DECISION MAKING WITH ANALYTICAL HIERARCHY PROCESS (AHP) FOR Viable MANUFACTURING OF SCREW

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A project report submitted in partial fulfillment of the requirement for the award of the Degree of Master of Mechanical Engineering

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This study is an approach to investigate the viable impacts of screw manufacturing and to choose the suitable material for selected manufacturing process of screw by putting environmental aspects as important as economic aspect. The parameters involved were types of material and manufacturing process of screw that using the available data of environmental and production volume. The two different manufacturing approaches being evaluated were machining and forging process. The types of material concerned for forging process encompassed low carbon steel, alloy steel, stainless steel, and aluminium alloy. On the other hand, for machining process, the material being considered in screw manufacturing were cast iron, low carbon steel, alloy steel, stainless steel and aluminium alloy. The information of environmental impacts that generated from SolidWorks Sustainability tool and screw production cost were calculate using Manufacturing cost model, both information was used in Analytic Hierarchy Process (AHP) analysis to obtain local priority of economic and environmental impacts. Then, the ranking of global priorities with combination of local priority from economic impact and environmental impacts had enabled the determination of appropriate material used for those selected screw manufacturing process. As result, low carbon steel was chosen for forging process whereas cast iron was excelled in machining process, at the same time, stainless steel was not suggested to be used in all two processes.
Kajian ini merupakan satu pendekatan untuk mengkaji gabungan kesan alam sekitar dan kesan ekonomi bagi pembuatan skru dan memilih bahan yang sesuai untuk proses pembuatan skru yang terpilih, aspek alam sekitar diletakkan sama pentingnya dengan aspek ekonomi. Parameter yang terlibat adalah jenis bahan skru dan jenis proses pembuatan skru. Jenis proses pembuatan skru yang dikaji adalah proses pemesinan dan proses penempaan. Jenis bahan skru yang dikaji dalam proses penempaan merangkumi keluli karbon rendah, keluli aloi, keluli tahan karat, dan aloi aluminium. Sebaliknya, untuk proses pemesinan, bahan yang dikaji dalam proses pembuatan skru ialah besi tuangkan, keluli karbon rendah, keluli aloi, keluli tahan karat dan aloi aluminium.

Maklumat impak alam sekitar yang dijana daripada perisian SolidWorks Sustainability tool dan maklumat kos pula diperolehi melalui modul kos pembuatan, kedua-dua maklumat telah digunakan dalam Analytical Hierarchic Process (AHP) untuk mendapatkan pemberatan untuk impak ekonomi dan impak alam sekitar. Kemudiannya, daripada pemberatan gabungan daripada kesan ekonomi dan impak alam sekitar telah membolehkan penentuan bahan yang sesuai dipilih. Hasilnya, keluli karbon rendah telah dipilih untuk proses penempaan manakala besi tuangkan cemerlang dalam proses pemesinan, pada masa yang sama, keluli tahan karat tidak dicadangkan untuk digunakan untuk kedua-dua proses yang dikaji.

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\[ M_i = V C_{mt} + R_c P_c \]

\( V \) = volume of material required in order to produce the component

\( C_{mt} \) = the cost of the material per unit volume

\( P_c \) = Basic processing cost for an ideal design of component by a specific process

\( R_c \) = relative cost coefficient assigned to a component design.

\( R_c = C_{mp} C_c C_s C_{ft} \)

\( C_{mp} \) = suitability of using various materials with different processes

\( C_c \) = Shape complexity

\( C_s \) = Section coefficient

\( C_t \) = Tolerance coefficients

\( C_f \) = surface finish coefficients
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CHAPTER 1

INTRODUCTION

Joining process is a process to join two or more parts together. Welding, brazing, soldering, mechanical fastening, and adhesive bonding are few types of joining process. Mechanical fastening can be used to provide either temporary or permanent joints, while adhesive bonding, welding, brazing, and soldering processes are mainly used to provide permanent joints [1]. Joining process can either be permanent or temporary depend on the uses or the design that required, Mechanical fastener used widely in manufacturing industry, the advantage of mechanical fastening is that it doesn’t cause metallurgical reaction, it is suitable from joining material that is sensitive to heat. Mechanical fastening can join metal and non-metal, in mechanical assembly method Mechanical fastening play a central role, it is design for easy maintenance.

