Unit no-4 Reverse Engineering

Reference: Product design by Kevin Otto and Kristin Wood

Reverse engineering is another name for product dissection.

Reverse engineering is done for the sole purpose of copying a product.

Reverse engineering gives a snapshot of how other designers have combined parts to meet customer needs. **The "teardown" of a product is often a part of product benchmarking, but without the intent of copying the design**

In this context, by reverse engineering, you seek to determine:

1)What are the problems/limitations of the design?

2)What are the great features/functions of the design?

3) Is this product part of a family of similar products?

4)Are any online reviews/customer feedback available?

Product Teardown process

Teardowns are carried out in industry to benchmark work against the competition. Technology and architecture and cost of competitive products uncovered. Many large companies have in house staff whose sole job is to reverse engineer the competition.

One must able to analyze competitor product and transform this analysis in to information that can be used as a part of new design.

Step No-1 List the design issues-Design issues are mainly related to customer needs. Some basic factors are weight, material, colour /finish, manufacturing process, Geometric tolerances, cost per part, dimensional measurements

Step-2 Prepare for product teardown

Step-3 Examine the distribution and installation

Step-4 Disassemble, Measure and analyze data by assemblies

Step-5 Form a Bill Of Materials

Methods of product teardown:

Subtract and Operate procedure(SOP)

It is a five step procedure aimed at exposing redundant components in an assembly or subassembly through identification of the true functionality of each component.

Step1: Subtract one component of assembly: Removal of components may occur in any order .However it may be necessary to remove one or several components in order to remove desired component

Step2: Operate the system through its full range: This step should test the product through the range of customer needs. After removing component the product should be thoroughly tested for each customer need.

Step 3: Analyze the effect: This process is usually carried through visual inspection or with measuring instruments .

Step4: Deduce the subtraction of missing components:

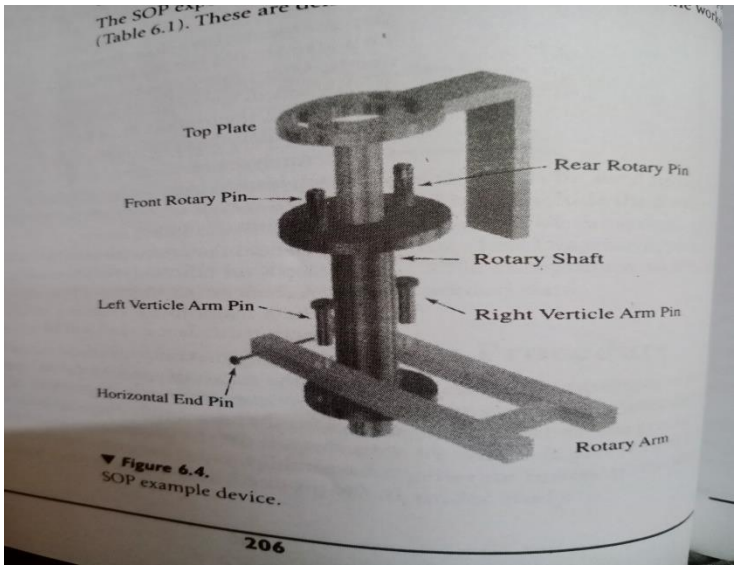
Step5: Replace the component and repeat the procedure n times.

Components that when removed cause no change in the DOF or other factors of the design are termed as Type 1 redundant components .Components that cause no change in DOF but do have effect due to their removal are termed Type 2 redundant components.

Type 1 components are always components for removal

Type 2 components may be removed if another component can be parametrically redesigned to compensate for the other effects.

Example of SOP



▼ Figure 6.4.
SOP example device.

TABLE 6.1. EXAMPLE SOP DEVICE WORKSHEET

Assembly/Part No.	Part description	Effect of removal	Deduced subfunction(s) & Affected customer needs
A-1	Shaft Assembly		
1	Top Plate	360° rotary freedom	Allow DOF Regulate Motion (Arc)
2	Rotary Shaft	No torque transfer	Transmit Torque
A-2	Arm Assembly		
1	Front Rotary Pin	**No effect**	Allow DOF Support Loads (Durability)
2	Rear Rotary Pin	**No Effect**	Allow DOF Support Loads (Durability)
3	Rotary Arm	No torq ıe transfer	Transmit Torque
4	Horizontal End Pin	**No effect**	Support Loads (Safety)
5	Right Vertical Arm Pin	**No effect**	Support Loads
6	Left Vertical Arm Pin	**No effect**	Support Loads

Force Flow (Energy flow filed)Diagram

Force flow diagrams represent the transfer of force through the products component. The components are symbolized as nodes using circle and forces are as arrows connecting the components in which the force transfer takes place. Force flow diagram focus on component combination.

