EARLY EUROPEAN MOTOR STAGE CARS PACKAGING ITEMS AND DESIGN ELEMENTS: CORRESPONDENCE ANALYSIS

Packaging Items and Design Elements: Comparison of Car Design (2)

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Abstract: The purpose of this research is to clarify the relationship between packaging items and design elements of four early European motor stage cars. The typical packaging items and design elements were compared in the scattergram graphs of the selected cars. Through this comparison, it was understood the design basic pattern and differences between these cars, created by correspondence analysis. These cars were the Citroën 2CV, the Fiat 500 Nuova, the Morris Mini and the Volkswagen Type 1. They were selected for their great success during the time they were built. Each of them from a different country of origin with different features. The environment features had influence in the car designs, making them so particular between the rest of the cars of the post war era. The most important design concept for the four cars have been identified as “Environment”. The two types of environment were found to be: Island and Peninsula, and Continental area, directly affecting the car packaging layout.

Key words: Early European Motor Stage Cars, Packaging Items, Design Elements, Design Concepts, Correspondence Analysis.

1. General Introduction

The purpose of this research is to clarify the differences between each of the four European cars of an early motorization stage to understand their design patterns.

This study is based on a previous research [1] were the same cars have been studied by the direct comparison method. The reason to select those cars is because they were very popular in Europe, as it could be seen in the old advertisements of Figure 1. Based on that fact, they could be considered a good reference to be used as standard cars.

The correspondence analysis method was used to create scattergram graphs of the four cars. A comparison of the graphs was performed to understand the cars’ patterns.

The difference with the direct comparison of the previous paper [1] is that in this research, a scientific method was applied to identify the design patterns as they appeared in the graphs. This analysis method was selected because, once the design concept of the cars were understood, it is more easy to identify the patterns of the four cars. And, it can be able to reproduce in the future, the same successful results when launching a similar car into the market.

Correspondence analysis was followed by the interpretation of the resulting groups in the scattergram graphs. And, the packaging items and design elements distribution in the graph space were analyzed, according to the features and type of car. In the process of design of a new car it is very usual to take a current production car from a competitor company to be used as the standard car. Based on the on sales volume, an assumption that the reference car has a design very well achieved is made. And, in this case, these four cars were used for reference as standard cars, because of their proved success in Europe.

2. Research Design

Based on the previous paper [1] results, the information gathered was processed categorized in the following way:

- Packaging items and design elements relationship

Packaging items and design elements relationship were evaluated to get the basic data for the research.
• **Data processing by correspondence analysis**
  Data was processed with Microsoft Excel and NewCorr [2] softwares. The latter was used to obtain the positions of the points distributed in the scattergram graphs.

• **Second data processing**
  With the SPSS software [3], the packaging items and design elements were classified into groups, according to their mutual proximity. The data was processed by hierarchical cluster analysis and dendrogram, using average linkage (between groups).

• **Arrangement of the scattergram graphs’ groups**
  In the scattergram graphs, the groups were identified and named for a better understanding and clear visualization of their packaging items and design distribution and car pattern recognition.

• **Interpretation of each car scattergram graphs’ groups**
  The relative importance of the groups was determined by their proximity to the center of the graph.

• **Comparison of the groups distribution in the graphs**
  The four cars’ graphs were studied together and the distribution and proximity of the groups determined the design pattern’s differences.

3. **Definition of Terms**
   In the course of this paper, several terms from the field of car design appeared. And, in order to avoid terminology confusion, the following terms were introduced at this stage:

• **Packaging Items and Design Elements:** For a detailed explanation see Arbello, Kamaike and Ueda [4].

• **FF layout:** According to Wikipedia [5], in automobile design, an FF or Front-engine, Front wheel drive layout, places both the engine and driven wheels at the front of the vehicle (Figure 2). This layout is typically chosen for its compact packaging. The FF takes up very little space, allowing the rest of the vehicle to be more flexibly designed. In contrast with the FR layout (Front-engine, Rear wheel drive) of Figure 3, the FF layout eliminates the central tunnel needed to accommodate a drive-shaft to take power to the rear wheels. Like the RR (Rear engine, Rear wheel drive) and MR (Mid-engine, Rear wheel drive) layouts of Figures 4 and 5, it places the heavy engine over the drive wheels which aids traction. As the steered wheels are also the driven wheels, FF cars are generally considered superior to FR cars in snow conditions. However, powerful cars rarely use the FF layout, because weight transference under acceleration unloads the front wheels and reduces grip. Electronic traction control can avoid wheel-spin but largely negates the benefit of extra power.