There several kinds of common Mechanical fastening such as bolts and nuts, screws and rivet, Screw can be consider the most versatile fastener and the most common uses of screws are to hold objects together in position required. A screw is an externally threaded fastener capable of being inserted into holes in assembled parts, of mating with a preformed internal thread or forming its own thread, and of being tightened or released by torquing the head [2]. Screw and bolt look alike and to differentiate it a bolt is normally intended to be tightened or released by torquing a nut, screw stands alone meanwhile bolt is paired with nut. Screw consists of two main parts that is head and shank. (see Figure 1.1). Screw head, is specially formed section it allows screw head to be turned by screw driver or wrench. The cylindrical portion of the screw from the underside of the head to the tip is known as the shank; it may be fully threaded or partially threaded [3]
Screws were made of wood when it was first introduced, used for fastening purpose for device such as wine presses, Used throughout the Mediterranean world by the 1st Century BC. Modern metal screw was introduce only the 15th Century but only towards the end of the 18th Century mass production were developed. Screw manufacturing is dealing with number operation and sequences of operation until it reach the desired state/design. The main shaping process for screw involves material removing process and also deformation process.

The two main shaping operations used in industry for screw production are machining and cold heading [4]. Machining is the oldest method of fastener production, and it is still specified for very large diameters and small production runs, although this process is time consuming and costly, it can apply on variety of size and head type. With the introduction of CNC machining in screw production it increase the production volume compare to conventional machining.

Cold heading is the more common in screw production this is because of it high production rate, Cold heading has many other advantages such as more economical use of materials, lower scrap, more cost-effective production and fewer secondary operations required. Cold heading transforms wire into the desired shapes by applying enough pressure to cause the metal to plastically deform into the die and punch cavities, no preheating the material that is why it is called cold heading.

1.1 Background of study

Screw manufacturing is being chosen for this study and it is among the most established manufacturing industry, screw can be categorized as non-permanent joint
or fastener, it is used to join parts that can be easily disassembled. Screw can join metal part with non-metal part, it can join any parts together from any kinds of material, and Screw is non-permanent join so it is suitable for design that need disassemble for maintenance purpose. That is why it widely used in furniture making industries, home appliance, automotive industries, and electronic industries and building structures.

1.1.1 Screw types

There are many types of screw available is the market, normally they are categorized with types of head, shape of screw head, types drive, and types of material. There few common types of screw found are cap screw, wood screw, machine screw and self-tapping screw. (see Figure 1.2). Cap screw normally has hexagonal shape head, designed to be driven by a spanner or wrench), Wood screw, designed for wood has a tapered shaft allowing it to penetrate, Machine screw has a cylindrical shaft and fits into a tapped hole and lastly self-tapping or self-drilling screw has a cylindrical shaft and a sharp thread that cuts its own hole normally used for sheet metal.

![Fastener Categories](image)

Figure 1.2: Fastener categories [5]

If categorized by shapes of screw head, common screw types found are flat head, oval head, pan head, hex head, socket cap, button and countersunk. (see Figure 1.3). A variety of tools exist to drive screws into the material, they are flat screwdriver, Phillips screwdriver, Allen key, spanner, wrench and some special tool.
1.1.2 Screw materials

There are many types of materials used in screws, such as Aluminium, Brass, Copper Alloy, Plastic, Steel, Hardened steel, Stainless steel, and others. Each material has its advantages; for example, Aluminium screws are light and easy to use, resistant to oxidation. Plastic screws are inexpensive and corrosion-resistant for light loads. Meanwhile, Stainless steel screws are chemical and corrosion-resistant with an appealing finish. There is a growing demand for better materials for screws, and new materials are being introduced in screw production.

