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# Product Modularity and its effect on Service and Maintenance

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**ABSTRACT**

This paper discusses the relationship between modular products and their service and maintenance. The relationship is based on an expanded definition of modularity which incorporates the potential of modularity based not only on end uses of a product but also the method of service and maintenance. By incorporating this expanded definition of modularity, called service modularity, into product development, a more robust product modularity can be achieved.

Modularization, due to the functional independence it creates, has been called the goal of good design. Industry has made an effort to modularize products to easily meet the functional needs of end users and marketing. Occasionally, modules are created with some aspects of service in mind. However, this modularization is done without fully understanding the financial implications of the design changes. Once other aspects of the product life-cycle is accounted for, this unstructured process of developing modular products often leads to costly redesigns or expensive products.

This paper focuses on the application of product modularity to service and maintenance. This is done by concentrating on the three main aspects of product modularity, namely: 1) maintaining independence between components in different modules; 2) encouraging similarity in all components in a module; and 3) maintaining interchangeability between modules. By creating service modules, a product can be flexible to changes in service procedures. This flexibility will lead to a decrease in the life-cycle service cost of the product.

## 1. INTRODUCTION

Life-cycle engineering is a methodology of incorporating a product's life time values at the early stages of product design (Barkan, 1988). These values include functionality, business concerns, manufacturing, assembly, service, product retirement, and any other requirement put on the product from concept to grave. Boothroyd and Dewhurst (1985) and others (Sturges, 1992; Miyakawa, 1990) have shown that Design for Assembly (DFA) can lead to significant savings during production. One aspect of DFA is minimizing the number of components in the product. Modular products tend to have fewer components for assembly. By increasing pre-assembly and using common interfaces, modularity decreases the cost of assembly. Assembly modules are usually dictated by the supplier sub-assemblies and are not necessarily the optimal choice for lowest cost.

When discussing Design for Serviceability (DFS), it is important to begin by defining service. For this research we are including the diagnosis, maintenance, and repair of consumer products. Research into the effect of maintainability on systems design is not new (Goldman and Slattery, 1964; Blanchard and Lowery, 1969). Most maintainability work originates in military or aviation applications. The key concern in these applications is optimizing "up time" at almost any cost. In DFS, we try to balance the "up time" with the cost of service. It is for this reason that there is less of a concentration on predicting mean time between failures and more of a concentration on product redesign and reconfiguration. Makino, *et al.* (1989) reports on the creation of a serviceability design expert system. They have used this system to try and integrate customer service field knowledge into the product development process. Gershenson and Ishii (1991) took this one step further by including a measurement of how "serviceable" a design was and redesign suggestions for improving serviceability. This cost based measure aided designers in making design decisions. This research resulted in Service Mode Analysis (SMA), a process similar to Failure Mode and Effects Analysis. SMA tracks how a defect or service need causes a mode of service, which in turn causes a set of labor operations, which in turn affects certain components and results in a set of component and labor costs. SMA is quite useful in partitioning service tasks into the service modes in which they occur.

In developing a methodology for modular service design, there are three main issues to be tackled: what is meant by service modularity; how can service modularity be applied to product design; and are the benefits of service modularity worth the effort. Previous research has answered parts of these questions while raising additional questions.

## 1.1 Previous research into modularity

Most of the research into the theory behind modularity originates from Suh's (1990) independence axiom which states that, "[i]n good design the independence of functional requirements is maintained." Therefore, if possible, each function that a product performs should be independent of all other functions the product performs. This axiom, coupled with a push toward understanding the relationship between the form of a product and its functions, has led to a search for a connection between physical independence and functional independence.

In one of the first works to discuss modular design theory, Ulrich and Tung (1991) define modularity in terms of two characteristics of product design: "1) Similarity between the physical and functional architecture of the design and 2) Minimization of incidental interactions between physical components." In an extension of this work, Ulrich (1995) states that a modular product or sub-assembly has "a one-to-one mapping from functional elements in the function structure to the physical components of the product." As in Suh's work, this definition only accounts for the functional aspects of a product, ignoring all other life-cycle characteristics.

