MALAYSIA TECHNICAL UNIVERSITY OF MALACCA

Study of Product Architecture for Design for Maintenance

Thesis submitted in accordance with the requirements of the Malaysia Technical University of Malacca for the Degree of Bachelor of Engineering (Honours) Manufacturing (Design)

By

Siti Balqis Nurilyani bt Ibrahim

Faculty of Manufacturing Engineering
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JUDUL: STUDY OF PRODUCT ARCHITECTURE FOR DESIGN FOR MAINTENANCE

SESI PENGAJIAN: 2006/2007

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(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat Tetap:
Lot 225, Kampung Jambu Merah,
Melor, 16400, Kota Bharu, Kelantan

Tarikh: ____________

Cop Rasmi: ZULKEFLEE BIN ABDULLAH
Pensyarah
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka
Karung Berkunci 1200, Ayer Keroh
75450 Melaka

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....

Main supervisor

Faculty of Manufacturing Engineering

ZULKEFLEE BIN ABDULLAH
Pensyarah
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka
Karung Berkunci 1200, Ayer Keroh
75450 Melaka

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DECLARATION

I hereby, declare this thesis entitled "Study of Product Architecture for Design for Maintenance" is the result of my own research except as cited in the reference.

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ABSTRACT

The purpose of this project was study of product architecture for design for maintenance. To achieve the purpose of this project, the concept of product architecture, maintenance and modularity have been research and study. The modular components of product architecture that can use for design for maintenance are identified. This project has to relate the product architecture with the maintenance. There are several modular should be consider during choosing it in design for maintenance. The modular approaches in product architecture are slot modular architecture, bus modular architecture and sectional architecture. In the maintenance there are four approaches that should be considered, the approach are preventive maintenance, breakdown maintenance, corrective maintenance and predictive maintenance. In this project the relationship between product architecture are important, how to design the product to ease maintenance using the modular in product architecture. When using the modular in architecture, it will help to improve the maintenance of product which is also can decrease time and cost of the product in maintenance. But before design for maintenance, the background of the product also should be considered. The man who involved in maintenance must know the component or part of the product before maintenance. At the end of this project, the product that has been choose will be improve by relate it with the product architecture and design for maintenance. Modularization of components reduces maintenance guess work, which in turn reduces maintenance downtime. Beside that, the maintenance also can be improved by the improvement of architecture.

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ABSTRAK

Tujuan utama projek ialah untuk mengkaji seni reka bentuk untuk mereka penyelanggaraan. Dalam mencapai tujuan projek ini, kajian mengenai konsep seni reka bentuk produk,konsep penyelengaraan dan konsep modul telah dilakukan. Komponen modul di dalam seni reka bentuk produk yang boleh di gunakan dalam mereka penyelenggaraan teleh di kenal pasti. Projek ini mesti mengaitkan seni reka bentuk produk dengan penyelenggaraan. Semasa mereka penyelenggaraan, beberapa pendekatan di dalam modul perlu di pertimbangkan . Modul pendekatan di dalam seni reka bentuk produk ialah senireka bentuk modul selit, senireka bentuk modul pembahagian dan senireka bentuk modul bus. Terdapat empat pendekatan di dalam penyelengaraan yang perlu di pertimbangkan. Empat pendekatan itu ialah penyelenggaraan secara berkala, penyelenggaraan pembetulan, penyelengaraan kerosakan dan penyelengaraan secara ramalan. Pengkaitan antara seni reka bentuk produk dan penyelenggaraan adalah penting di dalam projek ini. Di samping itu bagaimana merekabentuk produk untuk memudahkan penyelenggaraan dengan mengunakan modul di dalam seni reka bentuk produk juga penting d idalam projek ini. Dengan mengunakan mudul dalam seni rekabentuk , ia dapat membantu dalam memperbaiki penyelenggaraan sesuatu produk di samping mengurangkan masa dan kos semasa penyelengaraan. Sebelum, merekabentuk penyelenggaraan untuk sesuatu produk, kajian ke atas latar belakng produk perlu di pertimbangkan. Di akhir projek ini, produk yang di pilih akan di perbaiki dengan mengaitkan seni rekabentuk produk dengan rekabetuk penyelenggaraan. Pengunaan komponen modul dalam mengurangkan kerja penyelenggaraan akan mengurangkan penyelengaraan secara tiba-tiba. Selain itu proses penyelenggaraan ini juga dapat di perbaiki dengan membuat penambahbaik dalam seni rekabentuk produk.

