KESAN KEBOLEHMASUKAN DAN CARA PEMASANGAN KEPADA PENYELENGGARAAN PRODUK ATAU SISTEM

(EFFECT OF ACCESSIBILITY AND ASSEMBLY METHOD TO PRODUCT OR SYSTEM MAINTAINABILTY)

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ABSTRACT

This thesis is an outcome from a research on the effect of accessibility and assembly method to maintainability. This research is done based on some factors and elements that involved in maintainability process. A survey on customers and motorcycle mechanics to get their feedback on motorcycle maintenance that focus on the former brake system. Besides that an experimental work is done based on the brake system that have been built using the experimantal tools. The experiment is done to observe the factors that effect the brake system maintainability The fisrt step to make the system model is to make the frame. Then the brake system is jointed to the frame. A test has been done to the brake system model and by recording a time on different person in maintenance work done for the brake system. From the survey and experimental work done for this research, it is concluded that the brake drum design and skills level of a person are the major factor that effect maintainability. Other factor such as the component brand, tools that used, spare part used, spring attached also gives a minor effect on maintainability.

ABSTRAK

Tesis ini merupakan satu kajian yang berkaitan kesan kebolehmasukan dan kaedah pemasangan terhadap penyelenggaraan. Ini merujuk kepada faktor-faktor dan elemen yang berkaitan dengan penyelenggaraan. Dalam menjalankan tesis ini,satu kaji selidik telah dijalankan ke atas pengguna dan mekanik motorsikal. Kaji selidik ini dilakukan untuk mendapatkan maklumbalas tentang penyelenggaraan pada motorsikal dan difokuskan kepada sistem brek sedia ada. Kerja-kerja eksperimen juga dijalankan untuk mengesan faktor-faktor yang memberikan kesan terhadap penyelenggaraan sistem brek. Dalam projek ini, satu bingkai motorsikal telah dihasilkan dan sistem brek dipasang pada bingkai tersebut. Selain itu, satu eksperimen telah dijalankan ke atas sistem brek tersebut. Eksperimen tersebut dijalankan oleh beberapa individu dengan mengambil masa menyelenggara sistem brek tersebut. Daripada kaji selidik dan eksperimen yang dijalankan rekabentuk brek dan tahap kecekapan individu yang melakukan penyelenggaraan adalah memberikan kesan yang besar terhadap penyelenggaraan. Faktor lain seperti jenis dan jenama komponen, alat yang digunakan, ala ganti yang digunakan dan spring yang dipasang juga memberikan kesan yang kecil terhadap peneyelenggaraan.

CHAPTER 1

Introduction

Predictive maintenance, on the other hand, allows one to detect problems early and schedule maintenance when resources are available. New technologies such as web-enabled monitoring, maintenance-based artificial intelligence, multimedia data access, wireless sensors, improved diagnostics, and self-validating devices will allow improved monitoring of equipment and systems, which will enhance instrument maintainability. As we know, a good maintainability will make the task easier. It would be better and more convenient to open only a certain parts of a product rather than opening all of them. This will definitely reduce maintenance time, here by reducing cost. In Formula 1, for example, by less than 10 seconds, many parts could be changed such as oil, tires, car nose and other parts. The tires, for example, could be replaced simultaneously in a few seconds. Time is very important in winning the race. This methodology could be used to other systems or products. Therefore maintenance becomes very important to detect problems early and improve product value. The product will be very easy to be maintained. Repairs, parts change and other works will be very easy to be carried out. Figure 1.1 shows the crews of a Formula 1 team changing parts in a pit stop

Figure 1.1: Crews of a Formula 1 team changing parts in a pit stop

1.1 Objective

- To understand the basic concept of maintainability design.
- To understand the factor that should be considered when designing for maintainability.
- To conduct customer survey on product maintenance.
- To set up an experiment for time study.

1.2 Scope of the project

The project cover several aspects especially experimentation on maintenance procedures for motorcycle part. The particular part involved is the maintenance of motorcycle drum brake for the rear tire of the motorcycle. The work stages involve among other, design and fabrication of the brake system. After all parts are completed, then we will be testing the maintainability of the brake, especially regarding installation and assembly of the components involved. Besides that the survey is done on customer which related to the maintenance especially for the brake drum. An experiment also done by several people as time recorded for them to assemble and disassemble the braking system.

CHAPTER 2

Literature review

Design for maintainability includes among other, the evaluation of future repair and maintenance issues beginning in the design phase in order to minimize system repair and maintenance costs and reduce total life cycle costs. Besides, maintenance can have a dramatic impact on a system's total life cycle costs. By having relatively long life cycles, reduce maintenance cost than reduce production cost. The ultimate goal of design is to produce a system that provides customer satisfaction throughout its life. It should be noted that a key element in achieving this level of satisfaction is to include maintenance and support personnel on the integrated product team(s) early in the design phase [1].

Maintainability can be defined as the ease in time and resources of retaining equipment in or restoring it to a specified operational condition. It directly affects the bottom line because it can impact operations, downtime, maintenance costs, and safety. Maintainability is an important aspect of any system's lifecycle, but process plant engineers typically give it little direct consideration [2]. This is primarily the result of a short-term view of capital project costs that fails to consider lifecycle costs and downstream activities. Before you even start on a system design; here are two principles to keep in mind: Minimize maintenance from the beginning, and get your maintenance people involved.

The more reliable a system is, the less maintenance it will require. Identifying reliable components, installation types and arrangements, and vendors is a key step to improving the reliability of instrument systems. Getting maintenance involved early in a project can improve maintainability. Involvement also brings ownership and an improved relationship between maintenance and engineering. Modular design divides the system into physical and functional modules, which can be arranged to facilitate design and maintenance. Easily replaceable modules with logical organization reduce repair time, troubleshooting, training, and engineering. Engineering must consider what the future may hold and make reasonable accommodations. Failure to do so may make a system that is easily maintained today but difficult to work on tomorrow. Standardization of components reduces inventory and improves reliability and maintainability. The use of commercial off-the-shelf (COTS) components should also be considered, though care should be taken because some commercial components may not meet the necessary industrial requirements. While many instruments are unique and the technology in some cases changes rapidly, standardization of instrumentation can have the same benefits of reducing inventory and improving reliability. Documentation is extremely important in achieving good maintainability. This is particularly true as the complexity and sophistication of the system increases. Documentation is a matter of discipline, which, unfortunately, many engineering and maintenance systems do not have. Adhering to standard drawing organization, style, formats, symbols, and level and type of information provided can make life easier for the instrument technician. Some other considerations for documentation are accessibility, organization, readability, usability, applicability, and comprehensibility.