There are also several methodologies developed to optimize or organize the creation of product modules. DiMarco, *et al.* (1994) created a tool which groups components by the method of recycling, and assesses a qualitative recycling cost. They discuss the grouping of components, one aspect of modularity, in terms of clumping. A clump is a collection of "components and/or subassemblies that share a physical relationship and some common characteristic based upon the designer's intent." This work is significant because it discusses role of modules beyond end user functional independence. However, clumping is not meant to capture all aspects of product modularity.

*Ad hoc* modular design has been used for many years to create products with interchangeable functions. Some examples of functional modularity include: sectional sofas, kitchen mixers, stereos, vehicle roof racks, and computers. These products offer increased flexibility in meeting end user requirements through function grouping and standardized interfaces. Should end users want a new attachment in the years to come, it can be designed with a similar interface and it will attach to the end users' current product.

However, the nature in which these products are designed has led to these products being more costly than similar, non-modular products.

In the realm of service, very little has been done to promote modularity to reduce service cost. Often, modularity is created to aid product assembly. While this modularity can greatly reduce the labor cost of removing a component for service, it often precludes the repair of a component and necessitates complete replacement. This is often quite costly. One recent example is the one piece rear tail light on automobiles which incorporates all tail lights on both sides of the vehicle into a single module. This is an excellent idea for assembly and probably quite helpful for manufacturing. However, if a single bulb fails, the entire module must be removed. This is a difficult operation. In addition, a crack in the corner of the plastic casing requires replacement of the entire module, a $750 item.

In summary, work exists which defines functional modularity and applies it to product design. Modularity has also been widely implemented in the design for assembly of products, often to the detriment of serviceability. Modularity has not been applied to design and service concurrently. Two aspects missing in the current works include: a definition for modularity that takes into account characteristics of a product other than its function and a methodology for developing modular products. This paper supplies working definitions of modularity and service modularity, gives a design methodology to incorporate service modularity, and shows a short example of the definitions and methodology in use.

### 1.2 Benefits of modularity

Modularity arises from the division of a product into independent components. This independence increases the use of standardized components and allows designers to more easily create a wide variety of products using a much smaller set of components. Product variety is created by having several different versions of each component in the final product. The physical and functional interfaces between the components are the same. The result is that any combination of components can be assembled into the different versions of the same product, or even a different product, with minor modifications.

Ulrich and Tung's (1991) work details the costs and benefits of modular products. The benefits of modularity they discuss include: 1) component economies of scale due to the use of components across product families, 2) ease of product updating due to functional modules, 3) increased product variety from a smaller set of components, 4) decreased order lead-time due to fewer components, 5) ease of design and testing due to the decoupling of product functions, and 6) ease of service due to differential consumption. The costs of modularity they discuss include: 1) static product architecture due to the reuse of components, 2) lack of performance optimization due to lack of function sharing and larger size, 3) ease of reverse engineering and therefore increased competition, and 4) increased unit variable costs due to the lack of component optimization (although Ulrich and Tung don't discuss the decreased unit cost over a product family).

Modularity allows the designer to control the degree to which changes in service processes affect the product design. By promoting interchangeability, modularity also gives designers more flexibility, with decreased cycle time, to meet these changing processes. The flexibility that modularity offers is increasingly important as uncertainty in service requirements (due to new diagnostic and repair technology and ever changing warranty agreements) increase. This flexibility allows some design decisions to be delayed because they have a lower impact on the total product. Controlling the impact of changes and being flexible to respond to changes are the benefits of modularity. A flexible product can more readily adapt to a late influx of service technology or a late change in service strategy.

## 2. APPROACH

There are three key definitions which enable product design for manufacturing modularity. *Product modularity* is the foundation of this work. *Characteristic modularity*, an instance of product modularity, and *service modularity*, a specific case of characteristic modularity, are the functional definitions supporting the design methodology. The definitions of product and characteristic modularity are discussed briefly below but more detail can be found in Gershenson and Prasad (1997).

## 2.1 Product modularity

Components or sub-assemblies (heretofore referred to as components) which are, or are intended to be, relatively modular in nature are called *modules*. Modules contain a high number of components which have a high degree of dependency upon and similarity to other components in the module but which have minimal dependencies upon and similarities to other components which are not in the module. These dependencies and similarities include those which arise from the relationships between the components' attributes and those which arise from the relationships between the components during the various processes the components undergo in their life-cycle (Figure 1).

