

# A Study on Automobile Form Design Support Method “AFD-SM”

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## ABSTRACT

*In this research, by assigning attention to the automobile “form,” details that were previously ambiguous, such as “roundness” and “angle”, are represented numerically. With the aim of measuring the degree of influence of customer sensibility, the “Automobile Design Form Support Method (ADF-SM)” is utilized. Using CAD, the authors have constructed a model of a form-altered automobile to quantitatively evaluate the degree of influence of customer sensitivity. By using this support method, an automobile form is created, which expresses the concept sought by the customer, verifying its effectiveness.*

**Keywords:** Automobile, ADF-SM, Reverse Engineering, 3D-Design CAD

## INTRODUCTION

In this research, we aim to further the development of automobile design concept support research by giving attention to the automobile “form,” a domain of high novelty. Details that were formerly ambiguous, such as “roundness” and “angle”, are quantified with the aim of effectively supporting design and development by relating to customer sensitivity.

## BACKGROUND

In order to develop and offer appealing, customer-oriented products, it is important to incorporate customer feelings and words into the new product development process and to fully put into practice the concept of “Customer Science.” These days, changes in customer preferences toward automobiles are very pronounced and are becoming increasingly diversified and complicated. In order to build functionally into durable goods, it is becoming important to use “sensitive engineering” that both quantifies and grasps the images and feelings in customers’ hearts, such as their favorite foods.

Regarding automobile design, it is very important to use statistical methods to develop a commodity which precisely answers customer demands. Accordingly, various research studies have adopted this approach using “Design SQC” and the “profile design support tool.” Generally, customers notice three elements of the design: (1) profile design (proportions), which is noticed at long-to-mid distance, (2) form, which is noticed at mid-to short distance, and (3) surface, which is noticed at short distance to close range.

Regarding proportion, research to clarify the relationship between form and customer sensitivity has previously been undertaken from various points of view. Furthermore, Ando et al connected with customer sensitivity by paying attention to the modeling form of the front fender circumference and numerically evaluating “roundness” and “angle” via CAD. However, research findings regarding the basic actions taken when a customer looks at a car indicate that the slant viewpoint taken from the car front is also important.

Accordingly, this research expands upon the frontal view taken in previous research, by paying attention to the change of form accompanying a side view, which occurs when a customer looks at a car from an angle (i.e., at a

slant from the front), measuring the degree of influence of customer sensitivity to the form change and reflecting this information in the design.

**NECESSITY OF NUMERICAL FORM REPRESENTATION BY CAD**

In order to visualize the degree of influence of customer sensitivity due to the change of the form, digitalization of the form is indispensable. In this research, the CAD (Computer Aided Design) software is utilized as an expedient for form digitalization. The advantages of using CAD include: (1) “form digitalization”, in which a numerical definition of the form is created (parametrization), is possible using CAD; (2) since the front, side, rear, etc. of the automobile are verifiable from all angles, establishing a relationship with customer sensitivity is possible; (3) it may be noted that, as in the present design process, the use of CAD as a tool for expressing form for modeling, etc. is mainstream use. Further, in this research, CATIA V5 is used as a CAD software.

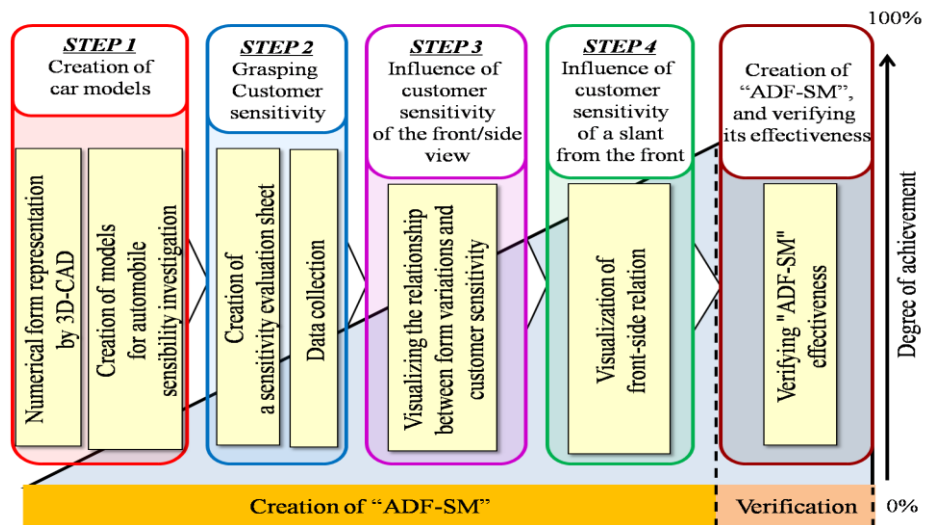
Furthermore, reverse engineering was used to increase the accuracy of the CAD model. This reverse engineering involved the measurement of a clay model made as a advance conceptualization of the product, with data regarding product form characterizing this actual object used as a basis for creating CAD data. In this research, the 3D picture measurement software, “QM-3000”, produced by TOPCON Techno House Corporation, was used. By non-contact measurement, it was possible to convert in 3D the delicate curved line of the design, which cannot be expressed by dimension.