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DEDICATION

To my beloved parents:
Ibrahim b Sulaiman
Zaiton bt Ibrahim
For your love and demonstration the values of education since I'm still a little kid.

To my siblings:
Siti Nur Bahjan bt Ibrahim
Siti Nur Baiti bt Ibrahim
Muhammad 'Izzat Zahin b Ibrahim
Siti Nur'izzah Basirah bt Ibrahm
For your love, encouragement, and support on this project was absolutely invaluable.

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CHAPTER 1

1.0 INTRODUCTION

1.1 Overview

In the field of product development and engineering design, approaches and strategies for variety design and product are prevalent. Product architecture can be defined as the way in which functional elements of a product are arranged into physical unit and the way in which these units interact. The approaches that are relevant to the product design are the development of product architecture. While maintenance can be defined as any change to any component of the product after it has passed the acceptance test of requirements, specification, design, implementation and documentation like manuals. There are 4 approach maintenance; preventive maintenance, breakdown maintenance, predictive maintenance and corrective maintenance. Preventive maintenance is all actions carried out on a planned, periodic, and specific schedule to keep an item/equipment in stated working condition through the process of checking and reconditioning; corrective maintenance is unscheduled maintenance or repair to return items/equipment to a defined state, carried out because maintenance persons or users perceived deficiencies or failures; and Breakdown maintenance is fix-it when broken and it is large maintenance budget. Predictive maintenance requires direct and frequent observations of the states of all system components. In discrete-part manufacturing

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processes, direct online measurements of tooling elements are often extremely costly. In design for maintenance the product that has been choose will be improved and refer to relations between design for maintenance and product architecture.

1.2 Objectives

1. To understand the elements and criteria of maintenance friendly designs.
2. To understand modes of product architecture that are available.
3. To understand the advantages and disadvantages of each product architecture mode.
4. To be able to relate product architecture to maintenance friendly (design for maintenance).

1.3 Scope of Project

1. Understanding Design for Maintenance and Product Architecture.
2. Making relations between Design for maintenance and product Architecture.
3. Choosing a product to be improved based on Design for Maintenance.

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1.4 Problem Statement

Maintenance is the important aspect that should be considered before design the product because the ease to maintenance and service the product, it can reduce cost in maintenance. The modules that are available in product architecture are a guide or references to design the new product. To design the maintenance for the product, the module in product architecture should be considered because there are different types of module for one product.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

For this chapter will be discussing about the study of product architecture for product for maintenance which is it contents the research and the previous study that is related with the project which is from the journals, internet, books and articles. The data from this sources is important to help and know what is the relevant topic should be discussed in this study.

2.2 Product Architecture

The **architecture of a product** is the schemes by which the functional elements of a product are arranged into the physical element of the product are arranged into physical **chunks** and by which the **chunk** interact. A **chunk** is the physical elements of a product which is typically organized into several major physical building blocks. One approach directly relevant to product architecture is the modular product architecture. According to Ulrich and Tung, the product architecture involved one-to-one mappings from functional elements in the function structure to a physical component of a product, where decoupled interfaces between components can be specified. Architecture has a two-part

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definition. The first part of architecture is a decomposition of the overall functionality of a product into a set of defined functions and the component parts of the product that are going to provide those functions. The second part of the definition is the specification of the interface between the components, in other words, how components are going to interact together in the product as a system. The architecture of the product, how it is divided into chunks and how the chunks are integrated into the total product, impacts a number of important attributes such as standardization of components, modularity, options for change later on, ease of manufacture, and how the development project is divided into manageable tasks and expenses. If a family of products or upgrades and add-ons are planned, the architecture of the product would determine the commonality of components and the ease with which upgrades and add-ons can be installed.(Robert Q. Riley Enterprises, LLC, 1999 - 2006)

Product architecture has been defined by Ulrich and Eppinger (1995) as (Figure2.2(a)) the arrangement of functional elements; (Figure 2.2(b)) the mapping from the functional elements to physical components; the specification of the interfaces among interacting physical components. A key issue in the design of product architecture is the ease in which the technical design of the architecture allows changes to be made to a product. Products with integral architectures require changes to several components in order to implement changes to the product's function. For products with a modular architecture on the other hand, desired changes to a functional element can be localized to one component. A modular product design therefore increases the likelihood to use standard components and also enables component interfaces to be identical across several products (Vuuren and Halman, 2001).