• **RR layout:** According to Wikipedia [6], an RR, or Rear engine, Rear wheel drive layout places the engine and drive wheels at the rear of the vehicle (Figure 3). In contrast to the MR layout. However, the engine gravity center itself is actually past the rear axle. This is not to be confused with the vehicle gravity center itself, as an imbalance of such proportions would make it nearly impossible to keep the front wheels on the ground. RR layout is typically chosen for a combination of several reasons. For optimal handling and to eliminate the phenomenon known as torque steer, the wheels which propel the car should not be the same ones that steer it. For optimum traction, the engine should be nearest to the driven wheels since the engine is typically the densest/heaviest component of the car. Thus, in a car which steers with the front wheels, it is better for the engine to be located in the rear of the car, either a RR or MR design.

4. **Car Type Study**
   In the previous paper [1], cars were classified according to their type, and it was considered that they could be
classified in two different ways. The first classification was done taking into account the size of the vehicles, and two groups were found:

- **Supermini (EU) / Subcompact car (USA)**: In the case of the Fiat 500 and Morris Mini.
- **Small family car (EU) / Compact car (USA)**: In the case of the Volkswagen Type 1 and Citroën 2CV.

Also, it was considered that cars could be classified according to the power plant unit location and the driving type system. And, in this case, two groups were found:

- **FF layout (Front Engine-Front Drive)**: It was used in the Citroën 2CV and Morris Mini.
- **RR layout (Rear Engine-Rear Drive)**: It was used in the Volkswagen Type 1 and Fiat 500.

Early cars using the FF layout include the 1948 Citroën 2CV and the 1959 Mini. In the 1980s, the traction and packaging advantages of this layout caused many compact and mid-sized vehicles to adopt it. Because the transversely-mounted engine does not require a bevel gear to change the direction of the final drive, coast down losses are reduced by approximately 2-3% of flywheel power and hence overall efficiency is slightly higher than with a FR design.

There are four quite different particular arrangements for this basic layout, according to the location of the engine, which is the heaviest component of the drive-train, with respect to the front wheels.

Alec Issigonis's Mini and a few successor cars had the engine laterally mounted (east-west), with the transmission in the sump below the crankshaft. This was just about as good as one could do to put the entire weight of the drive-train on the front wheels.

But the arrangement that really took over was that of Autobianchi Primula (built from 1964) designed by Dante Giacosa, that had the transmission on one side of the laterally mounted engine, and doubled back the drive-train to put the differential just behind it, but offset to one side. Hence the drive-shafts to the wheels are longer on one side than the other, something which was avoided in the past. This located the weight just a bit in front of the wheels. This is the system which dominates worldwide at present.

Vehicles with the Giacosa arrangement tend to suffer from *torque steer* under heavy acceleration since more power is required to overcome the inertia of the longer (and therefore heavier) drive-shaft than the shorter, lighter one. The differential then feeds more power to the wheel that's meeting least resistance (i.e. the one with the shorter drive-shaft) and the car pulls to one side under heavy acceleration. In the case of the RR layout, most manufacturers have abandoned it, apart from Porsche who has gradually developed their design with improvements to the suspension.
as well as electronic aids to reduce the shortcomings of the layout to acceptable levels.

The Volkswagen Type 1 (or Beetle) was an early car using the RR layout. The disadvantage of the RR configuration is that placing the engine outside the wheelbase creates significant problems for handling. When the car begins to slide on a corner, the end of the car will tend to want to swing wide and overtake the front, especially under braking. This tendency is referred to as over-steer and creates potential safety issues in racing applications as well as for ordinary drivers on wet or icy roads, although such behavior is desirable in drifting, a motor-sport based on intentional over-steer.