Primary intent of force flow diagrams is

1)Identify the functions of a sequence of components(subassemblies)

2)Identify potential avenues for component combination

Construction of force flow model: The motivation behind constructing a force flow diagram of product is to map the force flow through a product so that the diagram can be analyzed to help expose opportunities for component combination. Once the model is formulated the first step in analyzing force flow diagram is to place “R” on the flows that have relative motion between two components. Once this step is completed, the diagram can be decomposed in to groups separated by “R”s.

The component comprising “R” groups are candidates for combination if not prohibited by material or assembly/disassembly issues. Combination between a member of one group and member outside group requires more complex redesign.

Step1:Identify primary force flows transmitted through product

Step2:Map the force(Energy) flow from the external source through each component of product until the flow exits to ground.

Step3:Document the result in force flow diagrams

Step4:Analye diagram labeling relative motion between components with R

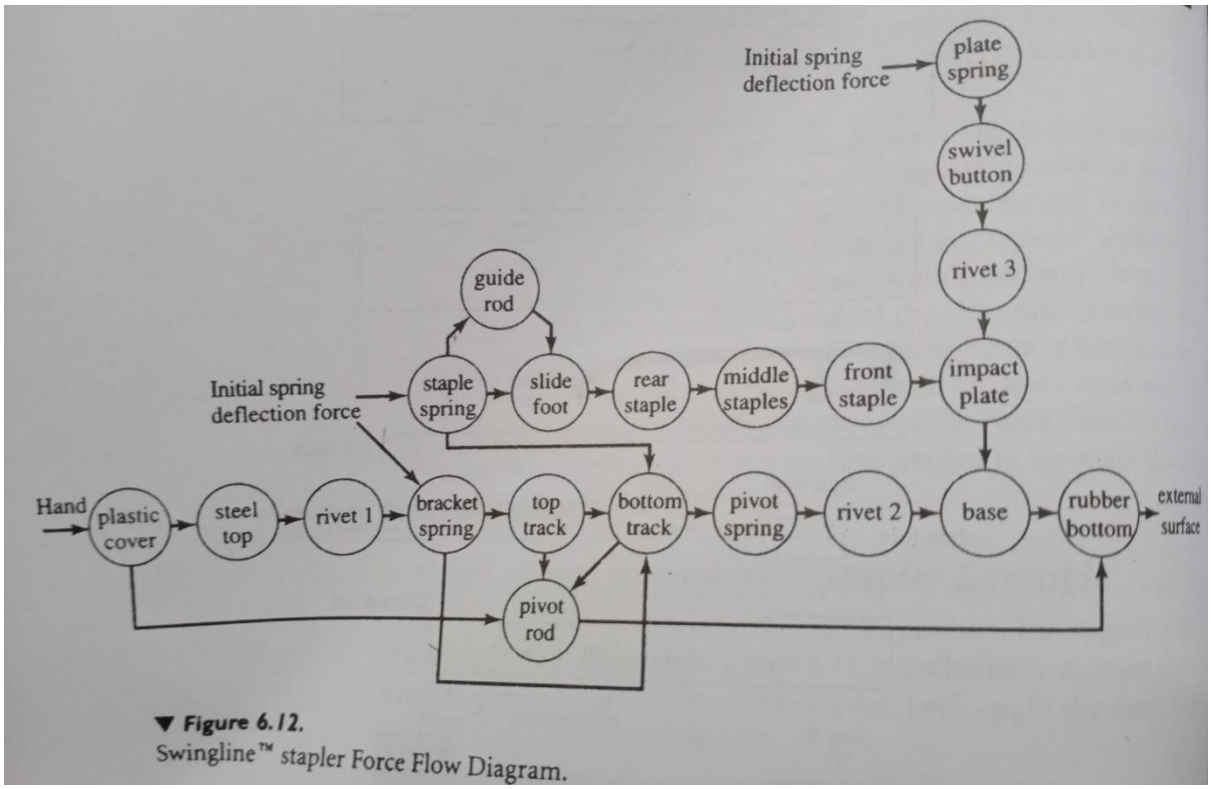
Step5:Decompose the diagram in to groups separated by “R”s. Box these components