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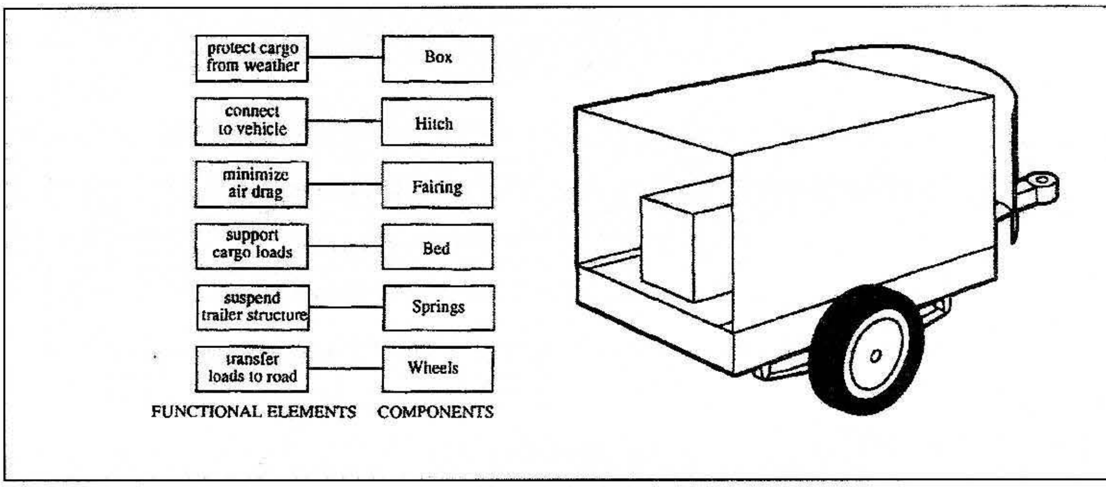

Figure 2.2 (a): A modular trailer architecture exhibiting a one-to-one mapping from functional elements to physical components Ulrich and Eppinger (1995)