In addition, even though the rear wheels benefit from the additional traction given by the added weight of the engine, the front wheels still need traction to steer the car effectively. For this reason, a RR layout car can also be prone to under-steer, like in the cases of the Volkswagen T1 and Fiat 500.

5. Packaging Items and Design Elements Correspondence Analysis

For a comprehensive description of the Correspondence Analysis method and its applications refer to the texts by Greenacre [7] and Benzécri [8].

The Packaging Items and Design Elements were evaluated by giving a five steps value to each pair. The lowest relationship importance value is 1 and 5 is the highest. Then, the cars’ data (tables of Figures 6–9) of the four cars used as the “standard cars” was analyzed by correspondence. Four scattergram graphs with factor groups were obtained. The packaging items and the design elements were grouped according to their relative positioning to the center of the graph. When the packaging items and the design elements were near the center it was indicated that their relative importance within the bounds of the factor groups was higher than those positioned far from the center. It was found that the factor groups were very much concentrated near the center of the graph, indicating the relative importance that those groups have in the context with respect to other ones.

5.1. Scattergram Graphs Analysis

In the comparison between the four scattergram graphs shown in Figures 10–13 the following features were observed:

Five factor groups were found in each scattergram graph, but the distribution of the groups in the graph’s space revealed very different patterns between those groups. And, some differences in the contents of each group were observed as well, between the size of the Compact and the Subcompact cars. The factor groups found in the four cars’ graphs received the names in the following way according to the representativeness of their components:
5.2. Factor Groups Location in the Scattergram Graphs

For a better interpretation of the graphs, names were assigned at the ends of the graphs' axes. In the case of the X axis, it was named Symbolic at the left end, and Practical at the right end. The Y axis was named Aesthetic at the upper end and Function in the lower end, in order to represent the majority of the packaging items and design elements positioned on each quadrant.

6. Packaging Items and Design Elements Grouping

The relative importance of the groups displayed in the four cars' graphs was found, and they were described from the most important to the least important.

6.1. Grouping of the Morris Mini

In the case of the Morris Mini, the group importance was as follows (Figure 10):

1) Marketing

It is positioned at the right side of the graph center, and its importance is similar to the one of the Status group. It has more packaging items and design elements than the latter and it is located in the “Aesthetic-Practical” quadrant. In the Marketing group, several car interior measurements appeared to be considered as very important in this particular design. It was noticed that the most important packaging measurements were included in the Marketing group.

2) Status

In the graph, it was positioned at the bottom left of the center, in offset position to that of the Marketing group. It has fewer elements than the latter, and it is located in the “Symbolic-Function” quadrant of the graph.

3) Comfort

This group had only one important packaging item, the Front Tread. However, it have not so many packaging items and design elements. And, that is why despite its location near the center, it is not as important as the Marketing and Status groups. The Comfort group is located in the “Symbolic-Aesthetic” quadrant of the graph.

4) Technology

This group is not as important as the three groups described before, because it is located far from the center of the graph, in the “Symbolic-Aesthetic” quadrant.

5) Structure

This group is located more far away from the center than the others. The two design elements that represents are not very important. And, it is located in the “Aesthetic-Practical” quadrant of the graph.
The Structure and Technology groups are located in the periphery of the graph, demonstrating their poor importance in the general context when considering the packaging layout of this car.

6.2. Grouping of the Fiat 500 Nuova

In the graph of the Fiat 500, the relative importance found between the groups (Figure 11) in decreasing order, is as follows:

1) Technology

This group, even when it is not the nearest group to the center, it plays the most important role due to the inclusion of the most relevant packaging items and design elements of this car packaging. It is located over the "Practical" axis, with the upper half on the "Aesthetic-Practical" quadrant and the lower half in the "Symbolic-Function" quadrant. Most of the packaging items related to the human body and design elements such as Lifestyle and Design Flexibility were gathered in this group, as observed in the graph.

3) Marketing

The Marketing group is completely located in the "Symbolic-Aesthetic" quadrant and it has only two design elements. It is near the Status group and it is considered to have a secondary important in this car.

4) Comfort

This group is located exactly in the opposite direction of the Marketing group, in the "Symbolic-Function" quadrant of the graph. And, same as the latter, its importance is secondary.