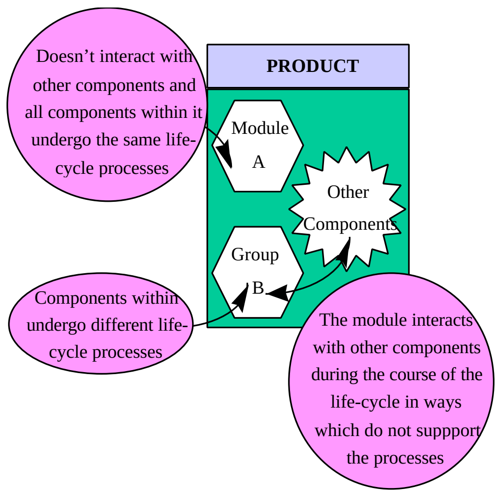



Figure 1: *Representation of a product with modular (Module A) and non-modular (Group B and Other Components) sub-systems.*

Therefore, in a module, each component is independent of all components not contained in the same module (independence). In addition, each component in a module must be processed in the same manner during each phase of it life-cycle (similarity) to reduce interdependencies between modules. This definition with independence and similarity parallels Suh's (1990) form-function independence definitions used in previous modularity research but considers the application of modularity to other concerns in addition to end user functions. The form-function relationship has been replaced with a form-process relationship. The last piece of our definition of modularity is the interchangeability of module interfaces which enable "plug in" modules for process changes (interchangeability). Interchangeability is important but does not affect modular design decisions. While complete modularity may be unrealistic except in the most trivial cases, a product which exhibits a higher degree of modularity is more likely to incur a lower total life-cycle cost especially when the entire product family is examined.

## 2.2 Service modularity

In previous work, *characteristic modularity* is defined as modularity applied to an individual life-cycle characteristics (Gershenson and Prasad, 1997-2). Characteristic modules contain a high number of components which have minimal dependencies upon and similarities to other components in the product with regard to a particular phase of the life-cycle (*e.g.*, end use, manufacturing, assembly, service, *etc.*). Examples of characteristic modularities are shown in Figure 2. *Manufacturing modularity* is detailed in Gershenson and Prasad (1997-1). Characteristic modularity may be more useful than total product modularity for a product, especially if there are one or two characteristics which dominate the requirements and costs of a product. Developing products which are modular in terms of characteristics besides the primary drivers could result in excessive modularity and/or decreased value.