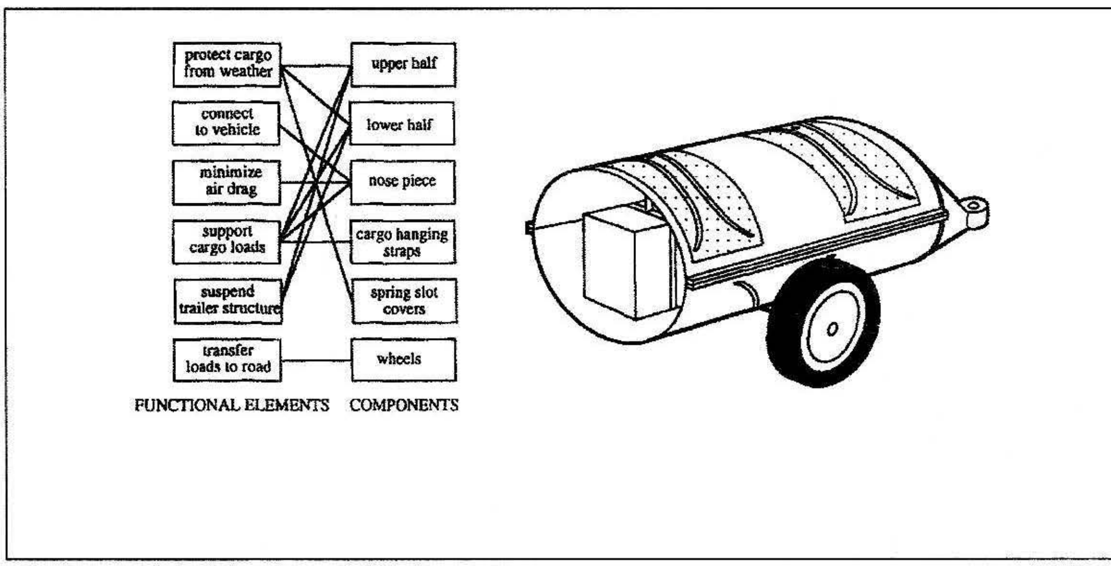

Figure 2.2(b): an integral trailer architecture exhibiting a complex mapping from functional elements to physical components Ulrich and Eppinger (1995)

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The desire to move the product architecture decision is between modular and integral. Earlier in the conceptual design stage necessitates basing the decision on a functional model of the product. A modular architecture is then formed by grouping sub-functions from a functional model such as a function structure and together to form modules. The modules identify opportunities for function sharing by components and lead to alternative layouts where concept generation techniques may be used to embody the layouts. To systematically explore product architecture possibilities across a wide variety of products, a common functional design language is needed

Typically, product architecture design occurs during the configuration design stage, that is, after conceptual design but before parametric design (Dixon et al., 1988).Configuration design is the process of synthesizing product structures by determining what components and subassemblies are in the product and how they are arranged spatially and logically. Certainly, product configuration controls a product's fabrication and assembly characteristics. It also controls a product's adaptability necessary to respond to changes in customer requirements.

2.3 Modular Architecture

Modularity allows the designer to control the degree to which changes in processes or requirements affect the product and by promoting interchangeability, modularity gives designers more flexibility to meet these changing processes. This flexibility allows for delaying design decisions until more information is available without delaying the product development process. Another benefit is the ability of modularity to reduce life-cycle costs by reducing the number of processes and reducing repetitive processes.
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, 2) ease of

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product updating, 3) increased product variety, 4) decreased order lead-time, and 5) ease of design and testing. The costs of modularity they discuss include 1) static product architecture, 2) lack of performance optimization, 3) increased unit variable costs, and 4) excessive product similarity. Other works (Ishii, 1995; Shah, 1996; Ulrich, 1991) concentrate on the benefits in the design process.

A product's architecture is thought of in terms of its modules (Ulrich and Eppinger, 1995). A module is a physical or conceptual grouping of components. Modularity is the concept of decomposing a system into independent parts or modules that can be treated as logical units (Pimmler and Eppinger, 1994).Modularity is the relative property of product architecture, product are rarely strictly modular or integral. There are different forms of modularity, types of modularity and drivers of modularity.

There are 3 types of modularity :(1) slot,(2)bus and (3)sectional.

1. slot (Figure 2.3(a))

   Each of the interfaces between components in slot architecture is the different types of the others, so the various components in the product cannot be interchanged.

2. bus(Figure 2.3(b))

   In bus architecture, there is common bus to which the other physical components connect via the same type of interface.

3. sectional (Figure 2.3(c))

   In sectional architecture, all interfaces are the same types and there are no single elements to which all the component attach.

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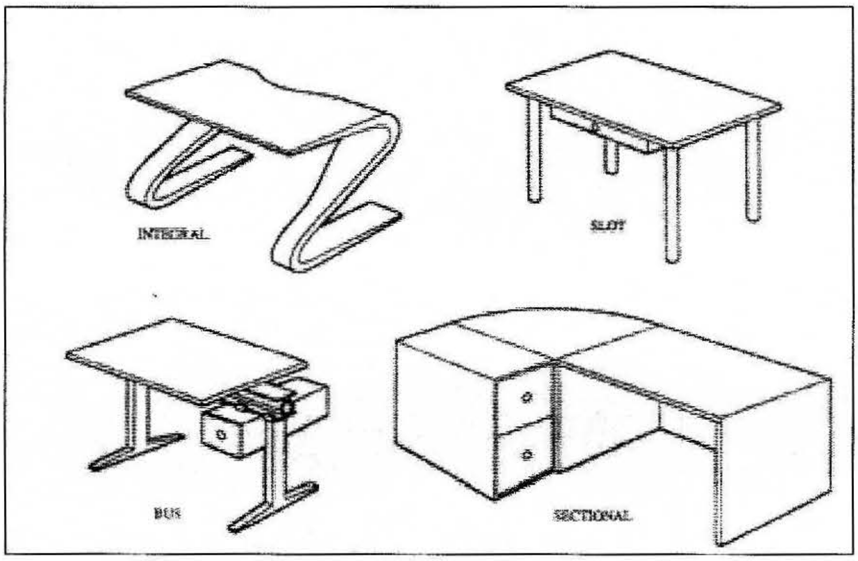