With the increase of screw manufacturing industries, our world is facing tremendous consumption of natural resources, which will bring environmental problems if proper selection of material is not taken into account. Besides the economic aspect, priority must be given to select a material that gives the least impact to the environment. The depletion of global resources, climate change, and environmental pollution problems are getting worse, so it is a challenge and responsibility for manufacturers to include sustainability in their product design.

1.1.3 Sustainability

The idea of sustainability dates back more than 30 years, it is not new to us. Sustain comes from the Latin word *sustinere*, which means to hold up or support. While sustainability can be defined as having the characteristic of being able to keep up or capacity to endure. Theoretically, although sustainability contains three pillars, which are economic, environmental, and social. (see Figure 1.4). The combination of economic growth and environmental protection pillars is known as the...
viable. This study will focus on economic element and environmental element only, that is viable aspect.

Figure 1.4: Venn diagram of sustainable development: at the confluence of three constituent parts. [6]

Brundtland report in 1987 had declared that the development which meets the needs of the present without compromising the ability of future generations to meet their own need is known as sustainable development. [7] Recently, public awareness on environmental issues is found to be increased, human being start realized that quality of the environment is essential to their own well-being and also for future generation. More customers will go for greener products, the market for the product with sustainability consideration is there, so no more excuse for manufacturers to neglect or ignore it.

1.2 Objective

The goals of this study are:

i. To investigate the environmental impacts and economic impacts of screw manufacturing.

ii. To choose suitable material with selected manufacturing process of screw for the best performance in environmental impacts and economic impacts.

1.3 Scope of study

To achieve the objectives of this study, the scope being narrowed down. The related scopes are listed as below:
i. This study will only focus on environmental and economic aspect of screw manufacturing, which is viable dimension in sustainability.

ii. CAE software (SolidWorks 2011) is used to sketch the 3D drawing of screw. After that, the tool which named SolidWorks Sustainability is applied to measure the four environmental impacts such as carbon footprint, water eutrophication and air acidification as well as total energy consumed.

iii. The hexagonal machine screw (M5x0.8) is selected as an example in this study.

iv. The main manufacturing processes of screw selected include forging and machining process.

v. The location of manufacture and distribution is assumed at Asia.

vi. The types of material being considered for forging operation are stainless steel, low carbon steel and aluminum alloy whereas for machining operation, the materials include stainless steel, low carbon steel, aluminum alloy and cast iron.

vii. The decision making method being used throughout the study is Analytic Hierarchical Process (AHP).

1.4 Limitation of study

As mention before there are 3 objectives in sustainability that are economic, environmental and social. Interlocking circles model to demonstrate that the three objectives need to be better integrated, current trend manufacturers only focus on economic objectives and neglect the environmental objectives. In order achieve sustainability goals economic objectives and environmental objectives must be equally balance, changes needed to increase environmental objectives. (see Figure 1.5). Combination economic growth and environmental protection pillars are known as the viable. Therefore, with the intention to make this study more significant, only viable objectives will be considered.
The main shaping process for screw involve material removing process and also deformation process, Although screw manufacturing involve sequence of processes, but in this study only forging or machining method are considered, both method must undergo thread cutting, heat treatment and coating, since the approach are the same so they are neglected in this study. Due to the limitation of manufacturing process in Solidwork Sustainability software only forging and machining is considered. Same problem while selecting the types of material available, because of limited material only these materials applied they are stainless steel, low carbon steel, aluminum alloy and cast iron.

1.5 Statement of problem

Today's societies are more aware of the state of the planet, awareness on environmental rise because they grew up with Earth Day already in place, Earth Day was first started on March 21, 1970, and the main objective for Earth Day is raise awareness. Societies felt the climax changes to our planet this also drew awareness to tackle environmental issues. Major current environmental issues include pollution, climate change, environmental degradation, and resource depletion.