System functional requirements, software functional description, flow charts, software annotation, configurations, and I/O and memory mapping are some of the types of documentation that improve software maintainability. Labeling must be consistent, standardized, clear, and accessible. While not a substitute for drawings, system identification that provides the capability of tracing wiring, power sources, and identification of components without use of drawings provides for more efficient and safe troubleshooting.

Accessibility means having sufficient workspace and access to perform maintenance safely and efficiently. Adequate workspace is needed not only to repair or maintain the system but also to troubleshoot it. Component accessibility within an instrument or piece of equipment must also be considered. Low-reliability components should be the most accessible. Components should be replaceable with the least amount of handling: Physical accessibility of field installations must be considered. This is a balance of functionality, cost, and reliability. Exposure of the system to weather, other environmental concerns, and stresses generated by other equipment such as heat, vibration, moving parts, etc., must be considered. Whatever maintenance we do must be done safely. No maintenance action should require a person to perform an unsafe act. Mechanical and electrical hazards must also be considered. Pinches, sharp bends, edges and points, trip hazards, head knockers, and abrasive surfaces should be eliminated or guarded.

Factors that should be considered when designing for maintainability [3]

1) Non-Interference of Preventive Maintenance - Preventive maintenance should be minimized and require as little crew time as feasible.

2) Flexible Preventive Maintenance Schedule - Preventive maintenance schedules should be sufficiently flexible to accommodate changes in the schedule of other mission activities.

3) Redundancy - If maintenance is necessary and system operations will be interrupted, redundant installations should be considered in order to permit maintenance without interrupting system operation.

4) Goals of Designing for Maintainability - The following are goals for optimizing crew involvement in both preventive and corrective maintenance.

2.1 Design for maintainability Goals

It is very important to set the goals in achieving maintainability for the product. These goals will determine the aspects that are required in achieving maintainability. The most important objectives in design for maintainability are to achieve quick access to components, parts and assemblies. It is also vital to rapidly isolate and detect faults. The best way towards achieving maintainability is to have a minimum number of maintenance activities and operations. The type of environment impacts the maintenance and support requirement. It should be noted that the ultimate goal of design is a system designed that support efficient and effective execution of the maintenance and support activities.

2.2 Advantages

Design for maintainability is an important part of product/system design. Design changes during production are very costly, but if design for maintainability is implemented early in the design stage, a great number of benefits would be realized including longer life of systems and products. Lowering unscheduled and scheduled downtime, presents failures and decrease time required to perform a particular maintenance task.

2.3 Elements of design for maintenance and support

There are several important elements in the design for maintenance and support. The elements should be given adequate attention to avoid design failure.

1) Accessibility

This may be described as the relative ease with which an item can be reached for replacement, service or repair [3]. One component can be worked on with as little interference as possible with other components. Parts that have been identified as having high failure rates should be designed so they can be accessed without removing other parts. An example in accessibility is easiness to access screws and components. Figure 2.1 shows how a technician doing the accessing works on a component of a machine.

Figure 2.1: A technician is accessing a component of a machine.

2) Diagnose ability

Diagnosability is the characteristics of a product that allow any faults (or potential faults) in the operation of the product to be identified. Commonly problem ability can be identify for maintain a high level of system. It is a difficult task and takes a significant amount of time. To ensure high readiness of the system, designers should be known the problem and diagnosis. We can also put in the ability of functional experimentation or built-in testing facilities in the equipment or system module. Diagnosis is done for the machine to determine if there is any problem.

3) Replace ability

Replace ability is described as substitution of a person or a thing for another that is broken or inefficient or lost or no longer working or yielding what is expected. Components and sub-assemblies should be designed so that they can be replaced in the least amount of time the least amount of skill and effort. Component and assembly should be designed for easy changing in short time. For example is changing the tire in workshop as shown in Figure 2.2.

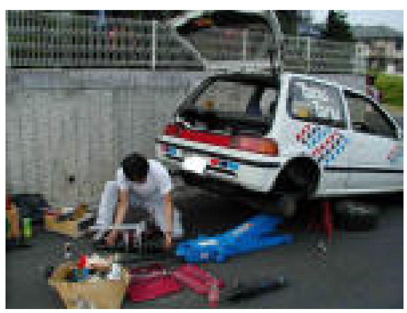

Figure 2.2: Foreman is changing the tire.

4) Repair ability

The repair ability is fixing any sort of mechanical or electrical device should it get out of order or broken. Maintenance is how to fix components in the field rather than replacing them._Other repair ability, include to new or advanced technologies in a system. For example, repair car in workshop as shown in Figure 2.3.

Figure 2.3: Foreman repair a certain part of car in workshop

5) Rebuild ability

Rebuild ability is the ability to restore an item to a standard as close as possible to original state in performance, life expectancy and appearance [3]. Costly components can be rebuilt at greater savings than achievable through replacement. One strategy to consider is the use of component modules with BIT capabilities. For example, the ability to rebuild car parts, such as the whole engine that is being overhaul. Figure 2.4 shows a picture on a car engine model.

Figure 2.4: A car engine model.

6) Upgrade ability

Upgradeability is the act of improving something (especially machinery) by raising it to a higher grade (as by adding or replacing components). It can also be defined as the ability to modify components to meet changing technology and prevent or prolong product obsolescence. Modular design can again directly impact system enhancement and upgrades. For example, upgrade the motherboard to support graphic card as shown in Figure 2.5

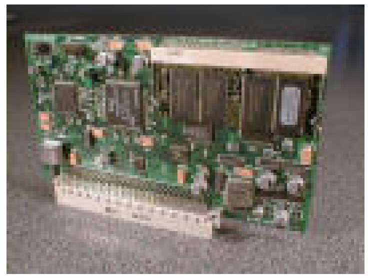

Figure 2.5: A motherboard model

2.4 Related work

Rydzewski (2000) Maintainability was defined as the ability to maintain in the least amount of time at the lowest cost [4]. Design for maintainability is not terribly expensive if it is considered early in the design process. Failure to provide for maintainability can be very expensive--retrofits to correct problems are notoriously expensive; emergency repairs brought about by poor maintenance are often done in a non-competitive environment; and equipment failure can lead to disruption of operations, system damage, and/or building damage. Poor maintenance can also result in increased day-to-day equipment loads.