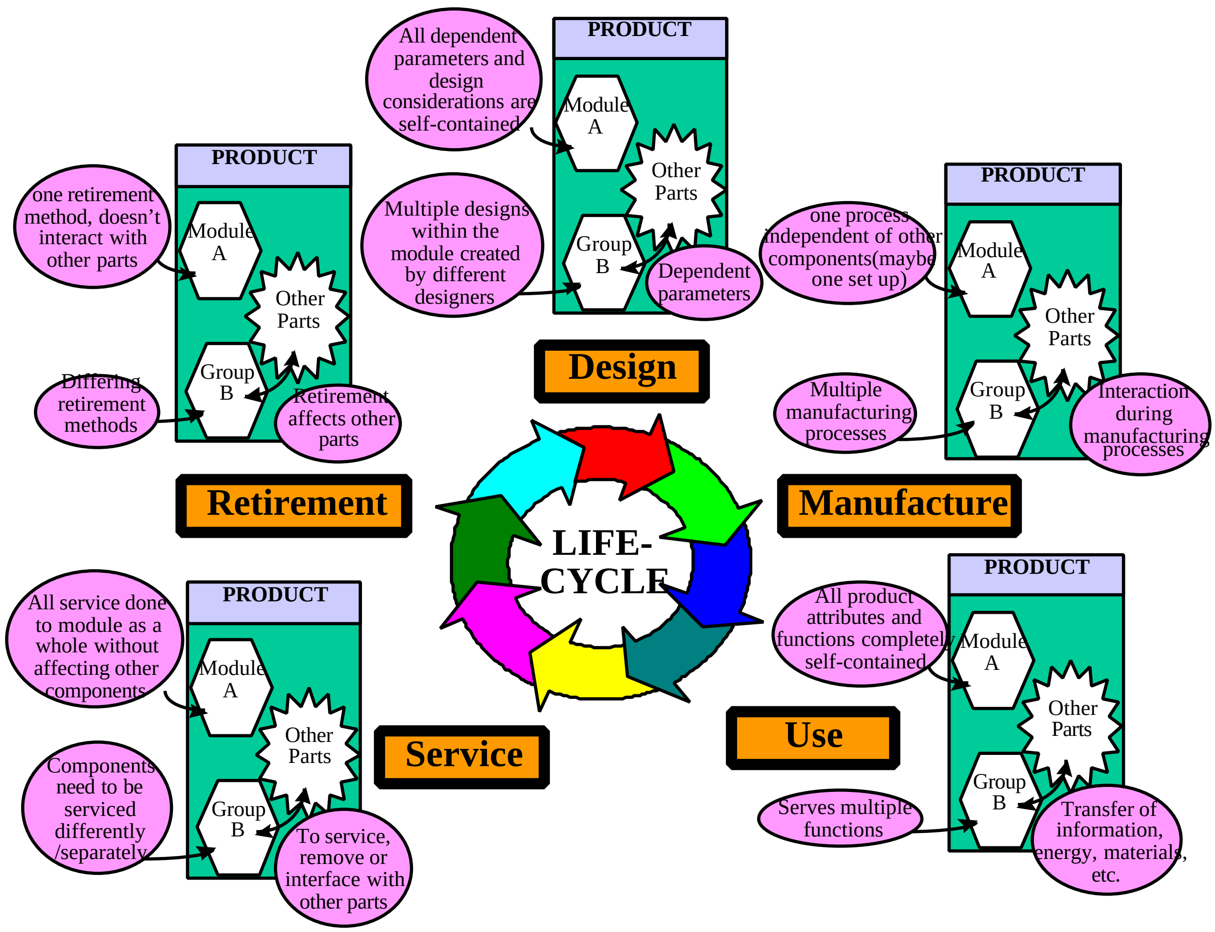



*Figure 2: Views of a product as it goes through some of the major life-cycle processes. Once again, Module A is modular while Group B and Other Parts are non-modular.*

*Service modularity*, a particular characteristic modularity, is the development of product modules with minimal dependencies upon other components in the product with regard to service and maintenance processes. In addition, the components within the module have maximal similarities to each other and minimal similarities to external components with regard to their service processes.

An important consideration when defining the service modularity of a product is the chosen level of abstraction of the service process itself. The service of a product is made up of many tasks. These tasks are, in turn, made up of sub-tasks. A product may be modular (independent and similar) when examined from the standpoint of the overall service processes, called service modes (*e.g.*, repair tail light and replace and fill radiator affect different modules) but at some task level, called labor operation, the structure may not be very modular with respect to the service process (*e.g.*, similarity of trim parts needed to be removed for access to different modules within the door). Therefore, when defining the relative service modularity of a product, one must do so with respect to the labor operations as well as of the service mode. This is parallel to considering the level of abstraction of the physical product (*i.e.*, assemblies and sub-assemblies).

Lastly, it is important that service modularity takes into account service's effect on each product attribute. When looking for dependencies and interactions between modules and components, each attribute of the product, modules, and components must be considered. As an example, when designing a module to be easily serviced, all fasteners in the module should use a certain tool. In addition, the fasteners should be of similar length to avoid errors in replacement. Product attributes include: geometry, features, tolerances, surface condition, materials, and facilities (Gershenson and Stauffer, 1995).

## 3. DESIGN METHODOLOGY FOR *SERVICE MODULARITIES*

It is important to view service modularity from the standpoint of creating more modular products. This is quite different from designing products with interchangeable or reconfigurable parts. It is also quite different from maintaining form/function independence. Modular design for serviceability techniques are the crux of this research. It is the goal of modular design to group all attributes with similar service modes into a single module and decouple them from all other attributes and service modes. Creating modular products involves making sure that, at each level of abstraction, the product's attributes are as independent from one another as possible for each level of abstraction of the service modes. If a dependency does occur, it should occur within a module. In addition, within a module, every service mode should be similar for every component.

Part of the goal of modular design for serviceability involves a closed form/process relationship within a module (independence). This includes maintaining both form/form and process/process independence as well as the relationship between form and process. Another aspect of modular products is the similarity of how the module and its components are serviced (similarity). For each part of the form (module), the entire module must undergo the same service modes. The last aspect of modular design is minimizing the different types of interfaces (interchangeability). This is more easily done and common in industry today.

