and task allocation in teams
- Details on cost requirements, when, how much sourcing of funds
- Milestones to be set in the implementation sequence.

Task 8 – Implementation of Selected Options

After the above areas have been ascertained, the GP team can now proceed to the implementation of the GP options. However, the GP team should not implement all the options simultaneously. They should conduct a trial pilot run by implementing a few options first to monitor the impacts of the options on the existing system. This would allow the GP team to make better adjustments and modifications to the options to reduce the negative impact of the options on the existing system.

The implementation of productivity improvement or waste prevention solutions is similar regardless of the nature of the industry. The task comprises preparation of drawings, ordering and procurement of equipment, transportation of the same to the site, installation and commissioning.

Task 9 – Training, Awareness Building and Developing Competence

To ensure a smooth implementation process, it is also important to train and prepare the workforce. A dedicated trainer is needed to facilitate an effective training program. Training is applicable for all levels of the organization including external suppliers and customers. The objective of conducting training is to explain the concept of GP, inform the workforce on the benefits of GP and also any new changes to processes arising from implementation of GP options. Training would also allow the work force to have a clear understanding of their roles and expectations. This in turn will translate into greater commitment from the management and workers in identifying potential areas for improvements.

2.5 Step V: Monitoring and Review

Task 10 - Monitoring and Evaluation of Results

The performance of the options implemented should be monitored. The actual results obtained should be compared with the set target. The causes of the deviations should be identified and reported to the management. Management will then have to make the necessary corrective actions. After that, a report would be prepared for documentation. The contents of the report would include results obtained from the observations made, an evaluation of the results, a comparison between the results and the targets, the identification of non-complying options and the corrective actions that have already been taken.

Examples of causes of deviations may be: faulty or missing procedures, poor communication, equipment malfunction / lack of proper maintenance, inadequate training, weakness in option generation due to inadequate preparation, inaccurate planning of the implementation plan and unrealistic targets.

Task 11 – Management Review

Management Review is used to determine whether the overall GP Methodology has been applied effectively. The areas to be reviewed may include: the effectiveness of the GP Options implemented, tangible and in-tangible benefits yielded, financial savings achieved, difficulties faced when applying the GP Methodology and areas identified for future improvement. Furthermore, the management review should also assess how changing circumstances might influence the suitability, effectiveness or adequacy of the GP program. Changing circumstances may be *internal* to the organization (i.e., new facilities, changes in products or services, new customers, etc.) or may be *external* factors (such as new laws, new scientific information, or changes in adjacent land use). The key question that a management review seeks to answer is: “Is the GP program working?” or “Is the GP program suitable, adequate and effective in improving the organization’s productivity and environmental performance?”

The reviewing team should be composed of the decision makers of the company. The decision makers would decide the frequency of such reviews. Management Review is the key to goals attainment and continuous improvement.

2.6 Step VI: Sustaining Green Productivity

The biggest challenge in achieving Green Productivity lies in its sustainability. Otherwise, the euphoria of the GP program will die out very soon and the original situation will return.

Task 12 – Incorporate Changes into the Organization's System of Management

Green Productivity would not be sustained in isolation. It should be integrated to become a part of the day-to-day management practices. The GP team should establish a structured system for ensuring continuous improvement in Green Productivity. Most companies would integrate their GP activities with the Standard Operating Procedures that are part of their ISO 9000 Quality Management System or ISO 14000 Environmental Management System. In order for such systems to be effective, it is essential that the policies, targets, objectives and procedures be updated as and when required.

Task 13 – Identify New/ Additional Problem Areas for Continuous Improvement

By the time the first cycle is completed, there would be fresh opportunities of productivity improvement or waste prevention in the new focus area and the entire cycle would be repeated in a similar manner. New problems can appear because of factors like: changing prices and availability of resources, formulation of newer products and newer markets, new legislation related to environment, products, labor and packaging, improvement in processes, new competition, lost markets, change in cash flow and so on. Green Productivity would therefore be a continuous process and will never end. The application of GP tools and techniques that will complement the GP Methodology will be covered in the following chapter.

3. GREEN PRODUCTIVITY TOOLS AND TECHNIQUES

A set of GP Tools and Techniques will be used to support the GP Methodology. The GP Tools and Techniques can be used to draw both quantitative and qualitative conclusions. These tools and techniques are adapted from various management theories and improvement practices. Practitioners are reminded that this is not an exhaustive list as there are many other tools and techniques not listed here that can also be adopted. Additional tools would of course further enhance the effectiveness of the GP Methodology. Figure 6 below shows a list of GP Tools and Techniques that can be used.

GP Tools and Techniques / Steps of GP Methodology	1 Brain Storming	2 Flowchart	3 Process Flow Diagram	4 Plant Layout	5 Eco-Map	6 Concentration Diagram	7 Material Balance	8 Energy Balance	9 Ishikawa Diagram	10 Cause-Effect Analysis	11 Pareto Chart	12 Cost Benefit Analysis	13 Decision Matrix	14 Source Reduction	15 Recycle, Reuse and Recovery	16 End-of-Pipe Treatment	17 Design for Environment	18 Life Cycle Assessment	19 7 Wastes of Production	20 5S Good Housekeeping
Step I: Getting Started																				
Task 1: Team formation	X																			
Task 2: Walk through survey and Data Collection	X	X	X	X	X	X	X	X			X	X								
Step II: Planning																				
Task 3: Identification of problems and causes	X	X	X	X	X	X	X	X	X	X	X	X								
Task 4: Setting objectives and targets											X	X	X							
Step III: Generation, Evaluation and Priortization of GP Options																				
Task 5: Generation of GP Options	X													X	X	X	X	X	X	X
Task 6: Screening, Evaluation and Priortization of GP Options											X	X	X							
Step IV: Implementation of GP Options																				
Task 7: Formulation of GP implementation plan	X																			
Task 8: Implementation of selected options														X	X	X	X	X	X	X
Task 9: Training, awareness building and developing competence		X	X	X	X	X	X	X	X	X										
Step V : Monitoring and Review																				
Task 10: Monitoring and Evaluation of results		X	X		X	X	X	X			X	X								
Task 11: Management review											X		X							
Step VI : Sustaining GP																				
Task 12: Incorporating changes into the organization's system of management		X	X	X																
Task 13: Identifying new / additional problem areas for continual improvement	X	X	X	X	X	X					X	X	X							

Table 4: Steps of GP Methodology vs GP Tools and Techniques

3.1 Brainstorming

Brainstorming is a tool commonly used for generating ideas. Its primary objective is to generate as many ideas as possible for the intended purpose. This tool is used by Improvement Teams in instances like identifying possible root causes or seeking solutions to a problem. Brainstorming can also be used in the development of the implementation plan especially in identifying the various task or activities that may form part of the plan. Below are steps used in conducting a brainstorming exercise.

1. Define the topic clearly
2. Keep the meeting in a relaxed setting
3. Set a time limit
4. Go round and take turns
5. Record all ideas, do not evaluate ideas
6. Team leader should facilitate session
7. Generate new ideas from suggested ideas

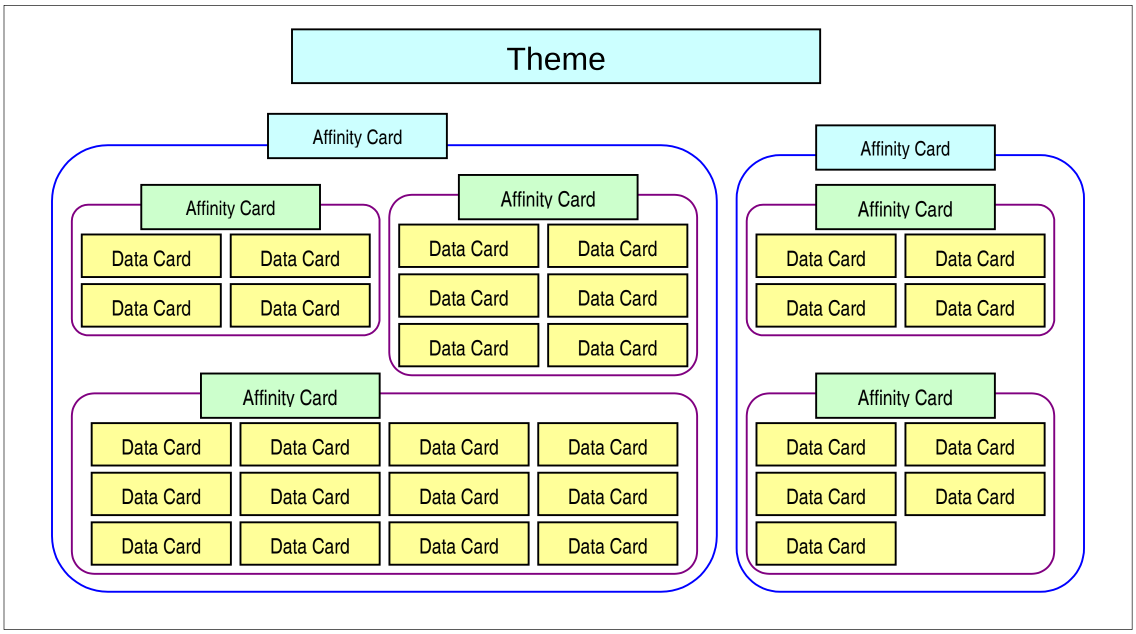


Figure 7 : Affinity Diagram

The **Affinity Diagram**, also known as the **KJ Method**, is a highly effective and structured method of brainstorming. It is an effective group approach for identifying and structuring issues when the situation is fuzzy, intermediate or ill-defined. This method has very often resulted in higher participation by the employees and the generation of highly creative ideas. Steps for executing the Affinity Diagram exercise are:

1. Define the topic clearly
2. Collect verbal data and write each idea on a separate data card
3. Spread and arrange the cards on the table
4. Group 2 or more cards that are closely related together
5. Create a new (affinity) card describing the group of cards

6. Place and clip the affinity card on top of the group of cards
7. Continue the card arrangement (steps 4 to 6)
8. Unfasten each stack of cards and systematically arrange the cards on a big sheet of paper
9. Finalize the placement and create the affinity diagram

3.2 Flowchart

The Flowchart is a graphical method used in organizing the sequence of work activities or decision processes. It explains pictorially how work activities are linked together by a series of steps. In this way, we can then review each step of the process and identify gaps for improvement. Steps used in creating the flowchart include:

1. Identify the first step of the process
2. Draw the first step in a rectangular box
3. Identify subsequent steps
4. Connect all steps with arrows pointing in the direction of the workflow
5. A diamond box is used when a decision (Yes or No) is required
6. Review the entire flowchart and check for accuracy

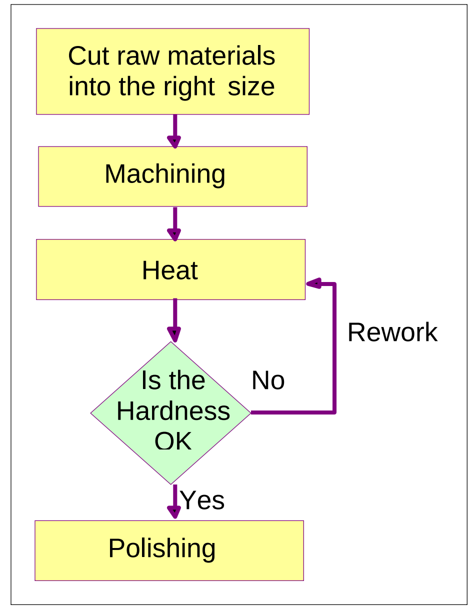


Figure 8 : Flowchart

The **Process Flow Diagram (PFD)** is a special flowchart that organizes the sequence of work activities along with their respective materials and/or energy flows in a particular process or factory after a walk-through survey. The PFD can be constructed using the following steps:

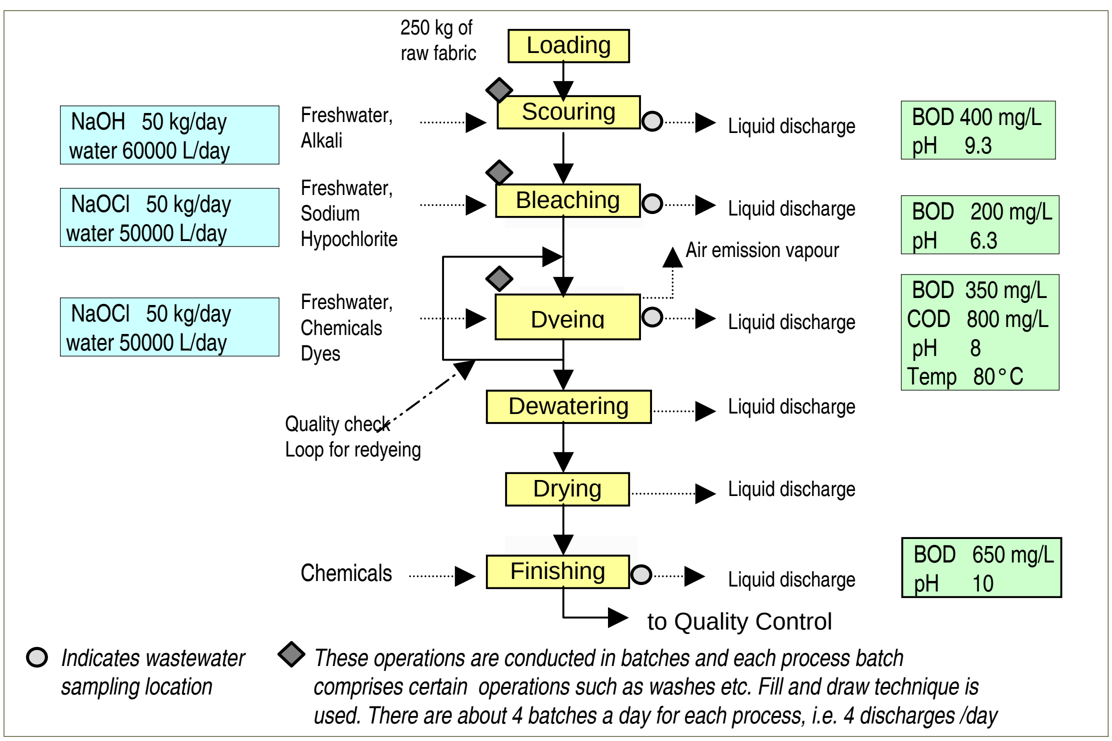


Figure 9 : Process Flow Diagram

1. Draw the flow chart of the process. This flowchart must start with raw materials at the top of the diagram and end with the final product at the bottom.
2. Identify the inputs and outputs for each work activity. Indicate them clearly on the sides of each step. Releases or emissions in all applicable forms, such as air, water, solids should be clearly shown.
3. Identify the indicators and the points of measurement. Collect the data.
4. Complete the PFD by inserting the input and output measurements.

Walk through survey is used in Task 2 of the GP Methodology to identify and verify all process steps.

3.3 Plant Layout

A Plant Layout when combined with other tools like the Process Flow Diagram provides a complete understanding of the current situation and characteristics of the process. This tool is particularly useful in developing hypotheses to determine the locations where improvement is required. Plant Layout should be drawn to scale and important information like the north direction, existing facilities, operations, machines, furniture, utilities, passageways, entrances, exit gates, contours, etc. should be indicated in the layout.

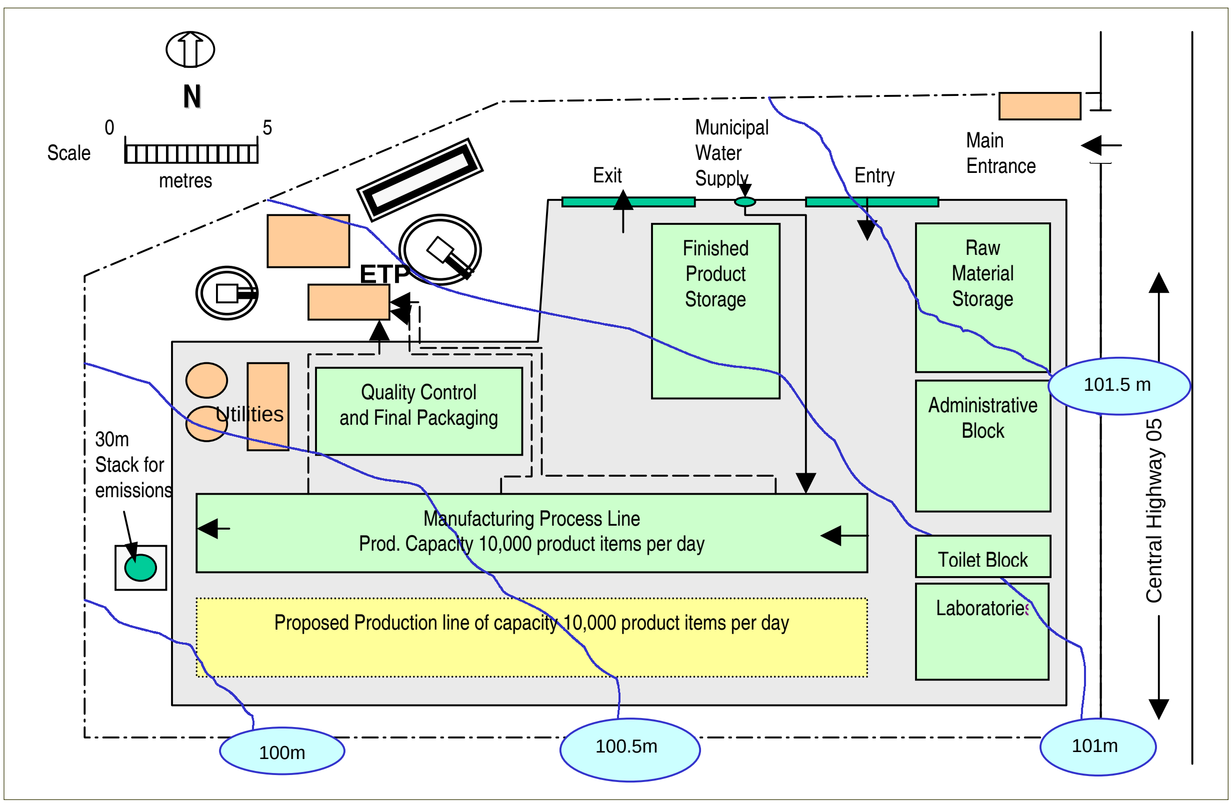


Figure 10 : Plant layout

The **Concentration Diagram** is a variation of the Plant Layout and it provides information on the location of the events or problems. It helps in identifying the source or origin of a problem. The Concentration Diagram is also used to identify the causes of problems in relation to their physical locations. Its nature is similar to that of a check sheet. Furthermore, the Concentration Diagram can be used for collecting data, defining problems as well as monitoring of an implemented solution. To draw the diagram, a simple Plant Layout must first be drawn for the factory or workplace. This is followed by choosing and deciding which symbols to be used for each category of the data. Lastly, the data is plotted on the plant layout.

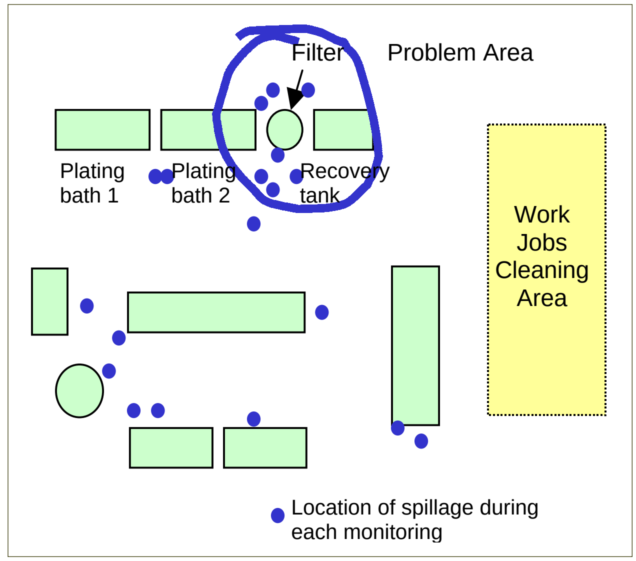


Figure 11 : Concentration Diagram

Another tool in this same family is the **Eco-map.** This is a simple and practical visual tool used to identify present environment and productivity related problems. The Eco-map provides a bird's eye view of the company's operations and gives a quick orientation to the various types of problems faced by the company. Eco-maps are drawn for various themes such as: Water, Solid waste, Energy, and Wastewater. The drawing procedure is relatively simple. The first step is to produce a simple plant layout and then copies of the various themes are then produced. Any problem spotted should be indicated briefly on the Eco-map.

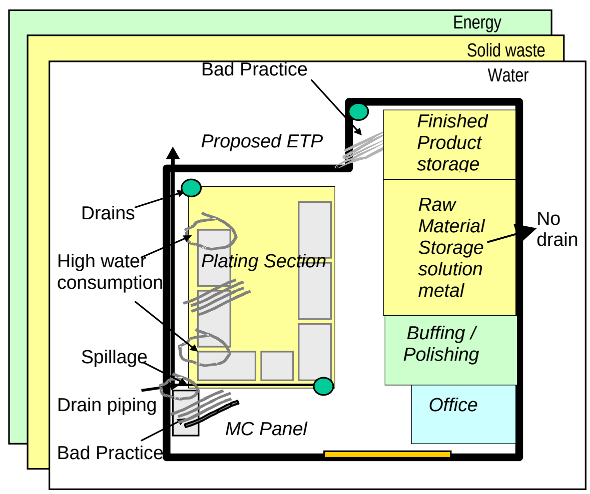


Figure 12 : Eco- Map

3.4 Material and Energy Balance

The Material Balance is a basic inventory tool that allows quantitative assessment of material inputs, outputs and wastes. When resolving Green Productivity issues, the Process Flow Diagram (PFD) is required as a basis for the development of the Material and Energy Balance. Inputs to a process or a unit operation may include raw materials, chemicals, water, air and energy. Outputs include the primary product, by-products, rejects, wastewater, gaseous wastes, liquid and solid wastes. In its simplest form, a

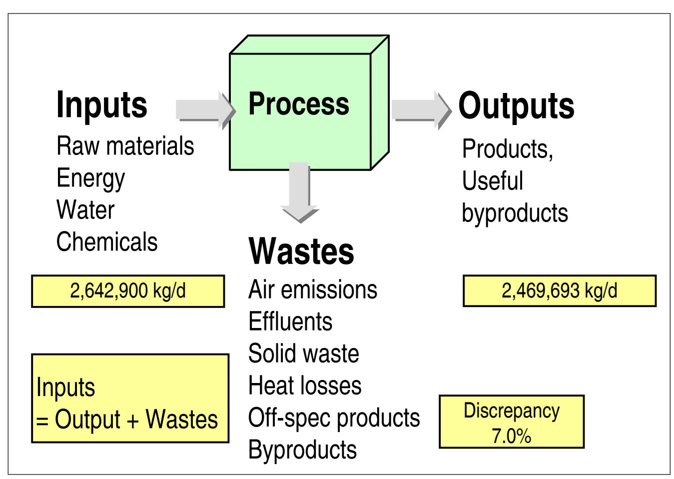


Figure 13 : Material Balance

Material Balance for any production system is drawn up according to the following steps:

The steps in developing a Material Balance include:

(1) Finalizing the PFD and checking it for accuracy
(2) Installing the equipment to record and measure parameters
(3) Determining Inputs, quantifying Outputs and select Tie Compounds
(4) Do a preliminary material balance based on the inputs and the outputs
(5) Calculate discrepancies and repeat measurements if required
(6) Refining by verifying during site inspections and by brainstorming

An **Energy Balance** gives a quantitative account of the input and output of energy in different forms in a production process. In addition to water and raw materials, energy is an important tie compound particularly for energy intensive industries like iron and steel, coke oven, textile, pulp and paper, etc. The development of the Energy Balance is similar to the Material Balance except that energy comes in many forms like fuel, steam, hot water, electricity and so on. The output to be measured may be products, by-products, hot or cold wastewater, solid waste, etc. Energy losses may be steam leakage, low yield of electricity, etc.