Environmental degradation is the reduction of the capacity of the environment to meet social and ecological objectives, and needs, day by day our planet grow worse through depletion of resources such as air, water and soil. And also the destruction of ecosystems and the extinction of wildlife, Earth's resources must be used at a moderate rate at which they can be replenish in order to live sustainably. Since humans have only been given one Earth to work with, and if the environment becomes irreparably compromised, it could mean the end of human existence.

Over Consumption of resource and over production of manufacturing lead to environmental degradation, Industry contribute directly to environmental degradation, illegal disposal of their waste material and irregular dumping of hazardous and toxic wastes are the worst contributor, this kind of waste cannot be reuse and cannot be
properly dispose. Sustainability is the key to preventing or reducing the effect of environmental issues, effort is needed to return human use of natural resources to within sustainable limit.

Industry can implement sustainability through various methods such as reduce demand for scarce resources when new products and manufacturing approaches introduced. Considering development of cost-effective renewable and alternative energy sources like solar and wind power, this will reduce environmental issues. Fully utilize technologies to re-use energy and re-engineering production systems to eliminate wasted motion, materials and energy consumption. Lastly by implementing strategies such as lean manufacturing, this enables to cut out and reduce waste across all areas of production. (see Figure 1.6). Suitable material and appropriate manufacturing method will bring screw manufacturing to a minimal impact to environmental, greener manufacturing.

<table>
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<th>A truly sustainable company</th>
<th>Uses the waste of other processes as its input, and minimizes or eliminates the use of virgin materials extracted from the earth</th>
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<td>Creates output that can be used by other processes or returned to a natural state, and eliminates waste that can’t be used or returned to a natural state</td>
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<td>Uses the least amount of energy to achieve the desired outcome, and uses energy ultimately derived from renewable sources</td>
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Figure 1.6: Sustainable company criteria. [8]

1.6 Expected result

Through this study, expected result will be appropriate material that used for selected manufacturing process of screw. Materials will be rank according viable elements in sustainability

1.7 Thesis outline

This thesis consists of 5 chapters, which include introduction, literature review, methodology, result and discussion and last chapter is conclusion. First chapter explain briefly about this thesis, the objective, scope and problem statement, second chapter will do some literature reviews, third chapter will explain how this thesis is carry out, next chapter will discuss result obtain and lastly conclusion will summarize whole thesis and state some recommendation.
CHAPTER 2

LITERATURE REVIEW

This chapter is presented the literature review of selected journals, articles, reference book, thesis and online source. Keywords of this study are Screw manufacturing, Sustainable, Environment, Economic, Viable and Analytical Hierarchy Process.

2.1 Manufacturing industry and impact on environment

Manufacturing is derived from the Latin word *manufactus*, means made by hand. In modern context it involves making products from raw material by using various processes, by making use of hand tools, machinery or even computers. [10] Modern manufacturing operations are accomplished by automated machine, and it is supervised by workers. Manufacturing is the production of goods, in which raw materials are transformed into finished goods or products on a large scale. Finish goods or product will be used for other manufacturing or directly sold to wholesalers.

Environmental pollution getting serious during the industrial revolution, with the emergence of large factories and consumption of large quantities of coal and other fossil fuels gave rise to unprecedented air pollution. Growing load of untreated human waste also rise during this era. Industries such as metals production factories, plastics factories, and other heavy industry are main contributor to environmental problem. Research done on 2005 shows that manufacturing industry are no 1 in global total final energy consumption with 33%, and they are also no 1 in total global direct and indirect CO$_2$ emissions with 38%, (see Figure 2.1). With the statistic as a proof, there for there is an urgent need for green manufacturing; in product life cycle consideration for environmental aspect must also be taken seriously, mostly manufacturers only looking at economic benefits. Nowadays, prerequisite for
manufacturers to survive in the competitive market is the ability to cope with the needs of sustainable development.