Figure 2.3(a):4 desk architecture, Ulrich and Eppinger, (1995)

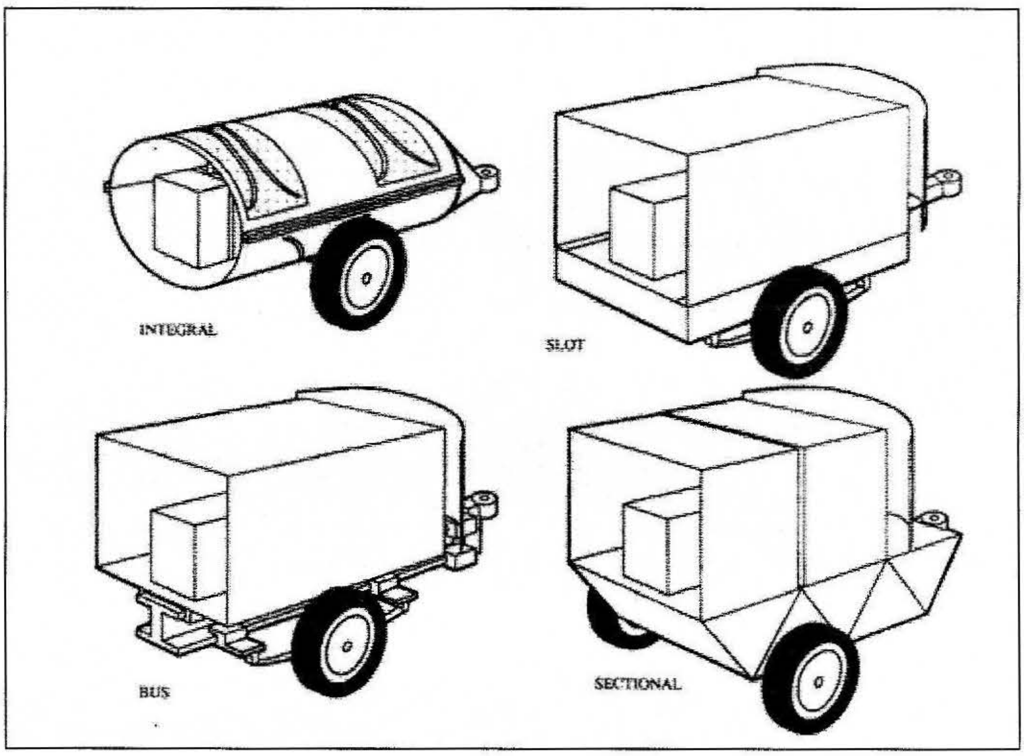

Figure 2.3(b): 4 trailer architecture, Ulrich and Eppinger, (1995)