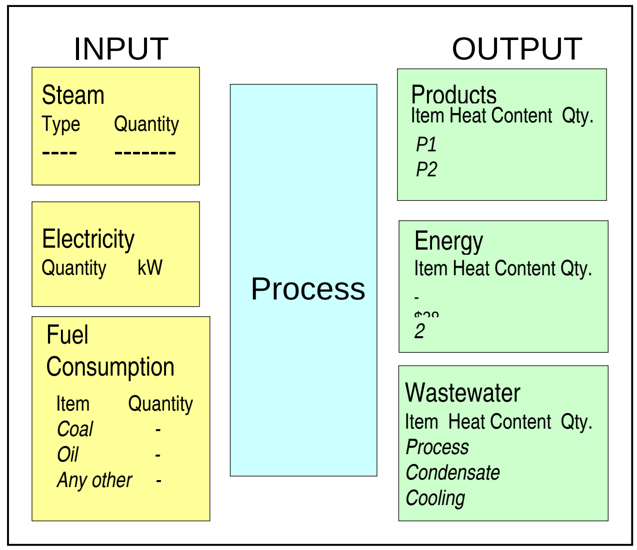


Figure 14 : Energy Balance

Tie compound is the parameter or substance for which material balance is established around a unit operation or process. Examples of tie compounds are; water, chemicals, Chemical Oxygen Demand (COD), Bio-Oxygen Demand (BOD), suspended solids and so on.

3.5 Ishikawa Diagram

The Ishikawa Diagram is one of the 7 QC tools and is also known as the Cause-and-Effect Diagram or the Fishbone Diagram. This tool is widely used by Quality Control Circles in identifying the root causes of problems. This is a valuable tool for any work processes. It helps in guiding group discussions and all the information gathered is displayed in an organized manner. The completed diagram is a useful training aid as it allows junior employees to see the problems and their causes as a complete picture. Hence, they can take the necessary precautions to prevent the problems from recurring.

The simplest way of constructing the Ishikawa Diagram is to use the 4M1E method to categorise causes. The 4M1E method basically involves categorizing all the causes and sub-causes of problems into these categories: Man, Machine, Material, Method and Environment. However, experienced users may create their own tailored categories of causes. Steps for construction of this tool are:

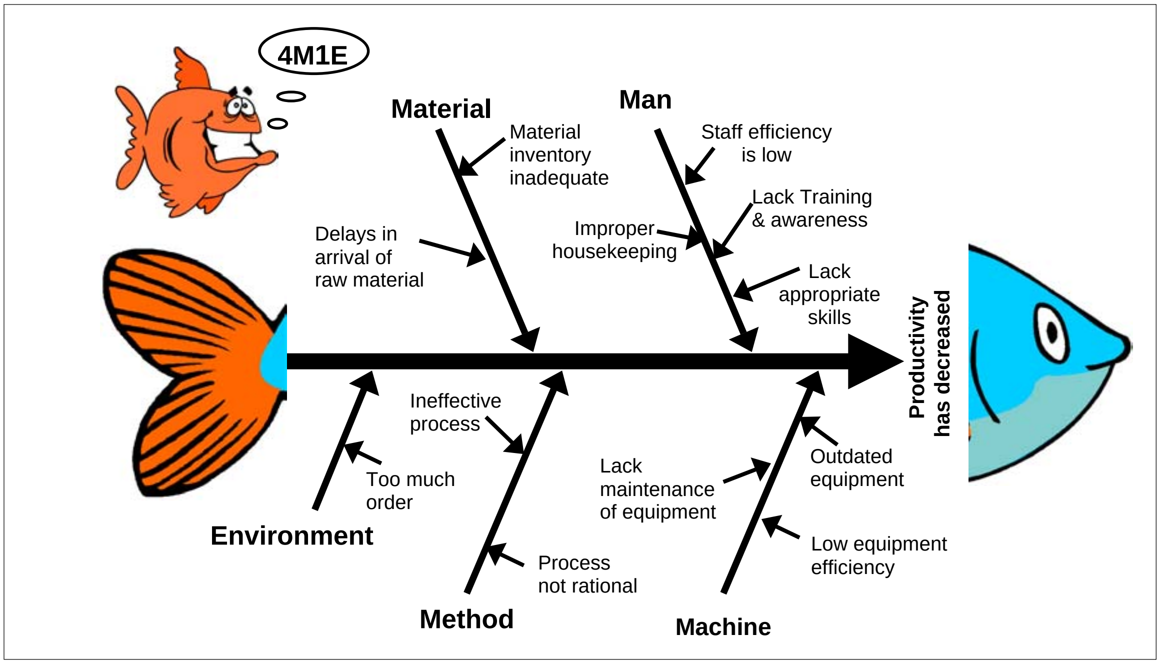


Figure 15 : Ishikawa Diagram

(1) Define the problem effect and put it on the right side of the diagram
(2) Identify main causes, use 4M1E or others and draw in the horizontal and sloping lines
(3) Brainstorm subordinate causes and attach to main cause
(4) Identify and attach as many causes if possible
(5) Identify and circle the root or critical cause(s)
(6) Verify the root cause(s)

Another similar tool is the **Cause and Effect Analysis**, which helps us analyze the cause(s) of a problem or problems. A problem may have several causes as outlined in the Ishikawa Diagram above. For this case, the key is to focus on the most critical causes. However, there are times where the cause identified is also applicable to two or more other problems identified. That means that it will be highly productive if we resolve this particular cause, as it will help us solve the other two or more problems at one time. The third scenario is that one problem can also be related to many other problems. Solving this problem will also resolve the other related problems. In this case, it is important to identify the most the critical problem so that our efforts will pay off.

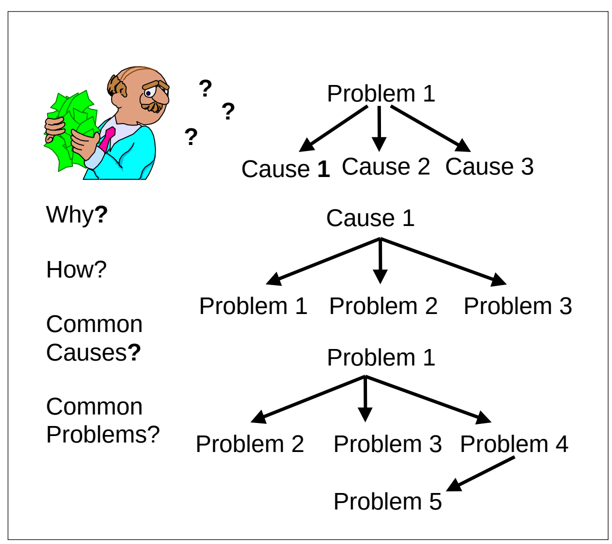


Figure 16 : Cause and Effect Analysis

Refer to the 7 tools commonly used by quality circles in their problems solving projects. The 7 QC tools consist of the cause-and-effect diagram, check sheet, pareto diagram, histogram, graph, stratification and scatter diagram

3.6 Pareto Diagram

Pareto analysis is a method for identifying the few vital causes (typically 20%) that contribute to most of the problems (typically 80%). Pareto analysis can be used in situations where there are many causes to a problem and that it is important for you to know which of the causes are more important. This tool is particularly useful for option selection, prioritization and implementation. The Pareto diagram provides a strong visual presentation of a prioritized list of issues, and allows us to decide on where to concentrate our resources to achieve best results. While interpreting the results, it is essential to use common sense as well as the data available to ascertain causes and priorities. Steps for constructing the Pareto Diagram are as follows:

(1) Review the data and categorize them into 5 to 8 categories. Group all minor categories into a category named “others”.
(2) Prioritize the data according to the magnitude of occurrence from large to small.
(3) Draw a Pareto table and compute the cumulative occurrence, percentage occurrence and cumulative percentage occurrence.
(4) Draw the axles of the Pareto diagram. Fill in the columns indicating the occurrence of each category.
(5) Draw in the cumulative line and complete the legend of the Pareto Diagram.

Types of Complaints	Occurrences	Cumulative Occurrences	Percentage	Cumulative Percentage
Lights not working	120	120	60%	60%
Low water pressure	36	156	18%	78%
Poor TV reception	20	176	10%	88%
Damaged furniture	10	186	5%	93%
Room noisy	4	190	2%	95%
Others	10	200	5%	100%
TOTAL	200		100%	

Pareto Table

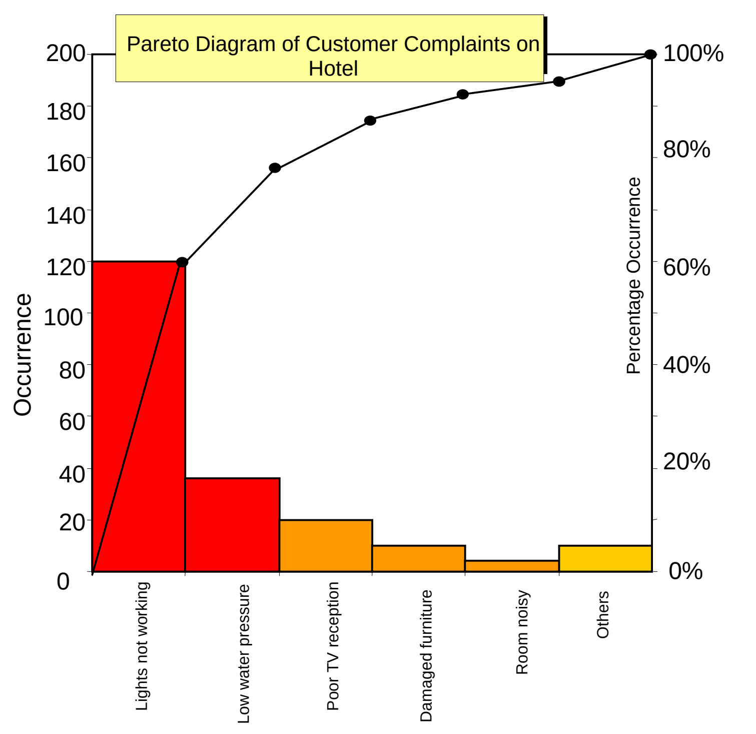


Figure 17 : Pareto Diagram

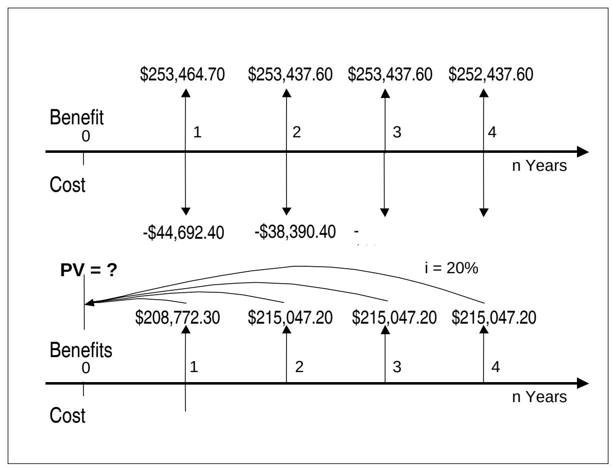
3.7 Cost Benefit Analysis

Cost Benefit Analysis is a technique for identifying opportunities for improvement by comparing both the costs and benefits of a proposal. Usually two types of information are used in this technique: Quantitative and Qualitative. Quantitative information is expressed in dollars or other quantities relating to size, frequency and others. Qualitative information is descriptive in nature and is based on one's judgement.

The **Profitability Analysis** is a quantitative method that uses money as an indicator. The Profitability Analysis forms the basis of the prioritization and implementation of the selected options. It is most commonly used by companies. The techniques for Profitability Analysis are: Pay Back Period, Net Present Value (NPV) and Internal Rate of Return (IRR). These methods can be used to evaluate and select the most economically feasible GP options.

The **Pay Back Period** is a method used to measure the time taken to fully recover the initial outlay of investment. Other things being equal, the shorter the Pay Back Period, the smaller the liquidity risk of the company. This concept is used only as a rough assessment because it ignores depreciation and the time value of money.

Payback = Capital Investment / Annual Savings



The **Net Present Value (NPV)** is the discounted present value of all future cash flows generated by the investment minus the initial cost of the investment. The decision rule is that if the NPV is positive, the investment is accepted. However, if the NPV is negative, the investment will be rejected.

NPV = Present value of cash inflow – initial investment

$$NPV = \sum_{t=1}^{n} CF /(1 + i) - I$$

Where CF = Cash Flow, t= year 1, 2, 3 …n, n = number of interest period, I = capital investment and i = interest rate.

The **Internal Rate of Return (IRR)** is the rate of interest (in %) that a project is expected to earn over its lifetime. If the IRR is used as the cost of capital for discounting project cash flows, the net present value of the project would be zero. Thus, the IRR is the rate that makes the present value of the project cash outflow equal to the present value of the project cash inflow. This method is generally considered inferior to the NPV method because of its built-in assumption that the net cash inflows are reinvested at the project's internal rate of return.

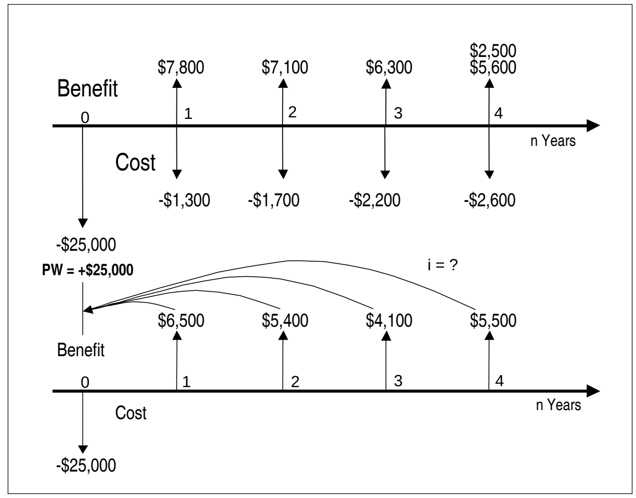


Figure 19 : The Concept of Internal Rate of Return (IRR)

3.8 Decision Matrix

A Decision Matrix, also called an Evaluation Matrix, is used to achieve collective agreement among members of a group in decision-making. It is obvious that decisions based on real data are ideal, but in practice data are difficult to obtain in the initial stage of the project. However, this tool can be bias if most members of the group give high ratings to a particular problem or option. Nevertheless, Quality Circles or Project Teams still use the Decision Matrix to achieve consensus among the members. In general, the steps to create a Decision Matrix are:

Problem	Severity	Frequency	Cost implications for resolving the problem	Cost of inaction	Score (1-10) 10 is top priority
Productivity					
Material consumption	High	Always	High	High	9
Product quality	Medium	82% success	Moderate	Moderate to High	6
Housekeeping	High	Always	Minimal	Moderate to High	10
Environment					
Legal compliance	Medium to High	Occasionally on air, always on effluents	High	High	7
Business					
No. of rejects from customers	Minimal	5%	Minimal	High	4

Figure 20 : Decision Matrix

(1) Decide on the objective of the Decision Matrix.
(2) Select a list of criteria like cost, frequency, cost of inaction, time, benefit to team, frustration, safety, environmental enhancement, delays, etc.
(3) Create the table for the Decision Matrix. Decide on the rating system
- Give scores of 1 (low) to 5 or 10 (high) for each criterion
- Evaluate the quantitative and qualitative parameters of each criterion

(4) Rate each problem or option against the criteria by giving scores objectively. It is important that the team must not be bias towards any problem or option.
(5) Select the problem or option with the highest total score.

3.9 Source Reduction

The Source Reduction technique includes practices that reduce the amount or toxicity of waste, hazardous substance, pollutant, or contaminant entering a waste stream (or otherwise released to the environment) prior to external recycling, treatment or disposal. Source reduction measures generally fall into the following categories.

Input Material Changes

Hazardous substances can be introduced into a process through the input materials used to manufacture a product. These hazardous materials can be present in both primary (raw) materials used to manufacture a product (e.g. hydrocarbons used to make plastics) and secondary materials. The latter is not a component but is being consumed in the process (e.g. solvents used in cleaning process equipment). Input material changes fall into two major categories:

Material Substitution is the substitution of existing material inputs to a process by materials that are environmentally friendlier, without adversely affecting the product quality.

Material Purification is when raw materials that are of higher purity are used to reduce the quantity of wastes generated.

Process Change

This method is concerned with how the product is made. This would include **Technology Change and Improved Operating Procedure**. Such changes reduce workers' exposure to the pollutants during the manufacturing process. Process changes may be implemented more quickly than product changes. Typically, improved operating procedures can also be implemented more quickly and inexpensively than input material and technology changes.

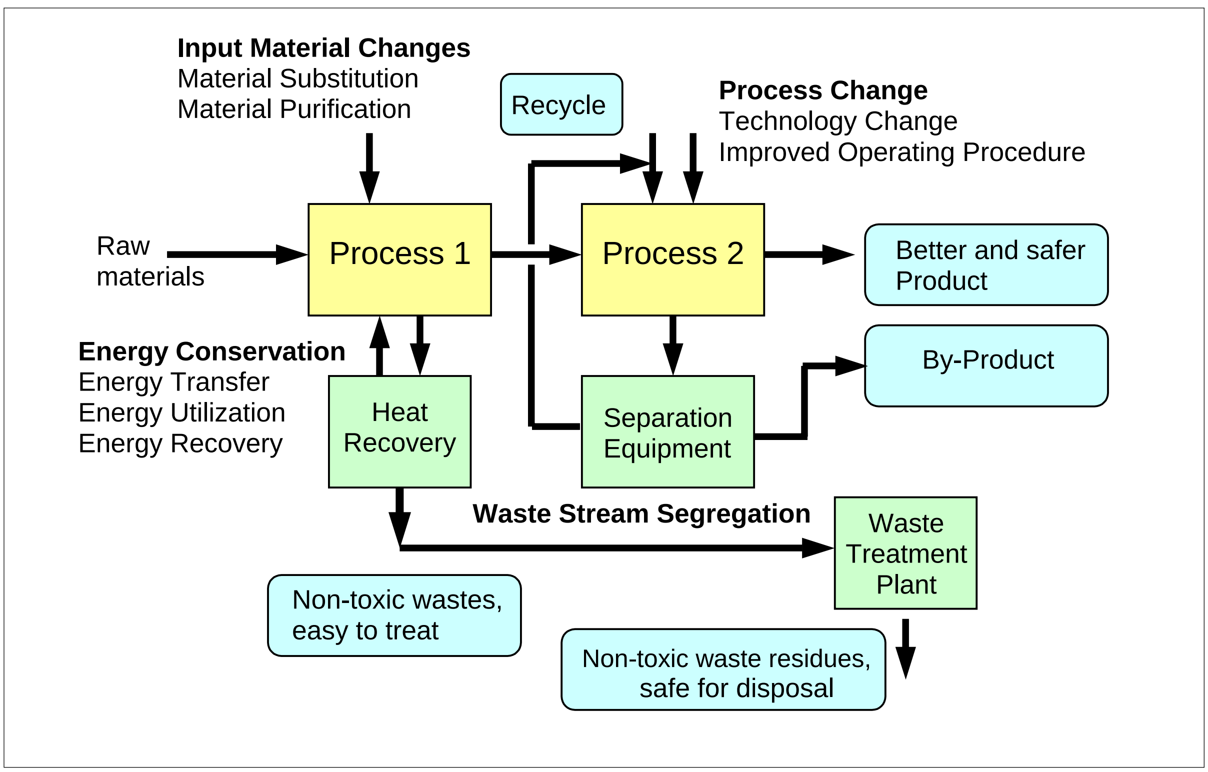


Figure 21 : Source Reduction

Technology Change involves modifying the technology used to produce a product or service. It is one of the most effective methods of preventing pollution generation. This method is less common among companies as it generally involves greater personnel and capital investment, and the result often takes a longer time to realize. Although some Technology Change may apply only to specific processes, the general categories are: **Process Modification**, **Operational Adjustment**, **Equipment Modification** and **Automation Improvement**.

Improved Operating Procedures can be implemented in all areas - production; maintenance; raw material, product, and waste handling; and storage. Since good operating procedures can often be implemented at a low cost, they usually have a higher return on investment. Procedural aspects of a manufacturing operation include the management, organizational, and personnel functions of production. Efforts in improving operating procedures could be: **Scheduling Improvements**, **Material Handling and Storage**, **Spill and Leak Prevention**, or **Personnel Practices**.

Waste Stream Segregation

Waste Stream Segregation refers to the separation of waste streams according to points of generation, composition, volume or media. Hazardous waste that is normally hauled to off-site disposal facilities is often a combination of two or more waste stream types. Segregation at the source can reduce the quantity of disposal of hazardous wastes. When a non-hazardous waste is mixed with a listed hazardous waste, the entire mixture is classified as hazardous; not allowing hazardous and non-hazardous wastes to mix reduces the amount of hazardous waste that requires disposal and yields substantial savings. Some benefits of Waste Segregation include: ease in end-of-pipe treatment of a non-compatible pollutant stream and increased possibility of recycling / reusing a waste stream.

Energy Conservation

Production facilities consume energy basically in two different forms: electricity and process heat. Combustion of fossil fuels in primary heat sources such as boilers or fired heaters provides a major source of heat input to industrial processes.

In the techniques of **Energy Conversion,** the focus is on the energy conversion efficiency of the units such as industrial boilers, power reactors, etc. that convert fuel to steam, or fuel to electricity. Alternately, we can also focus on **Energy Transfer** where the energy transfer efficiency of the energy conduits and steam piping can contribute significantly to reduce losses during operation. We can also conserve energy through reducing **Energy Utilization** by improving the individual equipment efficiency in terms of unit product output per energy utilized. In situation where energy utilization is already in an optimum state, **Energy Recovery** techniques can be used. Heat exchangers are deployed to draw the excess heat in the effluent and the recovered heat is subsequently used back in the process.

3.10 Recycle, Reuse and Recovery

Recycle, Reuse and Recovery are considered as the second most preferred methods after source reduction techniques in the environmental management hierarchy. This methodology is advantageous because of the following reasons: conservation of natural resources, elimination of waste management options like treatment or land disposal and reduction in raw materials needed in the processes. However, Recycle, Reuse and Recovery can incur somewhat increased risk and liability due to additional handling and management of materials. Thus, this may affect the quality of the final product.

Recycle is a technique where used materials, energy or leftovers in some cases are recycled within the production facility. For example, scrap metal or old parts can be melted down and cast into new material for processing. Heat generated in some processes can be recycled through waste heat exchangers to heat other parts of the process.

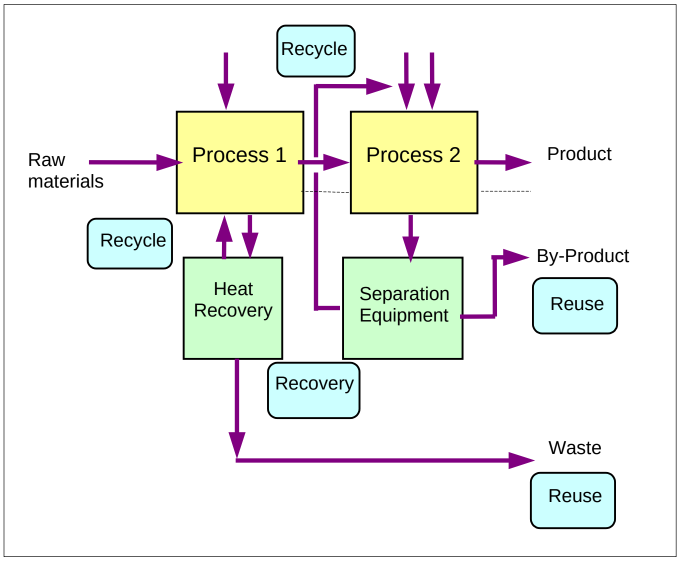


Figure 22 : Recycle, Reuse and Recovery

Reuse is technique where the waste materials generated in a manufacturing process are subsequently reused in the original process with or without treatment to remove impurities. For example, material containers (such as 55-gallon drums) can be reconditioned and re-used with minimal efforts. If waste material cannot be directly reused in the original process because of potential contamination, it may be treated to remove contaminants. For example, organic solvents used in parts cleaning and pharmaceutical manufacturing processes are often collected, distilled, and reused in the original process.

