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# The Application of Modularization Concept for Redesign of Panasonic KX-2315 Product Based on Design for Remanufacturing (DFR) and Design for Disassembly Criteria (DfdA)

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**Abstract.** Modular product is defined as product consists of detachable modules, which can be manufactured, assembled, and serviced separately. Modularization components of a product into modules can be done based on several criteria. Design for Remanufacturing (DFR) and Design for Disassembly (DFdA) criteria is being used in this research. The DFR criteria are related to the stages of remanufacturing a product when it has reached its end of life cycle. The first stage of remanufacturing is disassembly. Therefore, the DFdA criteria, which is related to the easiness of product disassembly is also being used.
The object of this study is Panasonic KX – T2315 telephone. Modularization process is carried out by identifying the values of the relationship between each part of product based on the DFR and DFdA criteria. These values are structured into an interaction matrix and then will be grouped into modules using two clustering method, Hierarchical Clustering Algorithm and Quadratic Programming Model respectively.
For both clustering method, the recommended number of modules are 5 modules. Those modules consist of grouped components that perform certain functions and objectives. The clustering result from both clustering method was compared, and the best result was chosen to be the final module recommendation.

**Keywords**: Design for Remanufacturing (DFR), Design for Disassembly (DfdA), product modularization

## 1. BACKGROUND

Nowadays, greater competition in industries makes manufacturing companies have to be aware in responding the flexiblilty of the market. Globalization and market segmentation force company to diversify. What used to be a large demand for standard mass-market products has fragmented into a demand for different variations of similar products. Thus, there is a need to create the desired product variety economically. One way that can be used to achieve this goal is by using the product modularization concept.

Gu & Sosale (1999) define modular product as a product which is consist of modules which can be produced, assembled, and maintained separately, where a part of modules can be used again (reuse), recycled, or reproduced until the period of product usage is end. Modularization of product can be used to split the structure of product in several modules which it makes the producer easy in designing modules to yield a new variant of product.

Designing product modularly gives any advantages for producer, such as a high product variation level, easy in upgrading the product technology, prompting the development of new product, and decrease of production cost (Eggen, 2003).

Grouping the product components become a module can be done based on particular criteria, such as easy in assembly, manufacture, environmental security, etc. In this investigation, criteria will be modularized base on Design for Remanufacturing (DFR) and Design for Disassembly (DFdA).



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Table 1: Componen of Panasonic KX – T2315

| Comp. Number: | Component | Comp. Number: | Component |
|---|---|---|---|
| 1 | Upper case | 14 | Metal |
| 2 | Bottom case | 15 | Speaker |
| 3 | Stand Assembly | 16 | Printed Circuit Board (PCB) |
| 4 | Dialing | 17 | Skrew XTW3+S12P |
| 5 | Direct Call Button | 18 | Skrew XTW3+S8P |
| 6 | Auto, Program, Pause, & Redial Button | 19 | Handset Coil |
| 7 | Flash, Mute, Hold Button | 20 | Upper Handset |
| 8 | Phonespeaker Button | 21 | Bottom Handset |
| 9 | Volume Knob | 22 | Front handset speaker |
| 10 | Hook Button | 23 | Back handset speaker |
| 11 | Kartu Memori Telepon | 24 | Speaker coil |
| 12 | Handset Hunger | 25 | Metal |
| 13 | Baterai case | | |

Base idea of remanufacturing is any components of a product which have longer usage periode than others. It is can be used by reuse a component of product through a particular manufacture process to the same function as well as different function. Another advantages are the components can decrease a waste that throw into the environment and drive the production cost, because the company do not have to makes a product from begin completely.

There are many industries that had carried out a remanufacturing because it is gives any advantages including decrease of product manufacturing cost and reduce an environment impact because of the manufacture process (Amezquita et.al., 1995). The numbers of company that has carried out remanufacturing is Xerox, Kodak, Hewlett Packard, etc. For example, Xerox did remanufacturing on their copy machine and printer in the large scales and sale to the customer by leasing system or pay-per-use.

Based on all above conditions, the objective of this study are to determine of DFR and DFdA criteria that will be used to modularizing Panasonic KX-T2315 product and make redesign the product using modularization concept.