The most typically encountered problem was failure to make equipment accessible. Examples of poor accessibility included equipment installed above inaccessible ceilings, hard-wired electrical switches mounted on access panels, access panels on the wrong side of equipment (where there was no space for access), and air-handling units with no coil access.

Avoiding the use of special-order items was noted as a means of reducing maintenance costs. Maintainability should be considered during original design, during renovations, and during equipment/system replacement. Inadequate detailing for access and installation and improper specifications (indoor equipment being used outside) were noted as recurring problems.

Russell (2000) reported on the results of the cost-effectiveness of design for maintainability [5]. The research project identified three primary barriers to design for maintainability. Firstly was inadequate communications. Secondly, was involved the existence of two distinct cultures and finally barrier was a misunderstanding of cost versus value. Sibley (2000) described an activist approach to design for maintainability. Sibley recommended that construction documents show all balancing and test points on the drawings; provide for maintenance access and isolation of all equipment; and provide electrical outlets and lighting for maintenance operations [6].

Maintainability is described in MIL-HDBK-470A as relative ease and economy of time and resources with which an item can be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair [7]. In this context, it is a function of design.

Design for maintainability requires a product that is serviceable (must be easily repaired) and supportable (must be cost-effectively kept in or restored to a usable condition better yet if the design includes a durability feature called reliability (absence of failures) then you can have the best of all worlds.

Supportability has a design subset involving testability a design characteristic that allows verification of the status to be determined and faults within the item to be isolated in a timely and effective manner such as can occur with build-in-test equipment (BIT) so the new item can demonstrate it's status operable, inoperable, or degraded and similar conditions for routine trouble shooting and verification the equipment has been restored to useful condition following maintenance.

Maintainability is primarily a design parameter [8]. The design for maintainability defines how long equipment will be down and unavailable. The amount of time spent can be reduced by having a highly trained workforce and a responsive supply system, which paces the speed of maintenance to achieve minimum downtimes. Unavailability occurs when the equipment is down for periodic maintenance and for repairs. Unreliability is associated with failures of the system the failures can be associated with planned outages or unplanned outages. Maintainability has true design characteristic. Attempts to improve the inherent maintainability of a product/item after the design is frozen is usually expensive, inefficient, and ineffective as demonstrated so often in manufacturing plants when the first maintenance effort requires the use of a cutting torch to access the item requiring replacement. Poor maintainability results in equipment, which is unavailable, expensive for the cost of unreliability, and results in an irritable state of conditions for all parties who touch the equipment or have responsibility for the equipment. Reliability and maintainability are considered complementary disciplines from the inherent availability equation. Inherent availability looks at availability from a design perspective [8]:

$$A_i = MTBF/ (MTBF+MTTR).$$

If mean time between failure or mean time to failure is very large compared to the mean time to repair or mean time to replace, then you will see high availability. Likewise if mean time to repair or replace is miniscule, then availability will be high. As reliability decreases (i.e., MTTF becomes smaller), better maintainability (i.e., shorter MTTR) is needed to achieve the same availability. Of course as reliability increases then maintainability is not so important to achieve the same availability. Thus tradeoffs can be made between reliability and amenability to achieve the same availability and thus the two disciplines must work hand-in-hand to achieve the objectives. A_i is the largest availability value you can observe if you never had any system abuses. In the operational world we talk of the operational availability equation. Operational availability looks at availability by collecting all of the abuses in a practical system

$$A_o = MTBM/ (MTBM+MDT).$$

The mean time between maintenance includes all corrective and preventive actions (compared to MTBF which only accounts for failures). The mean down time includes all time associated with the system being down for corrective maintenance (CM) including delays (compared to MTTR which only addresses repair time) including self imposed downtime for preventive maintenance (PM) although it is preferred to perform most PM actions while the equipment is operating. A_o is a smaller availability number than A_i because of naturally occurring abuses when you shoot yourself in the foot. The uptime and downtime concepts are explained in Figure 2.6 for constant values of availability. Figure 2.6 shows the difficulty of increasing availability from 99% to 99.9% (increase MTBM by one order of magnitude or decrease MDT by one order of magnitude) compared to improving availability from 85% to 90% (requires improving MTBM by less than ~½ order of magnitude or decrease MDT by ~¾ order of magnitude).