Recovery is a technique where valuable resources can be reclaimed from wastes in the form of raw materials, by-products or products. Recovery normally is the preceding activity to recycle or reuse. **On-site Recovery** is practiced by industries to recover resources that can be reused in the process or sold. **On-site Recycling** is employed when the resource can be easily segregated; when it has a substantial reuse value to the industry or an external market and when there are no risks involved to the industry in the recovery process.

When On-site reuse options are not feasible, then the next step is to consider **Off-Site Recovery & Recycling** option to save treatment/disposal costs. The recycled material could be either returned to the generator for reuse, or sold for use at other facilities.

3.11 End-of-Pipe Treatment Technologies

End-of-Pipe treatment aims to reduce waste generation to the point where treatment and subsequent disposal in the environment can be avoided. However, there are still some processes in which waste generation is inevitable. This waste, which cannot be eliminated, reduced, recycled or reused, must be treated and disposed within all applicable environmental regulations. Appropriate treatments that are in-line with environmental regulations do not include transferring pollutants to other environmental media or dilution. There are a number of end-of-pipe pollution control measures that are applicable to treat and dispose the pollutants generated.

Waste Treatment Processes are practiced widely in the industries. These processes involve changing the form or composition of a waste stream through control reactions to reduce or eliminate the amount of pollutants produced. The treated wastes that are within the limits of the local environmental regulations are then disposed into the environment. Examples are detoxification, incineration, decomposition, stabilization, and solidification, or encapsulation. Many control practices involve collecting the pollutants and moving them from one environmental medium (air, water, or land) to another. An example of the control practices is scrubbing. It is used to remove sulfur compounds from flumes of combustion process.

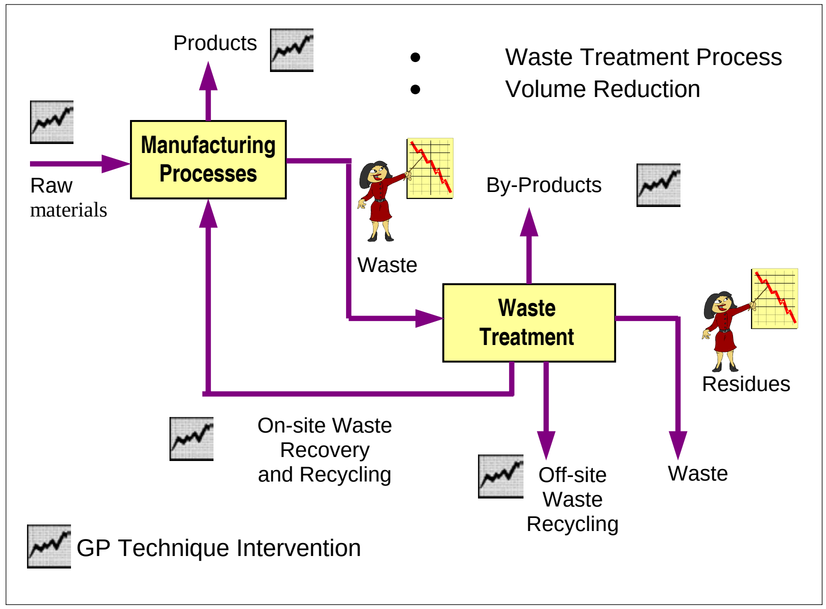


Figure 23 : End-of-Pipe Treatment Technologies

Volume Reduction refers to reducing the volume of the waste such that it can be easily managed, handled and disposed of in an economic manner. These approaches usually result in high concentration of the hazardous or toxic constituents. For example, pressure filtration and drying of a heavy metal-containing sludge prior to disposal decreases the sludge water content and waste volume, thereby reducing the cost of disposal.

3.12 Designing Environmentally Compatible Products

Environmentally compatible products minimize the adverse impacts on the environment resulting from their manufacture, use and disposal. The extent of the environmental impact of a product is determined during its design phase. By taking environmental considerations into account during product planning, design and development, a company can minimize the negative impact of its products on the environment. Modern techniques like **Design for Environment (DfE)** and **Life Cycle Assessment (LCA)** can be used in the process of designing environmentally compatible products. Design changes made to prevent pollution should be implemented in a manner that the quality or function of the product is not adversely affected. Design for the environment can be achieved by the people directly involved or people that are within the framework of company policy. The resulting product changes would include Product Conservation and Product Design Changes.

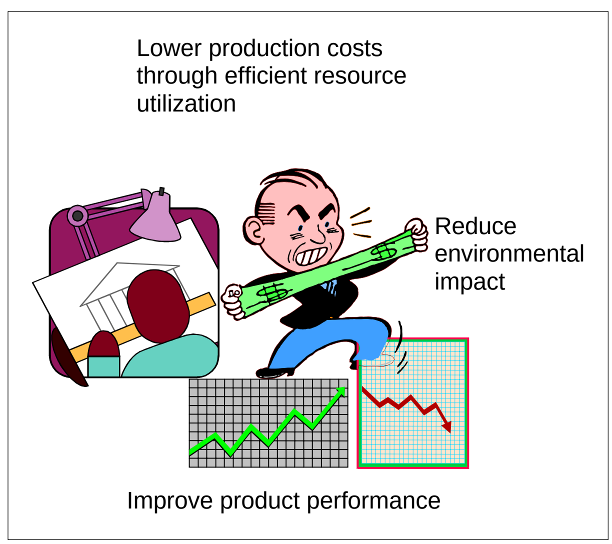


Figure 24 : Design for Environment

Product Conservation refers to the way in which an end product is used. For example, better maintenance of process equipment and components by industry can decrease the frequency of equipment component replacement, which in turn reduces the waste generated by the used component. A manufacturer can also alter a product to minimize the waste resulting from the product's end-use. For example, a manufacturer of lubricants could develop a product that lasts longer than conventional lubricants, thereby reducing the amount of waste lubricant generated.

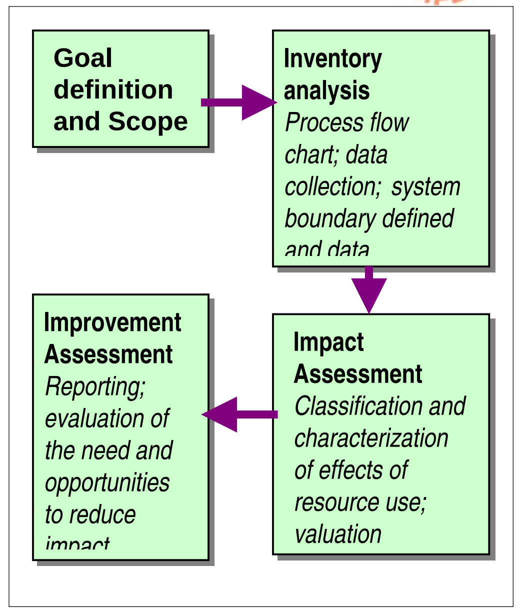


Figure 25 : Life Cycle Assessment

Product Design Changes involve manufacturing a product with a lower composition of hazardous substances or changing the products' composition so that no hazardous substances are involved. For example, a manufacturer could use an active ingredient in a formula with a non-hazardous solvent rather than a chlorinated solvent. Other examples include using mineral oil in electrical transformers instead of polychlorinated biphenyl (PCB) liquids or using organic pigments in paints rather than heavy metal pigments.

3.13 7 Wastes of Production

We often think of waste as physical items like materials, water, electricity, etc. However, in the context of Productivity, waste is defined as: Any form of work which does not add value to the final output! The following are 7 types of wastes identified by the famous **Toyota Production System**.

Waiting is one form of waste that we encounter everywhere. For example, workers waiting for a machine that is not functioning and delay in arrival of materials. The causes of such waste are often lack of planning, lack of proper training, lack of control and lack of discipline.

Transport waste refers to moving things from one place to another unnecessarily. Such actions do not add value to the product. Hence, it should be eliminated or reduced as far as possible. There are two aspects to be considered: improving the floor layout and improving the method of transport by using more advanced material handling equipment.

Processing waste is inherent in the production process or design. For example: an electronic type-writer has fewer parts and processes than a mechanical type-writer, replacing a metal dust-bin with a plastic dust-bin can reduce several steps in the production process and using pre-printed forms can save a lot of time during documentation.

Inventory waste occurs when the inventory turnover is low. This will consume valuable factory space and financial resources. Inventory wastes also occur when inventory has become obsolete.

Motion waste refers to the unnecessary movement of the body that does not add value to the work we do. Motion Study is one aspect of Industrial Engineering that assists us to reduce waste in motion. We can reduce motion waste by improving the workplace layout, practicing good housekeeping and workplace organization, introducing jigs and fixtures and low cost automation.

Defect waste is waste caused by producing bad quality products or poor service. Time is wasted when reworking the bad products or addressing customer complaints. Additional manpower and space is often required to handle the defective items.

Overproduction waste refers to producing more than what is actually needed. The unused products may have to be discarded when not required at a later stage. This waste will ultimately increase the unit cost of production. Poor planning, poor forecasting and producing too early are common causes of overproduction waste.

3.14 5S - Good Housekeeping Practices

Good housekeeping is not limited to keeping the work place clean and eliminating leaks and spills. It also includes improving operational procedures and systems to make them more resource efficient. Some examples of Good Housekeeping Practices are preparation of recipes in the right quantity to avoid surplus, efficient handling of materials, optimum storage procedures to avoid losses and material degradation during storage. In small-scale industries, Good Housekeeping Practices alone could lead to a reduction in waste generation of up to 20-25%.

One way of practicing good housekeeping is by using the Japanese 5S approach. 5S is a set of workplace management techniques that focuses on improving and maintaining processes, equipment, workplaces and people. 5S stands for the following Japanese words:

Seiri means sorting out what items are necessary and dispose those that are unnecessary.

Seiton means arranging the necessary items in a systematic manner. This means having items in the right places or the right layout, so that the items can be retrieved when needed. It is a way of eliminating unnecessary searches.

Seiso means cleaning and inspection. This step ensures that items can be kept clean and in good functional condition.

Seiketsu means improvement and standardization. This process is continually repeated until the required standard is achieved.

Shitsuke means self-discipline and doing what has been decided as a habit. By teaching everyone what needs to be done and having everyone practice 5S, bad habits are got rid off and good habits are cultivated.

4. CASE STUDY : MUSHROOM CANNING

Mr. Augustine is the owner of *Jaya Canning* Factory. He produces canned mushrooms for export to Japan. Raw materials come from the countryside in 50-kg bags. The mushrooms are weighed and then soaked in water to remove big particles of soil and sand. After that the mushrooms will be washed in stainless steel drums 3 times. They are then steeped in 3% brine solution. The mushrooms will then be boiled for one hour at 100°C and then cooled down by spraying water over them and steeping them into water. After that the mushrooms will be manually checked to separate the spoiled ones. They are later washed one more time prior to canning. The cans will be weighed and filled with brine solution (2% brine, 0.1% acetic acid). They will be heated for air removal and then closed. The cans are now washed and heated for pasteurization. They are cooled down by water and packed for distribution.

The factory has already built a wastewater treatment facility to treat their wastewater with the capacity of 160 cubic meters per day. During operation the neighbors often complain to the factory about the bad smell and bad water quality discharged from the factory. And sometimes it has got a warning from officers from the Department of Environment.

Mr. Augustine, owner of the factory, wants to solve this problem and has contacted Dr. Tay from Singapore to make a new design of waste water treatment plant so that the factory will be able to treat their waste according to the government standard.

Upon the arrival of Dr. Tay, they start to go through the factory together and here is their discussion:

Dr. Tay: After our survey I believe your wastewater treatment plant facility is too small to treat your waste right now.

Mr. Augustine: How do you know that our facility is too small? It was designed by a qualified engineer and it was working perfectly well in the beginning.

Dr. Tay: I can see from the color of your aeration system that there are not enough micro-organisms to digest your wastewater. This is because your wastewater flow is too high and it flushes most of the micro-organisms out of the system. You will have 2 options to select: either to enlarge your wastewater treatment plant to cope with the waste you generate or to reduce your wastewater so that your plant can cope with it.

Mr. Augustine: Do you think we can reduce our wastewater as we have already installed our equipment and we can not afford to buy a new one?

Dr. Tay: Certainly you can do that. Have you heard about GP that was initiated by APO? This GP methodology can assist the industry to reduce their waste at sources.

Mr. Augustine: Yes, I have heard about it. But don't you think it's going to be very expensive to go through the whole process? Don't you think it's easier and cheaper to enlarge the wastewater treatment plant and we can get away with this problem?

Dr. Tay: No, I think going along with GP methodology will be cheaper than enlarging the plant, and besides, in the long run you can even makemoney from your saving as you don't have much waste to treat and you use less raw materials.

Mr. Augustine: That sounds good. OK. We better start to work on GP in our factory. But how can we start?

Dr. Tay: This is the APO manual, which you can follow step by step, and you can start with the first one by forming a GP team to collect your base line information. Once you get your information, it will be very easy to see your problems and opportunities to generate options for GP practices.

Mr. Augustine: Yes, I will start with this GP team, but I would like to request you to be our expert to assist us in working on this GP and advice us in implementing it.

Dr. Tay: Yes, I can do that and we will start tomorrow to find the base line information and plant investigation. Please inform your staff about this as they will have to work closely with your GP team.

Mr. Augustine: Yes, don't worry about that. You will get our full support on this project. See you tomorrow. And we are looking forward to seeing the result.

After that the GP team was formed and started working in the factory to get information for GP approach. The initial assessment report produced by the GP team is shown in the attached Initial Assessment Report. From this information you are requested to work on the GP Methodology and obtain the following results:

1. Organize group members into GP team roles.
2. Material Balance (water and material).
3. Environmental aspects and problems of your factory.
4. GP options to reduce your wastewater.
5. Determine whether you will need to enlarge your treatment plant.

INITIAL ASSESSMENT REPORT - CASE OF MUSHROOM CANNING

1. Background

Jaya Canning Factory is a medium sized canning firm located in Jl. Samudera Barat, Selangor Darul Ehsan, Malaysia. The factory produces canned mushrooms for export to Japan. The background information is as follows:

Product	:	Mushroom, Lychee, Fruit salad
No. of employees	:	300
Total floor area	:	1000 m^2
No. of working days per week	:	6
Normal working hour per day	:	10

2. Manufacturing Process

The manufacturing process of mushroom canning is shown in Figure 26. Raw materials come from the countryside in 50-kg bags. The mushrooms are weighed and then soaked in water to remove big particles of soil and sand. After that the mushrooms will be washed in stainless steel drums 3 times. They are then steeped in 3% brine solution. The mushrooms will then be boiled for 40 minutes at 100 degrees Celcius and then cooled down by spraying water over them and steeping them into water. After that the mushrooms will be manually checked to separate the spoiled ones. They are later washed one more time prior to canning. The cans will be weighed and filled with brine solution (2% brine, 0.1% acetic acid). They will be heated for air removal and then closed. The cans are now washed and heated for sterilization. They are cooled down by water and packed for distribution.

2.1 **Raw Materials** used in the process are as follows:

Raw mushroom	9,600 kg/day
Salt	450 kg/day
Acetic acid	12 kg/day
Tap water	261.0 m^3/day

2.2 **Products** - Production of mushrooms on the day of investigation was 35,125 cans/day. The net weight of each can is 565.0 grams. The drained weight of each can is 250.0 grams.

2.3 **Wastewater** generation and its characteristics are shown in Table 5.

2.4 **Solid Wastes** generated within the process were as follow:

Broken and spoiled mushrooms.	279 kg/day
Soil and sand in steeping tanks.	144 kg/day

2.5 **Domestic Water** used for other activities apart from processing was measured to be about 12.5 m^3/day.

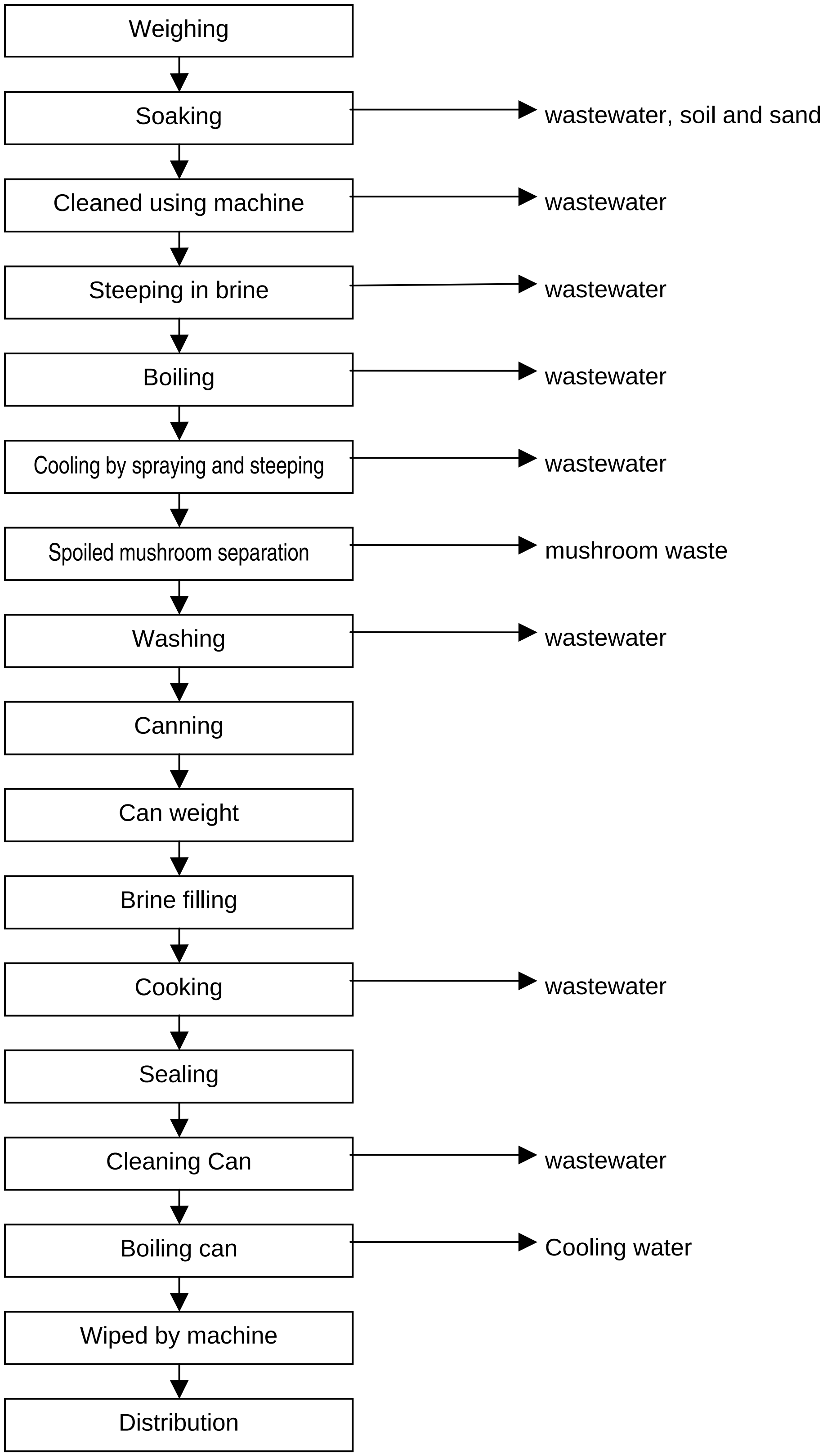


Figure 26 : Flow chart of mushroom canning process

Process Steps	Volume	Characteristic						
	(m³)/day	PH	Temp (°C)	SS (mg/L)	BOD (mg/L)	TKN (mg/L)	TP (mg/L)	Cl^- (mg/L)
	1/6/98	1/6/98	1/6/98	1/6/98	1/6/98	1/6/98	1/6/98	1/6/98
Washing of raw material								
1. Steeping mushroom	5.92	6.65	29	21,900	2,488	-	-	-
2. Primary wash	28.55	7.41	31	2,370	224	-	-	-
3. Secondary wash	26.40	7.43	30	1,110	220	-	-	-
4. Tertiary wash	28.72	7.59	30	120	18	-	-	-
5. Steeping in brine	7.10	6.37	31	250	-	-	-	10,940
6. Floor cleaning	32.70	-	-	-	-	-	-	-
7. Free discharge from unclosed valve	6.99	-	-	-	-	-	-	-
Total of washing from 1-7	136.38	-	-	-	-	-	-	-
Production								
8. Boiling mushroom	6.68	6.89	88	290	11,980	-	-	-
9. Spraying	5.32	7.34	53	80	612	-	-	-
Steeping	41.05	7.00	40	113	1,905	-	-	-
Washing	8.25	7.14	34	73	726	-	-	-
10. Leakage in water hose	0.11	-	-	-	-	-	-	-
11. Free discharging due to walking	8.31	-	-	-	-	-	-	-
for valve closing		-	-	-	-	-	-	-
12. Can washing	2.10	-	-	-	-	-	-	-
13. Floor cleaning	5.09	-	-	-	-	-	-	-
14. Cooling	21.80	7.07	60	0.57	1.04			
Total wastewater from 8-14	98.71	6.59	36	90	142	82	7.6	-
Grand total amount by calculation	235.09	-	-	-	-	-	-	-

Table 5 : Wastewater amount and characteristic at each step of the process

GLOSSARY

Agenda 21 - Agenda 21 is a 300-page plan for achieving sustainable development in the 21st century. It was adopted in the first international earth submit, at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, on June 14th, 1992. Agenda 21 deals with all issues related to the environment and its development. These issues include social-economic development, inequality in the use of resource between nations and within nations, inter-generation equity, population, the carrying capacity of the earth and the need for cooperation between nations.

Benchmarking - Benchmarking is an effective management tool for improving productivity, quality and environmental performance of a company. Benchmarking is a process of continuously identifying, measuring, comparing and improving products and services against the best performance practices of other companies in or outside the industry.

Biochemical Oxygen Demand (BOD) - An index of water pollution used for indicating the content of biochemical degradable substances in a water of effluent sample. The oxygen up-take by micro-organisms together with the sample is measured in grams per cubic meter.

Biodegradable - A substance is biodegradable when it has the ability to be broken down physically and/or chemically by microorganisms. For example, many chemicals, food scraps, cotton, wool, and paper are biodegradable; plastics and polyester generally are not.

Biodiversity - Biodiversity is the number and variety of organisms in the ecological complexes in which they naturally occur. Organisms are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes that must be present for a healthy environment. A large number of species must characterize the food chain, representing multiple predator-prey relationships.

Checklist - Checklist is a form of checksheet used to remind the process manager when a particular task is being executed. The relevant data is first obtained and thereafter a list of pointers is then listed to guide the user during the execution of processes.

Checksheet - Checksheet is a tool used for tallying and collecting data over time to show trends or recurring patterns that need to be understood and controlled. This tool is one of the 7 QC tools used by Quality Control Circles (QCC) to improve the quality of work processes.

Chemical Oxygen Demand (COD) - Chemical Oxygen Demand is a measure of the oxygen consumed in the chemical oxidation of organic matter in water or effluent. It is a quicker test than BOD but does not always correlate with that test.

Chlorofluorocarbons (CFCs) - A family of chemicals commonly used in air conditioners and refrigerators as coolants and also as solvents and aerosol propellants. CFCs drift into the upper atmosphere where their chlorine components destroy the ozone layer. CFCs are thought to be a major cause of the ozone hole over the Antarctica.

Cleaner Production (CP) - Cleaner Production is defined as the continuous application of an integrated, preventive, environmental strategy applied to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment. The intention of this approach is similar to that of Green Productivity and is being promoted by United Nations Environment Program (UNEP). Cleaner production requires changing people's attitudes, responsibility for environmental management and evaluating technology options. Other preventive approaches, such as eco-efficiency and pollution prevention, serve similar goals.

Control Chart - Control chart is a type of line graph used to assess and maintain the suitability of a process. A typical control chart will show deviations / variability of performance in a parameter of a process from the set tolerance limits.

