Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 6 (7): 1513-1519, 2006
ISSN 1812-5654

Application Design for Modularity Approach to Enhance Platform Architecture

Ahmad Baharuddin Abdullah and Zaidi Mohd Ripin
School of Mechanical Engineering, Universiti Sains, Malaysia,
Engineering Campus, 14300, SPS, Pulau Pinang, Malaysia

Abstract: The objective of this study, is to apply modularity approach to enhance platform identification from a family of product. Firstly several variants of products from same family are identified and then modules are developed by using conventional approach. Finally the platform is established by using a proposed approach. A case study of appliances fan family has been carried to clarify the work. The result shows that a systematic approach has been developed to form platform that can increased the design variants. The commonality and assembly criteria of the new design have been evaluated and show a tremendous improvement.

Key words: Product platform, modular approach, commonality, redesign

INTRODUCTION

The application of product platform has been suggested as a key component of a well-targeted development strategy for companies that aim better utilization from limited resources. Manufacturers and customers sometimes do not realize that most of the product in the market shares common parts or assemblies. Platform architecture is a set of selection and configuration choices shared among products (Gonzales-Zugasti *et al*., 2000). Product platform can be formulated as a general optimization problem in which the advantages of designing a common base must be balanced against the constraints of the individual product variants and of the whole family. Gonzales-Zugasti and Otto (2000) defines product platform as a set of shared functionality across multiple products from similar or different family. Each different product supported by the platform is called a variant, while a set of all variants derived from a platform formed a product family.

There are several approaches used in platform development, whether during, before or after product is designed. Some of the examples in developing platform are Sudjianto and Otto (2001) from multiple brand product using brand architecting rules for product modularization, i.e., dominant theme of product functions and aesthetic forms, brand signature and platform rules. Zugasti *et al.* (2000) used models of several spacecraft to identify possible subsystem that could be made common to all or some of the missions. Similarly Ripin and Abdullah, (2001) proposed a modular Unmanned Aerial Vehicle (UAV) based on the multi-mission requirements similarity. The advantages of product platform are that by using proven modules that are known to operate effectively at their designated sub-tasks can minimize design risk. Further, reuse of previously designed modules can bring saving at least in part, the cost of redeveloping those sub-system. Product platform also could reduce design risk and also deduct time and cost to market (Martin and Ishii, 1997).

The concept of product platforms and design variants has been successfully applied to consumer and industrial product for some time. For example Sony used three platforms to support hundreds of different personal portable stereo product in its Walkman family. Volkswagen also takes the advantages of platforming and components commonality by sharing between its four major brands such as VW, Audi, Skoda and Seat (Brenmer, 1999).

Basically in modular approach is utilized before platform can be identified, module is needed to be formalized. There are several methods to developed module (Abdullah and Ripin, 2002) but all of them are specifically applied to a single product and none can be used for a range of product variants. In this study, an approach to identify platform based on the developed modules from several variants of product is presented. The research can be divided into three phases, module identification, platforming and finally redesign process. The conventional module identification method developed by Kusiak *et al.* (1994) is used and then further extended by a proposed approach to identify platform from product variants. To clarify the work, a case study of home appliance fan family is carried out.

Corresponding Author: Ahmad Baharuddin Abdullah, School of Mechanical Engineering, Universiti Sains Malaysia, Engineering Campus, 14300, SPS, Pulau Pinang, Malaysia Tel: 604 5996332/604 594025

APPROACH

This approach starts by a list of variants from product family. Products are then decomposed for better understanding the overall configuration of every parts or assemblies in the product. The next process is the modularization, where existing modular approach is applied in determining modules. Here an approach developed by Kusiak *et al.* (1994) being utilized. From literatures, this is the easiest and systematic approach, where modules are identified based on assembly interaction among the components in the product. But it is limited only at product level, if it can be extended to the family level which contain of several product variants, so that more money can be save.