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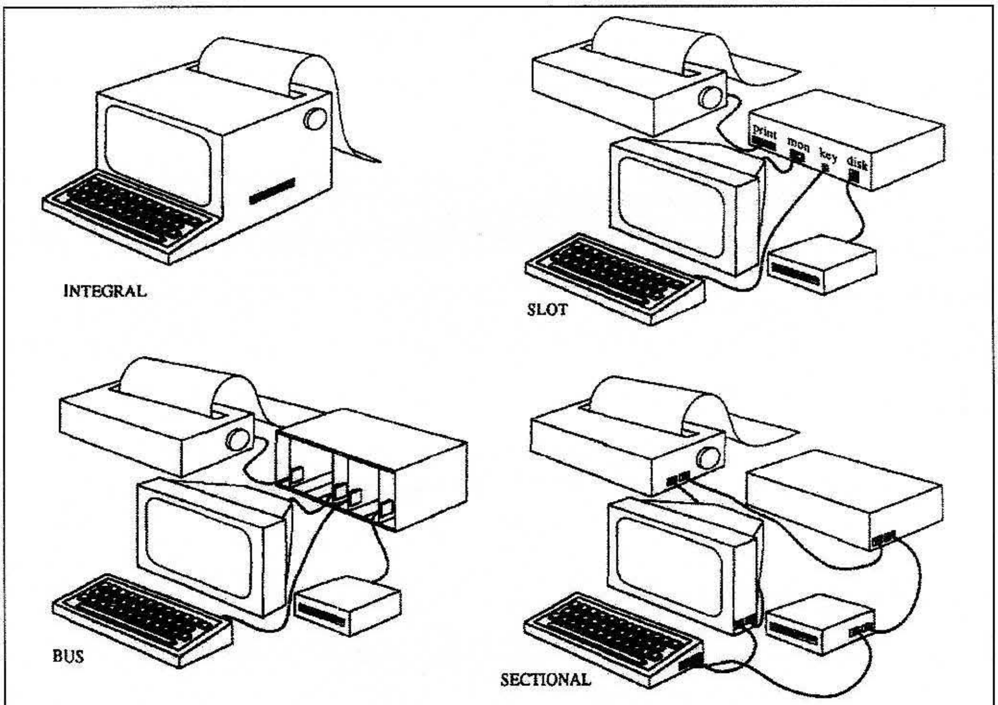
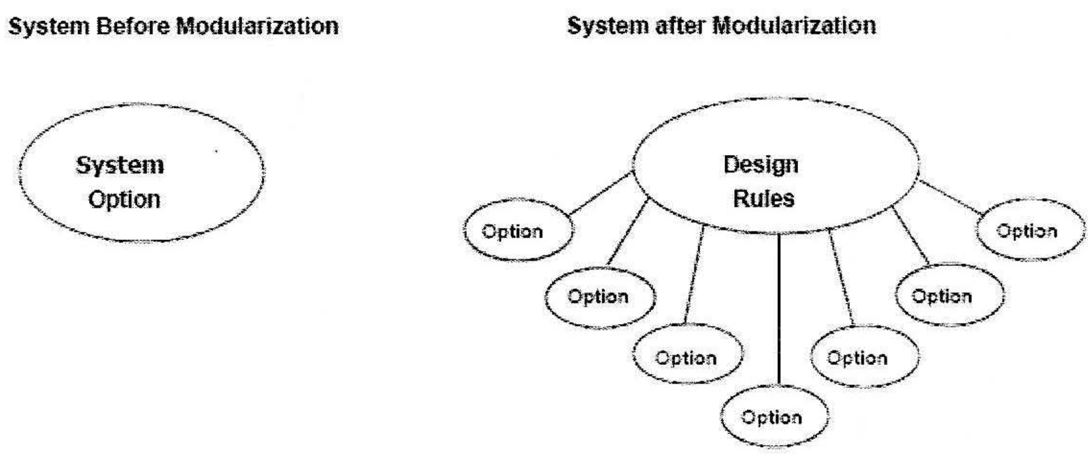


Fig. 7. Four personal computer architectures.

Figure 2.3(c): 4 personal computer architecture, Ulrich and Eppinger, (1995)



Source: Baldwin and Clark, 2000, p. 237.

Figure 2.3(d): Modularity Creates Options. Baldwin and Clark,2000

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The real options in a modular design are valuable. This is not a new or a controversial claim. Building on it, in Design Rules we sought to categorize the major options implicit in a modular design, and to explain how each type can be valued in accordance with modern finance theory. The option value of a system made up of modules in turn can be approximated by adding up the net option values inherent in each module and subtracting the cost of creating the modular architecture. A positive value in this calculation justifies the investment of resources in a 6 new modular architecture. It will be realized overtime via modular design evolution.