Design for Environment (DfE) - DfE is a design process in which environmental attributes are treated as a design objective to reduce the environmental impact and improve the performance of a product. If effectively applied, this process will lower production and operational costs. This is because efforts are made to ensure efficient use of natural resources throughout the entire life cycle of the product.

Eco-efficiency - Eco-efficiency is a strategy that emphasizes on economics in addition to environmental improvement. It not only focuses on reducing material use and waste, it is concerned with resource productivity, that is, maximizing the value added per unit of resource input.

Effluent - Effluent refers to the wastewater discharged from a factory.

Employee Suggestion Schemes (ESS) - ESS is a system that aims to harness ideas from the lower level of the entire organization. The ideas will be brought to the attention of the top management for follow-up actions. This system is usually comprised of structured and organized activities to capture, evaluate, implement, monitor and reward ideas generated.

Environmental Aspect - As defined by ISO 14000, environmental aspect is an element of an organization's activities, products or services that can interact with the environment. A significant environmental aspect can be referred to as the activities, products and services that have a significant impact on the environmental.

Environmental Impact - As defined by ISO 14000, environmental impact refers to any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.

Environmental Management System (EMS) - Environmental management system is a management approach which enables an organization to identify, monitor and control its environmental aspects. An EMS is part of an overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy. The International Organization for Standards (ISO) developed the **ISO**

14000 series in 1996 as a collection of voluntary consensus standards to assist companies to achieve environmental and economic gains through the implementation of an EMS.

Environmental Performance - Measurable results of the environmental management system related to an organization's control of its environmental aspects, based on its environmental policy, objectives and targets.

Failure Mode and Effect Analysis (FMEA) - FMEA is a disciplined method of using a skilled team to analyze the potential failures of components, subsystems or systems. It is an engineering planning tool undertaken during the design stage to reduce the risk of failure of an equipment, process or system.

Green Purchasing - Green purchasing is the action of procuring and using raw materials, goods and services that are more eco-friendly. This action is applicable to both the producer and consumer and will eventually place fewer loads on the environment.

ISO 9000 - The ISO 9000 is a series of international standards for developing, documenting, implementing and maintaining a Quality Management System in all kinds of organizations across all kinds of industry all over the world. It was first published in 1987 by the International Organization for Standardization. The series was revised in 1994 and subsequently republished in the year 2000.

ISO - ISO represents the International Organization for Standardization. It is an organization to which most national standards organizations are affiliated. An ISO standard supersedes national standards when issued.

Just-in-Time (JIT) Production System - The JIT Production System originated from the famous Toyota Production System. It is a system that helps companies improve their productivity by providing the right quantity, at the right time and at the right place, utilizing minimum amount of resources like manpower, materials and machines. Components of the JIT Production System include; 7 Waste, 'kanban' system, uninterrupted work flow, standardization of jobs, process design, multi-skill workforce, Total Quality Control (TQC), total employee involvement and supplier relations.

KAIZEN - Kaizen is a Japanese terminology that means small incremental continual improvement involving everyone in the organization.

Life Cycle Assessment (LCA) - LCA is the process of evaluating the effects a product has on the environment over the entire period of its life cycle by using a scientific approach that enables the effects to be quantified. A complete LCA comprises of three interrelated components; life-cycle inventory, life-cycle impact analysis and life-cycle improvement analysis.

OHSAS 18000 - A self-regulatory management technique, rather than a fixed set of safety guidelines, published by the British Standards Institute to assist companies in developing documenting, implementing and maintaining an Occupational Health and Safety Management

System (OHSMS). It is based on BS 8800 : 1996 (a guidance on the implementation of OHSMS).

PDCA Cycle - The PDCA cycle is the concept of continuously rotating the cycle. It was developed by a Quality Management guru, Dr. W.E. Deming. The PDCA cycle is also known as the Deming Wheel or the Management Cycle. The acronym of PDCA stands for Plan, Do, Check, and Action. This cycle acts as the basis for the development of the GP Methodology.

Pollution - Any substances in water, soil, or air that degrade the natural quality of the environment, offend the senses of sight, taste, smell, or cause a health hazard is termed as pollution. The usefulness of the natural resource is usually impaired by the presence of pollutants and contaminants.

Pollution Prevention (P2) - P2 is defined as the use of processes, practices, materials, products or energy to avoid or minimize the creation of pollutants and waste, and reduce overall risk to human health or the environment. P2 seeks to eliminate the causes of pollution rather than to treat the waste generated. It involves continuous improvement through design, technical, operational and behavioral changes. Pollution Prevention encourages changes that are likely to lead to lower production costs, increased efficiencies and more effective protection of the environment.

Productivity - As defined by The European Productivity Agency's Rome Conference, "The Concept of Productivity and Aims of the National Centres" in 1958: "Above all else, productivity is an attitude of mind. It is mentality of progress, of the constant improvement of that which exists. It is the certainty of being able to do better today than yesterday, and less well than tomorrow. It is the will to improve on the present situation, no matter how good it may seem, no matter how good it may really be. It is the constant adaptation of economic and social life to changing conditions, it is the continual effort to apply new techniques and new methods; it is the faith in human progress."

Quick Response System (QRS) - The QRS is adapted from the JIT production system with the aim of reducing inventory and production lead-time for companies in the garment manufacturing industries in Singapore. Components of the QRS include; wastage elimination, continual improvement, change of plant layout, production lead time reduction, small production lot size, quality control, supervisory responsibility, multi-skill workforce and low-cost automation.

Spider Web Diagram - Spider web diagram is a tool that is used to make a comparison between the performance achieved and the targets set. This tool is similar to the radar chart and it provides a visible or graphic perspective showing progress and performance against several criteria at the same time.

Sustainable Development - Sustainable Development as defined by the World Commission for Environment and Development in 1987 is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. According to United Nations Environment Programme (UNEP), sustainable patterns of production and consumption should simultaneously meet the demands of social equity and responsibility, environmental protection and economic efficiency.

Total Productive Maintenance (TPM) - TPM is a total approach to equipment maintenance. It is comprised of a set of activities that prevents quality defects in the products manufactured and equipment breakdowns. The implemented activities will lead to a safer work environment. In this approach, all resources in the organization are channeled to reduce the 6 Big Losses: Breakdown Losses, Setup Losses, Idling Losses, Speed Reduction Losses, Defect Losses and Yield Losses.

Total Quality Management (TQM) - Also known as Total Quality Control (TQC) or Quality Improvement Process (QIP), TQM is an operational philosophy that is totally committed to Quality. It emphasizes on continuous process improvement that involves everyone in the organization with the aim of achieving customer satisfaction. In this approach, Organizations can harness the collective wisdom of the employees through employee involvement programs like Quality Control Circles, Employee Suggestion Schemes and 5S. When improving work processes, the Management and Quality Improvement Teams often make use of the PDCA Cycle and the 7 QC Tools.

Value Added (VA) - Value added is a measure of the wealth created by a business enterprise. It is different from sales revenue because it does not include the wealth created by the suppliers or subcontractors to the enterprise. It can be said that value added measures the net output rather than the gross output of the business enterprise.

Value Engineering (VE) - VE is a management technique applied during the design and development stage of products and services. It uses a disciplined procedure to achieve the necessary functions of a product, project or service at the lowest cost, without compromising quality, reliability, performance and delivery. VE is usually complemented by the management technique, Value Analysis (VA). The latter is used to analyze and improve existing project, processes or system.

Volatile Organic Compound (VOC) - Volatile Organic Compound is the name given to non-methane organic compounds that evaporate easily. It is one of the secondary pollutants that destroy the ozone layer. VOC is present in solvents and hydrocarbons produced from petroleum.

Waste Minimization (WM) - WM is the strategic reduction of waste at source, through improved manufacturing methodologies, more careful work procedures and improved product specifications. It is capable of generating massive savings.

Work Sampling - Work sampling is also known as activity sampling. It is a method used in Industrial Engineering for finding the percentage occurrence of certain work activity by statistical sampling and random observations. This method helps to save time during data collection and analysis.

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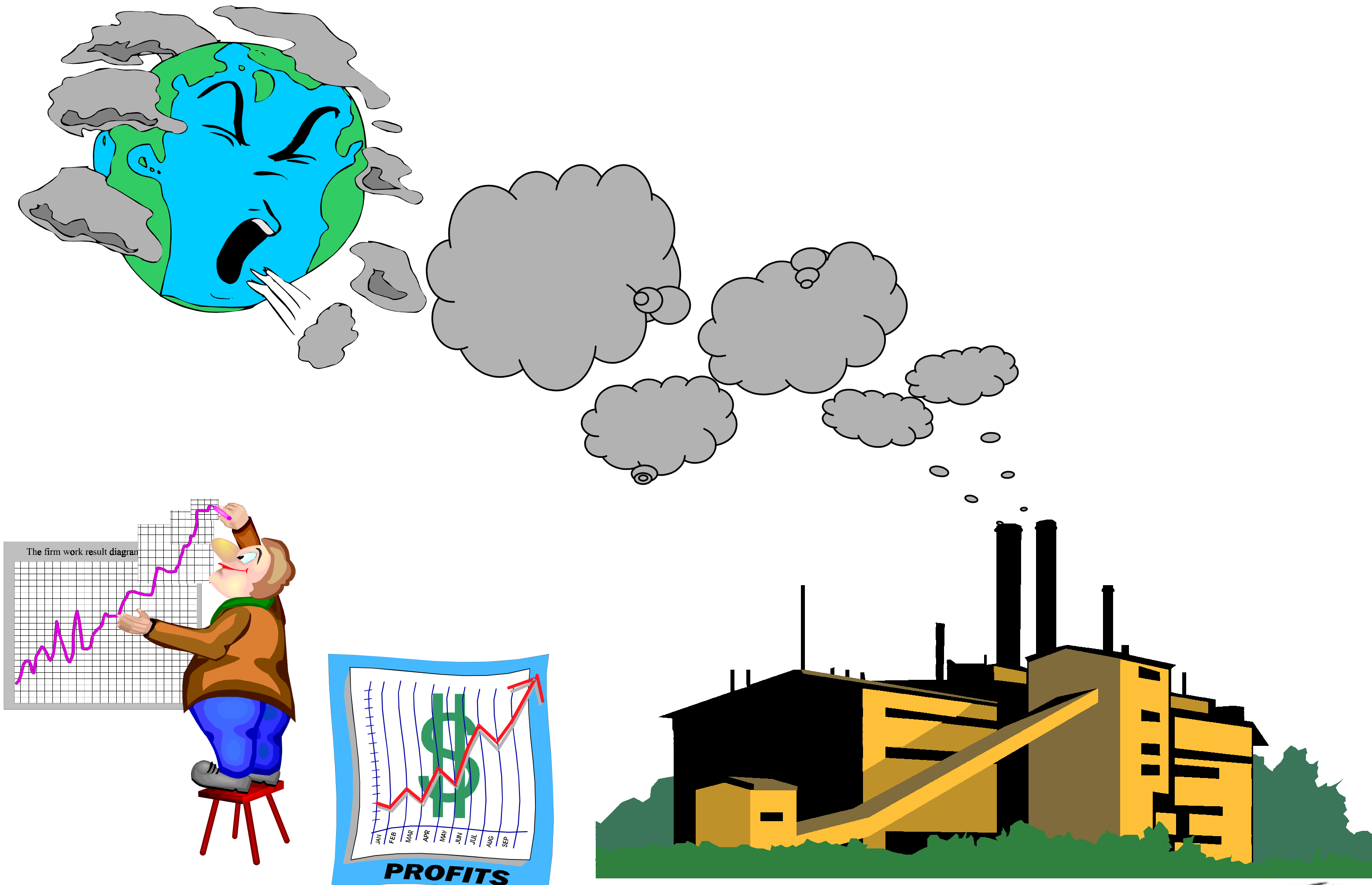
Part 1 : Understanding Productivity



Concern for Productivity

… International Level

- Need for more resources for supporting growing world's population
- Depletion of natural resources and environmental degradation

… National Level

- Expansion of nation's wealth and control of inflation
- Higher standard of living

… Enterprise Level

- Higher profitability and greater competitiveness
- Optimization on use of resources

… Individual Level

- Higher wages
- Better quality of work life

Definition of Productivity

- Quantitative

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

- Qualitative

Productivity = Doing things right + Doing the right things
Efficiency + Effectiveness

Definition by European Productivity Agency

"Above all else, productivity is an attitude of mind. It is mentality of progress, of the constant improvement of that which exists. It is the certainty of being able to do better today than yesterday, and less well than tomorrow. It is the will to improve on the present situation, no matter how good it may seem, no matter how good it may really be. It is the constant adaptation of economic and social life to changing conditions, it is the continual effort to apply new techniques and new methods; it is the faith in human progress."

~ The European Productivity Agency's Rome Conference, "The Concept of Productivity and Aims of the National Centres" in 1958.

Measuring Productivity

- There are several ways of measuring productivity and it depends on what is used for the input. Examples of some partial productivity measures are:

- Labor Productivity
- Material Productivity
- Energy Productivity
- Capital Productivity

OUTPUT	INPUT
Products	Labor
Services	Raw Materials
	Machinery
	Energy
	Capital

Total Productivity Measures

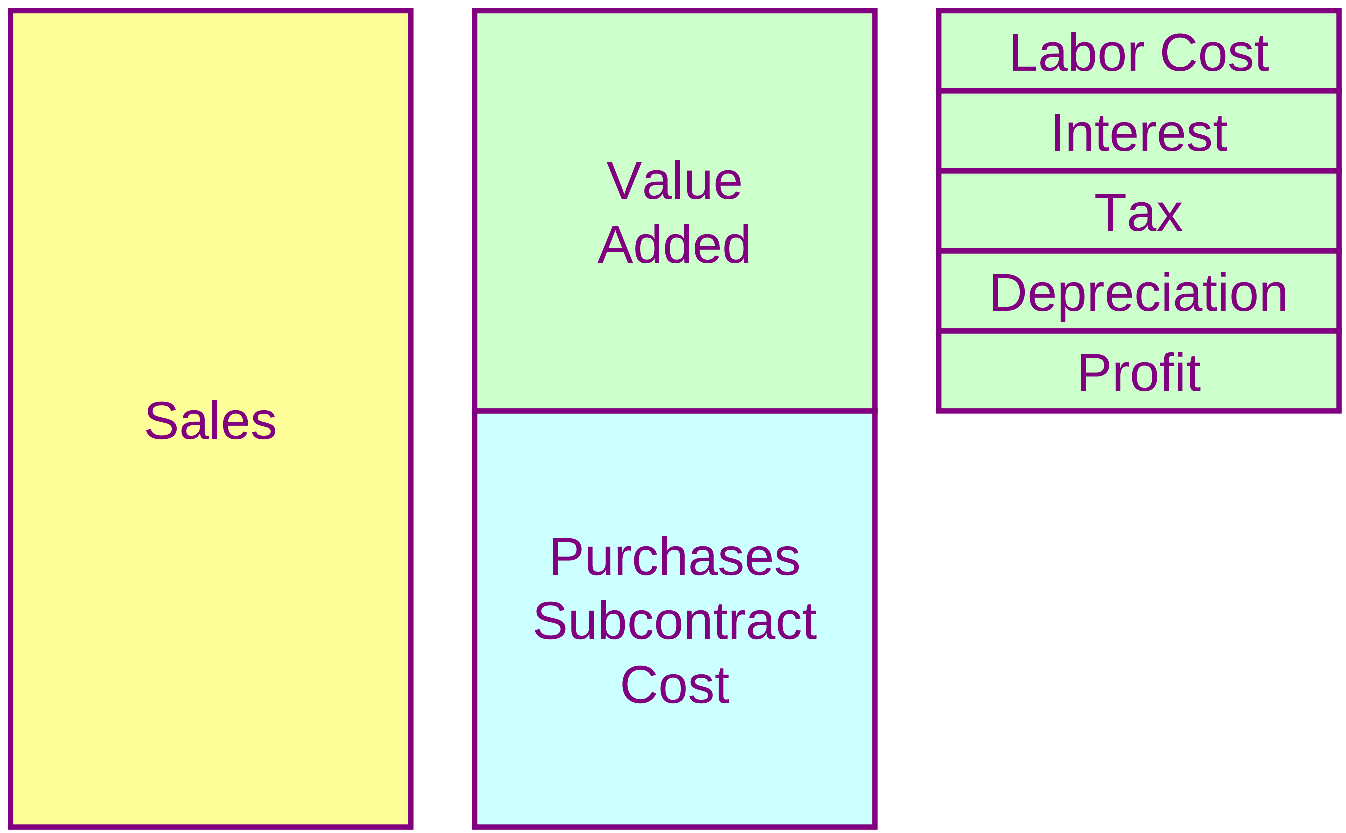
- Total Factor Productivity (TFP)
- Output generated per unit of combined inputs, viz, labor, capital, materials, services, energy, etc.

$$TFP = \frac{Output}{Labor + Capital}$$

- Owing to limitation in data in actual practice, the inputs considered is usually labor and capital
- Some prefer to call it “Multi-Factory Productivity”

Value Added

- Measures the wealth created by a business enterprise



Some Practical Partial Measures of Productivity

Labor Productivity

- Analyses the wealth generated by each employee in the enterprise

$$\text{Labor Productivity} = \frac{\text{Value Added}}{\text{No. of Employees}}$$

$$= \frac{\text{Value Added}}{\text{Sales}} \times \frac{\text{Sales}}{\text{No. of Employees}}$$

Labor Cost Competitiveness

- Analyses the competitiveness of the workforce in the enterprise

$$\text{Labor Cost Competitiveness} = \frac{\text{Value Added}}{\text{Labor Cost}}$$

$$= \frac{\text{Value Added}}{\text{No. of Employees}} \Big/ \frac{\text{Labor Cost}}{\text{No. of Employees}}$$

Some Practical Partial Measures of Productivity

Fixed Assets (Capital) Productivity

- Analyses the enterprise's level of capital or labor intensity

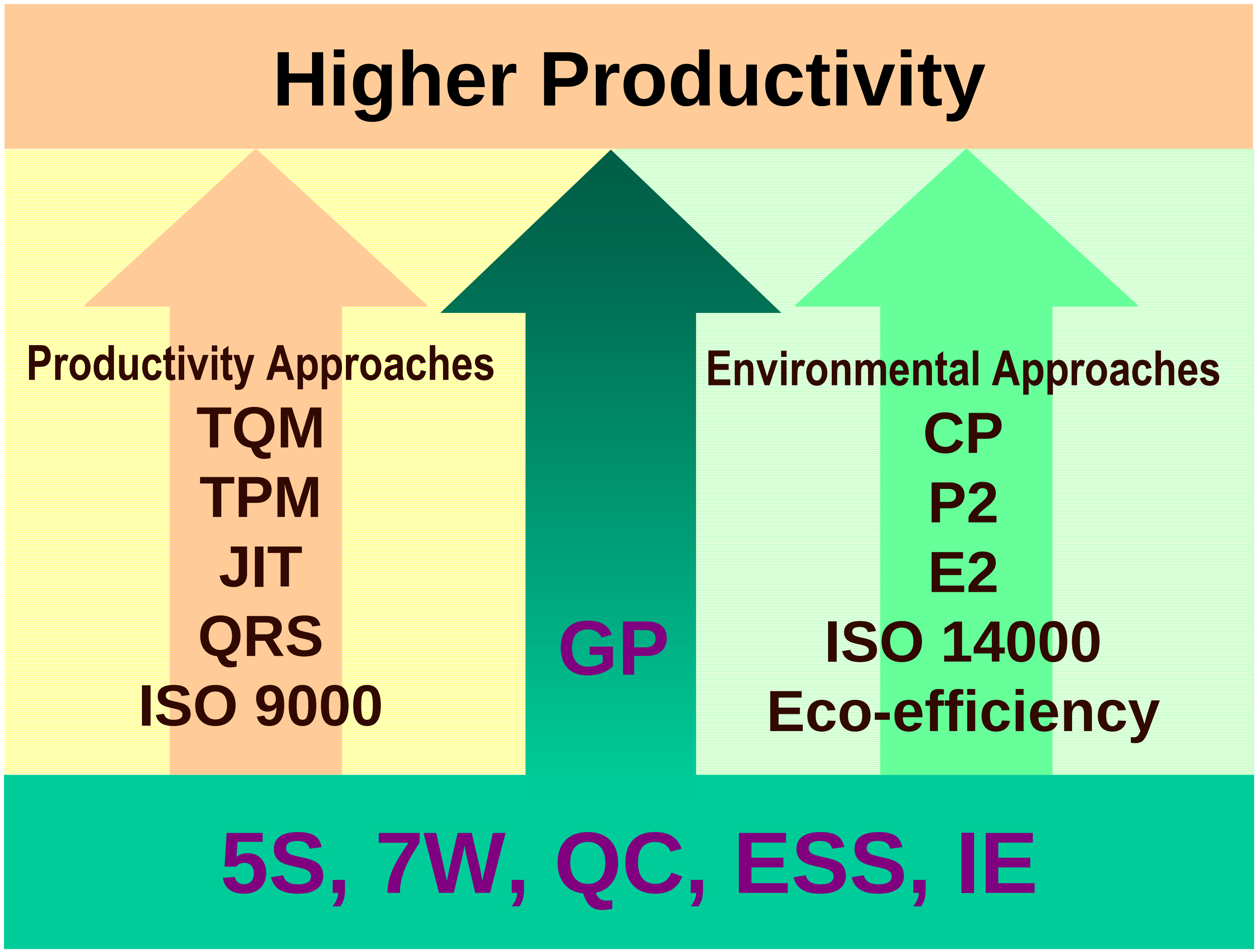
$$\text{Fixed Asset (Capital) Productivity} = \frac{\text{Value Added}}{\text{Fixed Assets}}$$

$$= \frac{\text{Value Added}}{\text{No. of Employees}} \Big/ \frac{\text{Fixed Assets}}{\text{No. of Employees}}$$

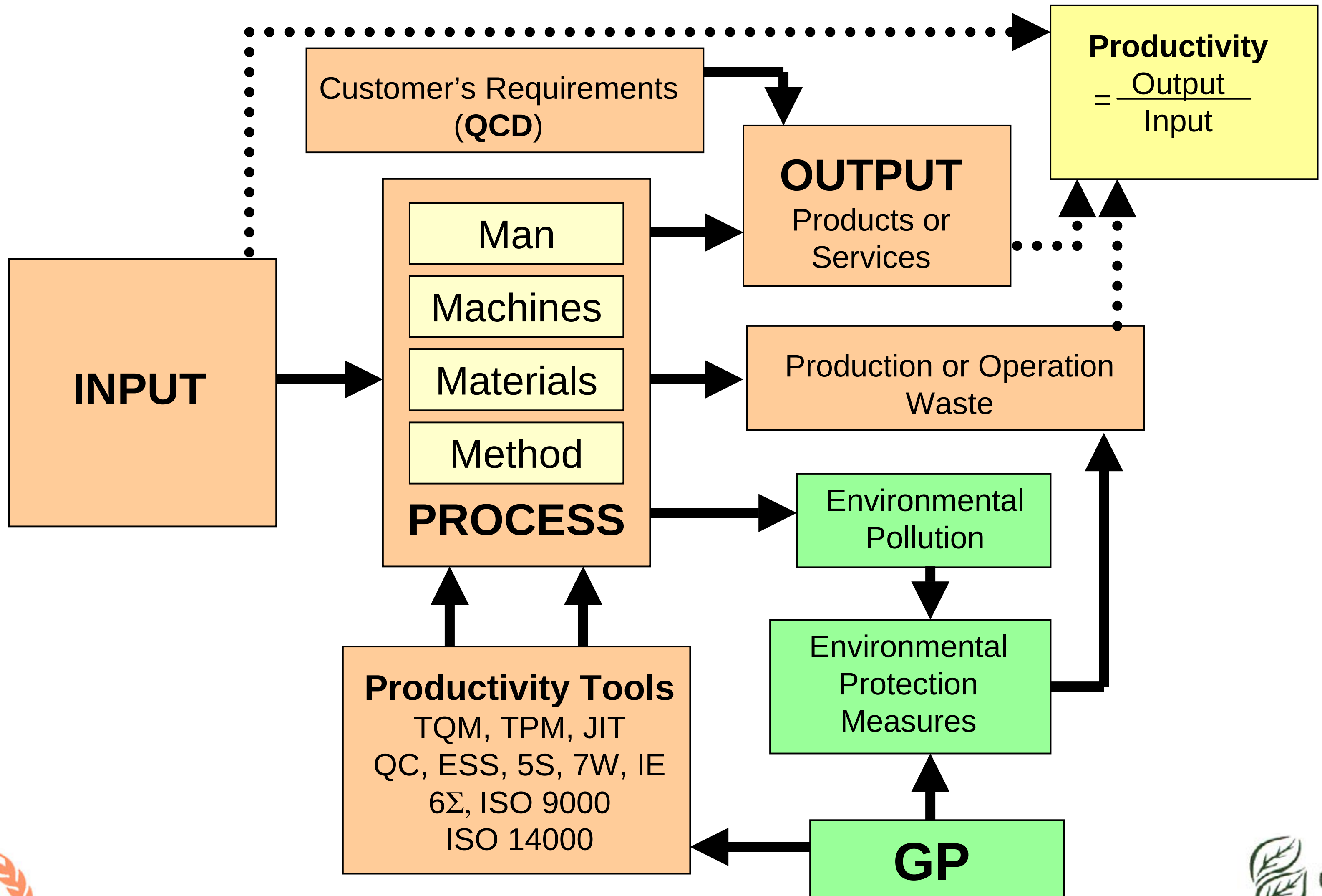
Performance Ratios

- Subsidiary ratios that compliment the productivity ratios of an enterprise
  - Cost of materials / Sales
  - Sales / Average merchandise inventory
  - Cost of goods for resale / Sales
  - Materials used in product / Total materials consumed
  - Number of rejects / Total number of products produced
  - Electricity used / Unit of product produced
  - Sales / Floor area of facilities
  - Number of complaints / Total number of customers served