**CONSTRUCTION OF THE AUTOMOBILE DESIGN FORM SUPPORT METHOD (ADF-SM)**

As mentioned above, it is an important research task to evaluate the “roundness” and “angle” of an automobile form, which have remained ambiguous until now, and to relate these quantities to customer sensitivity in our primary theme - development of an automobile design conception support method.

Thus, establishment of the “Automobile Design Form Support Method (ADF-SM)”, shown in Figure 1 for business solution, is undertaken. In STEP 1, in order to increase the accuracy of the CAD model, a CAD model design, which utilizes reverse engineering, is performed. In STEP 2, a sensitivity evaluation sheet, which uses nine respective form types for the front side, is created, and data collection to determine customer feelings is performed using the resulting sheet.

In STEP 3, the resulting data is used to quantitatively grasp the relationship between changes in form and the resulting customer feelings. In STEP 4, by connecting the data collected in STEP 3 regarding the front and the side areas, an analysis is made concerning the related characteristics of the whole (front and side.) Furthermore, a new model is created from the analysis result and verification by an additional questionnaire appraisal performed.



**Figure 1: Automobile Design Form Support Method “ADF-SM”**

Table 1: Form Shape Parameters for Nine Car Model Types (Side View)

Car type/Form shape	Angle of the front pillar(°)	Angle of the belt line(°)	Angle of the character line(°)
TypeA	45	2	25
TypeB	30	0	15
TypeC	30	0	55
TypeD	30	5	15
TypeE	30	5	55
TypeF	60	0	15
TypeG	60	0	55
TypeH	60	5	15
TypeI	60	5	55

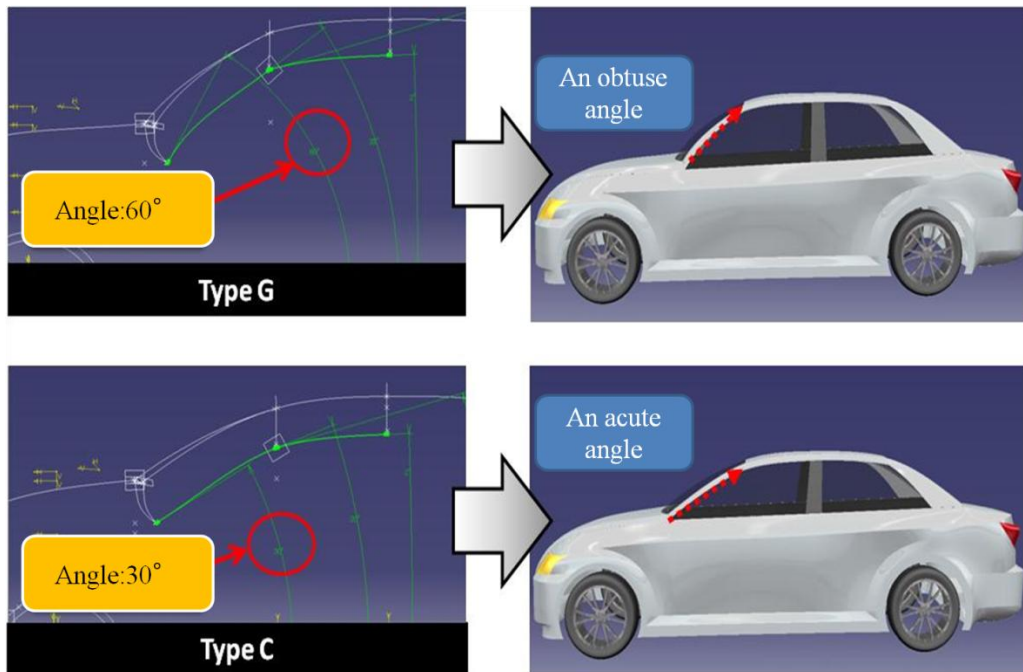


Figure 2: Example of A Change of Form (Angle of the Front Pillar)

**APPLICATION EXAMPLE**

Research findings regarding the basic actions taken when a customer is in front of an automobile clearly indicate that the main attention is on the front area. Thus, in order to investigate the influence of the front as part of the appearance design conception support method, the front and side are investigated independently and the relationship with customer sensitivity is visualized by investigating the mutual degree of influence.

