Development of User Satisfaction Models for Passenger Car Interior Materials

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Customer needs of passenger cars

- Customer needs shift from functional capability to aesthetic design

  - "For consumers, the look and feel of craftsmanship that comes from rich-looking materials, careful fits and elegant details can be more important than top rankings from Consumer Reports"
    (December 3, 2001, Wall Street Journal)

  - "For young women, easy seat adjustment and interior color coordination are more important than horsepower or trunk capacity"
    (March 4, 2002, BusinessWeek)

Importance of interior materials

- Efforts on interior materials
  - High quality leather
  - Exotic wood
  - Chromed material
  - Brushed metal
  - Rich looking plastic (wood/metal grain)

- Few Kansei (image/impression) studies on interior materials
  - Shape
    - Steering wheel and dash board shape (Jindo and Hirasago, 1997)
  - Color and shape
    - Color and seat design of construction vehicles (Nakata, 1997)
  - Impression of visual aspects
    - Roominess (Tanoue, 1997)
  - Only type of material considered
    - Jindo and Hirasago(1997) and Nakata(1997)

- Needs for an in-depth study for material design variables

Objectives of the study

- Identify the design variables of interior materials
  - Materials used in the various interior parts of a passenger car
- Propose a method of variable screening for model development
  - For stable and significant models in statistical and technical aspects
- Develop satisfaction models of interior materials for selected interior parts

Satisfaction survey of interior materials

- Passenger cars
  - 30 car models made in various countries
    - 7 (Japan), 6 (Korea), 6 (USA), 4 (Germany), 3 (France), 1 (Czechoslovakia), 1 (India), 1 (Italy), 1 (Spain)
    - 23 compact cars & 7 sport-utility vehicles

- Six interior parts evaluated

Design variables of interior materials

- Identifying material design variables for the selected interior parts
  - Web sites of customer reviews
  - Interior design engineers
  - Previous studies (Jindo and Hirasago, 1997; Nakata, 1997, Nishimatsu, 2001)

⇒ **8 ~ 15** variables depending on interior part

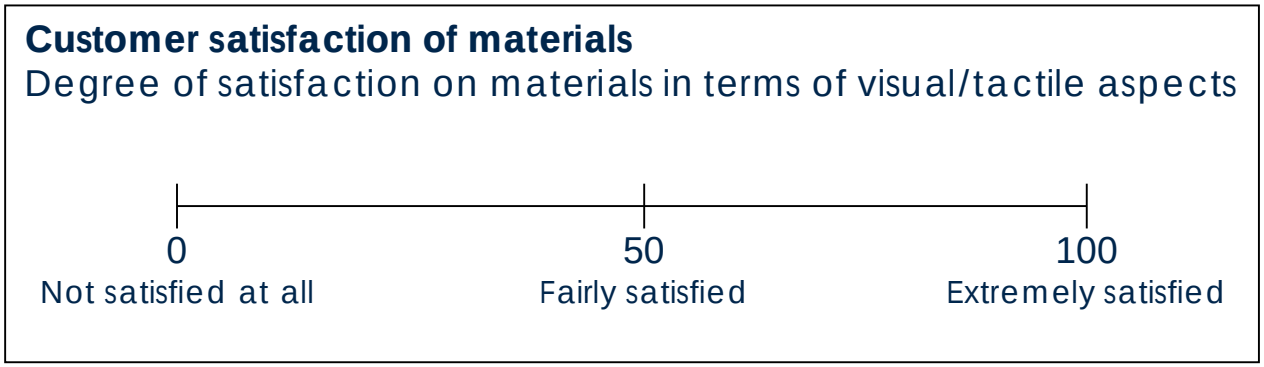
(e.g.) Material design variables - crash pad (selected)

