

THE ANALYSIS AND COMPARISON OF CUP-HOLDER AND ASHTRAY DESIGNS USING THE PRINCIPLE OF AXIOMATIC DESIGN

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ABSTRACT

The location of cup-holders and ashtray on vehicle instrument panel can affect instrument panel appearance as well as cup-holder and ashtray functionality. Axiomatic Design was used to analyze and compare the designs of cup-holders and ashtray for three 1999 model-year full-size pickup trucks. The customer domain was mapped into the functional domain by specifying customer needs in terms of functional requirements (FRs) and constraints (Cs). Design parameters (DP) were identified in the physical domain for each functional requirement. Design matrices were then defined to characterize the product design [1].

The ashtray and cup-holders are treated as one sub-system of the instrument panel. There are two functional requirements in this sub-system at the highest level: storing ash/garbage and holding cups. The corresponding DPs are: ashtray assembly and cup-holder assembly. Through zigzagging to decompose to the next level, one of the designs was found to be coupled. At this level, the free space required for holding cups was found to affect the opening of the ashtray. When the cup-holders are holding cups, the ashtray can not be opened. This coupled design is obviously a bad design because the functions of cup-holders and ashtray can not be achieved at the same time but customers sometimes do need to use both functions at the same time. Other designs are not coupled and therefore are better designs.

It is obvious the designers for this coupled design have not applied Axiomatic Design principles. Therefore, the design is a bad design and it lowers the customer satisfaction.

The analysis and comparison were based on only two basic main functions of the ashtray and cup-holder subsystem: storing ash/garbage and holding cups. In fact, there are many more functional requirements for this subsystem: providing flexibility to different cup sizes, providing stability for cups, providing the stability for the whole cup-holder assembly and ashtray assembly,

and providing ease of access to driver and passenger and so on. We are not discussing those details in this paper.

Keywords: Axiomatic Design, design optimization, instrument panel, cup-holders, ashtray

1 INTRODUCTION

The design of cup-holders and ashtray on the instrument panel for the GM Silverado 1999 Model-Year Pickup Truck is shown in Figure 1 and Figure 2 below:



Figure 1 1999MY GM Silverado Cup-holders and Ashtray on Instrument Panel

After the highest-level DPs were chosen, the FRs were decomposed to the next level through zigzagging. FR1 was decomposed as:

- FR11 = Open ashtray
- FR12 = Close ashtray
- FR13 = Hold in open position

FR2 was decomposed as:

- FR21 = Opening cup-holders
- FR22 = Closing cup-holders
- FR23 = Holding cups

The corresponding DPs are:

- DP11 = Open mechanism/free space for ashtray
- DP12 = Close mechanism
- DP13 = Ashtray structure

- DP21 = Open mechanism/free space for cup-holders
- DP22 = Close mechanism
- DP23 = Cup-holders structure

The overall second-level design equation is:

	DP11	DP12	DP13	DP21	DP22	DP23
FR11	X					X
FR12		X				
FR13			X			X
FR21				X		
FR22					X	
FR23	X		X			X

The Independence Axiom states that the independence of functional requirements must always be maintained. However, in the 1999MY GM Silverado cup-holders and ashtray design, DP11 and DP13, which were used to open the ashtray to dispose of ash or garbage, do affect FR23. As we can see from Figure 2 when ashtray is in open position, we can not put a cup into the right-side cup-holder. Similarly, DP23, which was used to hold cups, affects both FR11 and FR13. Because when cup-holders hold cups, the cup on the right side will interfere with the ashtray opening. This coupled design is obviously a bad design because the functions of cup-holders and ashtray can not be achieved at the same time. Other designs we will discuss are not coupled and therefore are better designs.

For example, Figure 3 shows the Chrysler Dodge Ram cup-holders and ashtray design on the instrument panel with cups in the cup-holders. The ashtray is above but completely to the left of the cup-holders. Both are open, and both can be used



Figure 2 1999MY GM Silverado Cup-holders and Ashtray on Instrument Panel with Cups in Cup-holders

Figure 1 shows the cup-holders and ashtray design on the instrument panel of the 1999MY GM Silverado. The ashtray is above and on the right side of the cup-holders. Both are in the open position. Figure 2 shows the same design on the same vehicle but with cups in the cup-holders. It is clear from Figure 2 that when there are cups in the cup-holders, the ashtray can not be pulled out far enough for use since the cup on the right side occupies the ashtray free space.

2 DESIGN ANALYSIS USING THE INDEPENDENCE AXIOM

In order to use Axiomatic Design principles to analyze the designs, the cup-holders and ashtray were treated as one subsystem of the instrument panel. The customer needs were mapped into two functional requirements for this sub-system at the highest level:

- FR1 = Storing ash/garbage
- FR2 = Holding cups

Mapping the FRs of the functional domain into the physical domain, the corresponding DPs selected to satisfy the functional requirements are:

- DP1 = Ashtray assembly
- DP2 = Cup-holder assembly

The design equation, which shows the relationship between FRs and DPs is:

$$\begin{Bmatrix} FR1 \\ FR2 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \end{Bmatrix} \quad (1)$$

simultaneously. Figure 4 shows 1999MY Ford F-150 cup-holders and ashtray on the instrument panel with both cup-holders and ashtray open. The ashtray is below the cup-holders. Both designs are uncoupled and therefore are better designs.

The analysis and comparison were based on only two basic main functions of the ashtray and cup-holders subsystem: storing ash/garbage and holding cups. In fact, there are more functional requirements in this subsystem: providing flexibility to different cup sizes, providing stability for cups, providing the stability for the whole cup-holder assembly and ashtray assembly, and providing ease of access to driver and passenger and so on. To make a complete comparison of those designs, we need to list all the functional requirements and use the second axiom of the Axiomatic Design to investigate how good DPs achieve their corresponding FRs. Since it is a multi-FR case and since there are human factors in estimating how good DPs can achieve their corresponding FRs, the authors suggest use both the Information Axiom and Expert Choice – a group decision making tool to make further investigations.

Figure 4 1999MY Ford F-150 Cup-holders and Ashtray on Instrument Panel

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4 REFERENCES

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Figure 3 1999MY Dodge Ram Cup-holders and Ashtray on Instrument Panel