Approach to Achieve Higher Productivity



The Mechanics of Business Operation



Quality, Cost and Delivery

- Quality

  ~ *must meet all requirements of customers*

- Cost

  ~ *price must be competitive in the market*

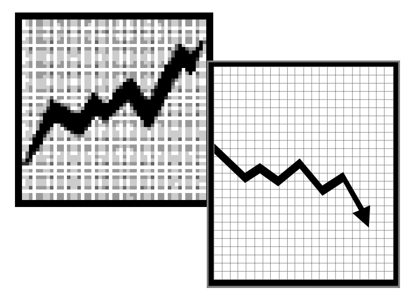
- Delivery

  ~ *goods or services are required to be delivered at the right time and place*

Definition of Green Productivity

Ensures profitability

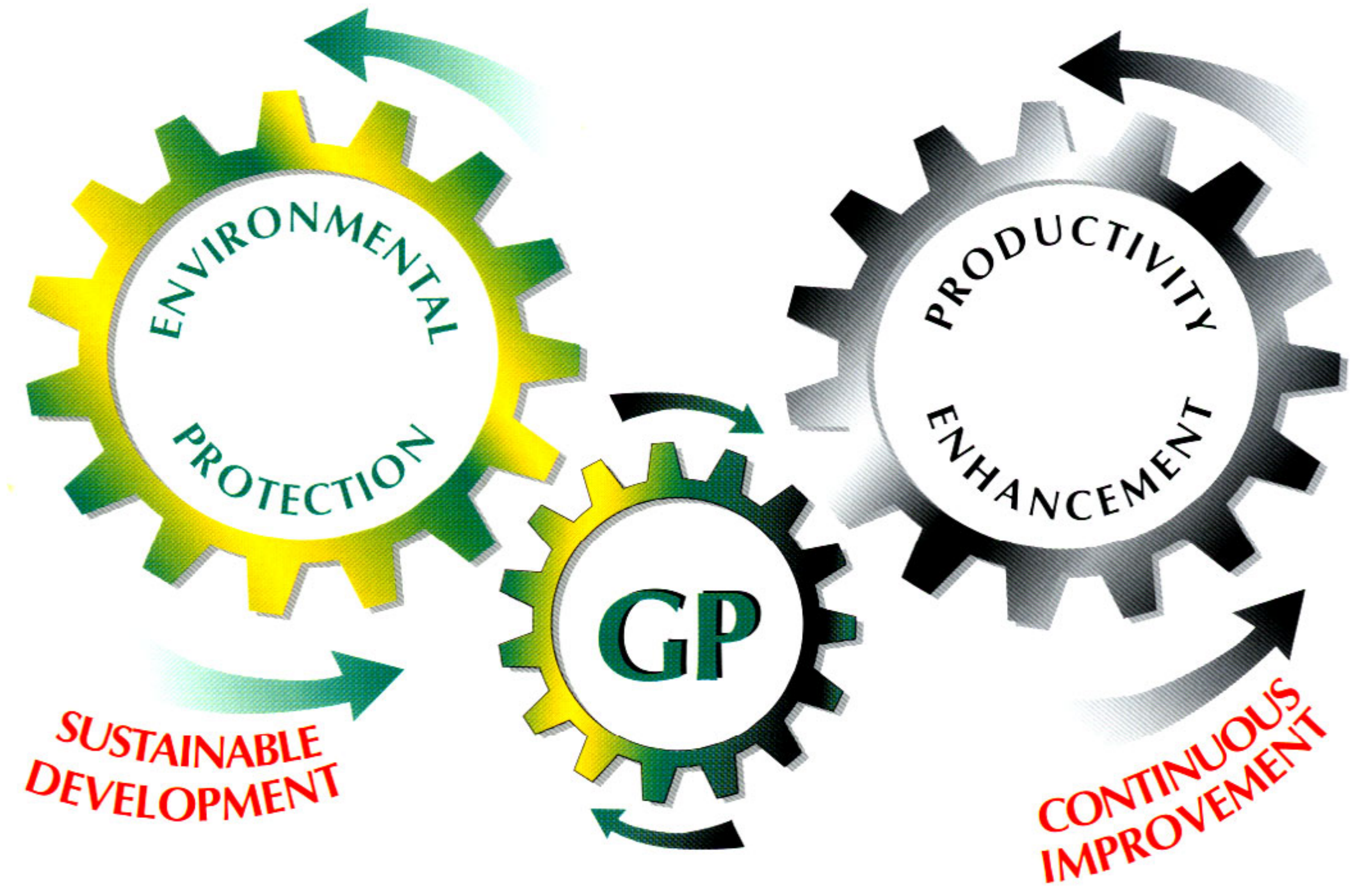
Enhances Quality of Life



Reduces environmental impact

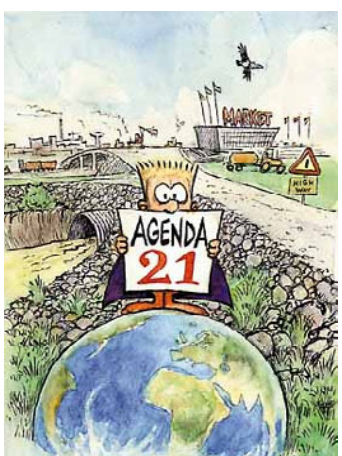
Green Productivity (GP) is a **strategy** for enhancing **productivity and environmental performance** for overall **socio-economic development**. It is the application of appropriate productivity and environmental management tools, techniques, technologies to reduce the environmental impact of organization's activities, goods and services.

Meaning of Green Productivity

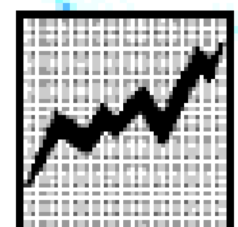


Sustainable Development

"Development that meets the needs of the present generation without compromising the ability of The future generations to Meet their needs"
… Our Common Future, 1987



Agenda 21 ~ 300 page action plan for achieving sustainable development in the 21st century
~ UNCED, 1992



Resource Efficiency

Factor 4, 10

Benefits of Implementing Green Productivity

…For enterprises

- *Reduction of waste through efficient resource utilization*
- *Lower operational and environmental compliance costs*
- *Reduction of long-term liabilities and clean-up costs*
- *Increase in productivity and better public image*
- *Compliance with government regulations*
- *Increase in competitive advantage, market share and profitability*

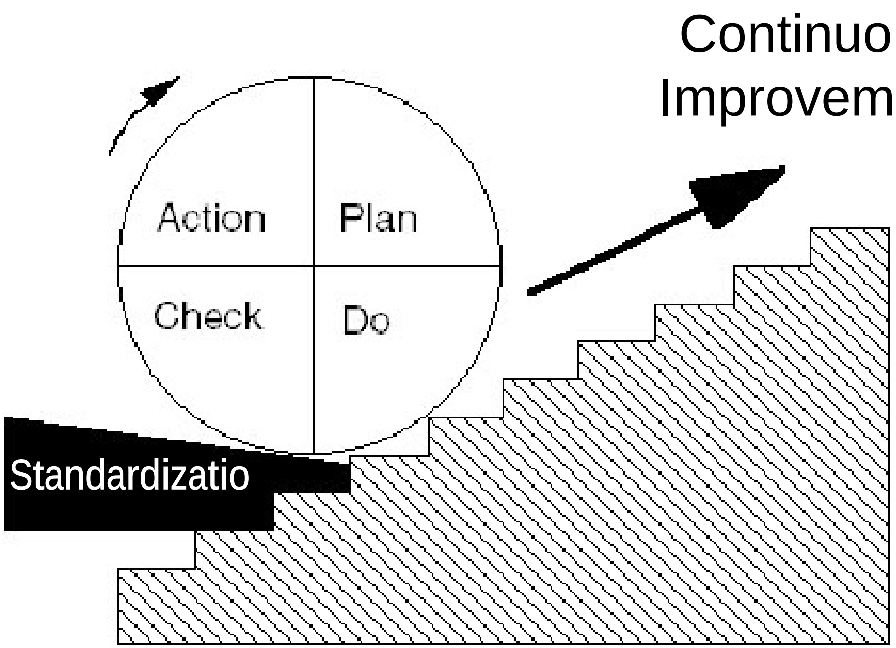
… For employees

- *Greater workers' participation*
- *Potential increase in employees' share of value-added*
- *Improvement in health and safety in the workplace*
- *Better quality of work life*

…For consumers

- *High quality products and services*
- *Reasonable pricing*
- *On time delivery*

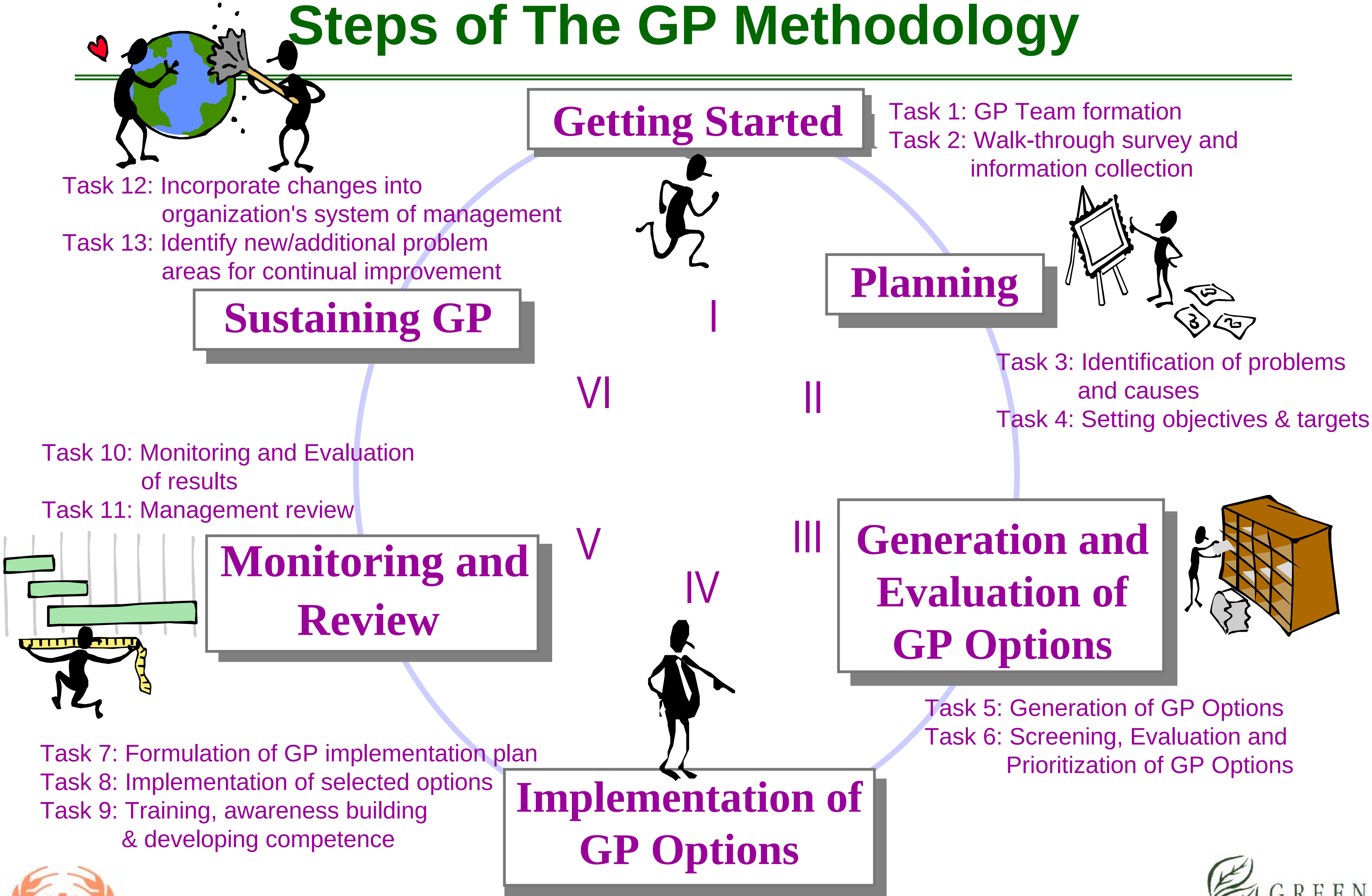
Part 2 : The GP Methodology



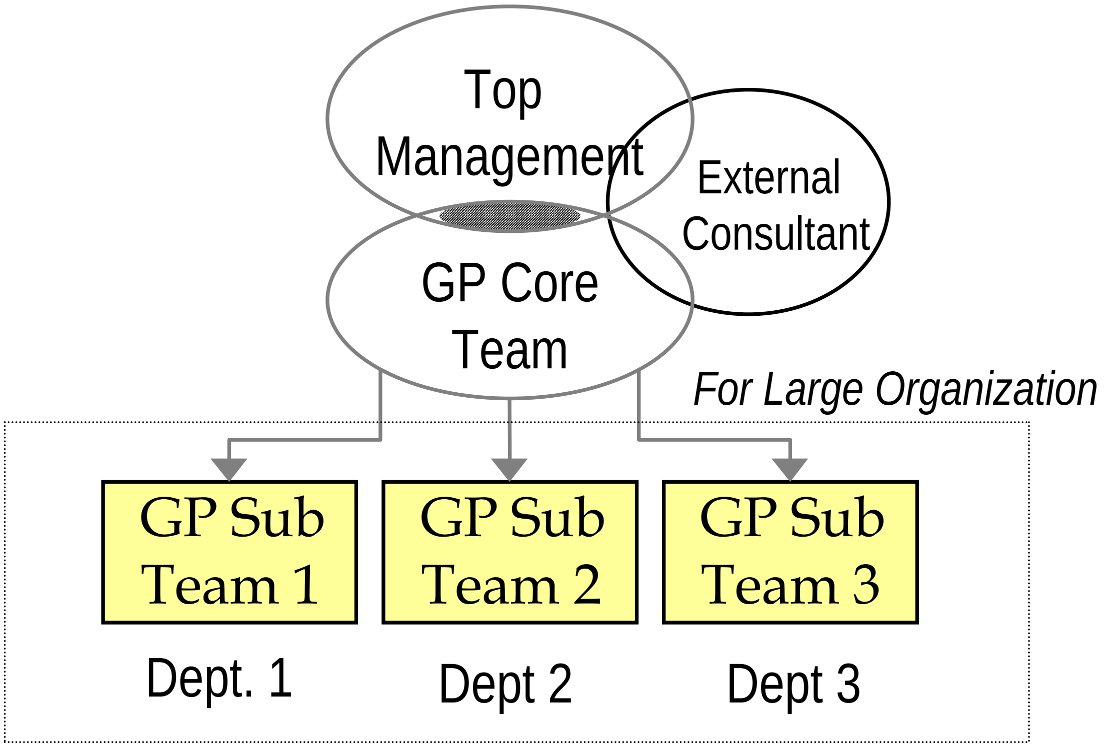
" The essence of Total Quality Control lies in repeated applications of the PDCA procedure until a goal is attained"

~ Dr. Kaoru Ishikawa

Steps of The GP Methodology



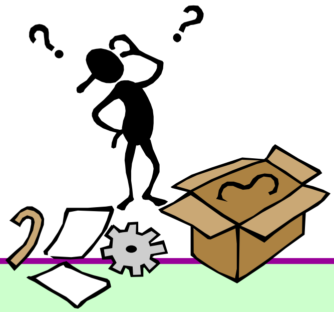
Task 1 : Team Formation



Overlap of the circles indicate the extent of common interaction

Step I

Task 2 : Walk Through Survey and Information Collection



Review Existing Documents

One-to-one Meetings

Carry out Updates

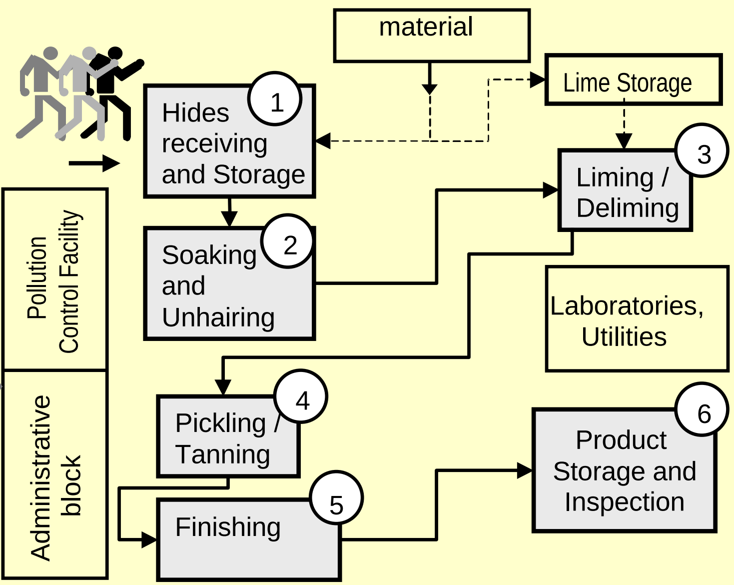
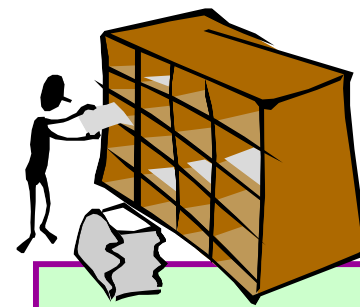


Illustration of Walk-through for a Tannery

Walk Through Survey

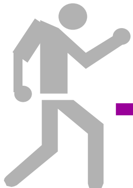


Update and Organize Information

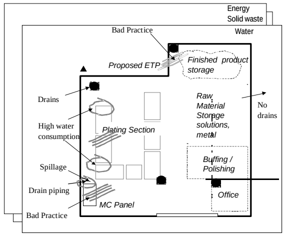
Easy to Access and Use

Step I

Task 3 : Identification of Problems and Causes



Baseline information on Production, Environmental Performance, etc.



Eco-Map to identify focus areas

Plant level comparison with norms

Process Flow Diagram

Plant level Material / Energy Balance

Unit level comparison with production norms

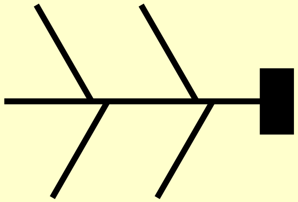
Detailed Unit Level Material / Energy Balance

Identification of Problems

Problem could be with the

- Process
- Water
- Chemicals
- Energy
- Labor
- Costs
- Waste Generated
- Production
- Capacity Utilization
- Product Quality
- Market Demand

Identification of Causes



Step II

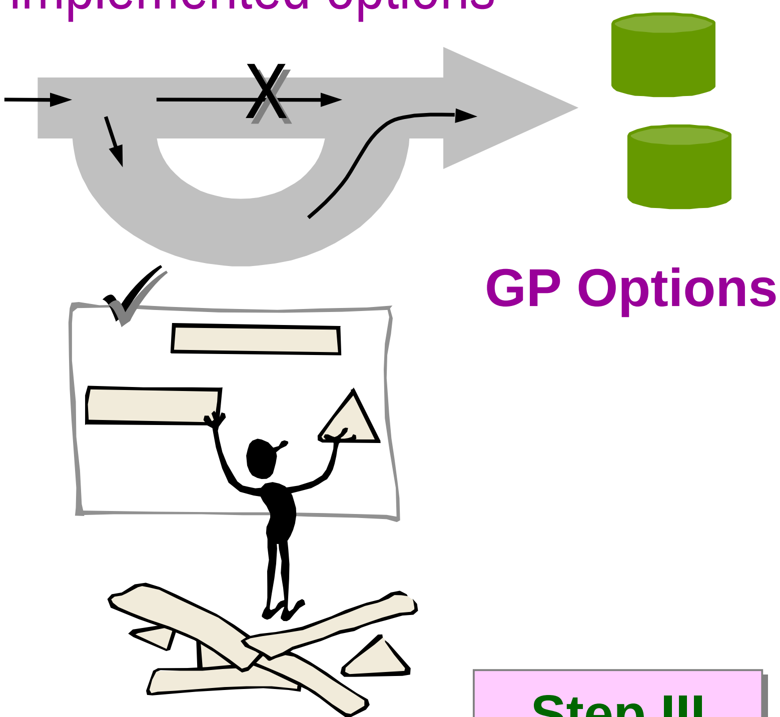
Task 4 : Setting Objectives and Targets

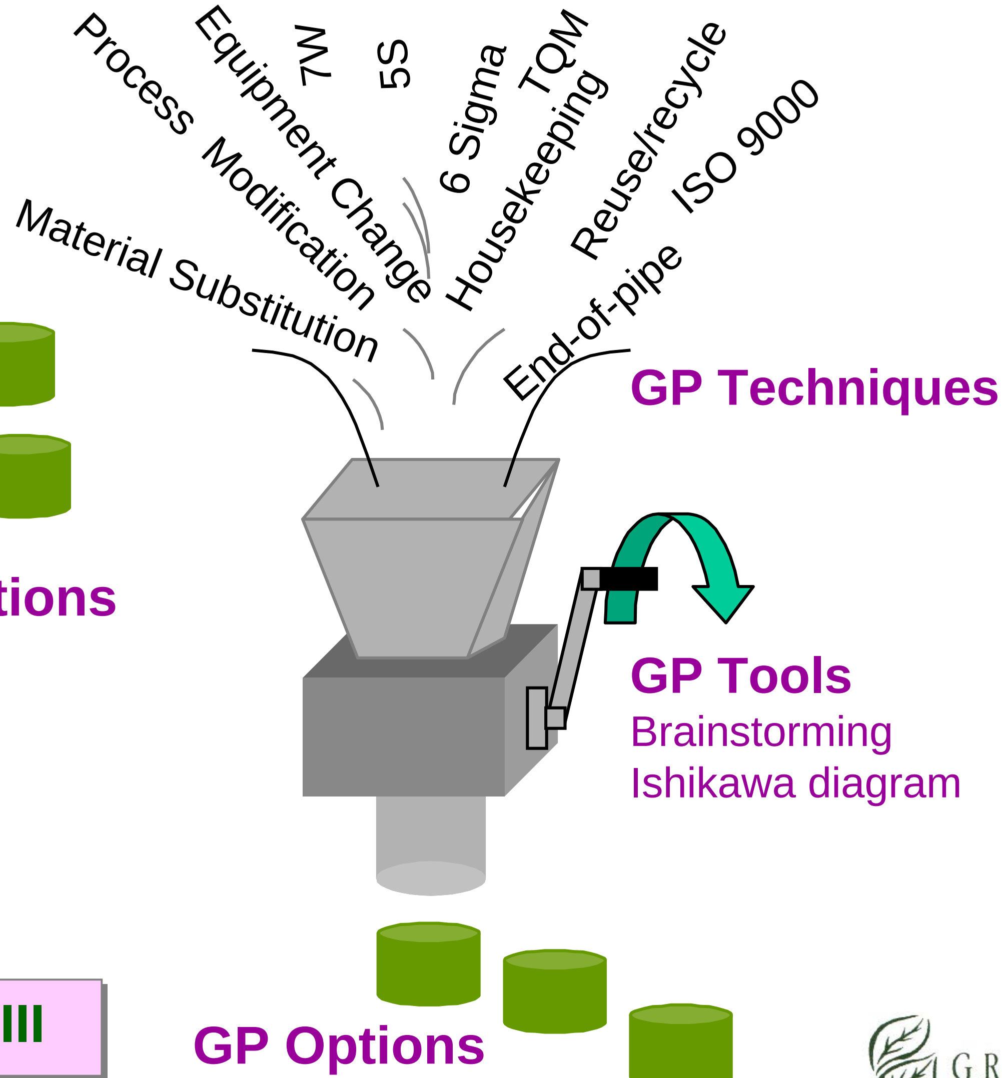
Objective	Attain the present applicable industry norm of 120 litres/kg water consumption		
Targets	***Targeted Achievement***	***Time Frame***	***Initial GP Options***
Target 1	Move from the present level of 180 litres/kg of water to 160 litres/kg	By March 2000	Practice housekeeping, strict process supervision, elimination of unnecessary washes, practice reuse of first washes
Target 2	Reach level of 140 litres/kg	By January 2001	Change dyes and chemicals that reduce wash-offs in the dyeing department
Target 3	Achieve 120 litres/kg	By April 2002	Change two winches to one soft-flow machine in the dyeing department