Design variable	Levels
Type of material	1~4 (1: plastic, 2: polyurethane, 3: leather, 4: miscellaneous)
Color	8 colors by standard color table
Shape of embossing	1~7 (1: pinhole, 2: circular concave, 3: circular convex, 4: leathery, 5: stony, 6: flat, 7: miscellaneous)
Size of embossing	1~7 (1: < 0.1mm, 2: 0.1~0.3, 3: 0.3~0.5, 4: 0.5~0.7, 5: 0.7~0.9, 6: 0.9~1.1, 7: >1.1)
Arrangement of embossing	0~1 (0: random, 1: regular)
Softness	1~7 (1: very soft, 7: very hard)
Slipperiness	1~7 (1: very slippery, 7: very frictional)

Participants and rating scale

- Participants
  - 30 males (21 in twenties, 9 in thirties)
  - Age average (S.D.) = 28.7(6.6)

- Rating Scale

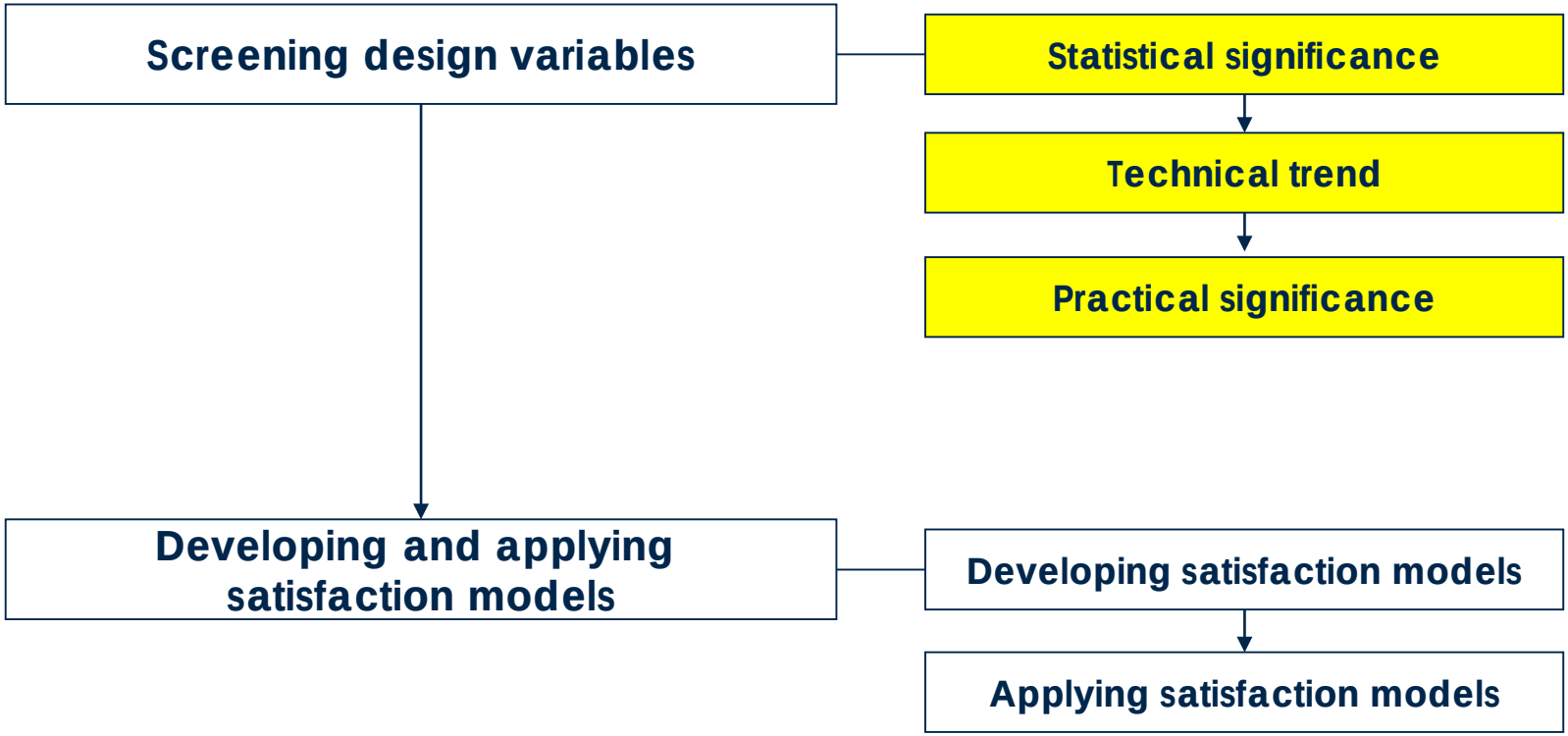


Modified magnitude estimation scale (Han et al., 2000)