## 2. METHOD

The object of research is Telephone Panasonic KX-T2315 consisting of 25 components which can be seen at Table 1.

### 2.1 Identification of Modularization Criteria

### 2.1.1 Identification of DFR Criteria

In modularization, it is must be established a criteria as the base of grouping component to be the modules. This study used 6 criteria DFR that each of them given value and separated again to be 3 level of sub-criteria such as high, medium, and low, so that each of components can be obtained an interaction value by other component. The DFR criteria, given score, and each of the sub-criteria, as follows:

1. Reused component (score 0.2)
   - Directly, component can used back when the live period of product usage is over (high).
   - The component can reused again after following a particular process when the live period of product usage is over (medium)
   - The component cannot be used back when the live period of product usage is end (low).

2. Easy for cleaning the component (score 0.15)
   - Component had a simply structure so that it is possible to clean the component surface only.
   - The structure of component is simple and had a holes and narrow edge, but not required a special cleaner (medium).
   - The component has a large holes and narrow rim so that it required a special cleaner (low).

3. The component had a code and special sign for easing an identification process and sorting (score 0.15).
   - The component has an identification code

with direct printed and permanent (high).
- The component has an identification code that released and temporary, such as label, sticker, and paint (medium).
- The component does not have an identification code (low).

4. Destruction in the component can identified easily (score 0.05)
   - Destruction in component can change physical structure of product (high)
   - Destruction in component can be done by trying the function at begun (medium).
   - Destruction in component can be done by particular tests (low).

5. Minimize of component consisting of flexible material (score 0.15)
   - The component consists of inflexible material, metal (high).
   - The component consists of semi flexible material, plastic (medium).
   - The component consists of flexible material, rubber (low).

6. The design of component makes possible to assembling from the same direction so that it can minimize a product orientation exchange (score 0.2)
   - Assembling the component can be carried out without change the product orientation (high).
   - Assembling the component can be carried out by change the product orientation one time (medium).
   - Assembling the component can be carried out by change the product orientation in twice or more (low).

### 2.1.2 Identification of DFdA Criteria

As a DFR criteria, in this stage will be used 4 DFdA criteria that each of them will be given score and split to be 3 levels of sub-criteria: high, medium, and low, so that can be found a score of interaction between components. The criteria of DFdA, given score, and each of sub-criteria as follows:

1. Minimizing of component consisting of different material (score 0.15)
   - The component consists only of one material (high).
   - The component consists of two different materials (high).
   - The component consists of more than two different materials (high).

2. Component easy for released (score 0.25)
   - Component assembly can be done by only entered (insertion) without locking (high).
   - Component easy for released (likes use snap-fits method) (medium).
   - Component hard to release likes bolt, nut, and screw (low).

3. Minimizing equipment usage in the disassembly process (score 0.25)
   - Disassembly carried out without use equipment (high).
   - Disassembly carried out by use equipment (medium).
   - Disassembly carried out by use two or more equipments (low).

4. The component design that give a possibility to assembly/disassembly process of product by minimizing product orientation exchange (0.15).
   - Disassembly of component carried out without change the product orientation (high).
   - Disassembly carried out by change the product orientation for one time (medium).
   - Disassembly carried by change the product orientation about twice or more (low).

### 2.2 Interaction Matrix

Each component will be scored based on the sub-criteria to gain an interaction between component according to the DFR or DFdA. Gu & Sosale (1999) give a combination to score this interaction, likes seen in the Table 2. Beside interaction between component based on the DFR and DFdA criteria, it must give an attention that interaction between each component based on functional relation between each component can evaluated by attachment and alignment of component. Gu & Sosale (1999) give the manner for scoring attachment and alignment of component as can be seen at Table 3.