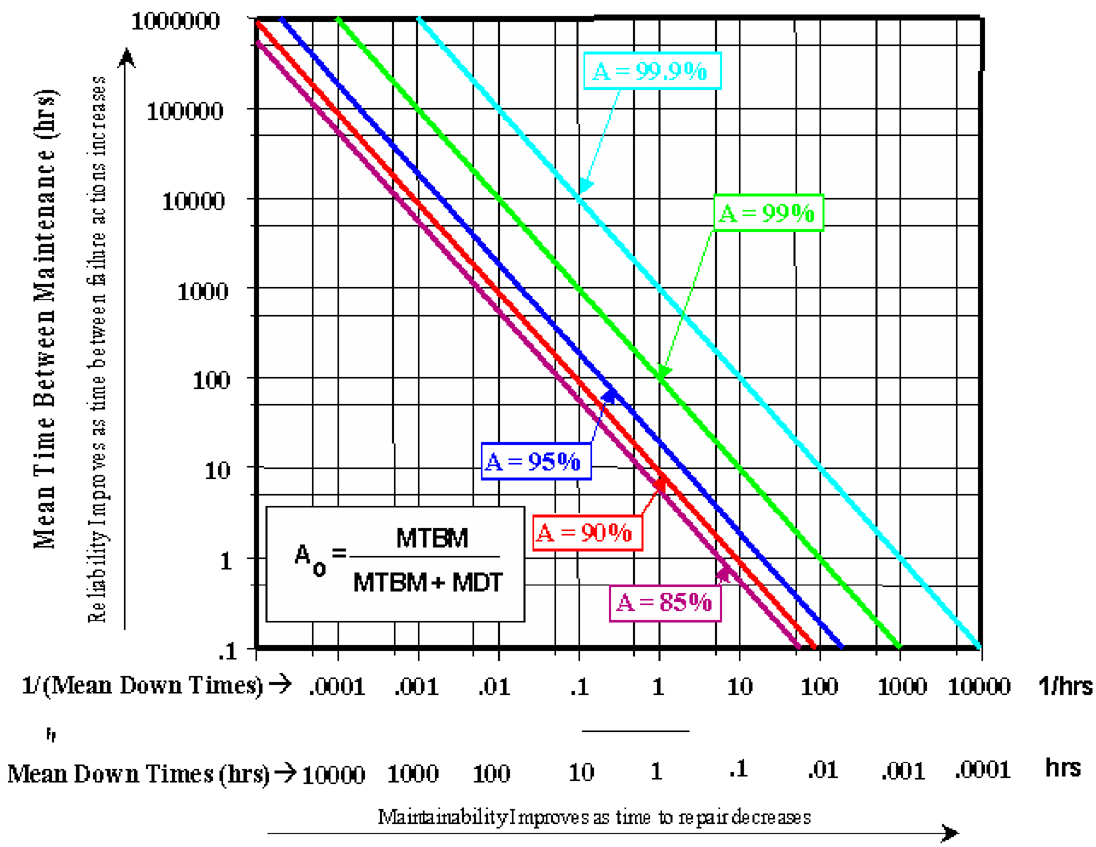

Figure 2.6: Availability relationships for fixed % Availability

Operational availability includes issues associated with: inherent design, availability of maintenance personnel, availability of spare parts, maintenance policy, and a host of other non-design issues (whereas inherent availability addresses only the inherent design). Testability, the subset of maintainability/ supportability, enters strongly into the MDT portion of the equation to clearly identify the status of an item so as to know if a fault exists and to determine if the item is dead, alive, or deteriorated these issues always affect affordability issues. Operational availability depends upon operational maintainability which includes factors totally outside of the design environment such as insufficient number of spare parts, slow procurement of equipment, poorly trained maintenance personnel, lack of proper tools and procedures to perform the maintenance actions. Achieving excellent operational maintainability requires sound planning, engineering, design, test, excellent manufacturing conformance, adequate support system (logistics) for spare parts, people, training, etc to incorporate lessons learned from previous or similar equipment.

Assembly methods also give effect to the maintenance [4]. This is because it affects cost, time and other factors. For example, in using screws as connection element in a product manufacturing process it will make maintenance easier if the product experience damage or modifications made. If welding is used as connection element, maintenance will be difficult to carry out compared with screw and takes longer time to do the maintenance. This also will increase cost of maintenance compared with maintenance of screw. Welding also requires skilled workforce in welding.

Chapter 3

Methodology

Flow chart as shown in Figure 3.1 describes the methodology of this project.

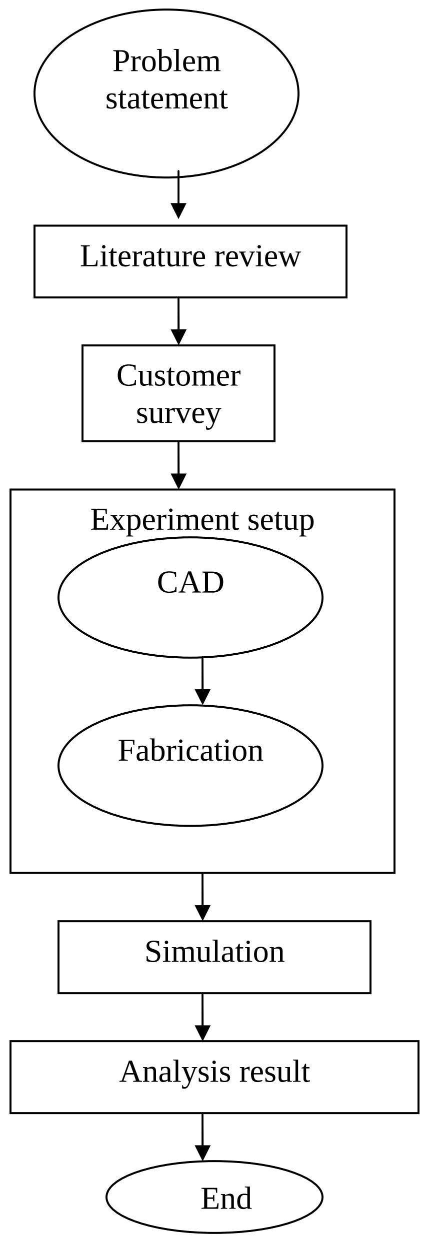

Figure 3.1: Flowchart shows the experimental methodology

3.1 Problem statement

The project cover several aspects especially experimentation on maintenance procedures for motorcycle part. The particular part involved is the maintenance of motorcycle drum brake for the rear tire of the motorcycle. The work stages involve among other, design and fabrication of the brake. After all parts are completed, then we will be testing the maintainability of the brake, especially regarding installation and assembly of the components involved. A new design of drum brake will be proposed. This new modular braking system efficiency will be determined and compared to the initial design.

3.2 Literature review

This section is theory part of definition of maintenance. It also covers the affect and good maintenance. Besides that state the factor of designing for maintainability, design for maintainability goals and it advantages for good maintenance. There is also are six element of design for maintenance and support, that is accessibility, diagnose ability, replace ability, repair ability, rebuild ability and upgrade ability. Related work theory of maintenance also given.

3.3 Customer survey

This survey was made on the motorcycle users especially for the students, mechanics and some of the motorcycle shop. The purpose of this survey is to get people's feedback on the matter that related with maintenance for example a frequent component managing, effect of assembly method on maintainability and recommendation to enhance maintainability.

3.4 Experiment setup

CAD – This is the drawing section where the motorcycle frame is drawn by using IDEAS-10 software with real scale taken from motorcycle (EX5) initial design. Besides that, the installation of the brake system part with the motorcycle frame is also designed by using the software.

Fabrication – The first step of fabrication is choosing the right material to build the motorcycle frame. Then the material is cut by using the true scale. The motorcycle frame as built by using welding process as connecting element. Besides that, the motorcycle frame is sprayed with black. Finally the motorcycle system brake components are listed and installed at the black motorcycle frames that have been built.

3.5 Simulation

Simulation will be done by an individual. Everyone will open the brake system and duration will be taken as the brake system is opened. Simulation duration for a person depends on their time to reinstall the system.

3.6 Analysis result

From the simulation that has been done, a few result can be expected. Some of them is the installment duration for the brake system for a person taken is depending on the person skills ability. Beside that the design is also give effect for the installment process. The design can make the installation easier. Furthermore the duration of installment is depending on the design too. This also depends on the individual experience.

Chapter 4

Customer Survey

Utilization duration is one of the important factors that involved in this survey customer. Most of the customer has an experienced using motorcycle for three years. This is shown as bar chart in Figure 4.1.