In this research, product platform can be described as a set of component or module which can be shared their functionality across multiple products from similar or different family to create product variants. Here module can only contain a single component. The process of platform development can be described by the proposed approach as shown in Fig. 1. In the approach a simple sorting technique is utilized to identify the common occurring modules to develop the platform. For example, there are three product variants (A, B and C) and have three modules each. Module 1 from variant A consist of components 1, 2 and 3 (CA1, CA2 and CA3), while from variant B consist of components 1, 2 and 4 (CB1, CB2 and CB4) and finally for variant C consist of components 1, 2 and 3 (CC1, CC2 and CC3). As a result after applying proposed approach, a platform that consists of components 1, 2 and 3 can be developed as shown in Fig. 2. Similar case is applied for module 2 and 3. Figure 3 demonstrate the one example of sorting technique developed.

Step 1: List down the variants, V_i ($i = 1, 2 \ldots n$)
Where n = number of variants
Step 2: List down the components in each variants, $C_{vi} = \{\ \}$
Step 3: Construct Interaction Matrix, $M_A = [a_{ij}]_{mxm}$ for each variant
Step 4: Applying the Extended Triangularization Algorithm (Kusiak *et al.*, 1994) on each mapped M_A for each variant to identify module.
Step 5: Set $j = 1$ ($j = 1, 2 \ldots p$)
Where p = number of modules
IF, $m_{1V1} = m_{1Vi}$,
m_{1Vi} = {Components in module 1 of Variants i}
THEN, $P_1 = \{m_1\}$
P_1 = Platform 1, m_1 = {Similar components in the module from the variants}
ELSE, Rearrange the matrix
END IF.
Step 6: Set $j = p + 1$ and m_{p+1} GO TO step 5
Step 7: IF, $m_{p+1V1} \cap m_{p+1Vi} = \{m_r\}$
m_{p+1Vi} = {Components in module p of variants i}
m_r = {Components in module p of variants 1 that intersect with components in module p of variants i}
THEN $P_q = m_r = \{m_{p+1V1} \cap m_{p+1Vi}\}$
IF, $m_{p+1V1} \cup m_{p+1Vi}$
THEN $P_q = m_r = \{m_{p+1V1} \cup m_{p+1Vi}\}$
IF, $m_{p+1V1} \neq m_{p+1Vi}$
THEN $P_q = \varnothing$
END IF
Step 8: Delete all modules associated with Platform, P_p from the matrix, GO TO step 5
Step 9: IF $M_A = \varnothing$, STOP