![Share of Global Final Energy Consumption and CO2 Emissions by Sector, 2005](image)

Figure 2.1: Shares of Global Final Energy Consumption and CO2 Emissions by Sector, 2005 [11]

2.1.1 Impact of recycling

Recycling is a process to change waste into new products to prevent waste of potentially useful waste and reduce the consumption new raw materials. Some of benefits of recycling are reduce energy usage for, reduce air pollution and reduce greenhouse effect. Aluminum is the most common recycle material. Aluminium’s recyclability has a significant impact on its life cycle. Recycling uses only 5% of the energy associated with producing new aluminium and produces 95% less greenhouse gas (GHG) emissions. Approximately 75% of all the primary aluminium ever produced since 1888 is still in use today. [12]. Statistic above shows that aluminium save energy, reduce greenhouse gas emissions and most the impressive is that 75% aluminium ever produced since 1888 still around and all this just because of recycling.

Although recycling found to be one of solution to reduce natural resource consumption but it is still far from meeting sustainability goals, the usage of resource is more than earth can replenish. Manufactures are considering sustainability in their
product life cycle, they take into account total environmental impact and minimizing resource consumption from raw materials to the consumer's disposal of their product.

2.1.2 Eco-design

The concept of eco-design, green design or life cycle design refers to the design of new products and services by applying environmental concerns aiming at prevention of waste, emissions and other forms of environmental impacts along the entire life-cycle of the product. [13]. Eco-design is just one term used to describe the use of sustainability principles in the design and development of products, from start to end of product life cycle.

Some other terms include sustainable engineering, environmentally sustainable design and green design, all serve the same purpose. Manufacturers, businesses, even individuals are responsibility for taking steps to limit their environmental impact, all must take responsibility for trading only with environmentally responsible suppliers, with that all indirectly can contribute toward sustainability environment.

2.2 Screw manufacturing

There are many kind of screw, normally they are differentiate by standards, materials, sizes, threads head shape, Specialty Steel Industry of North America define that two main shaping operations used in industry for screw production are machining and cold heading as mention in earlier chapter. Cold heading is another name for cold forging. In screw manufacturing industry machining is the oldest method, for mass production cold forging and hot forging are used, but regardless what type of screw manufacturing process, all are involved in series of process to achieve final design, the series process involve are heading, threading, heat treatment and finally coating. Screw head can be formed by two alternative methods before screw thread is continued. They are metal forming and machining method [14].

Metal forming can be defined as a process in which the desired size and shape are obtained through the deformation of metals plastically under the action of
externally applied forces [15]. Metal forming processes, also known as mechanical working processes, metal forming is shaping process that does produce any waste, so economically it is highly recommend, they also high in accuracy, able to produce complex shapes. Beside that metal forming product have good surface finish and better strength compare to machining. Metal forming processes like rolling, forging, extrusion and drawing are gaining ground lately. (see Figure 2.2).

![Figure 2.2: Types of metal forming. [16]](image)

2.2.1 Forging

Forging is the oldest shaping process used to produce metal product where accuracy is not important, the oldest of the metalworking arts. Parts are heated with fire then shaping is done by blacksmith by applying compressive force using hammer. Thus forging is defined as the plastic deformation of metals at elevated temperatures into a predetermined size or shape using compressive force exerted through some means of hand hammers. [17]. At 980 degree Celsius metal is entirely plastic and can be easily shape under pressure by repeat of hammering process. It is

Machinery replaced man during early the Industrial revolution. Forging machines are now capable of making parts ranging in size. In modern era there are two types of forging process that are hot forging and cold forging. Most forging
operations are carried out hot, Hot Forging process occur at elevated temperatures, required less or lower force and compare to cold forging hot forging produce lower quality surface finish and accuracy. Cold forging processes including cold forging fastener production, it is done at room temperature, require lots of force but parts have good surface finish and accuracy in dimension.

