INTERNATIONAL DESIGN CONFERENCE - DESIGN 2004
Dubrovnik, May 18 - 21, 2004.

DESIGN 2004

THE CONCEPTUAL DESIGN OF THE MERCEDES - BENZ CONCEPT MIDIBUS USING METHODIC DESIGN

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Keywords: function structure, use-value analysis, technic-economic rating diagram, weak- spot analysis

1. Introduction

The application of systematic design , especially in the conceptual design phase of complex technical systems is quite difficult. One of the main reason is the objects and methods, which are used for the analysis and the synthesis of complex technical systems are too *difficult* and *abstract* to use that is a problem for engineers who are used to work with *concrete* objects.
The aim of the study is to apply the systematic design (especially conceptual design) steps on the design of a midibus, which is quite a complex system. The problem during the design of the midibus is the assembly of the engine and the transmission elements at the rear part of the midibus because of the insufficient volume. Different solution alternatives are designed and these solutions are examined using steps of systematic design methods [Hubka, 1988 and VDI 2221, 1985] and than the best design is determined.

2. Clarification of the Task and Elaborating the Specification

2.1 Product Planing

At the beginning of the analysis, the *product planning process* is carried out and the market research is applied. During this research the minibus-bus market in Turkey is analysed using "Product - Markt-Matrix" [Gälweiler, 1974] and Claussen's matematical supported design methods [Claussen, 1973]. After the anayses, the need for a midibus (a new class between minibus and bus) is established. This class would complete the lack between minibus- bus market. (Figure 1)

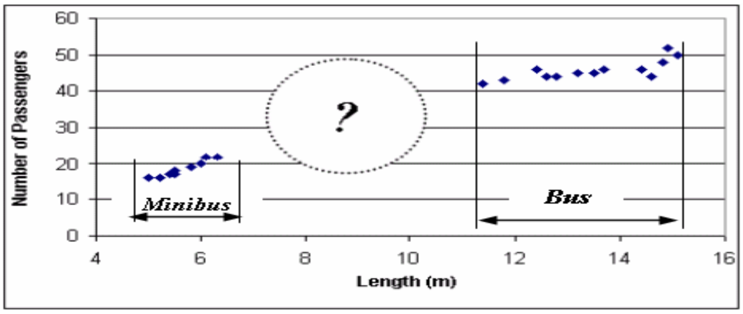

Figure 1. Market research results in Turkey

The target market of the new class midibus is to use them for the transportation purposes between cities close to each other and touristic places.

2.2 Product and Feature Definition

After the market research, the main properties of the midibus are identified. These are; 32 – 36 persons transport capacity, 8 – 9 metres in total length, engine at the rear part of the vehicle (for better properties of comfort and driveability), large luggage space.

The luggage space could be increased in two ways: by increasing the distance between axes of front and rear wheels or by decreasing the height of the chassis between axes of wheels. To establish the main dimensions of the midibus (Figure 2), these criteria (1) have to be considered.

$$\frac{B}{R} \leq 0{,}6 \quad (1)$$

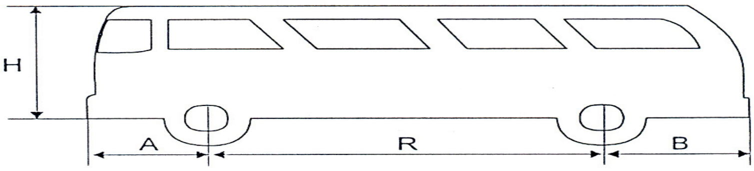

Figure 2. Main dimensions of the midibus

The length A is standart and 1615 mm (front door width is 600 mm). For a 8 meters midibus, the minimum length of R (according to (1)) can be 3990 mm and B maximum 2395 mm. The problem is in the total length of the engine and transmission elements (ETE), which are gearbox, shafts, axle and clutch, is 2370 mm. This means that ETE can not be assemblied at the rear of the vehicle because of the insufficient space. This problem can be solved by re-ordering (re- assembly) of ETE to decrease the length of B and increase R. Increasing R will not only influence the luggage volume of the midibus, but also will decrease the criteria (1) which will cause to an increase in the vibration comfort.