Fig. 1: The extended approach for platform development

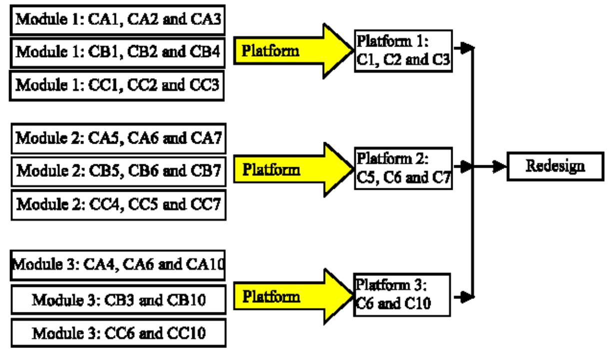

Fig. 2: The process flow chart of platform identification

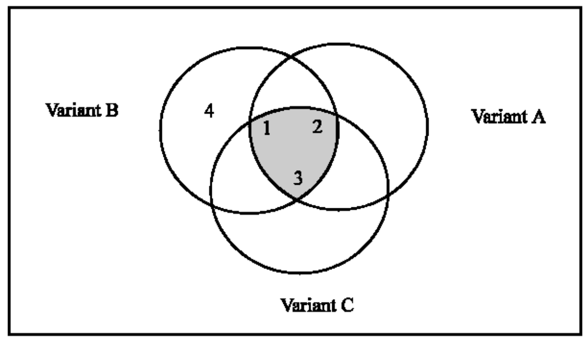

Fig. 3: An example of the approach for three product variants

CASE STUDY-APPLIANCES FAN FAMILY

In the market there are four types of home appliance fan variants, which are table fan, auto fan, stand fan and wall fan as shown in Fig. 4. Generally, the main function of the fan is to blow air to a targeted area. The approach begins with decomposition of the product to understand the product structure and to identify all components in the products. The decomposition can be demonstrated in the form of hierarchy structure. After that the components is then listed down in the matrix to constructed interaction matrix. The main task at this stage is to identify module. By applying the Triangularization Algorithm developed by Kusiak *et al.* (1994) the modules are then mapped in the modularity matrix. Similar case for other variants in the

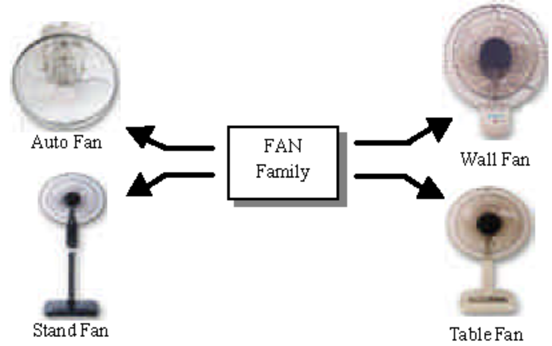

Fig. 4: Four variants of fan family in the market

Table 1: Module identified from the three product variants

Module	Name	Wall fan	Stand fan	Table fan
1	Guard module	1, 2, 3, 8	1, 2, 3, 8	1, 2, 3, 8
2	Swing module	4, 5, 6, 7	4, 5, 6, 7	4, 5, 6, 7
3	Drive module	9,11	9, 10, 11	9, 11
4	Body module	12, 13	12, 13, 14	12, 13, 20, 22
5	Switch module	14	-	14
6	Stand module	-	17, 18, 19, 20	-

Table 2: Platform identified from the three product variants

Platform	Wall fan	Stand fan	Table fan
1	1, 2, 3, 8	1, 2, 3, 8	1, 2, 3, 8
2	4, 5, 6, 7	4, 5, 6, 7	4, 5, 6, 7
3	9, 11	9, 11	9, 11
4	14	14	14
5	12, 13	12, 13	12, 13

family. After that the extended approach developed is used to identify platform.

Decomposition: There are five sub-system and mechanism of fan as decomposed in the Fig. 5. The decomposition process aid to fully understand and represent the current instantiation of the product that may evolved either at the subsystem, configuration, components or parametric level.

Components listing: There are total 22 components for three variants of fan family as listed in the Fig. 6. Here switch panel and motor assemblies are considered as one component. The number in the bracket depicted the number of components in the product, while X represent component that belong to the product and to show similarity between the variants.

Module identification: Consider a product with m number of components. Let the row I and the column set of J correspond to the component set C = {1......m}. The interaction matrix $M_A = [a_{ij}]_{m \times m}$ is a component incident matrix where a_{ij} is the number of possible assembly interaction between component i and component j, i and j∈C. The modules are selected based on module density and module efficacy (Huang and Kusiak, 1998). The process of module identification for all three fan variants are presented and discussed later.
Figure 7 show the exploded view of the wall fan.

For wall fan, there are 14 components and the constructed interaction matrix is shown in Fig. 8. As are result after applying the algorithm, there are 4 module identified as shown in Fig. 9. Module 1 consists of components 1, 2, 3 and 8. The conventional method of selecting module, which is through module density, cannot be used due to same value of module efficacy but based on the product structure, it's more compatible to include component 8 in the module 1. At the same time component 8 can form components swapping modularity module 2. Module 2 consists of components 4, 5, 6, 7 and/or 9. Conflict occurs whether to include component 9 into the module. Based on module efficacy, a module with components 4, 5, 6 and 7 have density of 6/12 or 1/2, whereas module that added by component 9 has density of 8/20 or 2/5, as a result, module only consist of components 4, 5, 6 and 7 only. Module 3 consists of components 9 and 11 which form full module density. Components 12 and 13 can be consider as module 4, while component 14 can also be consider as one separate module.