Satisfaction evaluation procedure

- Introduction
  - Purpose and evaluation method
- Satisfaction evaluation of interior part materials
  - Each participant evaluated all passenger cars
  - Balanced Latin-square design
- Debriefing

Satisfaction model development



1. Statistical significance

- Test the statistical significance of each variable
  - To include statistically significant design variables in the subsequent model development process
  - ANOVA
    - Design variable of interest
    - Age
    - Design var. × Age

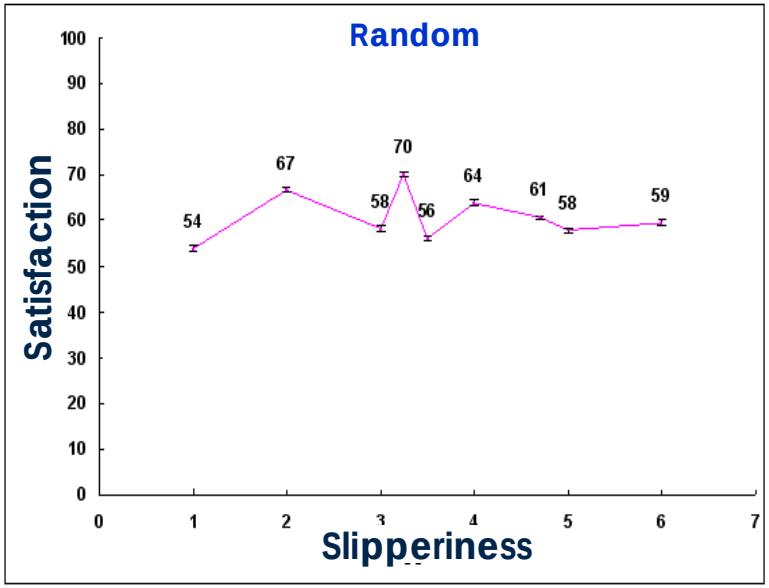
ANOVA Summary - crash pad

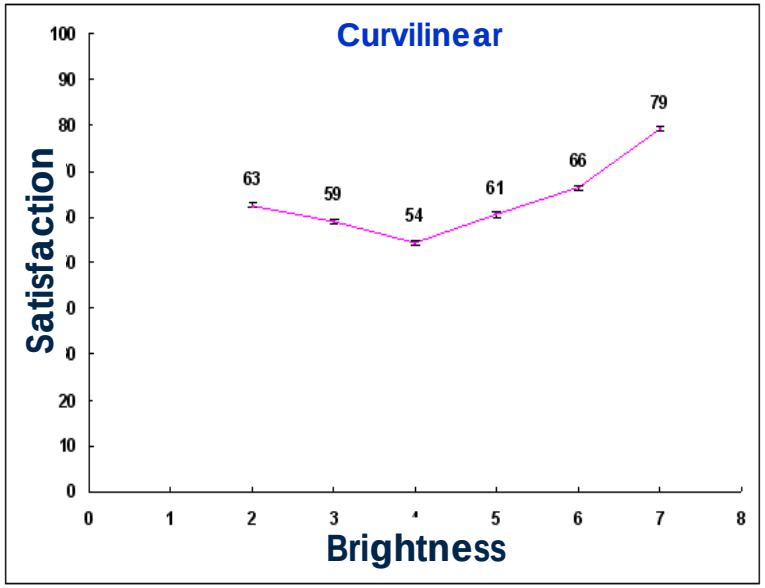
Code	Design Variable (DV)		Age	Age × DV
x1	Type of material	○	○	×
x2	Color	○	○	×
x3	Brightness	○	○	×
x4	Saturation	×	○	×
x5	Shininess	○	○	×
x6	Shape of embossing	○	○	×
x7	Size of embossing	○	○	×
x8	Marginal size of embossing	○	○	×
x9	Arrangement of embossing	○	○	×
x10	Clearness of embossing	○	○	×
x11	Roughness	○	○	×
x12	Softness	○	○	×
x13	Slipperiness	○	○	×