2.3 Establishing Function Structures

In the analyses and re-assembly of ETE system, Hansen's "Topological depictionof technical systems" is analysed [Hansen, 1976] and further developed "Koller's elemantary function system is used [Koller, 1996]. First the basic function structure of the elements is determined (Figure 3-a) and this structure is developed by placing a gear reducer into the system. For the help of the formation and systematic combination of different function structures Zwicky's "Morphologic Matrix" was used. [Zwicky, 1971]. In the mounting of the gear reducer, design, functionality and assembly crieterias are considered.

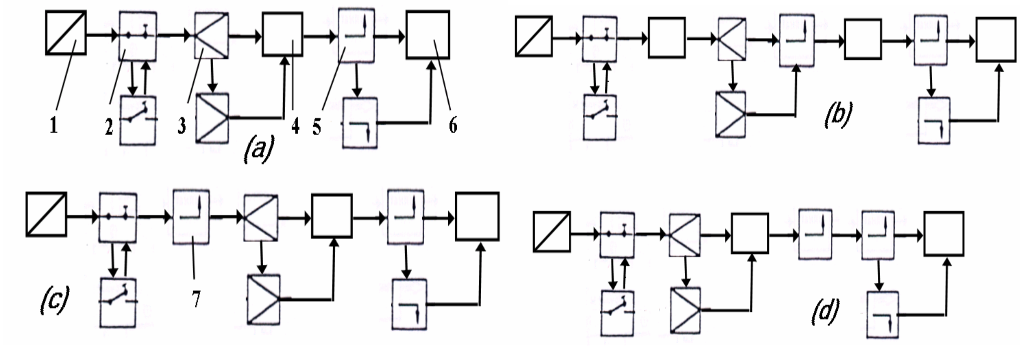

Figure 3. Basic (a) and developed function structures (b-d) (According Koller)
1: Engine, 2: Clutch, 3: Gear Box, 4: Shaft, 5: Differential, 6: Tyre, 7: Gear reducer

2.4 Layout Drawings

According to the function structures in Figure 3, ten different layout drawings are assemblied in different ways. Four of ten designs can be seen in figure 4. The 2.design in figure 4-a referses to the function structure b in figure 3, the eight design to c and tenth design to d.