To increase independence and similarity, a product must be designed with the following four facets of modularity in mind: 1) attribute independence, 2) process independence, 3) process compatibility, and 4) process uniqueness. The more independent, compatible, and unique the components and their service modes are, the more modular the product is. Attribute compatibility has been excluded due to its inclusion as a basic task of product design. Attribute uniqueness is excluded because it is not necessary for modular products as long as attribute independence is preserved. As an example, many different modules can have black components and still remain modular, however, if the components must all match in color then there is a dependency that reduces modularity.

Following are definitions and examples of the four facets of modular product design:

1) *Attribute Independence*: Attributes of components within the module have fewer dependencies on attributes of components outside of the module, called external attributes. If there are external dependencies, there should be fewer of them and they should be dependent to a lesser degree. Attribute independence yields form independence which enables modularity. Attribute independence enables the redesign of a module with minimized effects on the rest of the product. This makes a product more agile in meeting changing service requirements. A simplistic example of attribute dependence is a module containing multiple components that use the same electronic diagnostic tool. Each component has the same electrical connection so that if one connection changes, or the device changes, all connections must be redesigned. This dependence would cause difficulties in redesign if the components were not all contained in the same module.

2) *Process Independence*: Each service mode of each module has fewer dependencies on the service modes of external components. This requires that the service modes (including all labor operations) that a module undergoes are independent of the modes undergone by external components and modules. Once again, any dependencies that do exist are minimized in number and criticality. *E.g.*, the service modes of the door trim panel and the window regulator are dependent. If the door trim must come off to service the door hardware systems, then it must be easily and quickly removable. If the door trim does not need to be removed for other service modes then the door trim can use a more permanent

attachment method. Process independence allows for the redesign of a module in isolation if the service mode and labor operations of a product should change.

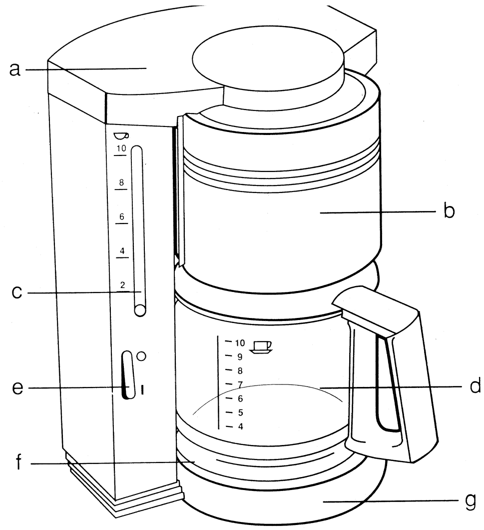
3) *Process Compatibility*: If multiple service modes are used to service a module, the modes must be compatible. All service modes must be compatible so that they can all feasibly occur within a single module. *E.g.*, two components (component x and component y) in the same module are both permanently fixed to the module. To replace either necessitates replacing the whole module. If they have very different life spans, say 1 year and 10 years, then many good components are being thrown away. These service modes (replace component x and replace component y) are incompatible in the same module. Process compatibility minimizes the impact of one service mode on another, unrelated service mode. This results in lower service costs as well as in a simplified product. There are no possibilities for "accidental" dependencies between service modes if incompatible service modes are kept separate.

4) *Process Uniqueness*: Group components and sub-assemblies which undergo the same service modes into the same module where possible. Therefore all components in the module undergo the same service modes and no external components undergo these service modes. This creates a strong differentiation between modules. *E.g.*, a component which is part of a module needs only be removed for servicing components in that module. But, it must be removed for all service modes of that module. Also, a diagnostic system is used only for one module. Process uniqueness also conserves redesign energy by insuring that changes to individual service modes only affect one module of the product. If the service modes of a module do change, the entire module is in need of redesign. This is important because any components in the module which did not undergo a particular service mode would normally not need redesign, except that components within a module are allowed to have attribute dependencies. These components would therefore be in need of redesign despite no change in their service modes or labor operations. This, coupled with the other three facets prevents the cascade of design changes caused by small changes in a product's service modes or labor operations.

While designing only for service modularity and ignoring the rest of the product life-cycle is not optimal, service modularity is important. Service costs and inconveniences are an important part of customer satisfaction and intent to repurchase. While service is not usually given as much input into product development as it should, post-manufacturing warranty costs are a significant output by auto makers and other consumer products manufacturers. In addition, understanding service modularity is, in itself, a useful end. Products which are modular in terms of service have decreased service parts proliferation, decreased service time, and decreased complexity of labor operations.