Step II

Task 5 : Generation of GP Options

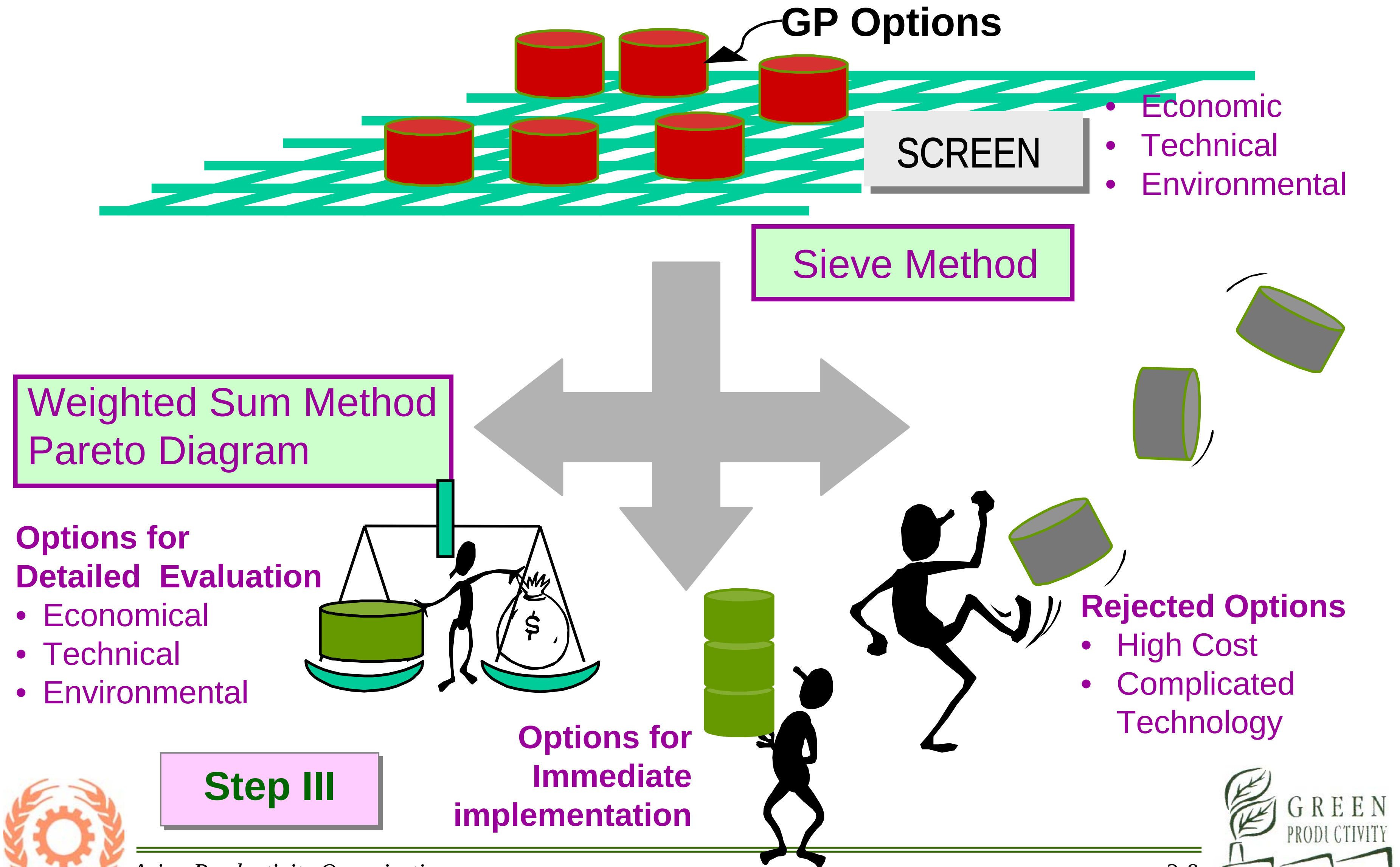
Reviewing past or already implemented options





Step III

Task 6 : Screening, Evaluation and Prioritization of GP Options



Step III

Task 7 : Formation of GP Implementation Plan

S/N	Task	By Whom	By When	Actual Date
1	Design machine modifications	John	End Jun	30 Jun
2	Modify machine	Wada	Mid Jul	12 Jul
3	Develop work instructions	Kim	Mid Jul	15 Jul
4	Training & Briefing of workers	Kelvin	16 Jul	17 Jul
5	Pilot Implementation	ALL	16 Jul	17 Jul
6	Review of pilot implementation results	ALL	16 Aug	20 Aug
7	Make recommendations for standardization to management	Lee	16 Sep	15 Sep

Step IV

Step IV : Implementation of GP Options

Task 8 : Implementation of Selected Options

- Management support needed
- Trial and small scale implementation
- Regular meetings to review and refine options

Task 9 : Training, Awareness Building and Developing Competence

- Assess training needs and establish a training plan
- Select suitable programs, methods and material
- Keep training records
- Evaluating effectiveness of training
- Continuously improve training program and plan

Step V : Monitoring and Review

Task 10 : Monitoring and Evaluation of Results

- Parameters and performance indicators affecting end results
- Appraise the performance of the option against the targets

Task 11 : Management Review

- Effectiveness of the GP Options Implemented
- Tangible and in-tangible benefits
- Financial savings achieved
- Difficulties faced (GP Methodology)
- Identify areas for future improvement

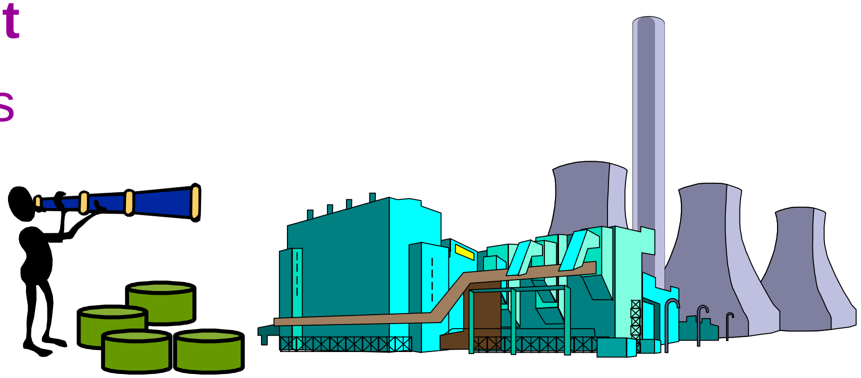
Step VI : Sustaining Green Productivity

Task 12 : Incorporate Changes into Organization's System of Management

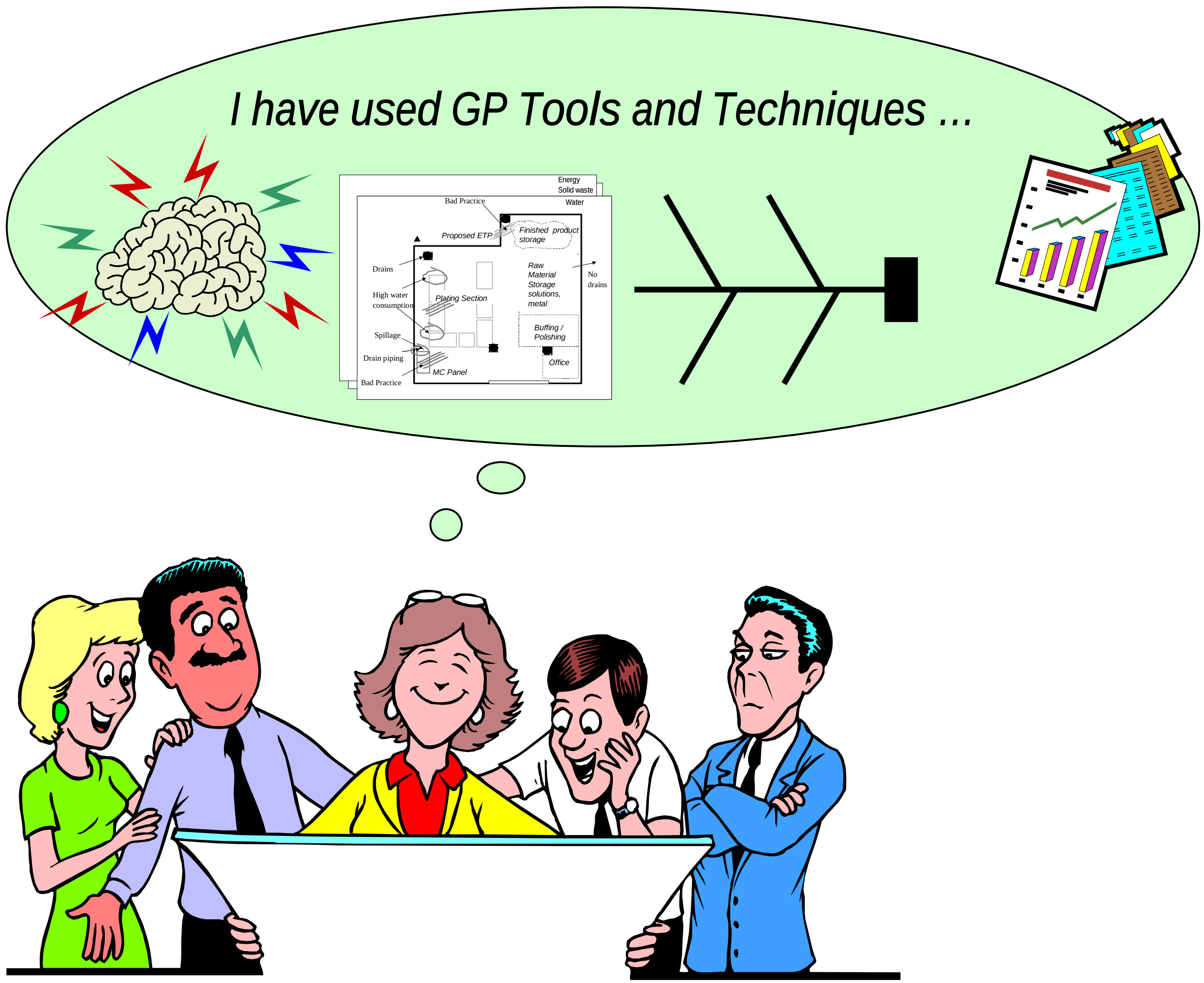
- Integrate GP practices with day-to-day activities
- Update documentation like operations manual, ISO 9000 QMS or ISO 14 000 EMS

Task 13 : Identify of New / Additional Problem Areas for Continual Improvement

- Prices / Availability of resources
- New Products / New Markets
- New Legislation / regulations
- New Competition
- Change in cash flow
- New Technology / New processes



Part 3 : GP Tools and Techniques

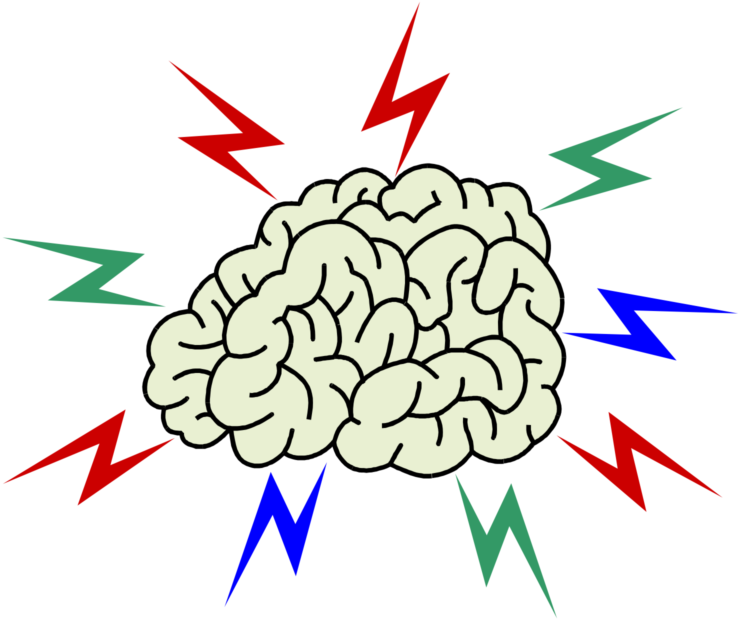


Part 3 : GP Tools and Techniques

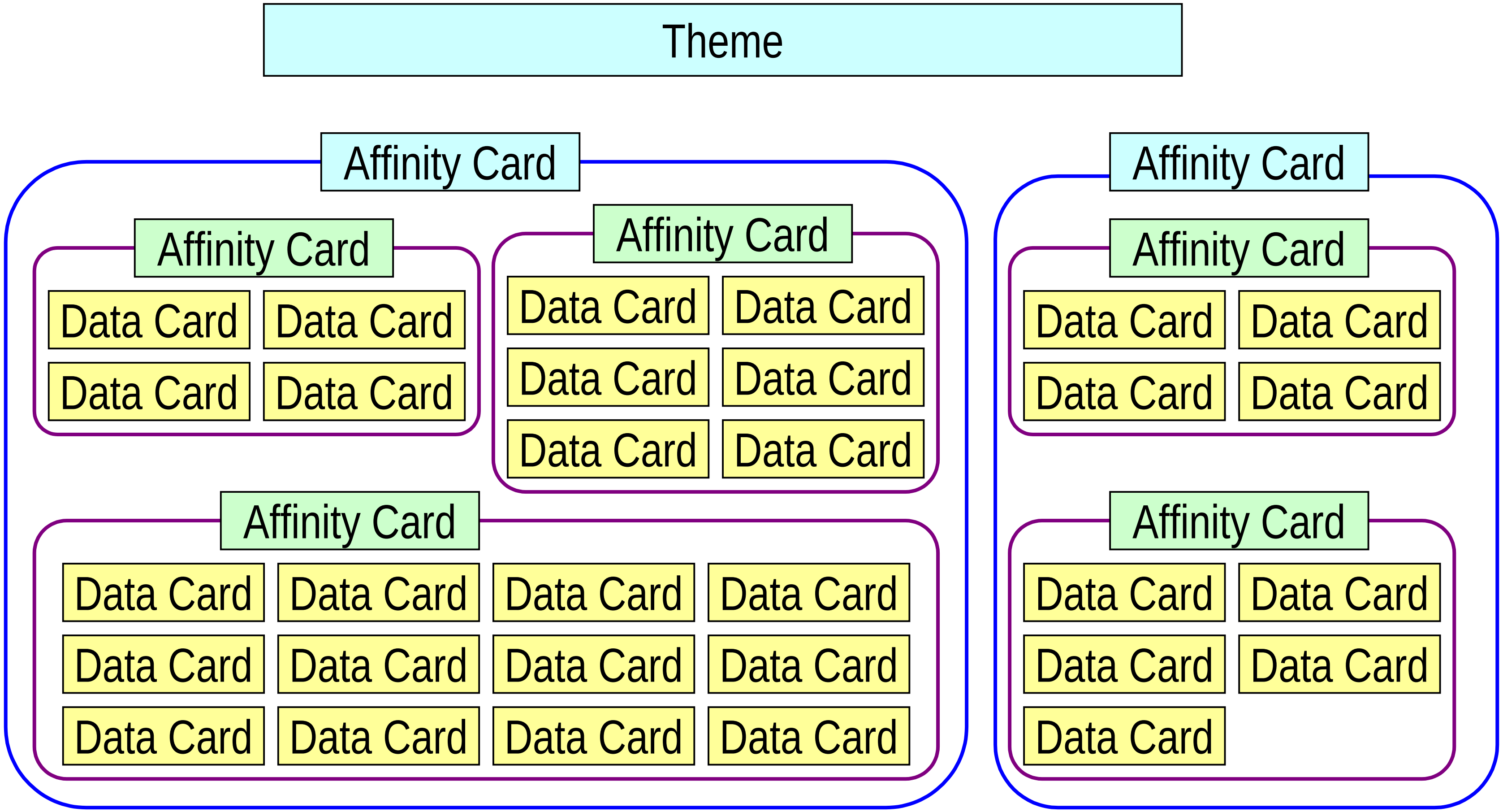
GP Tools and Techniques / Steps of GP Methodology	1 Brain Stroming	2 Flowchart	3 Process Flow Diagram	4 Plant Layout	5 Eco-Map	6 Concentration Diagram	7 Material Balance	8 Energy Balance	9 Ishikawa Diagram	10 Cause-Effect Analysis	11 Pareto Chart	12 Cost Benefit Analysis	13 Decision Matrix	14 Source Reduction	15 Recycle, Reuse and Recovery	16 End-of-Pipe Treatment	17 Design for Environment	18 Life Cycle Assessment	19 7 Wastes of Production	20 5S Good Housekeeping
Step I: Getting Started																				
Task 1: Team formation	X																			
Task 2: Walk through survey and Data Collection	X	X	X	X	X	X	X	X			X	X								
Step II: Planning																				
Task 3: Identification of problems and causes	X	X	X	X	X	X	X	X	X	X	X	X								
Task 4: Setting objectives and targets											X	X	X							
Step III: Generation, Evaluation and Priortization of GP Options																				
Task 5: Generation of GP Options	X													X	X	X	X	X	X	X
Task 6: Screening, Evaluation and Priortization of GP Options											X	X	X							
Step IV Implementation of GP Options																				
Task 7: Formulation of GP implementation plan	X																			
Task 8: Implementation of selected options														X	X	X	X	X	X	X
Task 9: Training, awareness building and developing competence		X	X	X	X	X	X	X	X	X										
Step V Monitoring and Review																				
Task 10 Monitoring and Evaluation of results		X	X		X	X	X	X			X	X								
Task 11 Management review											X		X							
Step VI Sustaining GP																				
Task 12 Incorporating changes into organization's system of management		X	X	X																
Task 13 Identifying new / additional problem areas for continual improvement	X	X	X	X	X	X					X	X	X							

Brainstorming

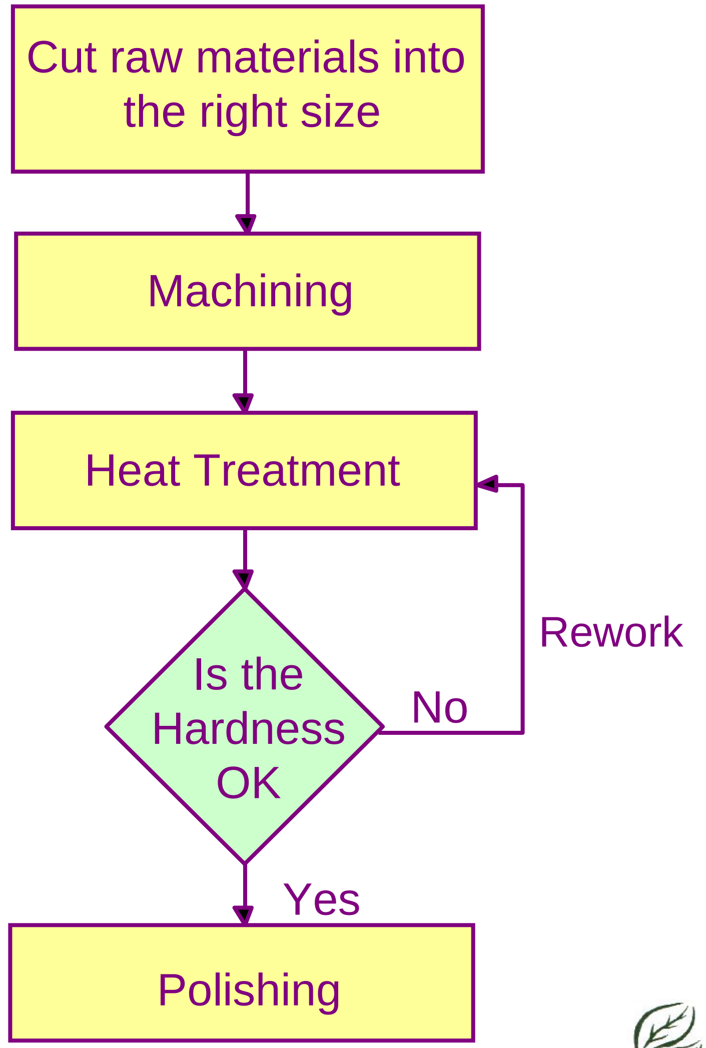
- Define the topic clearly
- Keep the meeting in a relaxed setting
- Set a time limit
- Go round and take turns
- Record all ideas
- Do not evaluate ideas
- Team leader to facilitate session
- Generate new ideas from suggested ideas