For stand fan as shown in Fig. 10, after interaction matrix has been mapped as shown in Fig. 11 depicts that module 1, 2, 3 and 4 are similar member of module as module in wall fan. But there is one more module (module 5) that consists of components 17, 18, 19 and 20 which has full module density. Components 16 and 21 become components swapping modularity to this module. While component 14 can form component swapping modularity to module 4 or can also consider as one separate module as decide for same component of wall fan. The resulting modules are shown in Fig. 12.

The exploded view of the table is shown in Fig. 13 together with components reference number and the mapped interaction matrix is shown in Fig. 14. The similar modules also identify for table fan as stand and wall fan as discussed previously (i.e., module 1, 2 and 3). But for module 4, component 14 is better to be including in the module which resulting higher module density compared than module which components 12, 13, 20 and 22. For module with only components 12, 13, 20 and 22, the efficacy is only 5/10 or 1/2, whereas with including component 14, the module density become 4/6 or 2/3. So that as a result module 4 will consist of components 12, 13, 14, 20 and 22. The result is as in Fig. 15.

For the overall result there are several module identified as shown in Table 1. There is similarity of components in module 1, 2 and 3 in all three of the variants. But for module 4, 5 and 6 there is obviously

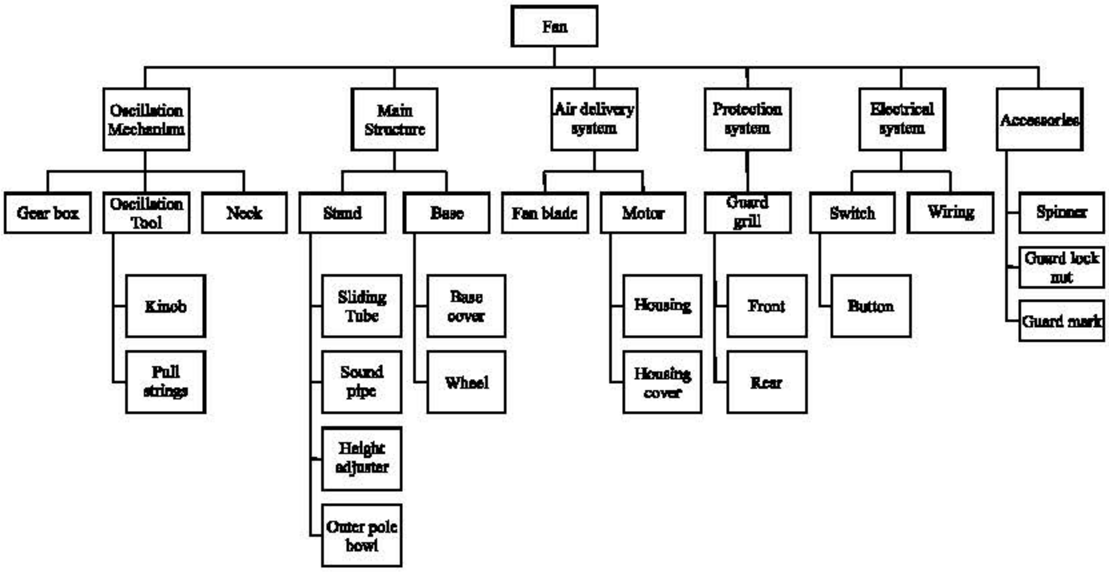

Fig. 5: Decomposition of home appliances fan components

Components listing	Wall fan (14)	Stand fan (20)	Table fan (17)
Guard mark	X	X	X
Front guard	X	X	X
Guard ring	X	X	X
Spinner	X	X	X
Fan blade	X	X	X
Guard lock nut	X	X	X
Housing cover	X	X	X
Rear guard	X	X	X
Motor housing	X	X	X
Oscillation knob		X	X
Motor	X	X	X
Neck	X	X	X
Stand	X	X	X
Switch panel	X	X	X
Pull string	X		
Height adjuster		X	
Sliding tube		X	