## 3.1 Example Application

In this brief example of an electric coffee maker (Figure 3), we can illustrate relative service modularity and how to increase service modularity through design.




**A: Hinged Lid**
**B: Swivel Filter**
**C: Water Level Indicator**
**D: Glass Carafe**
**E: On/Off Switch**
**F: Warming Plate**
**G: Hidden Cord Storage.**

Figure 3: *An assembly diagram for the electric coffee maker.*

The coffee maker's components are described in the component tree of Figure 4. A component tree details the levels of abstraction of a product. Although relationships between components are missing on this tree, one can still see the general partitioning of components. To explain the service modes of the coffee maker, a Service Mode Analysis (SMA) chart is shown in Figure 5. A SMA chart illustrates the labor operations necessary to service a product. The chart contains the top level service modes and the labor operations that make them up. Once again, one can see if the service modes are partitioned even without showing the dependencies. An SMA is performed similarly to a failure mode and effects analysis. SMA begins with an identification of the defects that arise in a product which will need servicing. In this example, no maintenance operations were used because regular maintenance is not common in this product. For each of these defects there may be multiple types of repairs that could fix the defect, these are called service modes. In addition, each defect has an impact on the customer. This impact is used to understand how critical it is that the repair be done. For each service mode, there is a way to diagnose it and a set of labor operations that are used to complete the service. In a more detailed SMA, one would get into the nuts and bolts of exactly what was done in every single service mode and labor operation of a product, including maintenance. However, for the purposes of this example only a cursory SMA was performed on the electric coffee maker.