2.2.2 Hot forging

Hot forging machines work alongside a furnace, one end part of the bar is heated for some length, then heated end of bar is than fed into the dies in forging machine. With the help of dies and a heading tool, screw head is forged by upsetting process. (see Figure 2.3). Illustration in figure show sequence of process for screw upsetting sequence, after head is forged, shearing process will cut the length of the screw. Then the bar is sent for heating again and the whole process is repeated. The hot forming manufacturing technique is an option only when the number of parts is too low for the cold forming process.

Figure 2.3 Hot forging processes for a screw. [16]

2.2.3 Cold forging

Fasteners are manufactured by cold forming. this process involves causing plastic deformation of metal at room temperature. Cold forming is the most
economic manufacturing method for screw. However, this is only commercially viable for production batches with large numbers of parts. Screw manufacturing through cold forging involves a sequence of processes such as forward extrusion, heading, and shearing. Wire comes in rolls, wire is fed in through the cut-off die to a wire stop. Wire stop limited the length of wire inserted. The cut-off knife shears the blank according to cut-off length. (see Figure 2.4 a). The cut-off knife holds the blank and transfers the blank to the heading die. Now the blank is ready to receive the first punch operation for the screw head forming, blank is in position to receive heading process. (see Figure 2.4 b). When punch is press cut of knife retracts from holding blank, this allowed upsetting process to be carried out. Proper cut-off of blank is critical this is because Blank mass equals mass of finished part. Any shortage will outcome in defect in screw produced. (see Figure 2.4 c). Upsetting of a screw head is accomplished by using one of these 4 methods. There are different types of upsetting method for different type of screw head different. Kickout pin is used to eject the blank when heading process is finish. (see Figure 2.4 d).

Figure 2.4 (a,b,c) cold heading, (d) methods of upsetting screw head[18]
Hexagonal machine screw is selected for this study, for a hexagon head bolt or screw, the manufacturing stages are arranged in the following order: Cutting the bar stock, pre-upsetting and ironing of the shank, upsetting a round head, trimming the head to a hexagonal shape, forming the bolt or screw end, and finally, on a separate machine, forming the screw thread by means of a flat or cylindrical die. [14]

Hot forging and cold forging are two different metal forming processes that deliver almost similar results. Forging is the process of deforming metal into a predetermined shape, main benefits of forging process are savings in material and machining costs are significant and forming complex shapes is possible.

2.2.4 Comparison between hot forging and cold forging

Traditionally, manufacturers choose hot forging for the fabrication of parts that have a greater influence in the technical arena. Hot forging is also recommended for the deformation of metal that features a high formability ratio. Manufacturers may choose cold forging over hot forging for a number of reasons since cold forged parts require very little or no finishing work, Cold forging is also less susceptible to contamination problems, and the final component features a better overall surface finish. [14].

Ultimately, the manufacturer will look at a number of criteria before choosing which type of forging is best for a particular application, for screw manufacturing since it is produce in high volume so cold heading is more suitable. The hot forming manufacturing technique is an option when the number of parts is too low for the cold forming process. For a better surface finish cold forging also better choice and beside that cold forging better part strength.

2.2.5 Screw machining

Machining is not only used to obtain cylindrical shapes by turning, but also implies processes such as milling of flat areas, drilling, grinding and similar fine work, e.g. to achieve a specified degree of roughness. [19]. Some fasteners like screws are also manufactured as machined parts, it is suitable for machining with
parts with special profiles, small radius or intentionally sharp edges, there are also some special materials that cannot be formed without machining. Shaping is performed by machining with the turning and milling tool, forging improves the finished part’s grain structure by making it conform to the flow of the design, the machined diagram show how the grain structure is weakened cutting operation. (see Figure 2.5).