**Creation of a Model for Automobile Sensibility Investigation - STEP 1**

As a means of associating customer sensitivity (as expressed through words) with form, a car model, including several types of determined parameters, is created by CAD, the meaning of which is clarified by performing a sensitivity evaluation. At that time, it is necessary to consider what kind of form change may be considered in the shape of each basic form. Then, according to the “character attachment of the automobile,” a

designer investigates the part to which the greatest importance has been attached.

For the front, the (1) bonnet edge, (2) bonnet, and (3) fender were used as factors, while the (4) front pillar, (5) belt line, and (6) character line were used as factors for the side, and the degree of changes in these form factors was regarded as a standard. In this research, the purpose was to intentionally vary the form so that the corresponding changes in customer impressions could be checked. Then a model for the investigation of nine car types (A-I) was created using three side regions of attention as factors.

The form shape parameters and corresponding customer impressions are shown in Table 1 for each car model type. Similarly, a model for investigating nine car types (Type A'-Type I') was created for the front. As a comparative example of a change of form, Figure 2 shows an example where the angle of the front pillar for Types C and G is used as the single axis of change.

**Grasping Customer Sensitivity – STEP 2**

The purpose of the sensitivity evaluation questionnaire is to explore the differences in the impressions felt by customers, regarding nine models in which the forms of the front and side have been changed. Accordingly, subjects are asked for questionnaire replies in the same form regarding all models. This data are analyzed to determine the relation between subject impressions and form. In addition, the candidates for investigation targeted the younger age group (the 20's).

In the questionnaire, a seven-step evaluation using sensitivity words, is performed. In order to select suitable sensitivity words, a bibliographic search and an investigation hearing with the designer were conducted and 42 sensitivity words related automobile appearance were extracted. This set of words was then narrowed to those having a close relation, yielding the 12 sensitivity words shown in Table 2.

**Table 2: 12 Sensitivity Words**

Sophisticated	Intellectual	Elegant
Traditional	Advanced	High class
Characteristic	Simple	Composed
Cute	Powerful	Sporty

**Visualizing the Relationship between Form Variations and Customer Sensitivity – STEP 3**

Analysis is conducted at two steps: 5.3.1 form change and visualization of customer sensitivity, and 5.3.2 visualization of front/side relation.

*Determination of Shape Parameter Sensitivity Word Weights*

In order to clarify the weights of the sensitivity words for each shape parameter, a multiple regression analysis was conducted by taking sensitivity words and shape parameters as subject and explanatory variables, respectively. In this case, each standardized partial regression coefficient of the explanatory variable is designated as the weight for the subject variable. In this research, since 12 sensitivity words exist, 12 multiple linear regression analyses were performed by fixing the explanatory variable and changing the subject variable.

Based on this, the weighted path diagram between the shape parameters and sensitivity words is created using the desired standard partial regression coefficients for the sensitivity words. The aim is, by using the model as an experiment, to be able to numerically read which kind of sensitivity feature the model serves as, and furthermore, to obtain the ability to distinguish which shape parameter should be changed to approach a target sensitivity feature of interest.

As an example, the shape parameter ~ sensitivity path diagram is shown in Figure 3 from the standardized partial regression coefficient for “sophisticated.” In this figure, the strength of the relationship for the shape parameter with strong weight is expressed by the thickness of the arrow, regardless of the positive/negative sign of the coefficient.

From the path diagram in Figure 3, it is seen that the angle of the front pillar exerts the strongest influence and an especially acute angle for the front pillar conveys an impression of “sophisticated.” Moreover, the degree of influence each word could be visualized by conducting the same analysis for the other sensitivity words.

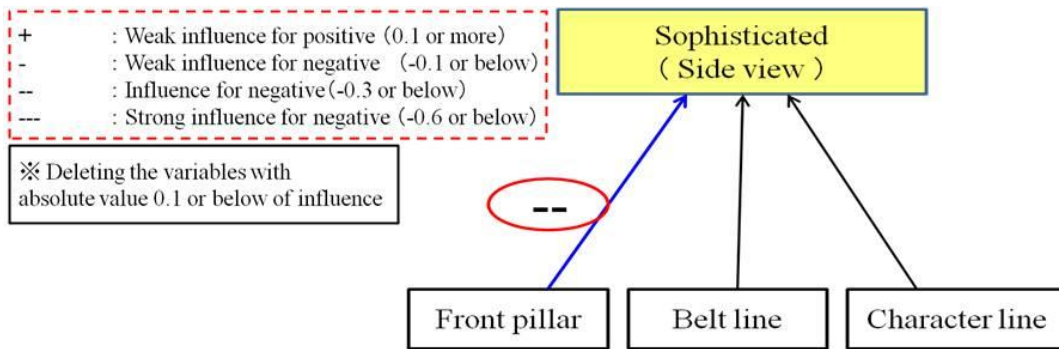


Figure 3 Shape Parameter ~ Sensitivity Path Diagram for “Sophisticated” (Side View)