Modular Product Architecture provides the following cost-saving benefits while enabling product differentiation:

- Reduce Product Complexity
- Increase Part Re-use
- Reduce Part Count
- Enable Configurable Products
- Enable both top down and bottom up design processes for optimal efficiency

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Table 2.3 shows the summary of the modularity.

Table 1
Summary of key ideas

	Integral	Modular-Slot	Modular-Bus	Modular-Sectional
Definition	• Complex mapping from functional elements to components.	• One-to one mapping between functional elements and components. • Interfaces between components are not coupled.		
	• And/or the component interfaces are coupled.	• Component interfaces are all different.	• Component interfaces are all the same.	
			• A single component (the bus) links the other components.	
Examples	• Automobile unit body. • Neon sign/lighting.	• Truck body and frame. • Table lamp with bulb and shade.	• Track lighting.	
			• Shelves with brackets and rails.	• Stackable shelving units.
	• "Boom Box" (some internal components are modular-slot).	• Consumer component stereo.	• Professional audio equipment in 19 inch rack.	
	• Cargo ship (hull in particular).	• Tractor-trailer.		• Freight train.
Product Change	• Any change in functionality requires a change to several components	• Functional changes can be made to a product in the field. • Manufacturers can change the function of subsequent model generations by changing a single component.		
Product variety	• Variety not feasible without flexible component production processes.	• Products can be assembled in a combinatorial fashion from a relatively small set of component building blocks to create variety. • Variety possible even without flexible component production processes.		
		• Variety confined to the choices of components within a pre-defined overall product structure.		• Variety in overall structure of the product possible (e.g. Lego blocks, piping).
Component Standardization		• Components can be standardized across a product line. • Firms can use standard components provided by suppliers. • Interfaces may adhere to an industry standard.		
Product Performance	• May exhibit higher performance for global performance characteristics like drag, noise, and aesthetics.	• May facilitate local performance. • Decoupling interfaces may require additional mass and space. • One-to-one mapping of functional elements to components prevents. *function sharing*-the simultaneous implementation of more than one functional element by a single component-potentially resulting in physical redundancy		
			• Standardized interfaces may result in additional redundancy and physical "overhead".	
Product Development Managment	• Requires tight coordination of design tasks.	• Design tasks can be cleanly separated, thus allowing the tasks to be completed in parallel. • Specialization and division of labor possible. • Architectural innovation may be difficult. • Requires the top-down creation of a global product architecture.		

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2.3.1 Modularity Strategies

The scope and dimensions of the modular architecture design are defined in terms of strategies. Particularly, modularity strategies about supply chain, life cycle, market and product are determined.

2.3.1.1 Supply Chain Strategies

The suppy chain strategies help to decide on the position of the firm in the supply chain. O'Graddy(1999) defines two basic strategies:

1. Module Povider

   Design, produces modules according to the modular product architecture and interfaces and supplies them to module integrator. The module provided is responsible for determining the hidden design parameters.

2. Module Integrator

   Defines the visible design rules and constitutes the final product out of the modules supplied by the module providers. Therefore the module integrator is responsible for assuring that the module providers conform to the visible design rules.

It is important to choose one of these strategies according to the definitions given by O'Graddy(1999).

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2.3.1.2 Life Cycle Strategies

Each product runs through different phases in its life cycle. Each phase sets different performance goals for the product.For this reason, a product that is optimized for one phase is not necessarily optimal for others. (Fixon, 2001). Ulrich and Tung (1991) stated the most architecture develop from being modular to being integrated. Because the information necessary is the early stages of the product life cycle might not yet be available and dealing with uncertainty and complexity is easier in a modular fashion, it is preferred to use a modular architecture on the other side, as the intersection are better understood and the focus shifts from variety to performances in the later stages of product life cycle, the idea of an integrated design is supported.

2.3.1.3 Product Strategies

According to Ummut Asan (2003), product strategies deals with the scope of the artifacts desired to be designed modular and determine which modularization process to use. There are two alternatives strategies: single product and product portfolio:

1. If the single product strategy is chosen, the most appropriate modularizations process to use is the structure-based design.
2. If the product portfolio strategy is chosen, the most appropriate modularization process to use is the customer-based design.
3. If both strategies are preferred the most appropriate modularization process to use is the function based design.

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