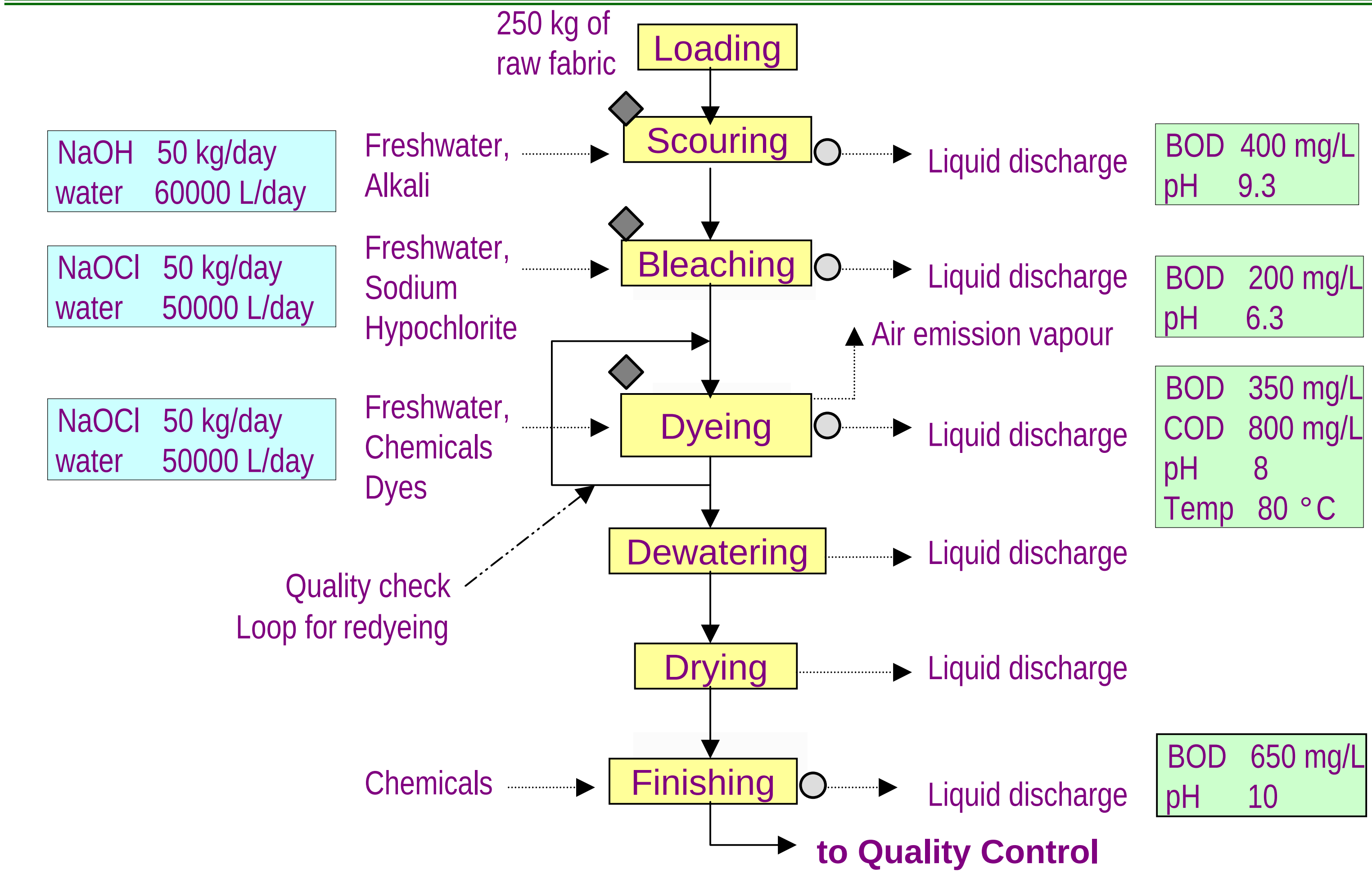
Affinity Diagram (KJ Method)



Flow Chart


Cut raw materials into the right size
Machining
Heat Treatment
Is the Hardness OK
No
Rework
Yes
Polishing

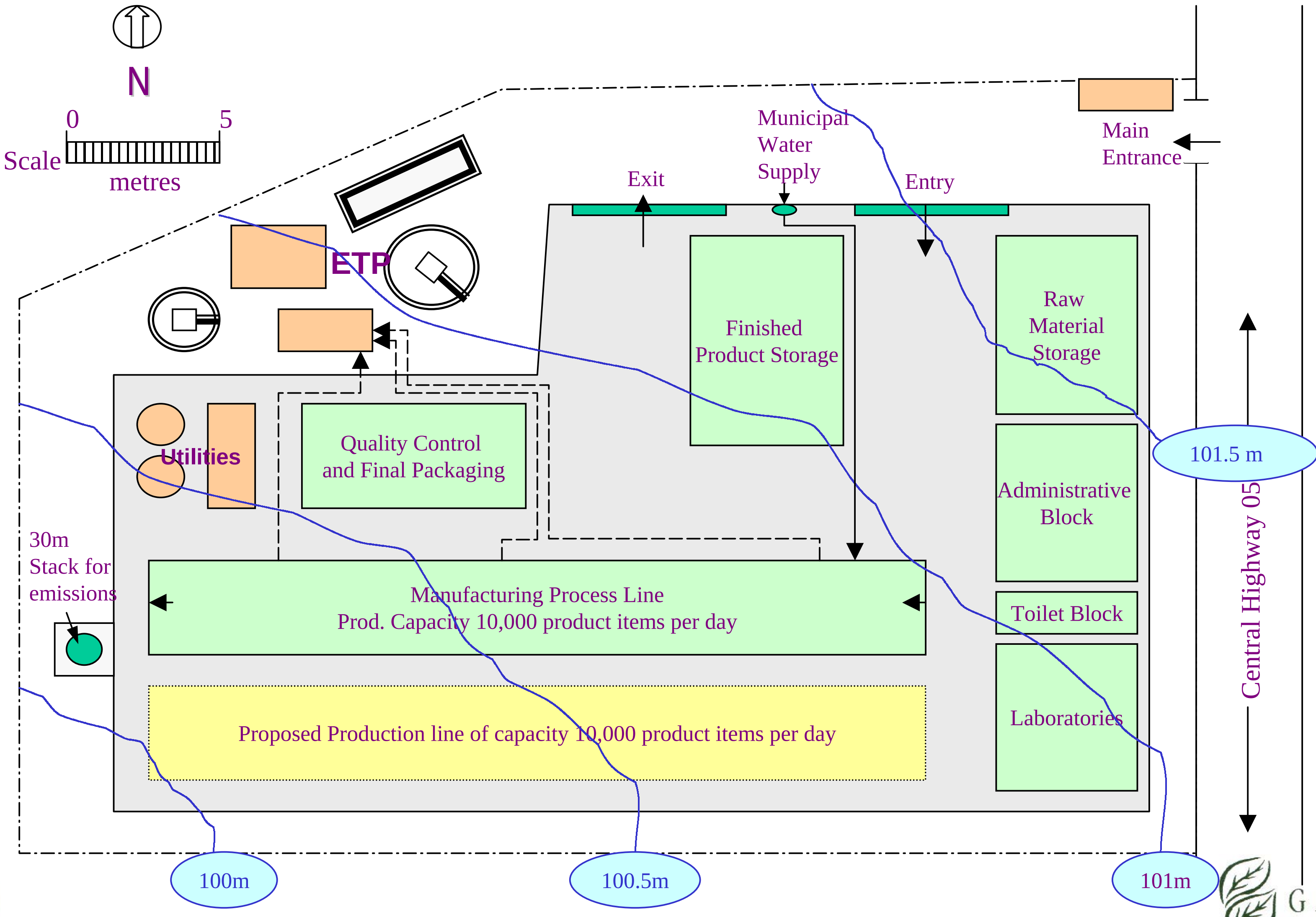
Process Flow Diagram (PFD)



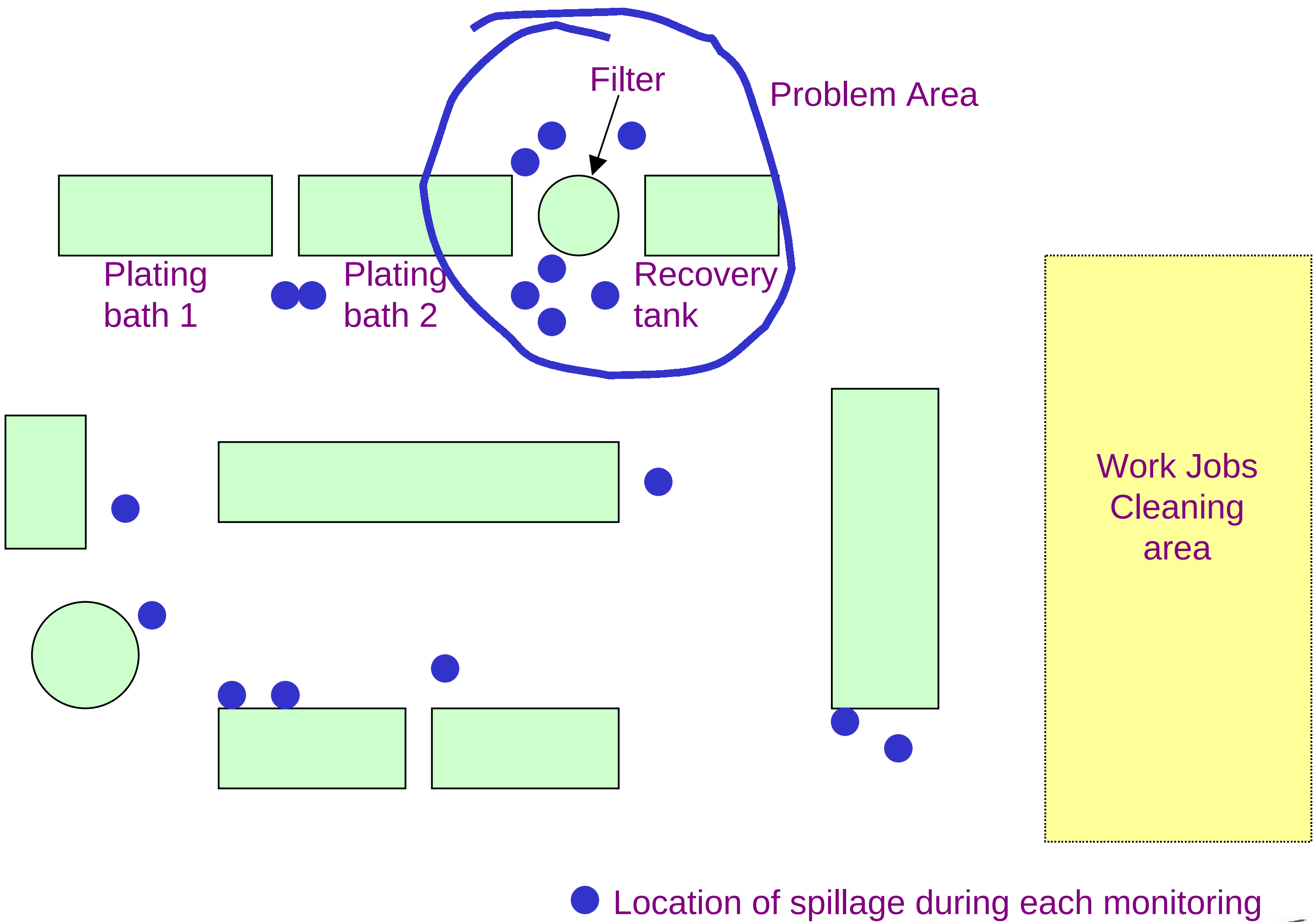
○ *Indicates wastewater sampling location*

◆ *These operations are conducted in batches and each process batch comprises certain operations such as washes etc. Fill and draw technique is used. There are about 4 batches a day for each process, i.e. 4 discharges /day*

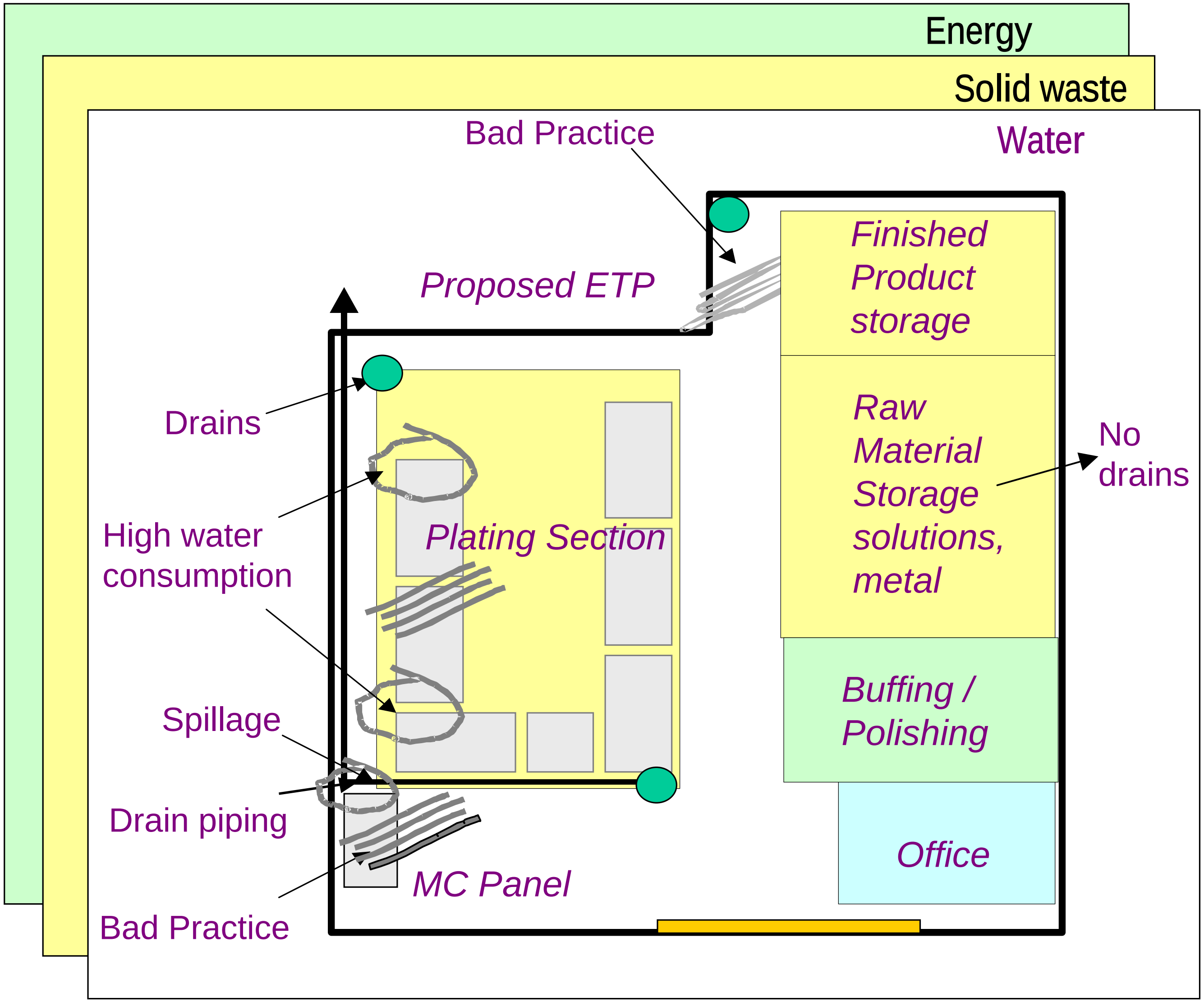
Plant Layout



Concentration Diagram



Eco-Map



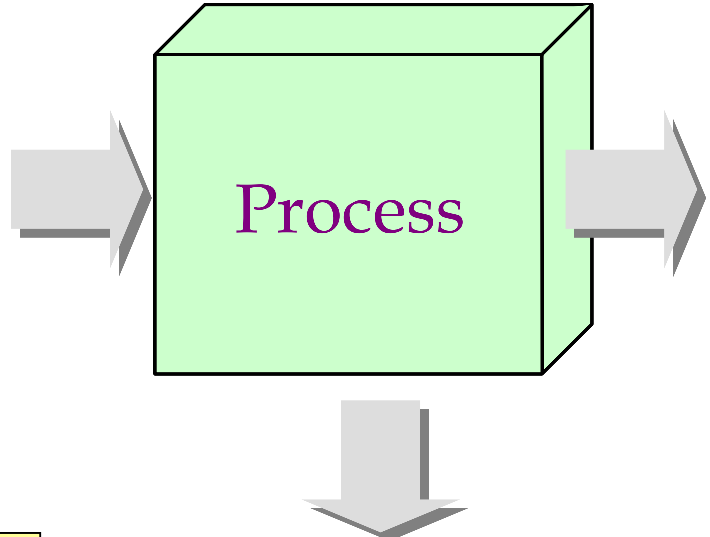
Energy
Solid waste
Water
Bad Practice
Proposed ETP
Finished Product storage
Drains
Raw Material Storage solutions, metal
No drains
High water consumption
Plating Section
Spillage
Buffing / Polishing
Drain piping
Office
MC Panel
Bad Practice

Material Balance

Inputs

Raw materials
Energy
Water
Chemicals

2,642,900 kg/d



Outputs

Products,
Useful
byproducts

2,469,693 kg/d

Wastes

Air emissions
Effluents
Solid waste
Heat losses
Off-spec products
Byproducts

Inputs = Output + Wastes

Discrepancy
7.0%

Energy Balance

INPUT

Steam

Type — Quantity

---------- ----------

Electricity

Quantity — kW

Fuel Consumption

Item	Quantity
Coal	-
Oil	-
Any other	-

Process

OUTPUT

Products

Item Heat Content Qty.

P1

P2

Energy Losses

Item Heat Content Qty.

1

2

Wastewater

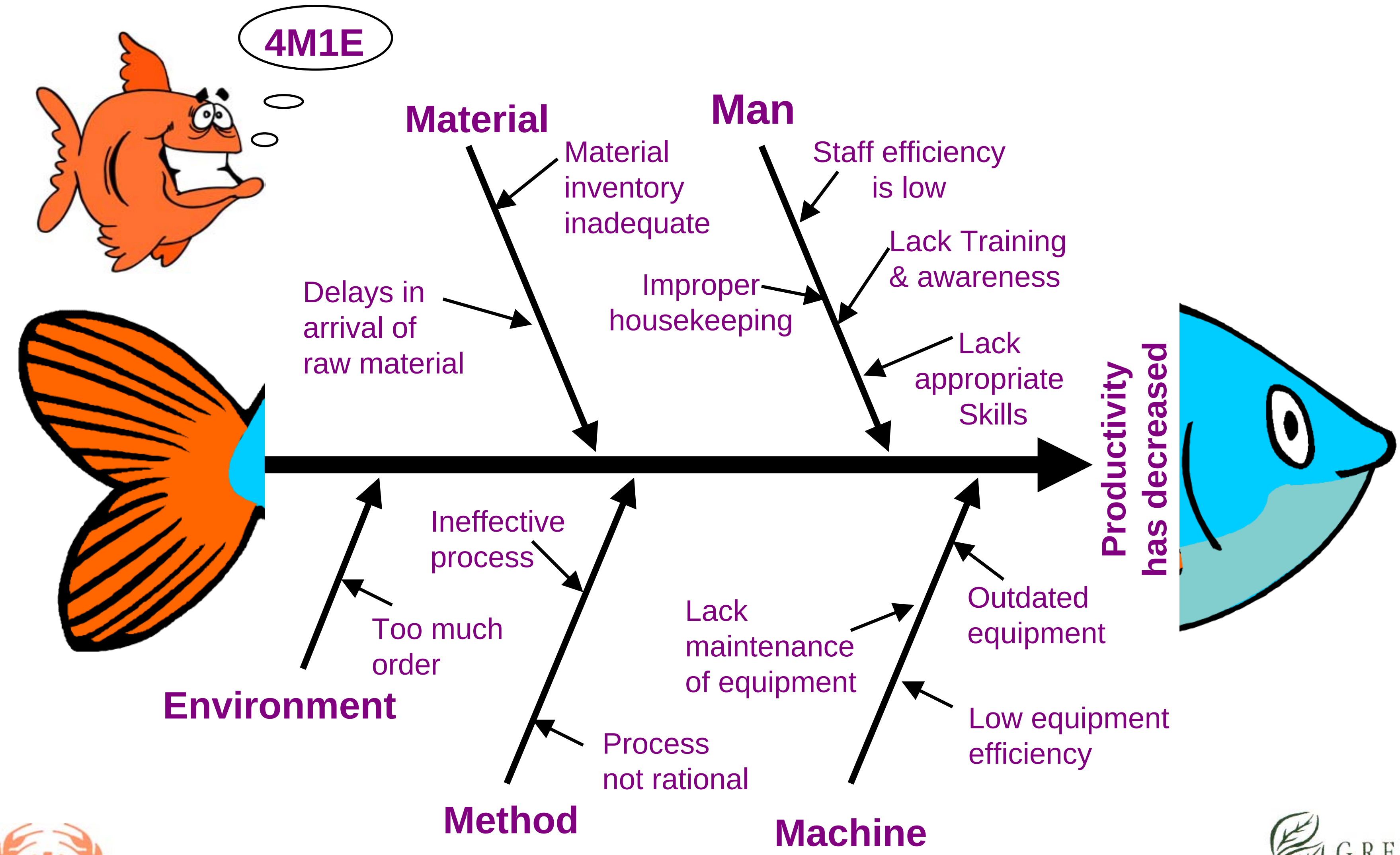
Item Heat Content Qty.

Process

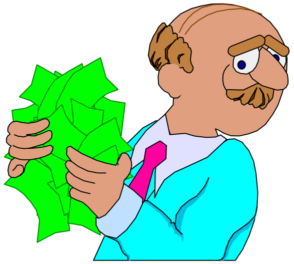
Condensate

Cooling

Ishikawa Diagram



Cause and Effect Analysis



? ? ?

Problem 1

Cause 1 Cause 2 Cause 3

Why?

How?

Common Causes?

Common Problems?