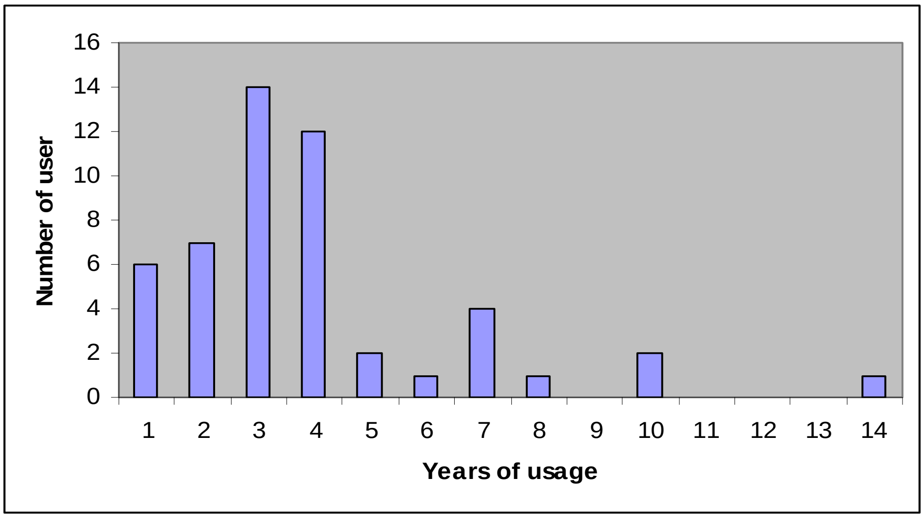

Figure 4.1: Bar chart on customer utilization period

The graph in Figure 4.2 below shows that the most frequent component managed is the brake drum with a total period of 81 months for five group of customer.

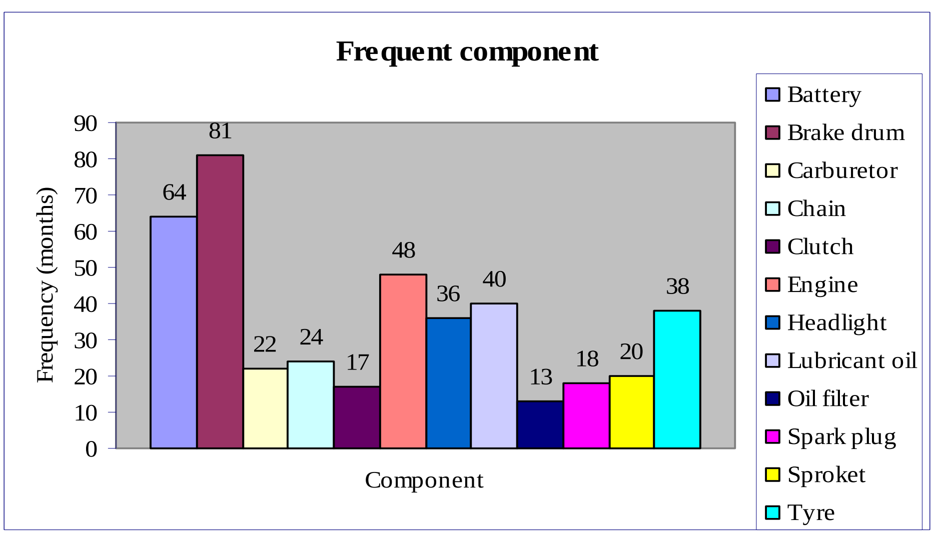

Figure 4.2: The frequent component managed by customer

Generally most of the customers prefer to do maintenance work by themselves rather than workshop service. Table 4.1 below shows the frequent personal maintenance from the survey that has been done. The table shows that out of 53, about 70% of the respondent are do maintenance by themselves.

Table 4.1: Frequent personal maintenance in customer view

Number of customer	Result
37	Yes
16	No

Assembly method effect and component position effect on maintainability on customer view are shown in Figure 4.3. The result from survey shows in the bar chart shows that 95.3% of customers agree that the assembly method and component position give effect to maintainability.

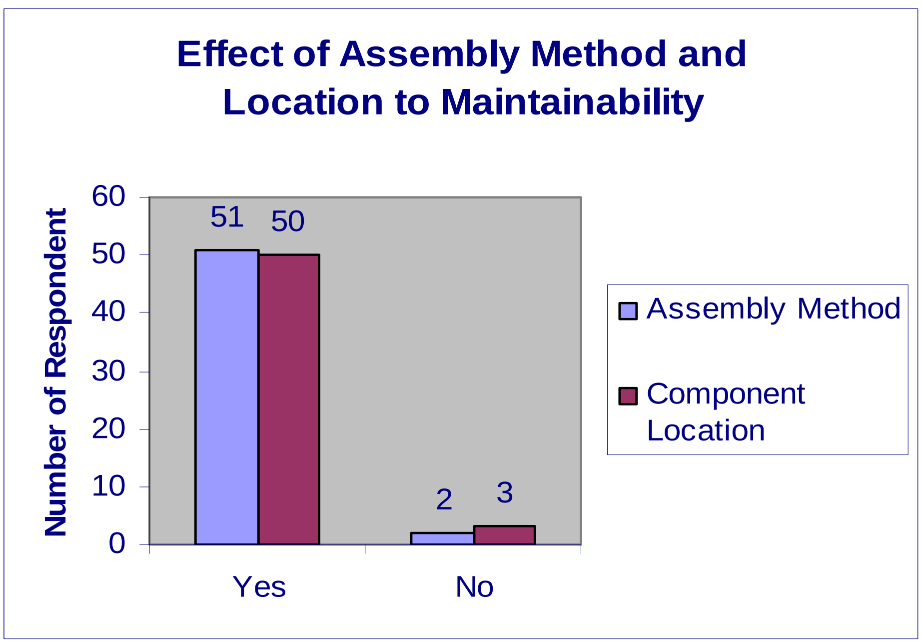

Figure 4.3: Bar chart for frequent of the effect of assembly method and component position on maintainability on customers view

Others factor effect maintainability is shows in a pie chart as Figure 4.4 below. The factor involved is such as financial credit, maintainability skills and etc.