Step6:Deduce the sub functions and affected customer needs for each group

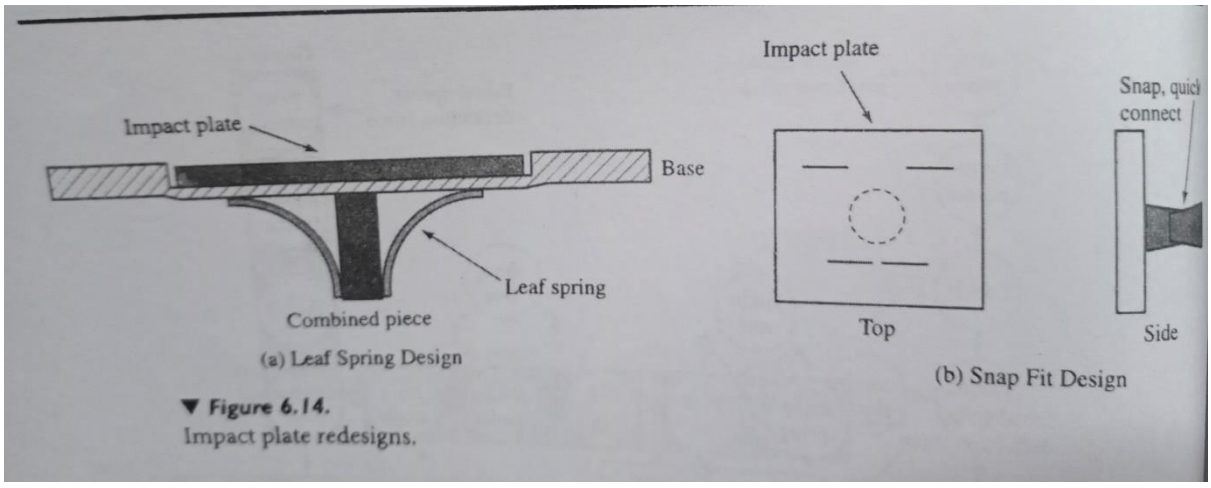
Step7:Devlop creative conceptual design to combine components together.

Step8:Repeat for each force flow.

Example of Force flow diagram for stapler



▼ **Figure 6.12.**
Swingline™ stapler Force Flow Diagram.



▼ **Figure 6.14.**
Impact plate redesigns.

Measurement and experimentation:

A products specification should provide a precise and measurable description of what the product must accomplish .Specifications consist of Metric , denoting the type of measurement and target value in the form of number or range. The product target values are performance levels that designer must achieve. The target values are generally determined by examining the uses the product will be put to or by examining performance of other similar products which is called benchmarking.

Most of design methods initially concentrate on various aspects of acquiring product information, and ultimately the data is covered into a set of quantifiable specifications. These matrices provide clear goal for evaluating product in form of target values developed by determining state of art in product benchmarks.

The importance of measurement in design is illustrated by noticing how design methods are concerned with ensuring that both the customer needs and functionality of product are quantifiable.

The key success in experimental work is to ask continually : What am I looking for? Why am I measuring this –does the measurement really answer any of my question? What does the measurement tell me?

Measurement method of product teardown :It majorly consist of four steps given below

Step1:Select a product domain

Step2:Determine the most important sub function

Step3:Destermine the necessary measurements

Step4:Selection of measurement devices

Benchmarking

Product developers must learn from competitors for which you must know your competitors in business. For this benchmarking is useful and regular activity in product based industries.

It consists of following steps:

Step1:Form a list of design issues

Step2:Form a list of competitive or related products

Step 3:Conduct an information search through various consumer report magazines, Trade magazines, Patents, market share reports, Libraries, reports from various rating agencies, Standards

Step4:Tear down multiple products in class

Step5:Benchmark by function: Summarize the product comparison by form. fit and function

Step6:Establish best in class competitors by function

Step7:Plot industry trends

Benchmarking of competitors is similar in spirit to the benchmarking of technical solutions and considers the performance over time of entire portfolio of a company .Corporate strategies may be deciphered from their performance on business criteria such as market share in different regions, price points in the market over time, assets over time, buyouts, inventory costs as fraction of sales, labour cost as fraction of sales.