![Figure 2.5 Grain structure after upsetting and machining](image)

2.2.6 Screw threading

After screw head process is done by forging and machining method next step is screw threading process. Screw threads can be produced by such removal process both manually using taps and dies as well as in machine tools of different types and degree of automation. Very basic type is thread cutting by hand operated tools, hand operated dies of common use for external screw threads are solid or button die, spring die, split die and pipe die. (see Figure 2.6).
Automatic machining of external threads on bolts and screws are usually produced by rolling with flat or cylindrical dies. The cold forming process can be carried out using flat dies, rollers or roller segments. Besides rolling with flat dies two other methods are thread rolling by plunge-cut method and thread rolling by through feed method. (see Figure 2.7). Threading will only be explained briefly since it is not the scope of study.

Machining screw threads in lathes are also produced in normal lathe, special purpose lathes and CNC lathes. Two methods external threads are produced in centre lathes they are by single point and multipoint chasing (see Figure 2.8(a) & (b)). Single point is the most basic threading method using machine but it can provide high quality. Multipoint chasing gives more productivity, reduce threading but at the
cost of quality to some extent. Machining of external threads in semi-automatic lathes for batch or small lot production in capstan. External threads in capstan lathe by self-opening die. (see Figure 2.8c)).

2.2.7 Screw manufacturing process flow chart

Screw manufacturing process mainly are divided into forging process and machining process, although they different kinds of process at the beginning at last both of screw manufacturing method must go through threading, heat treatment and coating process. (see figure 2.9).
2.3 Material selection

Design is the process of translating a new idea or a market need into the detailed information from which a product can be manufactured. Each of its stages requires decisions about the materials of which the product is to be made and the process for making it. [21]. Material play important role in engineering design, designer in any product will be facing with materials selection, in design choice of material is choose based on its properties, that suited specific design or task. The number of engineering materials is large: tens of thousands, at a conservative estimate. Engineering materials are evolving faster, and the choice is wider than ever before for designer to choose from, designer must understand the material then they are able to design the product.

2.3.1 Green materials

Thanks to advances in material science, today’s engineers and designers have more options for choosing greener materials. Choosing more sustainable materials
often means making informed tradeoffs. To make an informed choice you need good data on a material’s environmental impacts, and you need to consider that data alongside other design requirements. During product design when considering the environment properties of materials, look for materials that are abundant/rarely used, non-toxic, have low embodied energy, and meet regulations. Green design is now a major trend in product design, more manufacturers are looking into these matters.

2.3.2 Recyclable materials

Material selection must strongly be directed toward recyclable materials, depletion of resources is getting worse so impossible choose materials that are abandon and recyclable. Shortages of nonrenewable resources are not imminent in the 1990s. Supplies of many metals and fuels would last from 20 years to well over 100 years at present rates of consumption (i.e., at present levels of economic development); coal, in particular, will last for several centuries. For now, other environmental problems appear more urgent, including the threat of global climate change and the over exploitation of natural resources.

In the long run, however, the exhaustion of nonrenewable resources is sure to become critical. Steel, aluminum, oil, and even coal are depleting, and will eventually be used up. Materials used in our daily life will increasingly be made of renewable source, it is effort done by individuals and manufactures that care about the future of the earth and future generations.

2.4 Sustainability and sustainable development

Sustainability can be quite confusing term, it is difficult to actually pin down the meaning since it can cover so many domains. The World Commission on Environment and Development, known more popularly as the Brundtland Commission, created one of the best-known and often used definitions: Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. From the definitions above, sustainable development has been defined as balancing the
The performance of government towards sustainable development goals [26]. The structure of framework comprises four dimensions that are social, environment, economic, and institutional, and it is broken down into 38 sub-indicators and 15 main indicators. (refer figure 2.11). Economic, Social and Environment aspect are interrelated. (refer figure 2.12).