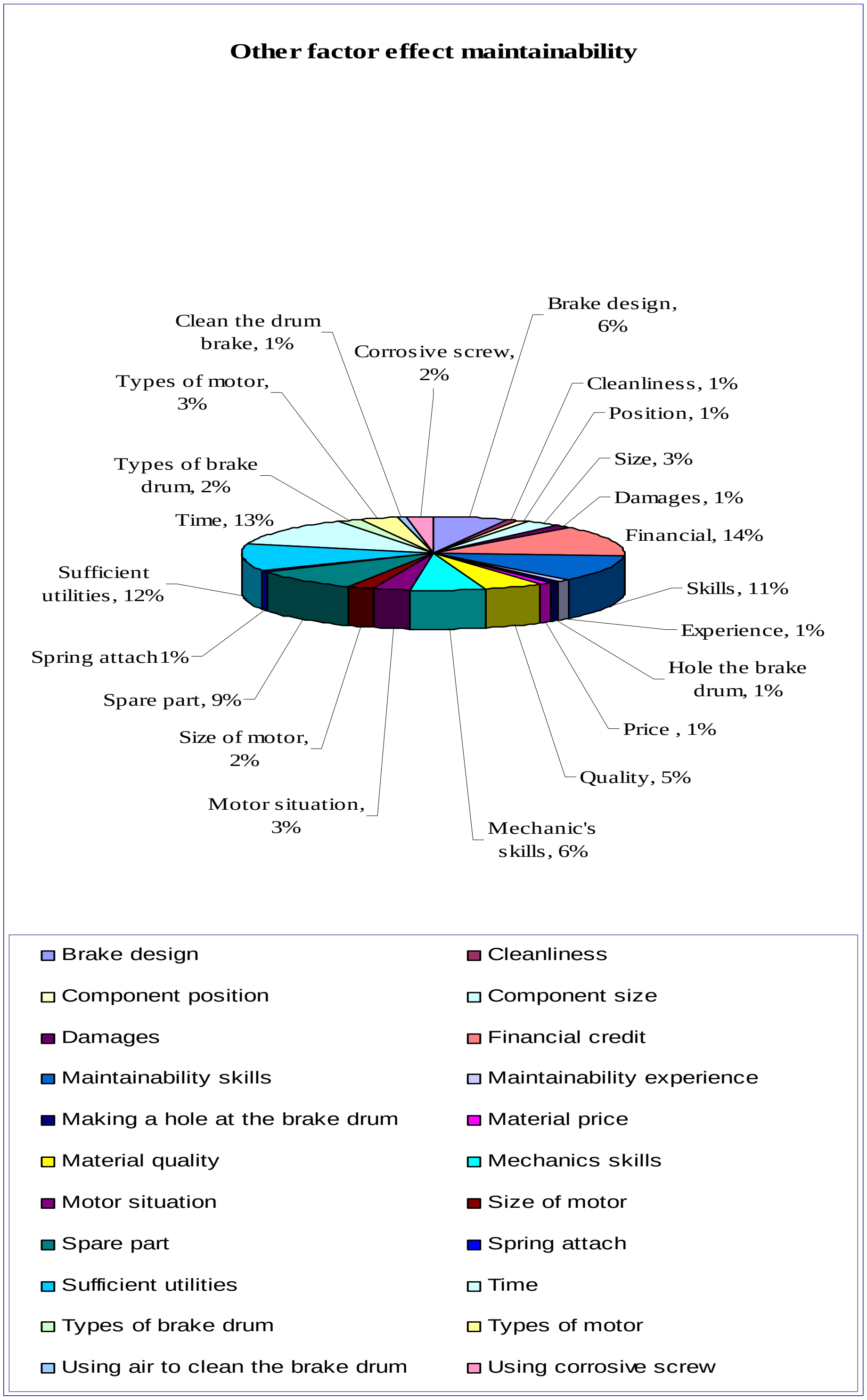

Figure 4.4: Others factor effect maintainability by customer view

Recommendation to enhance maintainability is shown as pie chart in Figure 4.5. Most customers decided that flexible installation and the quality and branded brake drum are important to enhance maintainability.