Examples of Benchmarking

Different Coffee making mills in market which are available at different costs are benchmarked on four major criteria

Like Noise max capacity, Drip timing and Espresso test

	Bosch MKM6003	Braun KSM2	Krups 203	Regal 505	Salton QC-6	Moulinex 843	Xcell EL1020	Black & Decker CBM122	Melitta CG-2
Price ($)	$25	$20	$28	$19	$15	$30	$20	$22	$22
Performance									
Drip	5	4	4	4	4	3	5	3	3
Espresso	5	5	4	5	4	3	4	3	3
Noise	2	2	3	1	1	3	1	3	3
Max. capacity (oz)	2.75	2.25	2.75	2.25	2.00	3.00	2.25	3.00	3.00

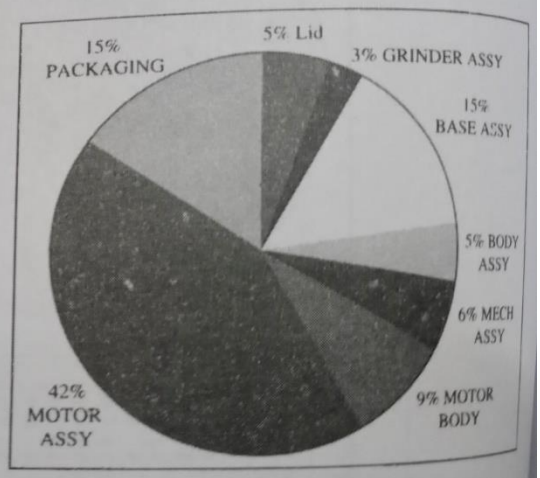
▼ **Figure 7.4.**
Coffee mills benchmarked.

Sporting tools of benchmarking:

1)Assembly cost analysis: One key result of a benchmarking activity is a comparative understanding of the cost structures that different competitors face. In teardown .one can estimate cost of each part which is function of material, equipment, labour cost.

Example of assembly cost analysis

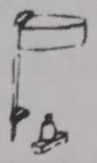
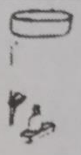
Part #	Part Name	Qty	Fabrication Totals	Assembly Totals	Sub Totals ($)
001	Lid	1	$ 0.19	$ 0.06	$ 0.24
A1	GRINDER ASSY	1		$ 0.04	$ 0.12
002	Transfer Pusher	1	$ 0.02	$ 0.07	
S1	BASE ASSY	1		$ 0.06	$ 0.66
003	Power Switch	1	$ 0.03	$ 0.03	
004	Power Cord	1	$ 0.10	$ 0.27	
005	Base	1	$ 0.07	$ 0.11	
S2	BODY ASSY	1		$ 0.04	$ 0.23
011	Blade	1	$ 0.09	$ 0.10	
S21	MECH ASSY	1		$ 0.04	$ 0.26
012	Chamber	1	$ 0.14	$ 0.08	
011	Felt Ring	1	$ 0.00	$ 0.06	
S211	MOTOR BODY	1		$ 0.04	$ 0.39
011	Screws	2	$ 0.01	$ 0.13	
015	Body	1	$ 0.18	$ 0.04	
S212	MOTOR ASSY	1		$ 0.10	$ 1.94
016	Motor Mounts	2	$ 0.04	$ 0.12	
017	Motor Screws	2	$ 0.01	$ 0.12	
018	Motor	1	$ 1.50	$ 0.06	
A2	PACKAGING	1		$ 0.04	$ 0.69
019	Box	1	$ 0.24	$ 0.09	
020	Bag	1	$ 0.02	$ 0.09	
021	Questionaire	1	$ 0.02	$ 0.05	
022	Dealer List	1	$ 0.02	$ 0.05	
023	Instructions	1	$ 0.02	$ 0.05	
	DIRECT TOTAL	22	$ 2.68	$ 1.90	$ 4.58
	OH		$ 0.27	$ 0.95	$ 1.22
	TOTAL		$ 2.95	$ 2.86	$ 5.80



▼ ***Figure 7.8.***
Combined manufacturing and assembly costs for a coffee mill product.

2)Function form diagram

This diagram basically list the various solutions that are proven on the market for particular product function. The result of benchmarking should be listed on function form diagram such as part count, cost and any material information Finally best in class solutions on the market should be called out such as highest quality and lowest cost models as shown in example mentioned below

Concept	Top Switch			Pivot Lid
	Braun	Krups 2	Quisinart	Krups
				
# Parts	5	5	5	3
Cost	$ 0.25	$ 0.23	$ 0.22	$ 0.20
Materials				
Lid	PS	PS	PS	PS
Pusher	PS	PP	PS	PP
Switch	PVC	PVC	PVC	PVC
Contacts	Brass	Steel	Steel	Steel
Class			Quality	Cost

▼ ***Figure 7.10.***
Function-Form diagram for the Actuate Power subfunction.