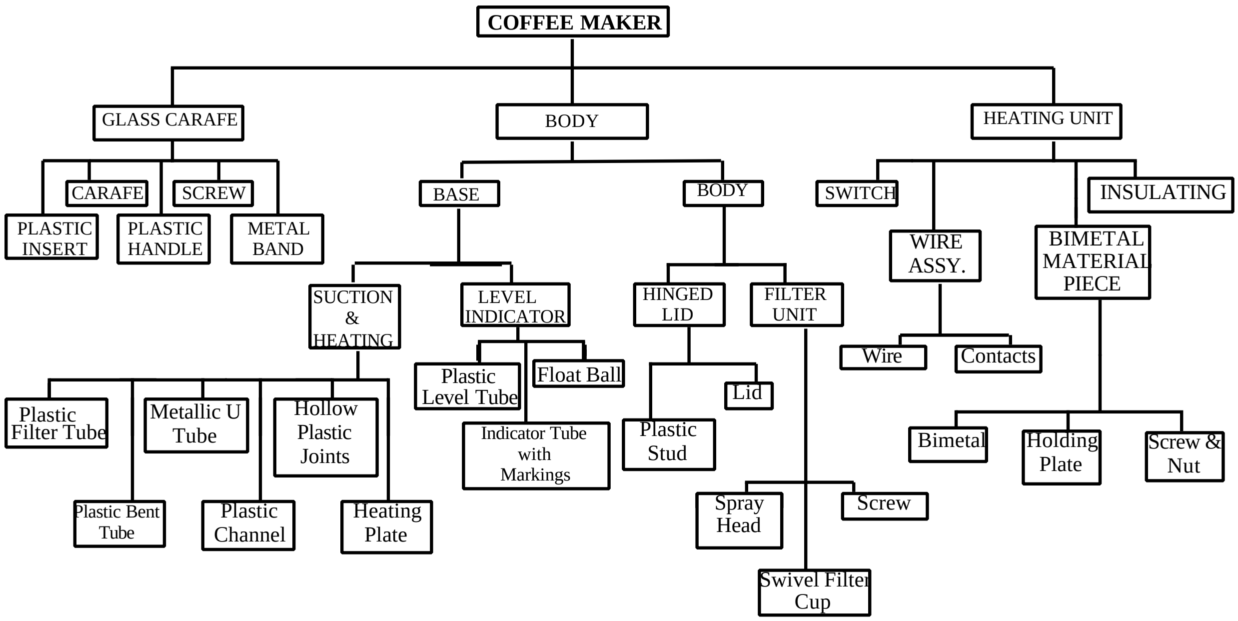



Figure 4: *A component tree diagram for an electric coffee maker.*

| ***DEFECTS*** | ***SERVICE MODE*** | ***CUSTOMER IMPACT*** | ***DIAGNOSIS*** | ***LABOR OPERATIONS*** | ***CRITICALITY*** |
|---|---|---|---|---|---|
| Unit not working | Complete unit to be checked | Coffee maker will not work | Power indicator on, heating unit not working | Loosen base screws, check power supply to heating unit | High cost of service |
| Liquid not siphoned | Complete unit to be checked | Coffee maker will not work | Crack in plastic filter tube, heating unit malfunction | Open hinged lid, remove plastic filter tube. Open base screw, check metallic U tube and heating unit | High cost of service |
| Coffee warmth not maintained | Loose electrical connection | Coffee gets cold quickly | Loose connection between the heating unit and the warming plate | Remove base screws, check connection | Low cost of service |
| Leakage | Tube is cracked or separated | Coffee maker will not work | Indicator lamp on but water is not siphoned | Open hinged lid, remove plastic filter tube. Open base screws, check metallic U tube | High cost of service |

Figure 5: *SMA chart showing the top service modes in terms of customer impact and criticality .*

By comparing the form partitioning shown in the component tree with the process partitioning shown in the SMA chart, one can see the service dependencies and similarities between modules of the coffee maker. This can be done by defect (failure of the product), by service mode, or by labor operation. We will concentrate on the latter two since the first is better done using failure mode and effects analysis and better discussed in the context of reliability. It should be noted that the electric coffee maker is not an ideal product for improvements to service modularity. The coffee maker was chosen because it has already been approached in terms of manufacturing modularity (Gershenson and Prasad, 1997-1) and overall characteristic modularity. What makes the coffee maker difficult is that it is a product whose service cost is relatively low and the product itself is relatively small with tightly grouped components. Following are the cases of a lack of service modularity in the coffee maker.

1) Since the coffee maker is not a large product and there are many small components, access to components is the most important serviceability concern. Although service is not performed often on this product, service costs are quite high for many service modes. Looking at the design of the coffee maker in terms of service modularity sheds light on the sources of this high cost of service. In the present design of the electric coffee maker, the attributes of the components of the hinged lid module are independent of the attributes of all other components in terms of service. However, the attribute independence of this product ends there as nearly every other module has components with attributes that depend upon external components. For instance, the screw, a component in the filter unit module, cannot be modified without changing the attributes of a similar set of screws that are part of the base module. The service modes of the heating unit module and the base module are partially dependent. This process dependency arises because the base of the coffee maker must be opened in order to service the heating unit. Opening the base of the coffee maker affects labor operations with multiple components in the base module.

2) The components of the filter unit module have a problem in that there is a lack of process compatibility in the module. The swivel filter and the spray head have differing service modes but both reside in the filter unit module. Only one component needs to be replaced at any one time. Yet, they are affected by each others' service modes. If one is serviced the other is removed and replaced decreasing its reliability and possibly necessitating an additional service call.

3) Lastly, in terms of process uniqueness, the hinged lid (its own module) and the plastic tubes which are in the suction unit module undergo the same service modes despite being in different modules. As a result, any changes to the individual service modes or their labor operations would have to be accounted for by redesigning both modules. While modular in terms of its assembly processes, the coffee maker is not as modular in terms of its service modes.

Although the assembly cost is much more important to the producer's bottom line, it has been shown that serviceability has a strong impact on customer satisfaction and intent to repurchase. With this in mind we looked at a potential redesign of the electric coffee maker which takes into account service modularity. Redesigning the coffee maker to increase service modularity without having serious detrimental affects on manufacturing modularity and assembly modularity (and their respective costs) was very difficulty. Following are two cases of redesigns to improve service modularity which directly affect the service cost of the electric coffee maker.

1) A detailed look at the SMA chart shows that most of the major and frequently occurring defects require diagnosis of the heating unit module. In addition, diagnosis of the heating unit module entails disassembly of the coffee maker from the base. While creating process independence is difficult without a complete overhaul to the design, creating attribute independence can be achieved. By using integral snap fasteners to attach the base module, the screws will not need to be kept the same as in the other modules. Besides making service easier (less time, fewer tools), this change allows for more

design freedom in the base. The designer is no longer constrained by the screw and its hole. The only constraints are on the outer shell where there are few other constraints.