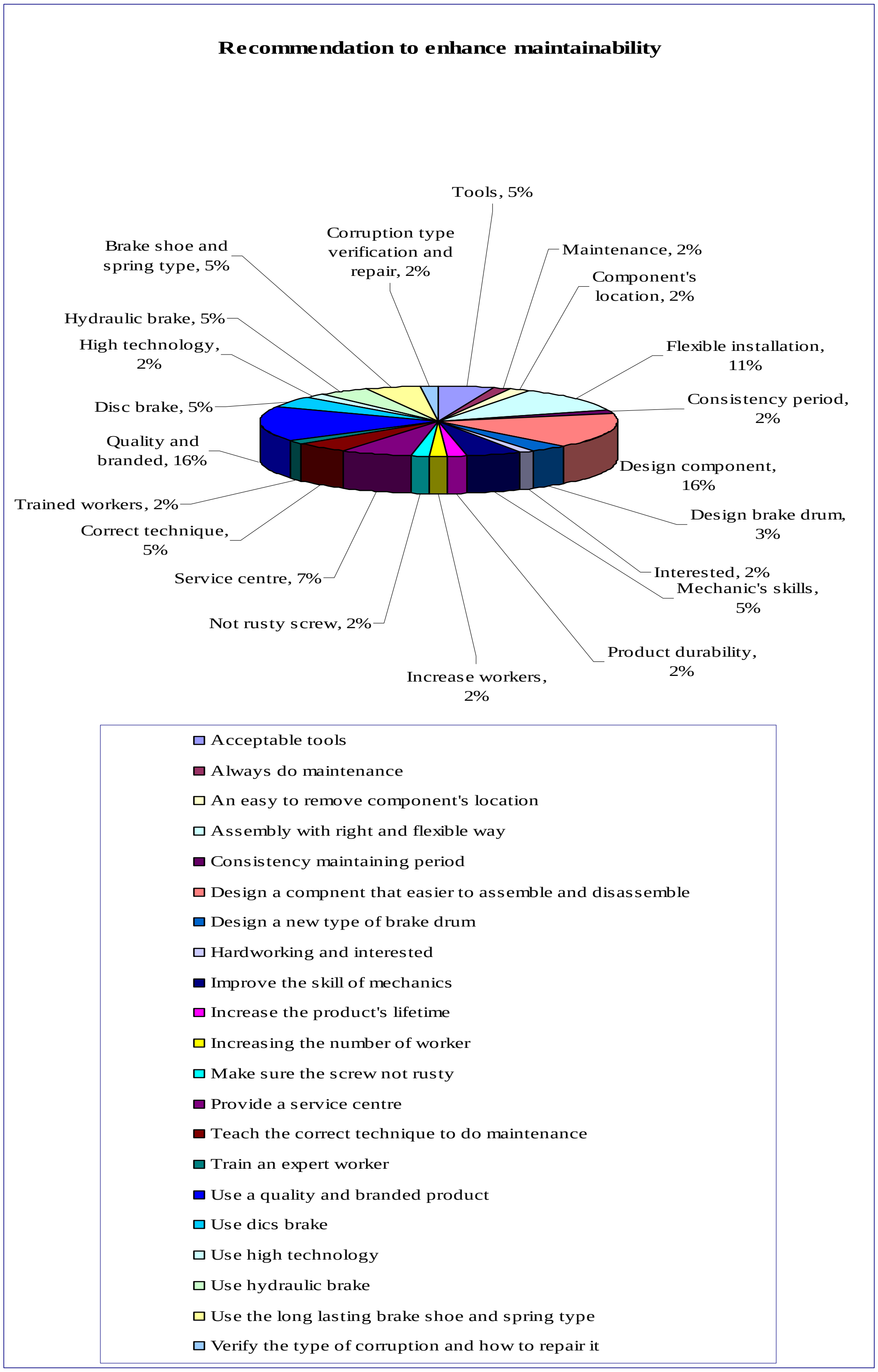

Figure 4.5: Recommendation to enhance maintainability by customer view

Satisfaction on former brake drum design is show in Figure 4.6. The pie chart shows that out of 53 customers, 62% decided that they are satisfied with the former brake drum.

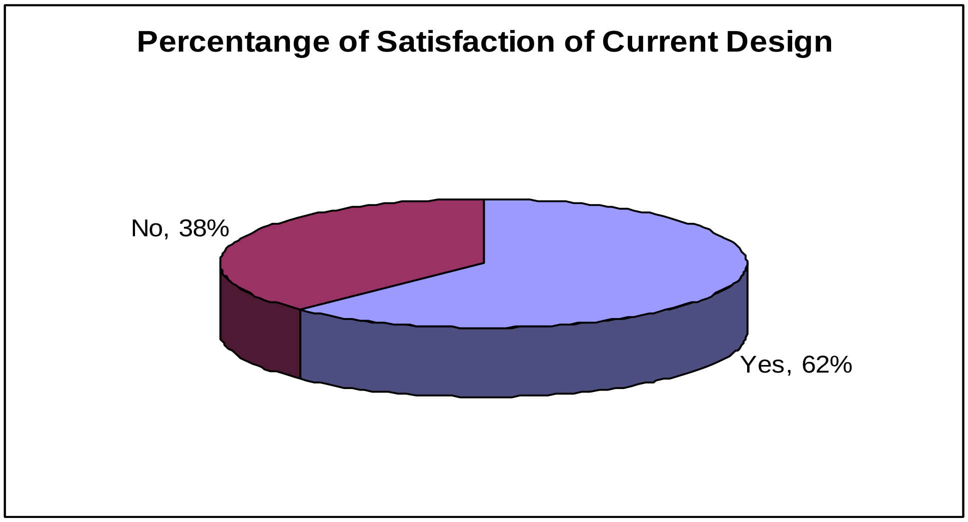

Figure 4.6: Percentage of satisfaction on former brake drum design by customer view

Figure 4.7 shows survey result on recommendation on former brake drum design modification. Most of the customer recommended designing a new component at the former brake system

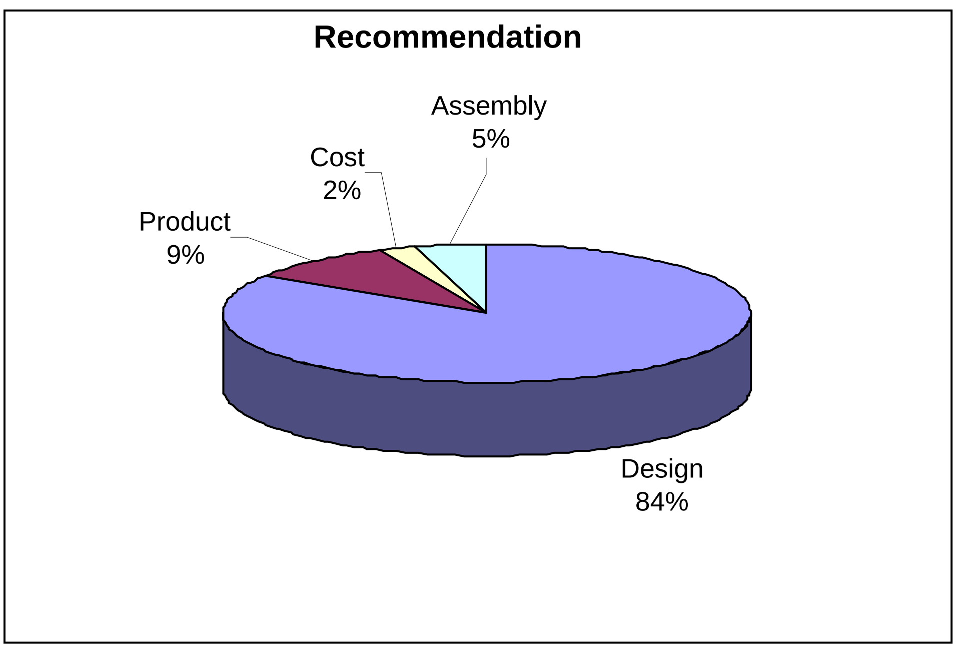

Figure 4.7: Type of recommendation by customer view

This survey is done on 5 mechanics that encompass a high skills level on maintenance and long period experience on maintenance. Working experience is one of the factor effects on maintainability. From the survey done most of the respondent are have between 3 to 10 years of experience in this work. From the survey, AN 110 (modenas) is the most favorites brand by the customer because the brand can be found easily in the market. Frequent component used and its frequency is shown in table 4.4. From the table, we can see that for every 4 – 6 months, riders must change their ear brake shoe as recommended by mechanics

Table 4 2: Frequent component used and its frequency

No	Component	Frequency	Customer
1	Rear brake cam	Not in the right position	1
2	Rear brake shoe	4-6 month	1
3	Rear brake shoe	4-5 month	2
4	Rear brake shoe	20000 km	1
5	Rear brake shoe	10000 km	2
6	Spring brake	Rusty	2

Maintenance method that effects the maintainability shows in Figure 4.8 where changing spare part is most favorable maintenance work chosen by the customer.