Methods to establish product specification:

Specifications for a new product are quantitative measurable criteria that the product should be designed to satisfy. They are the measurable goals for the design team .Product specifications should be established early and revised often. These are also called engineering requirements.

Functional requirements are statements of specific performance of a design i.e. what product should do. Product function is abstract formulation of the task that is to be accomplished and is independent of any particular solution that is employed to achieve the desired result.

1)Method of specification sheets

This has following steps

i)Compile specifications-Arrange functional requirements and constraints in to clear order

ii)Determine if each functional requirement is demand or wish

iii)Determine if functional requirement and constraints are logically consistent. Check for oblivious conflicts.

iv)Quantify wherever possible

v)Determine detailed approach for ultimately testing and verifying the specifications during product development process.

vi)circulate specifications for comment and amendments

Categories for searching and decomposing specifications:

TABLE 7.2. CATEGORIES FOR SEARCHING AND DECOMPOSING SPECIFICATIONS (FRANKE, 1975).

Specification category	Description
Geometry	Dimensions, space requirements, . . .
Kinematics	Type and direction of motion, velocity, . . .
Forces	Direction and magnitude, frequency, load imposed by, energy type, efficiency, capacity, conversion, temperature
Material	Properties of final product, flow of materials, design for manufacturing (DFM)
Signals	Input and output, display
Safety	Protection issues
Ergonomics	Comfort issues, human interface issues
Production	Factory limitations, tolerances, wastage
Quality Control	Possibilities for testing
Assembly	Set by DFMA or special regulations or needs
Transport	Packaging needs
Operation	Environmental issues such as noise
Maintenance	Servicing intervals, repair
Costs	Manufacturing costs, materials costs
Schedules	Time constraints

2)Method of house of quality: Discussed earlier unit

3)Value Analysis:

For any engineering requirement, a target value is determined by simultaneously judging the cost of attaining that target and customer desire in delivering that target. Value analysis method is very quantitative and numerical.

We can define value or worth as the difference in the desire of the customer from the cost of producing it. V=D-C and then we can pick a target value that maximizes this quantity.

But specifying desires of customer in various market situations is challenge.

Value analysis is a useful technique for comparing alternatives and alternative specifications in reasonably well understood domains, where the customer perceive and state well their expected and desired needs, and domains where the technology or markets are reasonably unchanging and can be foreseen.

Trend Analysis:

Trend analysis is important to know changing desires of the customer and changes in market segmentation. It's a dynamic process which is driven by various data points from market such as product sales figures, data related to market share, economic surveys, Technological breakthroughs, and demography.

Regular tracking of this data and drawing meaningful conclusions from it called trend analysis. It is very important process in defining future goals of organization and setting product specifications. It also provides base for various important corporate level decisions about organization.

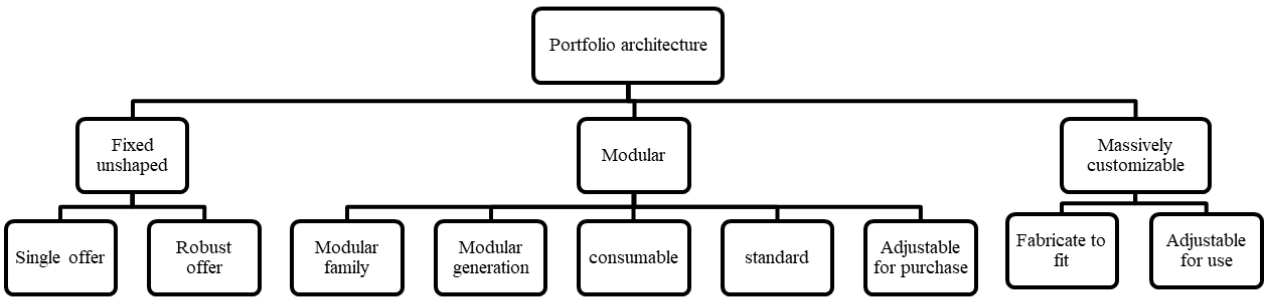
Product Portfolio and Product Architecture:

Product portfolios are the set of different product offerings that a company provides. Product portfolio architecture is the system strategy for laying out components and systems on multiple products to best satisfy current and future market needs.