Outer pole bowl		X	
Stand pipe		X	
Base		X	X
Wheel		X	
Base cover			X

Fig. 6: Features across various models of fan family

different, here the algorithm is needed in order to identify platform.

Platform identification: Here the algorithm is applied to the modules identified in the previous section. As a result five platforms are identified as summarized in Table 2. For platform and 1, 2 and there is clear decision in platform selection, where all three variants shows the similar components in the platform. But for platform 4, a conflict has occurred, where different components belong to

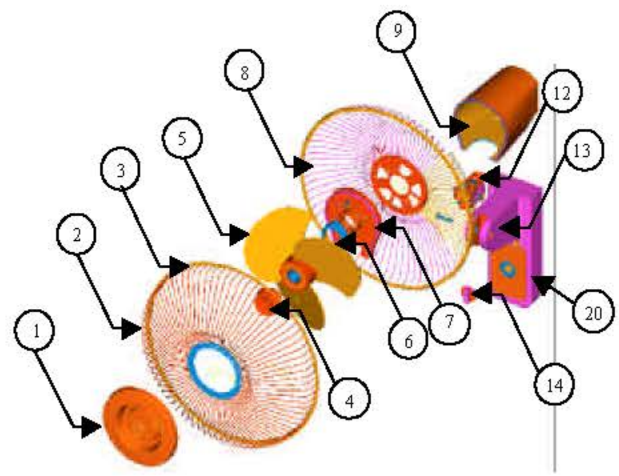

Fig. 7: Exploded view of the wall fan

	1	2	3	4	5	6	7	8	9	11	12	13	14
1	x	1											
2	1	x	1										
3		1	x					1					
4				x	1								
5				1	x	1							
6					1	x	1	1					
7						1	x	1	1				
8			1			1	1	x					
9							1		x				
11										x	1		
12										1	x	1	
13											1	x	
14													x

Fig. 8: Interaction matrix, M_A of wall fan

	1	2	3	8	4	5	6	7	9	11	12	13	14
1	x	1											
2	1	x	1	1									
3		1	x	1									
8		1	1	x			1	1					
4					x	1							
5					1	x	1						
6				1		1	x	1					
7				1			1	x	1				
9								1	x	1			
11									1	x	1		
12										1	x	1	
13											1	x	
14													x

Fig. 9: Modularity matrix, M_B of wall fan

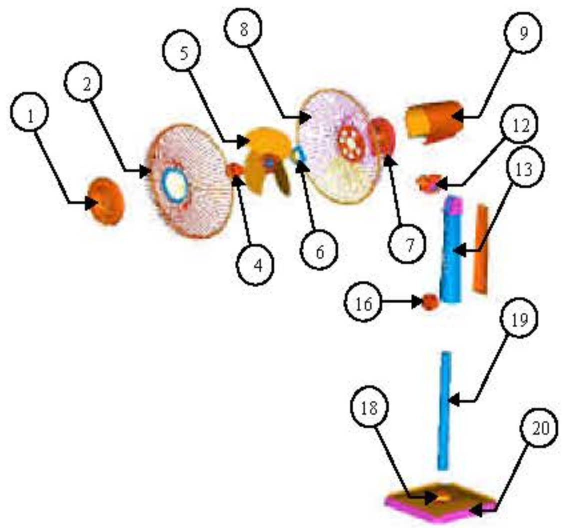

Fig. 10: Exploded view of stand fan

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	19	20	21
1	x	1																		
2	1	x	1																	
3		1	x					1												
4				x	1															
5				1	x	1														
6					1	x	1	1												
7						1	x	1	1											
8			1			1	1	x												
9							1		x	1										
10									1	x										
11											x	1								
12											1	x	1	1						
13												1	x							
14												1		x	1					
16														1	x					
17																x	1	1		
18																1	x	1		
19																1	1	x		
20																		1	x	
21																				x