2) One method of taking care of the process incompatibility problem in the filter unit module is to more tightly structure the module and combine the swivel filter and spray head components. Doing so would require that both are replaced when either needs service. Since they have similar life spans this is not too much of an added expense. However, by increasing the process compatibility within the module (they no longer are incompatible) and increasing the process uniqueness (giving them identical service modes), the possibility of harming one component while servicing the other is eliminated. While this may seem like a waste of money, it actually saves money. Harming the other component would require an additional service call. While the component replacement costs would not be affected, the labor costs of repeating the exact same labor operations would be incurred. In addition, customer satisfaction would increase from the decreased number of service calls.

This example highlights how the design methodology can be used to evaluate and redesign an existing product. It also highlights who approaching one life-cycle characteristic without regard to the others does not usually solve the problem when total costs are accounted for.

## 4. CONCLUSIONS

The benefits of modular design for service center around extending the elements of flexibility and economies of scale that modular products have used to greatly increase the end user value. "[I]ncorporating flexibility, modularity, and adaptability into design to provide additional freedom to adjust and adapt to change" (Shah, 1996). The benefits of service modularity include reduced service parts and streamlined service logistics (Ishii, 1995), as well as component economies of scale, ease of product update, increased product variety from a smaller set of components, and ease of design and testing (Ulrich, 1991).

This paper has proposed a definition of service modularity which accounts for form and process relationships. Defining the key elements of service modularity (independence, similarity, and interchangeability) set the premise for the development of a design methodology to create modular products. This methodology enables the benefits of service modularity. The key elements of service modularity are manifested in the four facets of the design methodology (attribute independence, process independence, process compatibility, process uniqueness). These facets were illustrated in the electric coffee maker example.

Developing more modular products by adhering to these four facets can be used in conjunction with a structured design process to decrease the life-cycle costs of a product. The four facets of the design methodology can be considered independently or as a group. Implementing the methodology early in the design process will allow for a more complete investigation of component, configuration, and service mode options.

While the development and application of a modular design for service methodology is quite useful on its own, there are three suggested extensions to this work: 1) a service modularity measure must be developed to aid the designer in moving towards more modular products; 2) a method of balancing the many different characteristic modularities should be developed to aid the designer in making modularity decisions; and 3) the point of diminishing returns for increased life-cycle modularity (and service modularity in particular) should be explored so that the designer knows where to stop increasing relative modularity.

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Modularity enables parallel work. Modularity is tolerant of uncertainty**. **By â€œtolerant of uncertaintyâ€ we mean that particular elements of a modular design may be changed after the fact and in unforeseen ways: see Design Rules, Volume 1 The Power of Modularity.Â  Agility, Adaptability and Low Maintenance are essential characteristics required by tomorrowâ€™s software ecosystems (e.g., Smart City and Industry 4.0). However, as DARPA realize, todayâ€™s software systems are complex and fail to meet these objectives.Â  Modularity and the runtime structural Hierarchy are therefore actually closely related concepts. If implemented correctly, as we climb up through this structural hierarchy cohesion should decrease and loose-coupling increase. Creating such modules bring modularity in software. Modularity is a â€œsingle attribute of software that allows a program to be intellectually manageableâ€. Meyer defines five criteria that enables us to evaluate design method with respect to its ability to define an effective modular system. 1. Modular decomposability. A design method provides a systematic mechanism for decomposing the problem into sub-problems. This reduces the complexity of the problem and modularity can be achieved. 2. Modular composability. A design method enables existing design components to be assembled into a new system. Both the maintenance service concept and the service path were developed using empirical data collected from the business customers of Veho Autotalot Oy PitÃ¤jÃ¤nmÃ¤ki. The theoretical framework was built around service concepts. The issues dealt in the theoretical framework are service path, service concepts, service blueprint, goods and service-dominant logic.Â  Keywords business customer, maintenance service, retail trade and repair of motor vehicles, sentence completion technique, service concept, service path. Laurea-ammattikorkeakoulu LeppÃ¤vaara Degree Programme in Service Innovation and Design. TiivistelmÃ¤.Â  (Section 2.4) â€¢ What is modularity and customization in maintenance services? (Section 2.5) â€¢ What is a service path?