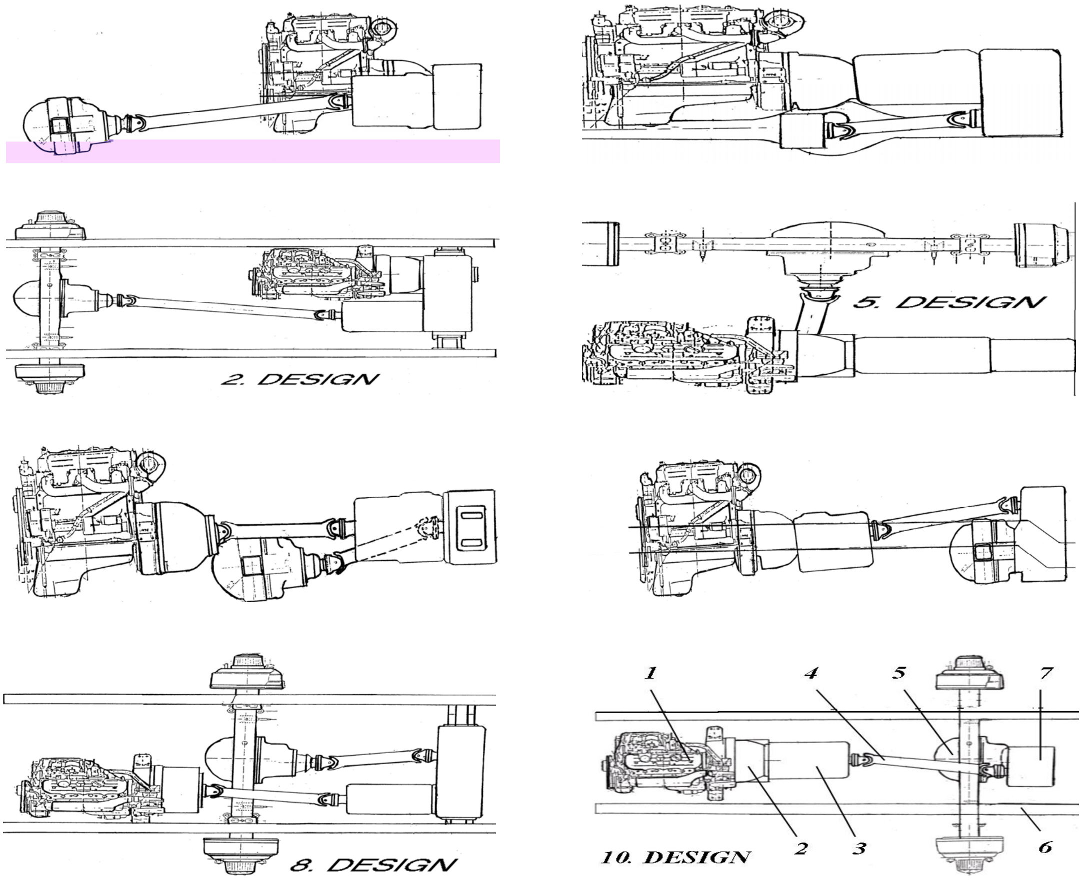

Figure 4. Different layout drawings
1: Engine, 2: Clutch, 3: Gear Box, 4: Shaft, 5: Differential, 6:Chassis, 7: Gear reducer

3. Evaluation of the Concept Design Solutions

3.1 Selecting Suitable Combinations

With a large number of alternatives, it is advisable to make a preliminary selection so that detailed design drawings and calculations. A selection chart is compiled [Pahl, 1986]. Ten design alternatives are checked according to the following criterias:

- Expecting to stay within permissable costs (Criteria A).
- Reliability in respect to performance, driveability and productivity (Criteria B).
- Fullfilling the demands of specificatins (such as high luggage space, low vibration level, low B/R ratio (Criteria C).
- Preventing modifications of present ETE system (Criteria D).
- Minimising the mounting and the assembly problems (Criteria E).

After the evaluation of selection chart, unsuitable five solutions are eliminated. One of them is unseccesfull in criteria A (two gear reducers increased the costs), one in criteria B (gear reducer is mounted to lower degree, so it can hit the ground even with a small pit), two in criteria C (luggage space can not be increased as desired and as high B/R ratio) and one in criteria E (mounting the engine is impossible).

3.2 Use-Value Analysis

Later the best five design alternatives are analysed using “Use-value analysis” [Zangmeister, 1970]. At first, evaluation criteria are identified and weighting of evaluation criteria is determined. (Table 1)

Table 1. Weighting of Evaluation Criteria

Criteria		*Cr. Weighting*	*No. of Cr.*
Increasing luggage space	Increasing the dimension -R-	0,2	1
	Reducing the height of the chassis	0,1	2
Vibration comfort		0,15	3
Assembly and mounting	The mounting of the engine	0,05	4
	The mounting of the gear box	0,05	5
	The mounting and assembly of the gear reducer	0,05	6
Keeping the original position of	The place of the differential on the axle	0,1	7
	Width of the chassis (800 mm)	0,1	8
	Gear box	0,05	9
	Number of shafts	0,05	10
Gear reducer	Ease of manufacturing	0,05	11
	Complexity of mechanism	0,05	12
		Σ= 1,00	

For the purpose of an objective evaluation, correlation parameters magnitude charts with value scales (evaluation charts) for seven of the criteria are determined. Two charts can be seen in tables 2 and 3.