Fig. 11: Interaction matrix, M_A of stand fan

	1	2	3	8	4	5	6	7	9	10	11	12	13	14	16	17	18	19	20	21
1	x	1																		
2	1	x	1	1																
3		1	x	1																
8		1	1	x			1	1												
4					x	1														
5					1	x	1													
6				1		1	x	1												
7				1			1	x	1											
9								1	x	1	1									
10									1	x	1									
11									1	1	x	1								
12											1	x	1	1						
13												1	x	1						
14												1	1	x	1					
16														1	x					
17																x	1	1		
18																1	x	1		
19																1	1	x	1	1
20																		1	x	
21																		1		x

Fig. 12: Modularity matrix, M_B of stand fan

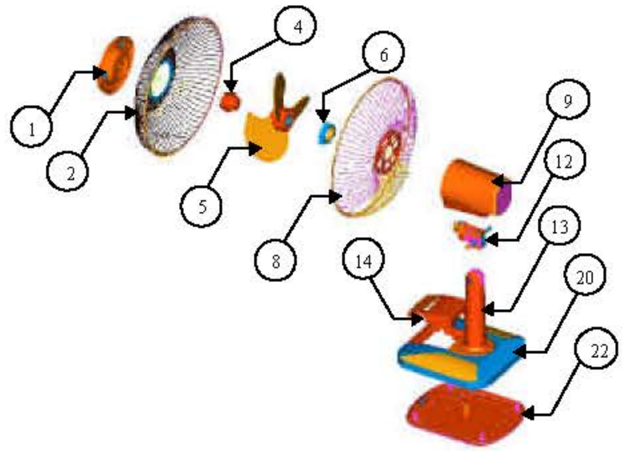

Fig. 13: Exploded view of table fan

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	20	22
1	x	1														
2	1	x	1													
3		1	x					1								
4				x	1											
5				1	x	1										
6					1	x	1	1								
7						1	x	1	1							
8			1			1	1	x								
9							1		x	1						
10									1	x						
11											x	1				
12											1	x		1		
13													x	1		
14												1	1	x		
20														1	x	
22																x

Fig. 14: Interaction matrix, M_A of table fan

	1	2	3	8	4	5	6	7	9	11	10	12	13	20	22	14
1	x	1														
2	1	x	1	1												
3		1	x	1												
8		1	1	x			1	1								
4					x	1										
5					1	x	1									
6				1		1	x	1								
7				1			1	x	1							
9								1	x	1						
11									1	x		1				
10											x					
12										1		x	1			
13												1	x	1	1	
20													1	x	1	1
22													1	1	x	
14														1		x

Fig. 15: Modularity matrix, M_B of table fan

different variants as for components 20 and 22, which belong to table fan but not for wall fan as shown in Fig. 15. But by considering the physical structure of the components, they should combine to become one module or platform in order to increase part commonality to be shared by other variants. This can be further discussed in the next section.

RESULT AND DISCUSSION

A methodology to identify module from group of product in same family or variants is presented. The conventional module identification method is applied and from that task, an extended approach is proposed in order to ensure that the identified module can be shared among the variants. The shared module is developed based on the similarity of the module identified among the product variants. Rather than that modification or changes of module of the module is done.

From case study carried out for fan family fine out that there is a minor modification needed to accommodate components sharing among product variants. By considering several factors in order to make the new design reliable as discussed in previous chapter is proposed.