5) Structure

This group, located far from the center represents the less important group of all, because it is located far from the center an also because it has only two design elements on it. It is located in the extreme right of the graph, and over the "Practical" axis.

6.3. Grouping of the Citroën 2CV

The relative importance of the groups (Figure 12), in decreasing order, were as follows:
Figure 11. Scattergram Graph of the Fiat 500.

1) Comfort
The Comfort group location is exactly in the center of the graph. And, with almost all the most concept related packaging items and design elements of this car, it is the most important group.

2) Technology
This group is the second in importance and it is located under the Comfort group. It is positioned in the "Function-Practical" quadrant and contains the packaging items of Rear Tread and Front Tread, strongly related to the design concept of Environment.

3) Status
Located exactly over the "Symbolic" axis, this group has only packaging items corresponding to the measurements related to the space for the passengers.

4) Structure
This group is represented only by two design elements, Road Performance and Climate, located in the "Aesthetic-Practical" quadrant. Its relative importance is very low.

5) Marketing
This group is located in the "Symbolic-Aesthetic" quadrant and it has only two design elements, Sides Styling and Sides Configuration. This group is the least important of all groups as seen in the graph.

6.4. Grouping of the Volkswagen Type 1
In this case, the relative importance of the groups found in Figure 13, were as follows:

1) Structure
The Structure group is located in the "Symbolic-Function" quadrant, very near the center of the graph. It is the most important group in the case of this car and it contains almost all the packaging items and design elements related to the design concept of Environment.

2) Status
This is the second most important group. It is located exactly over the "Practical" axis, with most of the components in the "Function-Practical" quadrant and the rest of them in the "Function-Practical". The Proportions design element is included in this group, and it have a strong relation with the design concept.

3) Marketing
The Marketing group is partially located over the "Aesthetic" axis and, almost completely positioned in the "Symbolic-Aesthetic" quadrant. Some of the packaging items and design elements are located in a similar and offset position to those of the Structure group. And, the difference is that in the latter, all the packaging items and design elements are related to the design concept of
Environment, while in the Marketing no one of them are related.

4) Technology
This group has only two design elements, Climate and car Self Expression. It is located in the “Symbolic-Function” quadrant of the graph and it is not so important compared to the other groups.

5) Comfort
According to the relative distance to the center of the graph, this group is the least important in the case of the Volkswagen. And, it has the packaging items reflecting the space for the passengers and the design elements of Pleasure and Life Style. It is located right over the “Practical” axis, with the upper half of the group placed in the “Aesthetic-Practical” quadrant and the lower half in the “Function-Practical” quadrant of the graph.

7. Discussion
A new comparison of the four cars’ scattergram graphs was performed to confirm if their basic patterns reflects the main design concept of Environment. Several packaging items and design elements reflecting the Environment design concept were analyzed to understand how were they affected by the main design concept, according to the distribution of the packaging items and design elements in the scattergram graph. The packaging items of Overall Length, Wheelbase, Front Overhang, Rear Overhang, Front Body Overhang, Overall Height, Front Tread, Rear Tread and Overall Body Length were specifically analyzed for this purpose. Also, the design elements of Proportions, Climate and Geography were included in these analyses.

7.1. Four European Cars Comparison Findings
When the graphs of the four European cars were compared, it was found out that each car has a different pattern that make it completely different even when they have a similar design concept. In the graphs it could be easily observed the most important group of each car, and it is explained as follows:

- Morris Mini (Marketing group)
The Morris Mini graph clearly shows the Marketing group as the most important. It represents a strong tendency from the market to prefer a practical and affordable car. And, it is mainly reflected in the packaging items related to the car exterior measurements and in the design elements of car drivability, proportions and equipment specifications of this car. The graph (Figure 10) shows how the priority design concept of Environment, found and described in a previous paper [1] was applied in
Figure 13. Scattergram Graph of the Volkswagen Type 1.

this car inside a highlighted area of the marketing group, near the “Practical” axis. It is positioned over the graph’s “Practical” axis. Moreover, the Island and Peninsula feature to which it belongs is clearly reflected in the Geography design element, also positioned over the “Practical” axis.