Cause 1

Problem 1 Problem 2 Problem 3

Problem 1

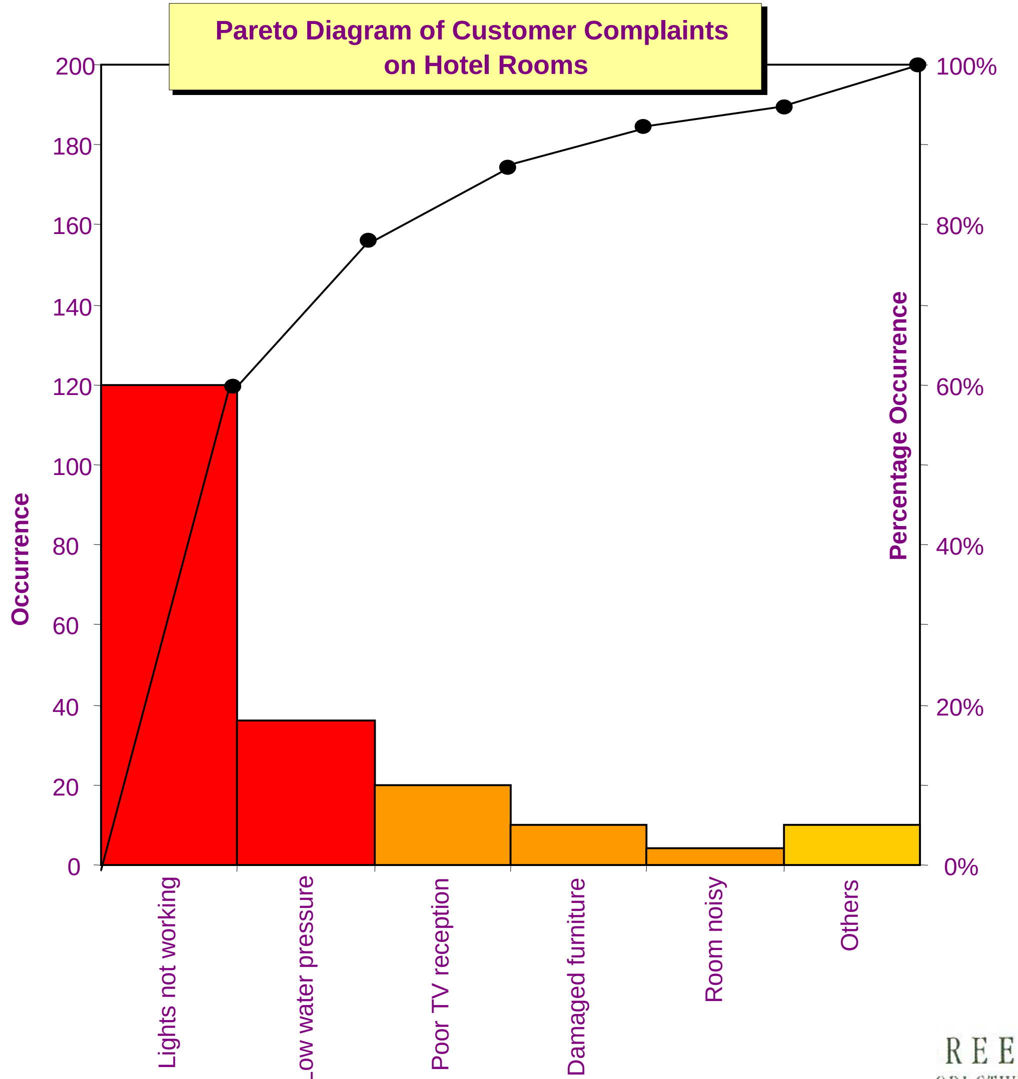
Problem 2 Problem 3 Problem 4

Problem 5

Pareto Diagram

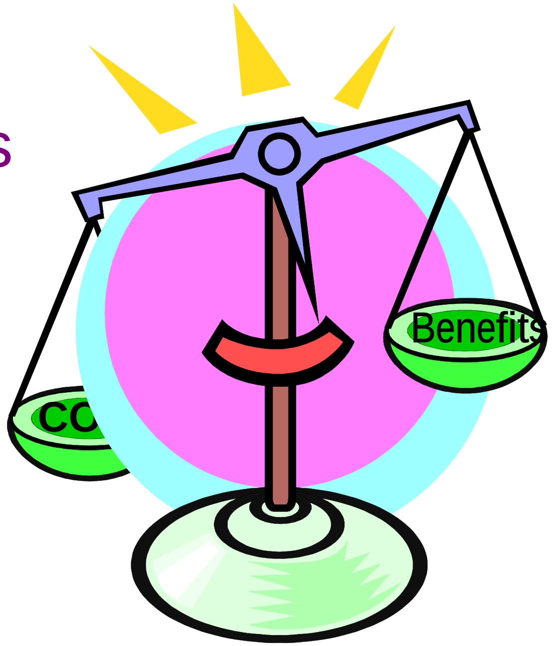
Types of Complaints	Occurrences	Cumulative Occurrences	Percentage	Cumulative Percentage
Lights not working	120	120	60%	60%
Low water pressure	36	156	18%	78%
Poor TV reception	20	176	10%	88%
Damaged furniture	10	186	5%	93%
Room noisy	4	190	2%	95%
Others	10	200	5%	100%
TOTAL	200		100%	

Pareto Table



Cost Benefit Analysis

- **Qualitative**
  - Advantages and Disadvantages



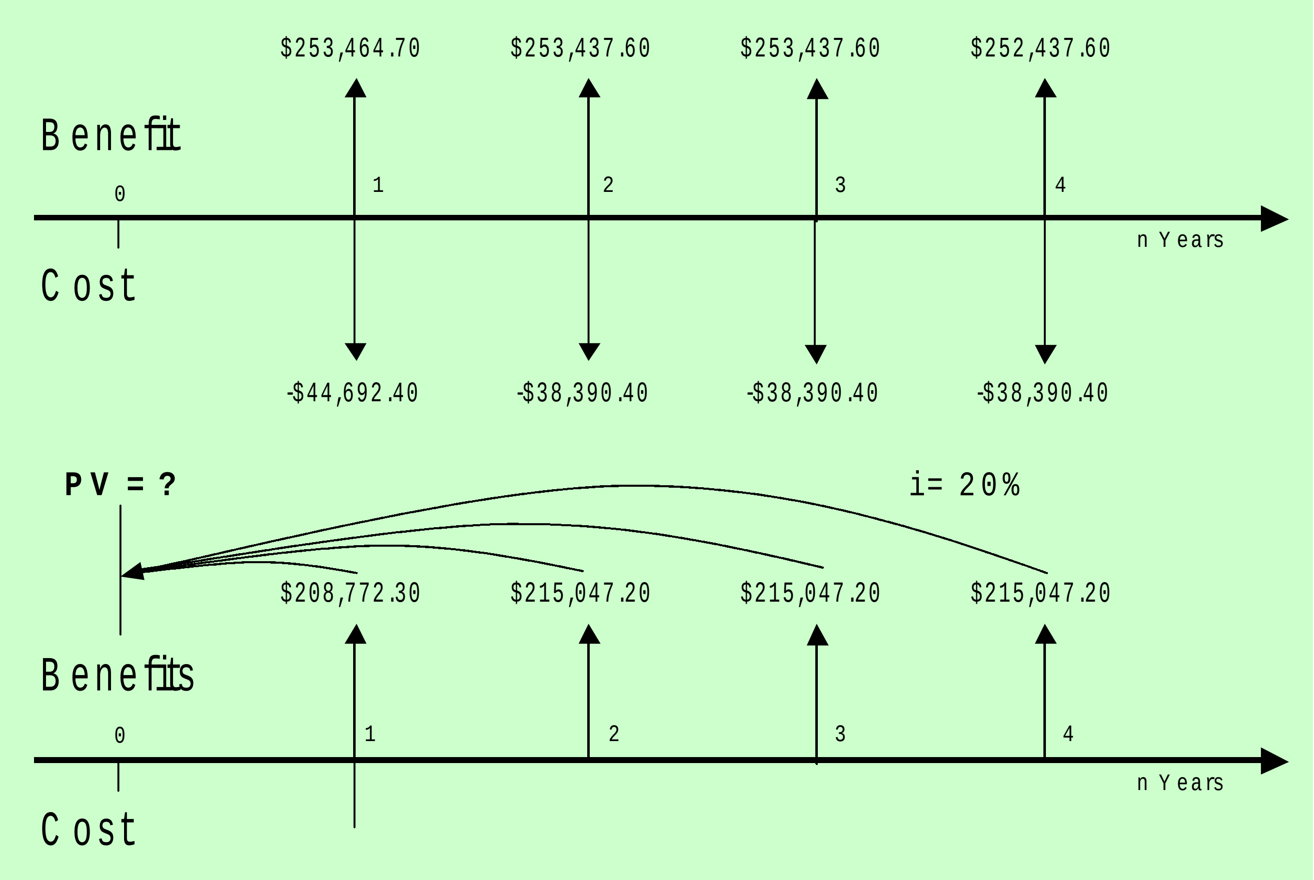
- **Quantitative**
  - Simple payback
  - Net Present Value (NPV)
  - Internal Rate of Return (IPP)

- **Pay Back Period**

$$\text{Pay Back Period} = \frac{\text{Capital Investment (\$)}}{\text{Annual Savings (\$/yr)}} \text{ years}$$

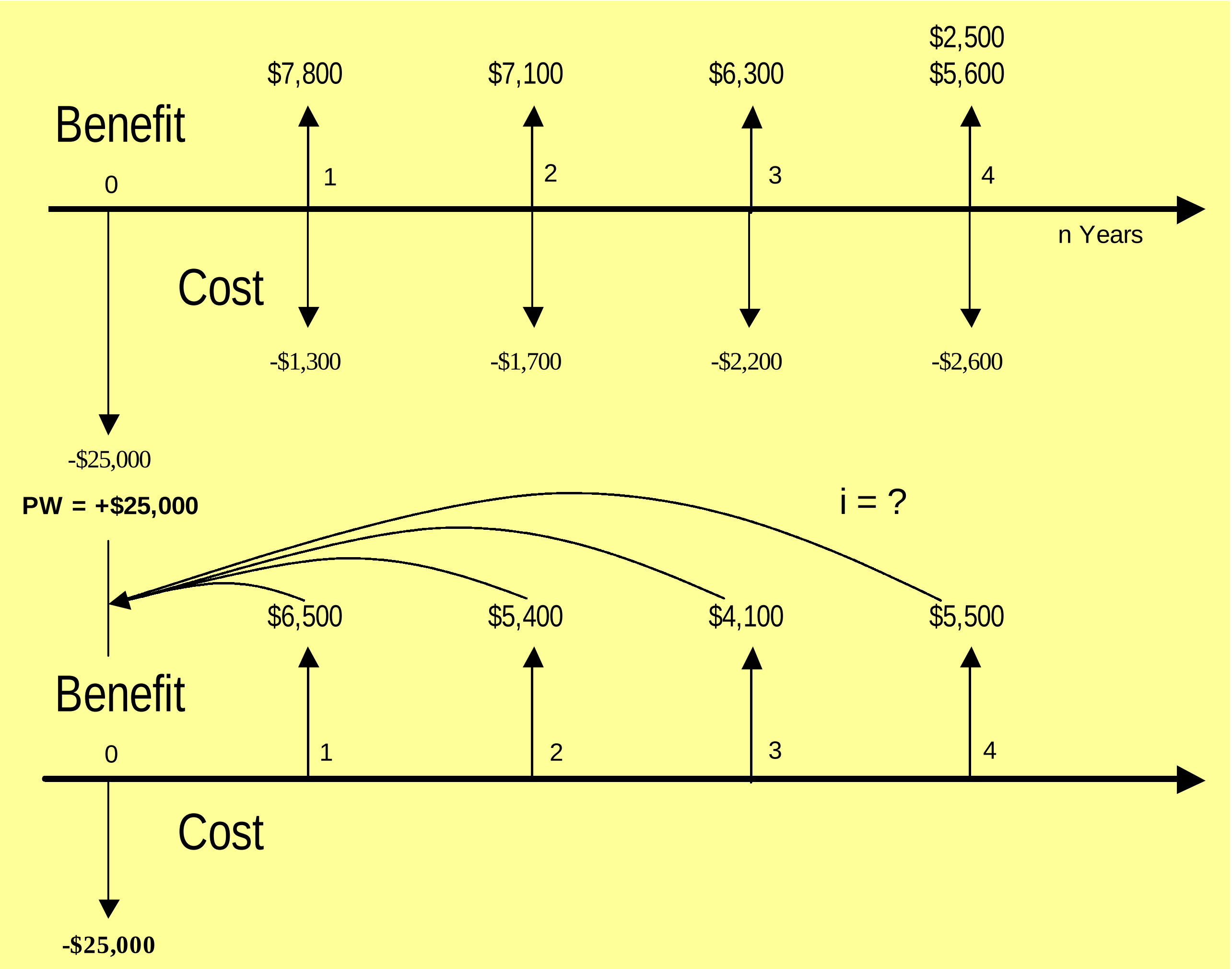
Net Present Value (NPV)

$$NPV = \sum_{i=1}^{n} CF / (1+i)^n - I$$



Internal Rate of Return (IRR)

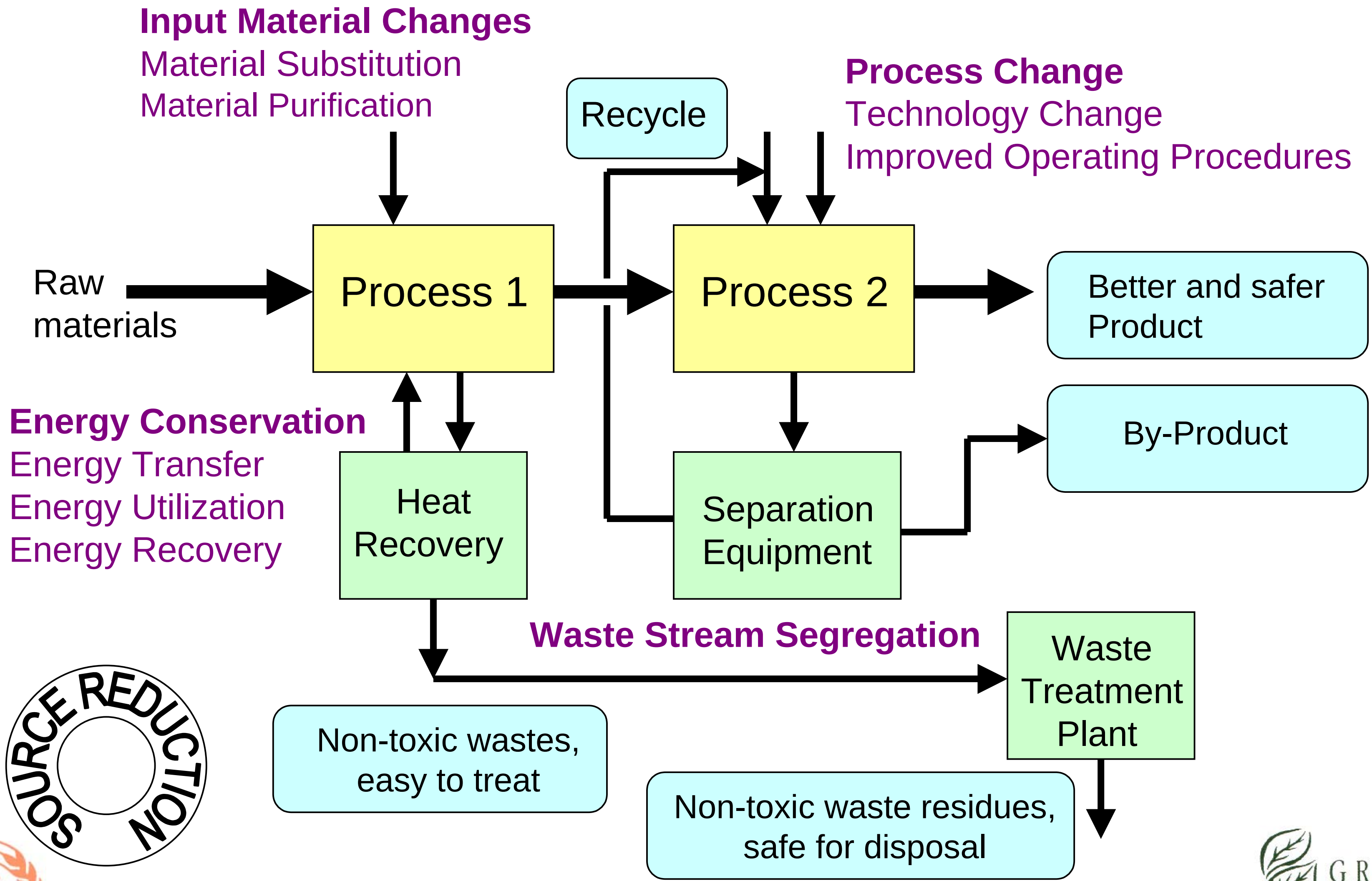
- Interest rate where Net Cash Flow equals to Zero



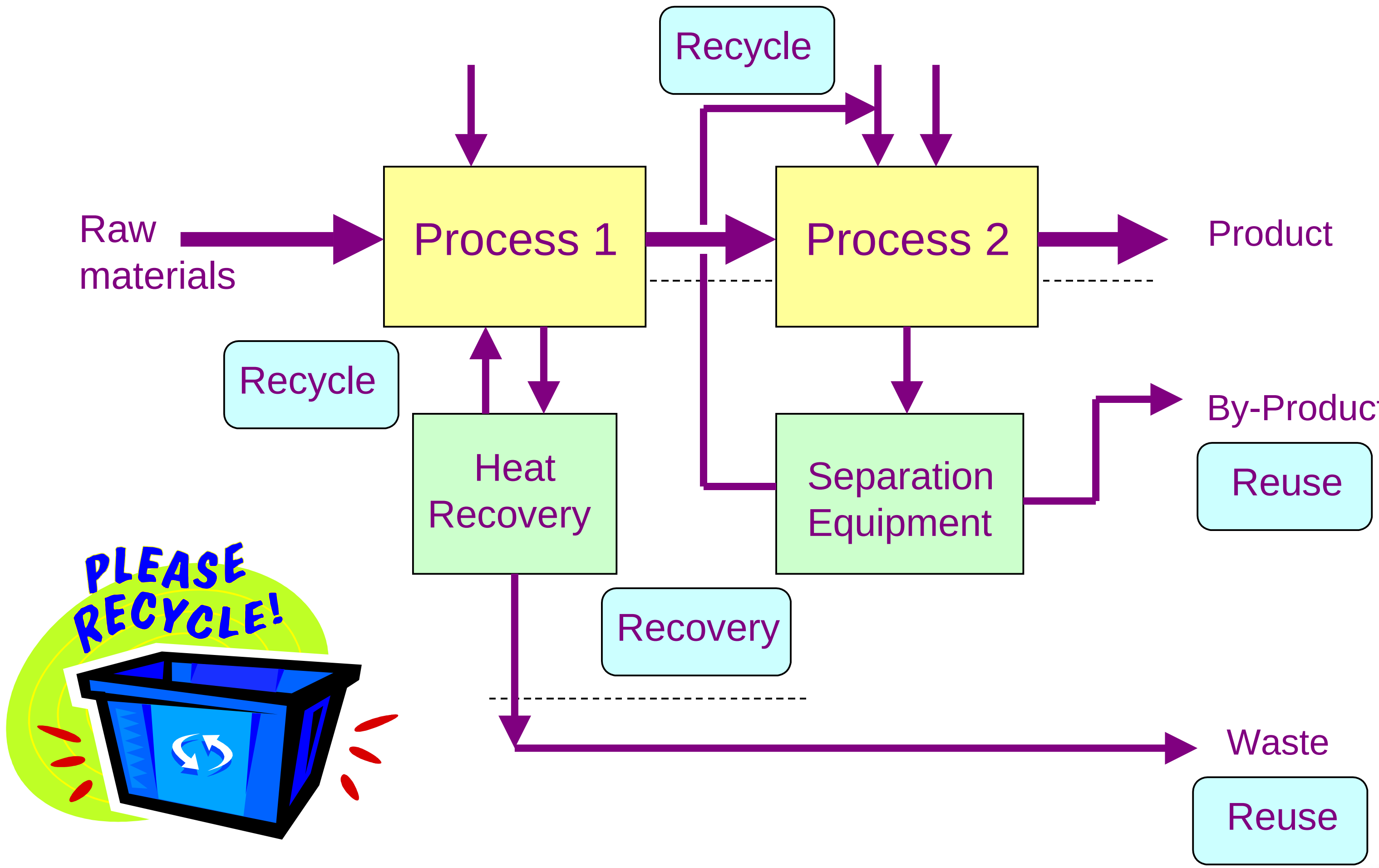
Decision Matrix

Problem	Severity	Frequency	Cost implications for resolving the problem	Cost of inaction	Score (1-10) 10 is top priority
Productivity					
Material consumption	High	Always	High	High	9
Product quality	Medium	82% success	Moderate	Moderate to High	6
Housekeeping	High	Always	Minimal	Moderate to High	10
Environment					
Legal compliance	Medium to High	Occasionally on air, always on effluents	High	High	7
Business					
No. of rejects from customers	Minimal	5%	Minimal	High	4

Source Reduction

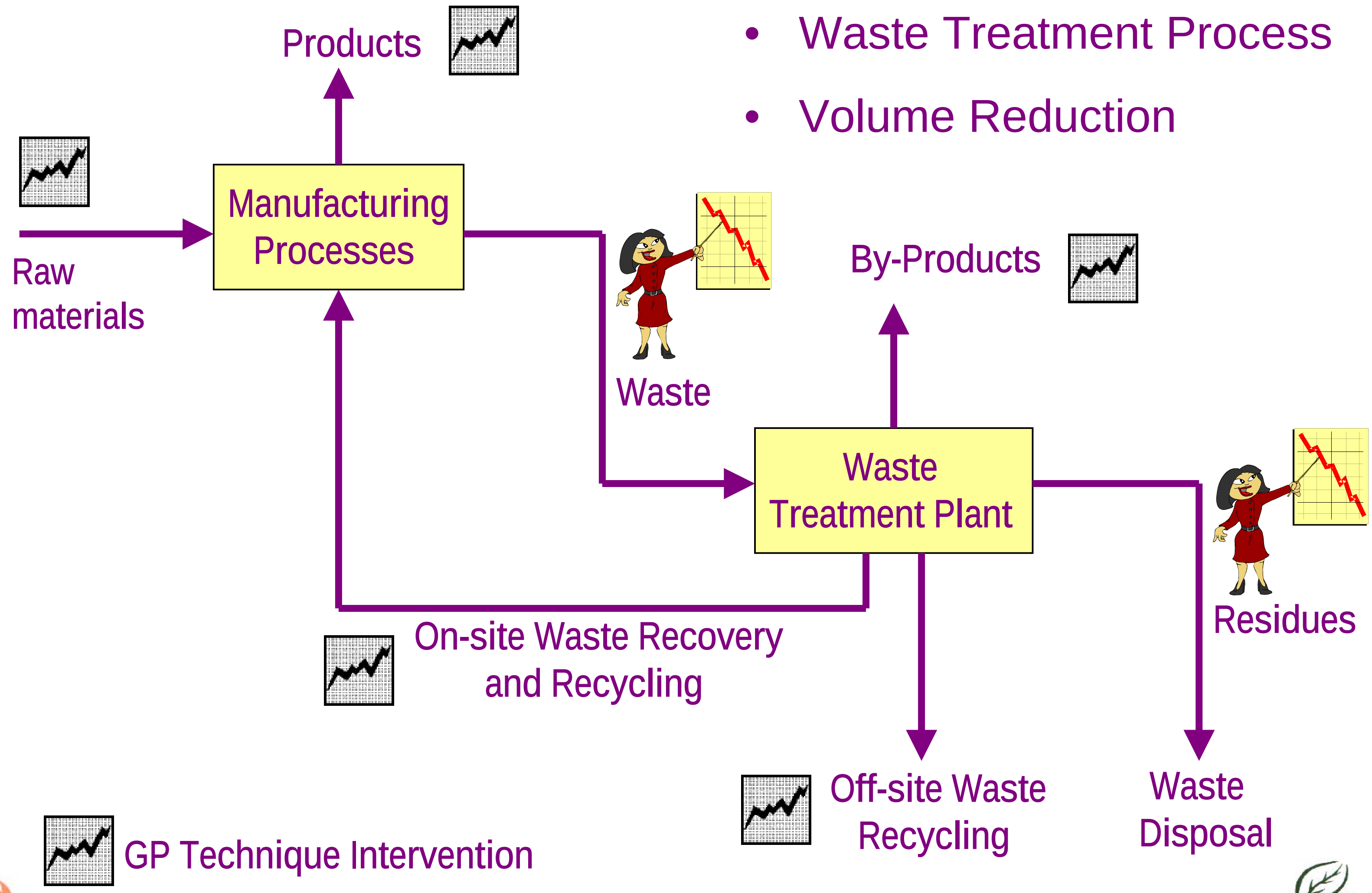


Recycle, Reuse and Recovery



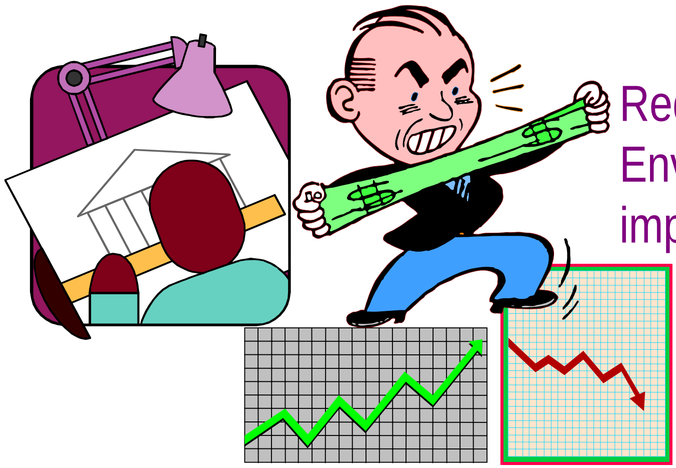
End-of-Pipe Treatment Technologies

- Waste Treatment Process
- Volume Reduction



Designing Environmentally Compatible Products

Lower production costs through efficient resource utilization



Reduce Environmental impact

Improve product performance

Design for Environment

Life Cycle Assessment

Goal definition and Scope →

Inventory analysis
Process flow chart; data collection; system boundary defined and data processing

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Impact Assessment
Classification and characterization of effects of resource use; valuation

←

Improvement Assessment
Reporting; evaluation of the need and opportunities to reduce impact

7 Wastes (7W)

- Waiting — *Leaving resources waiting during production*
- Transporting — *Moving materials unnecessarily in the factory*
- Processing — *Wastes inherent in the process or design itself*
- Inventory — *Keeping high inventory or work-in-process (WIP)*
- Motions — *Unnecessary movements of the worker during operation*
- Defects — *Producing defective parts or poor service*
- Overproduction — *Produce more than what is needed*

5S Good Housekeeping Practices

- Seiri - Sorting
- Seiton - Arranging
- Seiso - Cleaning and Inspecting
- Seiketsu - Improving and Standardizing
- Shitsuke - Self-Discipline