To evaluate the new design proposed two criteria has been consider, the commonality of the design and assembly and manufacturing aspect.

Table 3: Comparison of result by using Product Line Commonality Index (PCI) developed by Kota *et al.* (2000)

	Current design	New design	Improvement (%)
No. of Components, P	22	20	9
MAX CCI, N	3	3	0
Sum (CCI)	43.028	42.139	2.1
Sum (MinCCI)	8.943	7.833	14.2
PCI	59.74%	65.76%	10.1

Table 4: Result from DFA software simulation

	Current design	New design	Improvement (%)
Total assembly time, sec	144.20	115.23	20.0
No. of components	15	14	6.7
DFA Index	14.22	20.34	43.0

Commonality: One of the emphases of modularization is to create commonality. In this research common parts means that by using single new stand design, several variants of fan can be created. The advantages are that manufacturer need to produce only one design, which can be used for different variants. Established approach to evaluate the design that has been developed by Kota *et al.* (2000) is used. The result indicate that there a tremendous improvement in term of Product Line Commonality Index (PCI) of new design compared to the current design as shown in Table 3, although involving minor redesign and elimination of components.

Manufacturing and assembly: In order to consider the production aspect DFMA guideline by Boothroyd *et al.* (1994) is followed by avoiding sharp edge, complex shape and etc. In this design, assembly parameter such as handling time, geometries, number of parts and type of joints are taken into consideration. A simulation using DFMA software also carried out to evaluate the design efficiency of the new approach. Result indicated that there is small improvement due to minor modification and changes to product assembly (Table 4).

CONCLUSION

This study has looked into objectives of the research, which is developed product platform by utilizing the modularity approach. From the case study indicate that the platform form several variants of same family can be identifying systematically. The new design shows tremendous improvement in term of commonality and assembly convenience.

ACKNOWLEDGMENT

The authors would like to thank School of Mechanical Engineering, Universiti Sains Malaysia Engineering Campus and Universiti Sains Malaysia for their sponsorship of this research. (AC 073486)

REFERENCES

Abdullah, A.B. and Z.M. Ripin, 2002. Module Identification Method: A Qualitative and Quantitative Approach, World Engineering Congress 2002, Sarawak, Malaysia, pp: 38-42.

Boothroyd, G., P. Dewhurst and P. Knight, 1994. Product Design for Manufacturing and Assembly, New York, Marcel Decker Inc., pp: 64-70.

Brenmer, R., 1999. Cutting Edge Platform, Financial Times, Automotive World, pp: 30-38.

Gonzalez-Zugasti, J., J. Baker and K. Otto, 2000. A Method for Architecting Product Platform With an Application to Interplanetary Mission Design. Res. Eng. Design, 12: 61-72.

Gonzalez-Zugasti, J. and K. Otto, 2000. Modular Platform-Based Product Family Design. Design Automation Conference, ASME, Baltimore, MD.

Huang, C.C. and A. Kusiak, 1998. Modularity in design of products and systems. IEEE Trans. On Systems, Man and Cybernetics-Part A: Systems and Humans, 28: 66-77.

Kota, S., K. Sethuraman and R. Miller, 2000. A metric for evaluating design commonality in product families. J. Mechanical Design, 122: 403-410.

Kusiak, A., N.T. Larson and J. Wang, 1994. Reengineering of design and manufacturing processes. Comp. Ind. Eng., 26: 521-536.

Martin, M. and K. Ishii, 1997. Design for Variety: Development of Complexity Indices and Design Charts, ASME DETC, CA.

Ripin, Z.M. and A.B. Abdullah, 2001. A design study on modular platform of unmanned aerial vehicle. National Conference on Aerodynamic and Related Topics, Penang, pp: 190-199.

Sudjianto, A. and K. Otto, 2001. Modularization to Support Multiple Brand Platforms. ASME DTM, Pittsburgh PA.