Table 2. Correlation parameter magnitude chart for the length B

Parameter –B- magnitudes (mm)	*Value Scales*
1000 < B < 1099	10
1100 < B < 1199	9
1200 < B < 1299	8
1300 < B < 1399	7
1400 < B < 1499	6
1500 < B < 1599	5
1600 < B < 1749	4
1750 < B < 1899	3
1900 < B < 2049	2
2050 < B < 2199	1

Table 3. Evaluation chart for "Number of used shafts"

Number of shafts	*Value Scales*
1	10
2	3

Using evaluation charts (for an objective evaluation) and subjective criteria five design alternatives are evaluated. (Table 4)

Table 4. Evaluation of five design alternatives for the midibus

Evaluation Cr.		*Alternative 6*		*Alternative 7*		*Alternative 8*		*Alternative 9*		*Alternative 10*	
No.	Weight	Value	Weighted Value	Value	Weighted Value	Value	Weighted Value	Value	Weighted Value	Value	Weighted Value
1	0,2	4	0,80	6	1,20	10	2,00	9	1,80	2	0,40
2	0,1	1	0,10	2	0,20	3	0,30	3	0,30	10	1,00
3	0,15	3	0,45	3	0,45	5	0,75	4	0,60	7	1,05
4	0,05	5	0,25	9	0,45	3	0,15	2	0,10	10	0,50
5	0,05	9	0,45	2	0,10	4	0,20	3	0,15	10	0,50
6	0,05	8	0,40	7	0,35	10	0,50	7	0,35	3	0,15
7	0,1	9	0,90	9	0,90	9	0,90	8	0,80	9	0,90
8	0,1	7	0,70	9	0,90	4	0,30	6	0,60	10	1,00
9	0,05	9	0,45	7	0,35	4	0,20	5	0,25	10	0,50
10	0,05	4	0,20	4	0,20	4	0,20	4	0,20	10	0,50
11	0,05	7	0,35	2	0,10	10	0,50	9	0,45	4	0,20
12	0,05	6	0,30	1	0,05	9	0,45	9	0,45	1	0,05
TOTAL		***72***	***5,35***	***61***	***5,25***	***75***	***6,45***	***69***	***6,05***	***86***	***6,75***

It can be seen in table 4, that the 8. and 10. alternatives are the best two solutions to the problem. These two alternatives are analysed later in details. The other three solutions are eliminated.

3.3 Weak- Spot Analysis

The best two design alternatives are further examined and analysed in detail using the weak-spot analysis (Figure 5) [Beitz, 1986]. Through this analysis, the height of each criteria referse to its criteria weighting. The higher the criteria weighting, the larger the height of the related criteria.

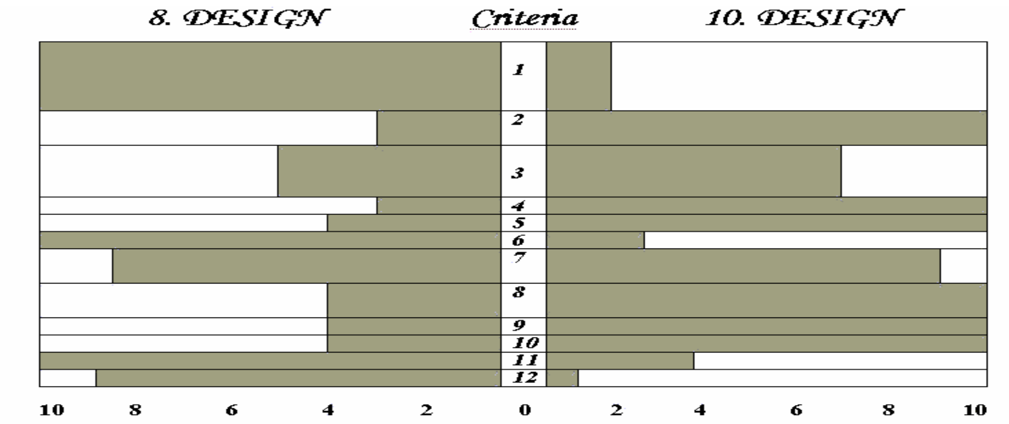

Figure 5. Weak-Spot analysis chart for the 8. and 10. designs

The main weakness of 8. design can be summerised in two main characteristics.