- Fiat 500 (Technology groups)
  The Fiat 500 graph shows the Status group as the most numerous. Therefore, a closer look revealed that the Technology group is more important. Because, in the highlighted area, it contains several of the packaging items and design elements influence by the Environment design concept. And, related to the Island and Peninsula type. The highlighted are is mainly positioned in the “Aesthetic-Practical” quadrant. Furthermore, the Island and Peninsula feature, is clearly reflected in the position of the Geography design element, near the “Practical” axis. The importance of the Technology group reveals that the car was made according to the remaining post-war technology that lead to the production of a popularly priced car.

- Citroën 2CV (Comfort group)
  The Citroën 2CV graph shows the Comfort group as the most important, easily recognizable in the graph. The highlighted area, influenced by the Environment is strongly oriented towards the center of the graph and, the Geography design element is located very near the “Practical” axis, which demonstrate a strong relation with the Continental features and the need to travel efficiently over unpaved roads of the countryside.

- Volkswagen Type 1 (Structure group)
  The Volkswagen Type 1 graph shows the Structure group as the most important, according to its position towards the center of the graph. And, the packaging items are entirely contained in the highlighted area influenced by the the Environment. In the Volkswagen graph, the highlighted area is similar to the one of the Citroën 2CV, in an offset position. This pattern is clearly favouring a speed performance, since the area is located over the “Symbolic” axis and in the “Symbolic-Function” quadrant. The highlighted area shows the Geography design element located far from the center an almost over the “Symbolic” axis, which emphasis the fact that this car was designed to be used in modern routes at high speed, where no running space needs to be compromised.

7.2. Remarks

In the four cars’ graphs, the groups shared the same names. On the other hand, it was observed a very different
grouping distribution even when the positioning of some packaging items and design elements were relatively similar. And, that fact determined the presence of a unique pattern in the design of each car. Furthermore, the groups’ distribution revealed how much the packaging design is affected by the car layout type.

In the case of the cars with an FF layout, it was clear to see that the most important packaging items were related to the quality and quantity of the passengers’ space. Because of the absence of a tunnel in the center of the floor for the drive-shaft (as it happens in the FR layout), the cars have a more roomy interior. This is the case of the Morris Mini, were the Comfort group is very near the graph center. Even though, this is the second most important group in the packaging configuration. And, it is also the case of the Citroën 2CV, which its Comfort group is directly placed in the center of the graph. The position of the front passengers is also more comfortable since there is more room for their legs.

In the case of the RR layout, it was also reflected in the position of the groups as in the case of the Fiat 500. In the latter, the Comfort group is far from the center, clearly reflecting the lack of space for the legs of the front passengers. And, due to the fact that front passengers position should be forward enough to make a good weight balance with the engine, the front passengers’ legs position is at the side of the wheel-house, thus reducing the space for the legs that should avoid the wheel-house. Same situation was observed in the Volkswagen Type 1 graph, were the Comfort group is far from the center, reflecting the same feature as in the case of the Fiat 500.

As a final observation, it was discovered that the cars with an FF layout have one dominant group in the center and smaller groups spread in the graph. On the other hand, the cars with an RR layout have three evenly distributed groups near the center but no one is positioned exactly in the center of the graph. Therefore, the groups share the relative importance, giving priority to the car competitiveness and marketability. Moreover, other necessary features to achieve a well balanced design for the users are disregarded.

8. Conclusions

Concluding, several aspects were found and described as follows:

- Through the use of correspondence analysis and hierarchical cluster analysis it was clarified the different concepts between the four European cars, found in the previous paper [1].
- Several differences were found in the patterns of the four cars’ scattergram graphs related to the FF and RR layouts.
- The two Environment groups of Continental area and Island & Peninsula were identified in the patterns of the four cars and displayed with highlighted background in each car’s graph.
- Correspondence analysis is a new method and it was successfully used to clarify the concept differentiation.

In this research the study of the Four Early European Motor Stage Cars was emphasized because of its relation with the previous paper [1] and because Europe is strongly related to the origins and history of the Argentine car market conditions which is the core of this entire research.

References