Figure 2.11: The United Nations Commission for Sustainable Development (UNCSD) theme indicator framework. [25]

Figure 2.12: Sustainable development triangle – key elements and interconnections [27]
2.4.1 Economic aspect in sustainability

Economic sustainability is the term used to identify various strategies that make it possible to use available resources to their best advantage. The idea is to promote the use of those resources in a way that is both efficient and responsible. The modern concept underlying economic sustainability seeks to maximize the flow of income that could be generated while at least maintaining the stock of assets (or capital) which yields this income [28]. In the case of a business operation, it maximizes uses of resources so that the business continues to function over a number of years, while consistently returning a profit.

True sustainability encourages the responsible use of resources. This involves not only making sure that the business is making a profit, but that the operation is not creating environmental concerns that could cause harm to the balance of the ecology and also choose raw materials that are more environmentally friendly and design a waste disposal strategy that does not cause damage. According to Maslow theory, Hierarchies of needs that provide psychic satisfaction, beyond mere goods and services. [29]. Contribution to financial welfare of the owners, the employees, and to the community where is business is located is important this enable profitable business is much more likely to remain stable and continue to operate.

2.4.2 Environmental aspect in sustainability

Globalization’s points of view is the environment that strongly depends on industries behavior and the utilization of natural resources. To improve environmental sustainability, industry’s management must be responsible with the environmental pollution. The environmental interpretation of sustainability focuses on the overall viability and health of living systems – defined in terms of a comprehensive, multi-scale, dynamic, hierarchical measure of resilience, vigor and organization. [30]. Sustainability consist of 3 aspect but environmental aspect is the most focused compare others. Holling originally defined resilience as the amount of change that will cause an ecosystem to switch from one system state to another. [31].
fulfillment of human needs with the protection of the natural environment so that these needs can be met not only in the present, but in the indefinite future. This interaction is often expressed as having three components that are environment, social equity, and economy.

In order to achieve progress in sustainability, some types of monitoring required, and sustainability need systematically monitored, measured, quantified and interpreted. The United Nations Environment Programme (UNEP) in association with the United States non-governmental organization, Coalition for Environmentally Responsible Economics (CERES) launched the Global Reporting Initiative (GRI) in 1997 for improving the quality, structure and coverage of sustainability reporting. [24]. Sustainability Reporting is the focal point of the guidelines. The GRI uses sustainability reporting on three dimensions viz. social, economic, and environmental (see figure 2.10).

![Figure 2.10: The hierarchical structure of the GRI framework. [25]](image)

The United Nations Commission on Sustainable Development (CSD) devised a framework of monitoring the various sustainability indicators for assessing the
Adaptive capacity is an aspect of resilience reflects a learning element of system behavior in response to disturbance.

Healthy ecosystems provide vital goods and services to humans and other organisms. There are two major ways of reducing negative human impact and enhancing ecosystem services, first of these is environmental management and second approach is through demand management of human resource use. Herman Daly, one of the early pioneers of ecological sustainability, looked at the problem from a maintenance of natural capital viewpoint. In 1990 he proposed that: (refer table 2.1).

1. For renewable resources, the rate of harvest should not exceed the rate of regeneration (sustainable yield);  
2. [For pollution] The rates of waste generation from projects should not exceed the assimilative capacity of the environment (sustainable waste disposal); and
3. For nonrenewable resources the depletion of the nonrenewable resources should require comparable development of renewable substitutes for that resource.

Table 2.1: Herman Daly proposal [32]

2.4.3 Social aspect in sustainability

Social development usually refers to improvements in individual well-being and also the overall social welfare, that result from increases in social capital, the accumulation of capacity for individuals and groups of people to work together to achieve shared objectives [33]. The general definition of social sustainability is the ability of a social system to function at a defined level of social well-being indefinitely. That level should be defined in relation to the goal of mankind, which is to optimize quality of life for those living and their descendants.

"The relationship between human rights and human development, corporate power and environmental justice, global poverty and citizen action, suggest that
References


[9] *The IUCN Programme*, IUCN, Switzerland, 2005