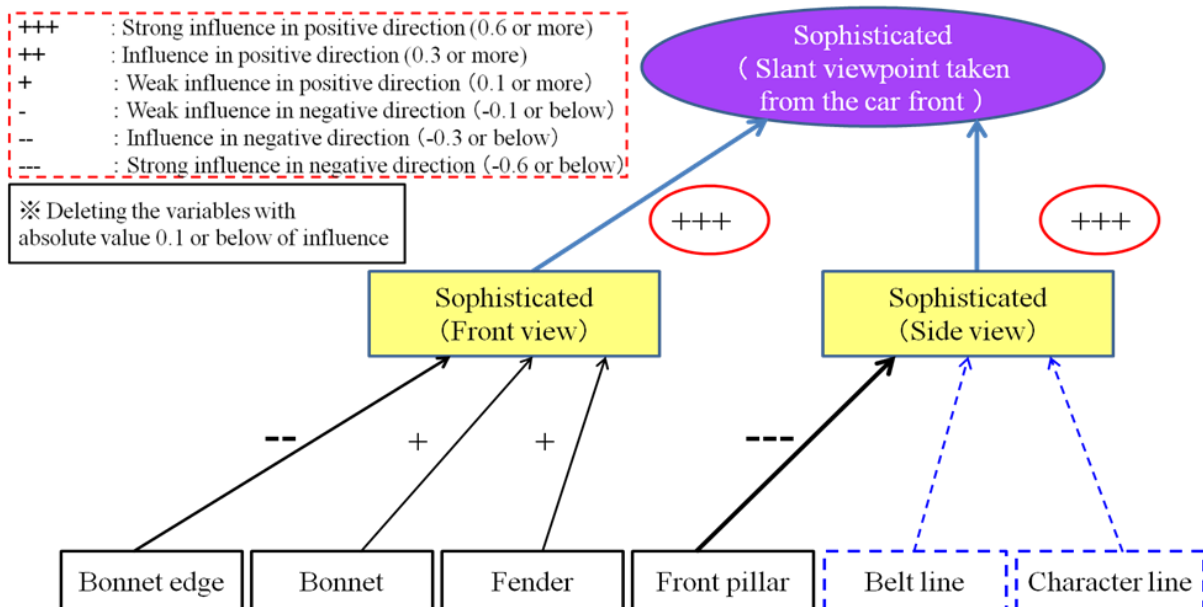


Figure 4: Path Diagram for “Sophisticated” Utilizing Covariance Structural Analysis

#### **Visualization of the Front/Side of Relationship - STEP 4**

Covariance structural analysis was also conducted to obtain an overall sensitivity evaluation by combining separate sensitivity evaluations for a front part and a side part into a synthetic variable in order to examine their mutual influence. As an example, the path diagram for “sophisticated” is shown in Figure 4. Here, the model was improved by deleting the variables in 5.3.1 with very small degrees of influence, and the analysis was undertaken. From the path diagram in Figure 4, one front part and one side part each exert large degrees of influence and the angle of the front pillar conveys the sensitivity evaluation “sophisticated” as the shape parameter with the largest degree of influence. By conducting the same analysis for all sensitivity words, the front/side relationships can be comprehensively evaluated.

#### **VERIFICATION**

Based on the above information, it is clear that to the younger generation, the concept of “advanced”, conveys a sense of stylishness. As a result, it is clear that an “advanced” image can be expressed via a specific combination of five points: (1) deep bonnet edge, (2) bonnet with swelling, (3) front pillar in an acute angle, (4) upward belt line, and (5) strengthened character line, each parameterized and materialized by CAD as a design. As a result of conducting a secondary questionnaire and analysis as verification of the new model, the expectation that it was possible to express the form, which conveys an impression of “advanced” to younger age group customers, was confirmed. Accordingly, the effectiveness of this research was considered to be verified.

#### **CONCLUSION**

A multiple regression analysis was undertaken to grasp the weight of the response of each sensitivity word to each shape parameter by determining the associated shape parameter-sensitivity word weights. By using each standardized partial regression coefficient of an explanatory variable as a subject variable weight, a path diagram, with weights between shape parameters and sensitivity words, was created. In this manner, the model was established on an experimental basis and it became possible to distinguish the types of sensitivity features the model serves to read numerically. Furthermore, when approaching a sensitivity feature, interpreted as an aim, it was possible to distinguish which shape parameter should be changed.

In addition, covariance structural analysis was applied to obtain a whole sensitivity evaluation, in order to comprehensively grasp the relationship of front and side regions to the 12 selected sensitivity words, by combining separate sensitivity evaluations of front and side parts into a synthetic variable.

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**NOTES**