Table 2: Interaction score

| | Classification | Sub-criteria | | |
|---|---|---|---|---|
| | | High | Medium | Low |
| **Sub-criteria** | High | 9 | 2 | 0 |
| | Medium | 2 | 6 | 0 |
| | Low | 0 | 0 | 3 |

Table 3: Evaluation Criteria to Assembly Component

| Relationship | Attachment | Alignment | Interaction Score |
|---|---|---|---|
| Very strong | Permanent attachment | More than two component align by more than one component | 10 |
| Strong | Component attachment hard to released | More than two component align by one component | 8 |
| Medium strong | Attachment use a key and spline | Two component must aligned one and each other | 6 |
| Medium weak | Attachment use a screw | One component aligned by other permanent one | 4 |
| Weak | Attachment easy for released | Alignment block a component to slab the way of other component | 2 |
| Not related | Component do not contact at all | Component do not have to aligned | 0 |

The calculation sample of DFR interaction score, in this case between component 1 and 2, can be seen in the table 4. The same way be used to search interaction score of other component, whether in the DFR interaction or DFdA so that it will give a result as DFR interaction matrix and DFdA with the measure 25 x 25, according to the number of component.

## 2.3 The Clustering Matrix of Final Interaction

The final interaction matrix is clustered to be module by use two clustering methods, Hierarchical Clustering Algorithm (HCA) and Quadratic Programming Model (QPM).

In order to produce a constructed module setting, whether by use a Hierarchical Clustering Algorithm or Quadratic Programming Model, it is have to establish any module according to the research object. The number of constructed modules can be founded by analyze a constructing component characteristic of Telephone Panasonic KX-T2315, as follows:

1. Product Main frames
2. User interface component.
3. Receiver and trasmiter component
4. Electronic component
5. Appendage.

Table 4: DFR Interaction score for component 1 and 2

| DFR Criteria | Weight | Component | | Interaction Score | Weighted Score |
|---|---|---|---|---|---|
| | | 1 | 2 | | |
| Attachment | 0.05 | Medium Weak | | 4 | 0.2 |
| Alignment | 0.05 | Medium Strong | | 6 | 0.3 |
| 1 | 0.2 | High | High | 9 | 1.8 |
| 2 | 0.15 | Low | Medium | 0 | 0 |
| 3 | 0.15 | High | High | 9 | 1.35 |
| 4 | 0.05 | High | High | 9 | 0.45 |
| 5 | 0.15 | Medium | Medium | 6 | 0.9 |
| 6 | 0.2 | Medium | High | 2 | 0.4 |
| Total | | | | | 5.4 |

Table 5: Recomendation for Pansonix KX-T2135 module

| Module | Comp. number: | Component Name | Module | Comp. number: | Component Name |
|---|---|---|---|---|---|
| 1 | 19 | Kabel *Handset* | 2 | 9 | *Volume Knob* |
| 3 | 4 | Tombol *Dialing* | | 13 | Kotak Baterai |
| | 5 | Tombol *Direct Call* | | 15 | *Speaker* |
| | 6 | Tombol *Auto, Program, Pause & Redial* | | 16 | *Printed Circuit Board* |
| | 7 | Tombol *Flash, Mute, & Hold* | 4 | 20 | Gagang Atas |
| | 8 | Tombol *Speakerphone* | | 21 | Gagang Bawah |
| 5 | 1 | Kabinet Atas | | 22 | *Speaker* Atas |
| | 2 | Kabinet Bawah | | 23 | *Speaker* Bawah |
| | 3 | *Stand Assembly* | | 24 | Kabel *Speaker* |
| | 10 | *Hook Button* | | 25 | Besi Pemberat |
| | 11 | Kartu Memori | | | |
| | 12 | *Handset Hunger* | | | |
| | 14 | Plat Logam | | | |
| | 17 | Sekrup 12P | | | |
| | 18 | Sekrup 8P | | | |

## 3. RESULT

The redesign of Panasonic KX-T2315 can be seen in table 5 and figure 1 until 3:

- There is combination between components (Figure 1).
- Handset connection with snap fit (Figure 2).
- Simplify the hook button design (Figure 3).

Figure 1: Initial and proposed design for Module 3

Figure 2: Proposed design for Handset connection

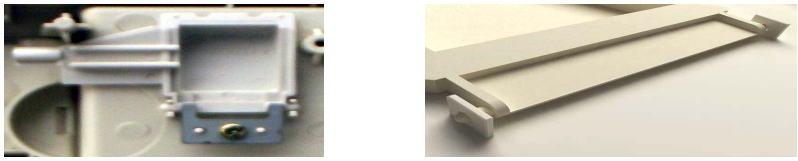

Figure 3: Initial and proposed design of Hook button

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