There are two basic corporate objectives considered in developing a product portfolio architecture: cost and revenue.

Revenues increase with expanded offerings in a larger portfolio, as company can then make products more tailored to each customer in the market but cost go up with added complexity of developing, supporting and manufacturing larger set of different products.

Product Portfolio architectures falls into three basic categories: Fixed unsharing platform, modular and massively customizable as shown in below figure



1)Fixed unsharing portfolio architecture:

In it each product in portfolio is unique and shares no components or systems with any other product member in portfolio. It is used for high volume products eg. screw driver set

Single offer example is car model available in one colour only and example of robust type is electric appliance suitable for 50Hz and 60 Hz frequency simultaneously.

2)Modular architecture:

A modular product family is defined as the set of products supported at any one time by a platform. e.g Two and four slice toaster

Modular product generation is defined as the architecture for product offerings that share the same modular components in offerings that succeeded each other through time. E.g.same capacity engines used in different types of car model.

Consumable platform :Two products using same consumable items e.g. Printer cartridge

Standard platform- A subset of a product system in the standard portfolio platform where a subset of product system in a portfolio of products is a platform that conforms to an industry agreed standards e.g. two different software running on same operating system.

Adjustable to purchase-Different market segment may have different requirements for some of the subsystem in product e.g. computer manufacturers sell to a variety of customers with different electrical power input requirements. To meet this the power supply function might be isolated from the rest of the product as a module like SMPS.

3)Mass customization

Fabricate to fit:It is mass customization platform where the customer can special order the platform at the exact specification desired e.g. In 1990 TOYOTA permitted customer to specially order vehicle from large array of operation which led to increase in cost and TOYOTA finally dropped the idea.

Adjustable for use-camera that permits adjusting focus to different distance are adjustable to use type of architecture.

Types of Product architectures:

Developing product architecture is strategic decision for any class of products. It is where we begin to take key decisions on how the product will physically operate..

Product architecting ,at basic level, starts the creation of effective layouts of components and subsystems, where different tasks are completed by subset of product development team.

Creating a product architecture is focused on transforming product function to product form.

1) Integral product architecture-are physical structure where all the subfunctions map to a single or very small number of physical elements. E.g. Two headed spanners.

2) Modular architecture-Product modules are integral physical product substructures that have one to one correspondence with a subset of product's functional model. E.g. Machines with different assembly components.

Comparison of modular and integral architectures:

	Pros	**cons**
Modular architecture	1)Improves device reconfigurability 2)Increase the device variety and speed of introduction for new devices 3)Improves maintainability and serviceability of device 4)Decouples development tasks and manufacturing tasks	1)May make device look too similar 2)Makes imitation easier to competitors 3)Reduces device performance 4)Modular design may be more expensive than integral design
Integral Architecture	1)Harder for competitors to copy design 2)Tighter coupling of team with less interface problems 3)Increase system performance 4)Possible reduction in system cost	1)Hinders change of design in production 2) Reduces the variety of devices that can be produced.

Product Modularity:

Two benefits of modular design are standardization of components and reconfigurability of devices. We define two major types of modularity: Function based and manufacturing based.

A)Function based modularity:

1)Slot modularity: One basic devices uses several different components to allow it to perform multiple tasks. This is also associated with the concept of component standardization.

e.g Different models of Power tool set having different operation tools but uses the same battery to operate.

2)Bus modularity: A device that is equipped with a standard interface that accepts any combinations of different functioning module. e.g. USB slots in computers

3)section modularity: chained interconnections of modules each equipped with an identical interface- A device common heating element used in Travel hairdryer cum iron .

4)Mix modularity-Componets combines to make endless combination of products e.g. Mechano toy sets

B)Manufacturing based modularity:

Different subassemblies are grouped on basis of manufacturing technique and assembly operations. e.g .American Axle and Jamna Auto together provides Transmission Axle and leaf springs to various models of different Original Equipment Manufacturers(OEM car companies)

Basic method for modular design:

It is a four step process which has following four steps

Step1:Create a function structure of the product

Step2:Cluster the elements in to modules or chunk

Step3:Create rough geometric layouts

Step4:Define interactions and detail performance characteristics

References:

1)Product design book by Kevin Otto and Kristin woods

2)Engineering Design by George E Dieter

3)Product Design and development by Karl T Ulrich and Steven Eppinger

4) Various Web sources