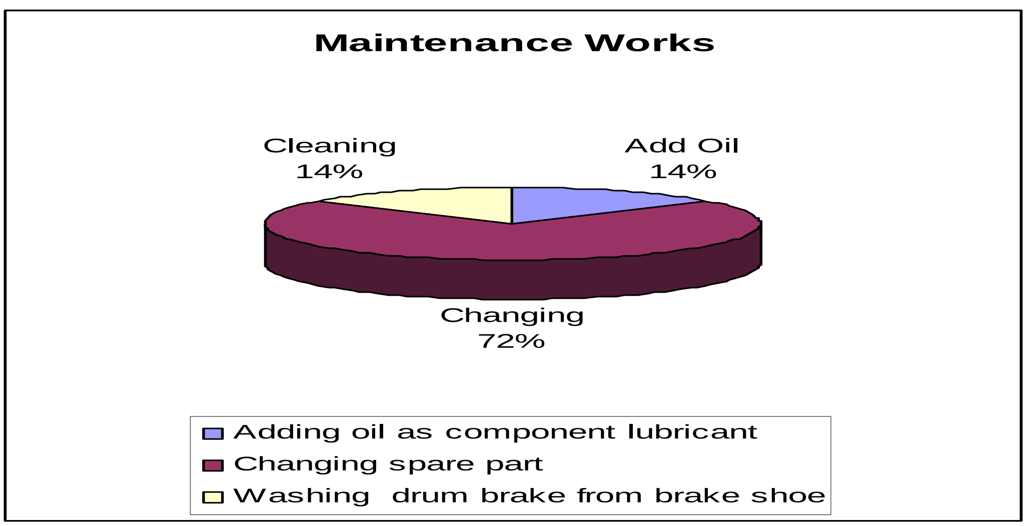

Figure 4.8: Maintenance work method by mechanics view

Figure 4.9 shows the assembly effect and component position on maintainability in mechanics view where the result is clearly show that every respondent agree that the assembly does effect the maintainability. Table 4.7 shows the other factor effect maintainability such as pirate parts, skill or the operators and types of drum brake also have important role.

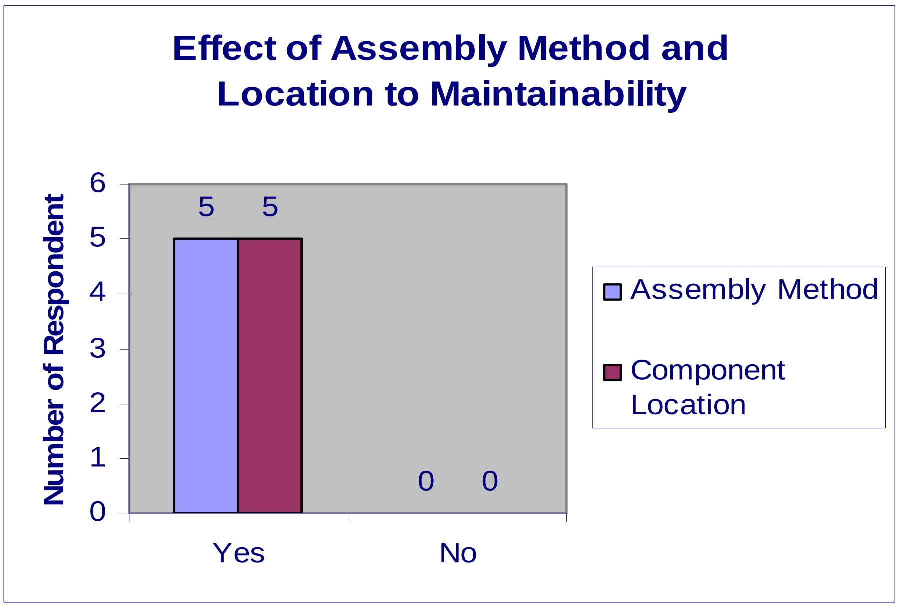

Figure 4.9: Assembly effect and component position on maintainability by mechanics view

Table 4.3: Factor effect maintainability in mechanics view

No	Factor	Mechanics
1	The cheap brake shoe effect the assembly (surface not plane)	3
2	Drum brake maintenance experience	5
3	Types of drum brake	2

Recommendation to enhance maintainability shows in Figure 4.10. The chart shows that the most important factor to enhance maintainability is simplifying the design and the operator skills.

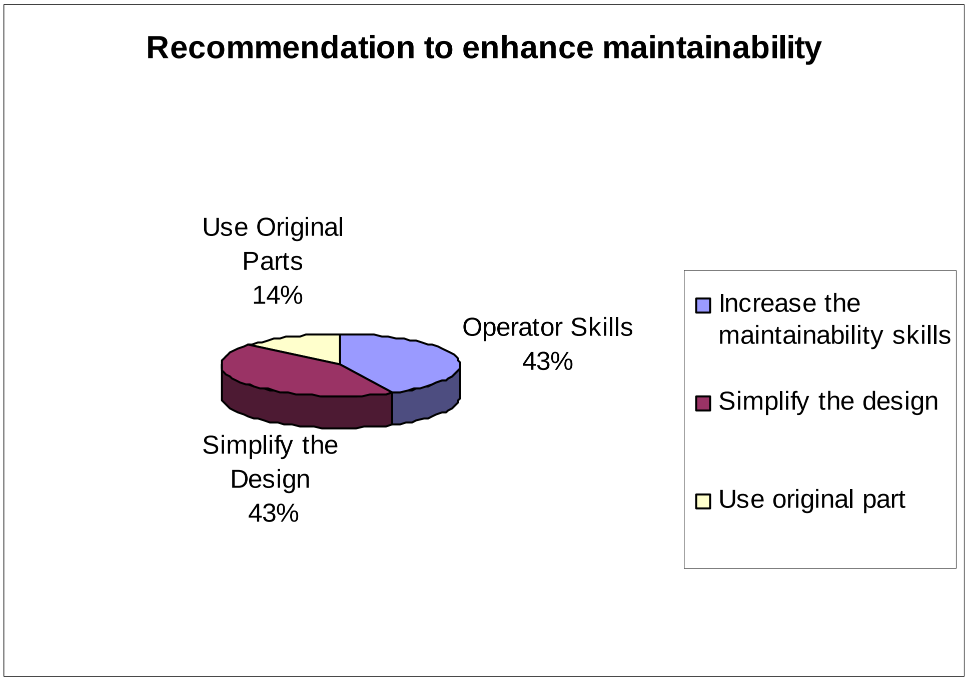

Figure 4.10: Recommendation to enhance maintainability by mechanics view

Satisfaction on former brake drum design is shown as table 4.8. All of mechanics are satisfy with the current design of drum brake and they recommend that for future, drum brake must be flexible and used additional spring in order to make it more efficient and maintenance can be accomplished faster and easier.

Table 4.4: Satisfaction on former brake drum design by mechanics view

Number of mechanics	Result
5	Yes
0	No