- Not being able to keep the most of the engine transmission elements (ETE) in original position. This means that the engine, chassis and gear box must be re-designed (modified) and the mounting problem of the engine must be solved, all of them will cause an increase in cost.
- The other aspect is the negative effect of the assembly of gear box and gear reducer between the front and rear wheels. This will not only reduce the luggage space, but also will cause vibration problems.

The main problems in 10. design are;

- The design of the *complex* gear reducer and
- Insufficient decrease of the length –B-. (Figure 2)

But most of the ETE are in original position, which do not have to be re-designed.

3.4 Economic Value

The technical evaluation is determined during the use-value analysis. Determining the economic evaluation is quite difficult. The reasons are: The technical, manufacturing and assembly drawings of the ETE are not completed and similar vehicle type (according ETE assembly) does not excist in the market for a comparative study.

For the purpose of objective economic evaluation, two aspects are considered: The gear reducer and the ETE system. (Table 5). These aspects are evaluated according manufacturing, complexity of reassembling and material selection.

Table 5. Correlation parameter magnitudes chart fo the length B

Aspects	8. Design	10. Design
ETE System	40	100
Gear reducer	80	30
Economic values	**60**	**65**

The economic value for the ETE system at 8. Design is low (40) because of a the new design for the chassis (enlarging the width of the chasis from 800 mm to 1140 mm) and mounting problems of engine and gear box, which will cause an increase in cost. The economic value of gear reducer of 10. design is low, (complex internal mechanism of gear reducer, which is necessary for the integration with the differential will cause high manufacturing cost) and high quality material selection.

3.5 Determination of the Optimum Design

To determine the optimum design solution, two evaluation methods are considered: Weak spot analysis (Figure 5) and technical-economic rating diagram (Figure 6) [VDI 2225]. The technical value refere to the weighted value in table 4. In two evaluation methods can be seen that the 10. design solution is the optimum solution.

Analysis on the 10. design solution will be carried out. Weak points, such as "Difficulty and problems in designing of gear reducer" (11. and 12. criterias) and "Insufficient luggage space" (1. criteria) will be solved. To increase the luggage space, chassis height can be reduced and/ or total length of midibus and passenger floor height can be increased according to the equation (1).

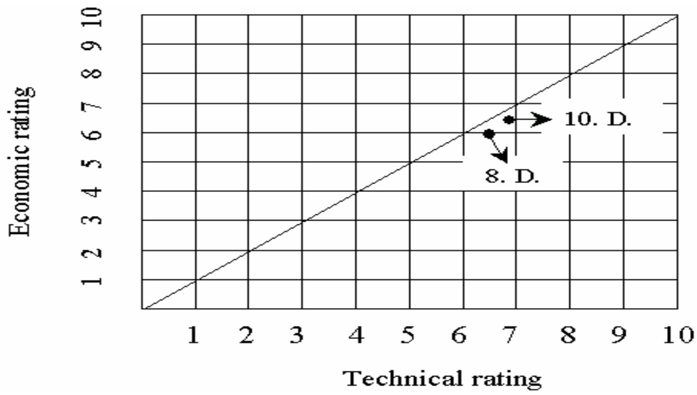

Figure 6. Technical-economic rating diagram

4. Conclusion

During the design of the concept midibus, the problem is to place the engine and power transmission elements at the rear of the midibus, which is very difficult because of the insufficient space. This problem is solved using methodic design steps. Especially the successfully application of combination of function structures, morphological matrix analysis, evaluation criteria and weak spot analysis, which are the main and specific steps of conceptual design phase, is achieved successfully. Throgh the systematic analysis of conceptual design phases, optimum design is found. During this study, the application of CAD tools are auxiliary to the analysis of solution of alternative designs.

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