* ○: significant at $\alpha = 0.05$; ×: not significant

2. Technical trend

- Evaluate the technical trend of each design variable
  - For each quantitative variable with statistical significance
  - Objectives
    - To include design variables showing systematic effects on satisfaction in the model
    - To determine the order of a design variable in the model
  - Plot of satisfaction scores over the range of each variable





3. Practical significance

- Practical significance testing
  - To include design variables whose effects on satisfaction were large enough from a practical aspect in the model
  - Difference of satisfaction means among grouped levels by the Duncan test was compared with a designated value (e.g., 5)

Shininess *	N	Mean	Duncan Grouping	Group average	Difference of group averages
1	90	65	A		
3	269	63	A	63	
2	210	61	A		
4	90	57	B		7
6	29	55	B	56	
5	148	55	B		

* 1~7(1: very dull, 3: dull, 5: shiny, 7: very shiny

Results of variable screening

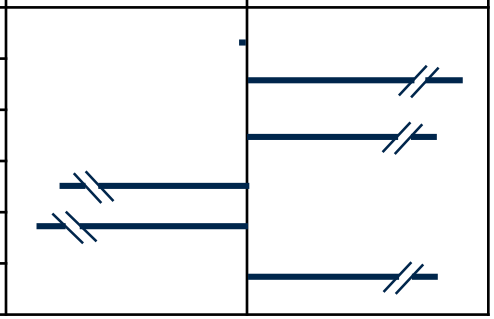
- Example of crash pad material design variables

Code	Design variables	Statistical significance	Technical trend	Practical significance
X_1	Type of material	○	N.A.	○
X_2	Color	○	N.A.	○
X_3	Brightness	○	○ (2^{nd} curvilinear)	○
X_4	Saturation	×	-	-
X_5	Shininess	○	○ (linear)	○
X_6	Shape of embossing	○	N.A.	○
X_7	Size of embossing	○	N.A.	○
X_8	Marginal size of embossing	○	○ (linear)	×
X_9	Arrangement of embossing	○	N.A.	×
X_{10}	Clearness of embossing	○	N.A.	○
X_{11}	Roughness	○	○ (linear)	○
X_{12}	Softness	○	○ (linear)	○
X_{13}	Slipperiness	○	×	-

Satisfaction model development

- Developed a model for each interior part with design variables screened
- Applied the quantification I method
  - Similar to generalized linear model
  - Used in Kansei engineering
  - Focus on quantification of design variable effects

(e.g.) Interior material satisfaction model – crash pad (illustrated)

Design variables	Levels	Partial corr.	Partial reg. coeff.	Not satisfied ⟷ Satisfied (-0.5 … 0.5)
X1(type of material)	Plastic	0.0123	-0.24	
	Polyurethane		0.32	
X6(shape of embossing)	circular convex	0.1936	-0.02	
	circular concave		13.07	
	pinhole		8.38	
	leathery		-1.51	
	stony flat		-2.63	
	miscellaneous		8.38	

Preferred material characteristics

(e.g.) crash pad material

Code	Design variables	Preference
x_1	Type of material	**Polyurethane** > Plastic
x_2	Color	**Orange** > reddish yellow > Blue > Achromatic > Deep blue > Dark purple > Dark blue > Yellow
x_3	Brightness of color	**Bright** > Dark
x_5	Shininess	**Dull** > Shiny
x_6	Shape of embossing	**Circular concave** > Pinhole > Circular convex > Leathery > Stony
x_7	Size of embossing	**0.3 ~ 0.5 cm**
x_{10}	Clearness of embossing	**Indistinct** > Distinct
x_{11}	Roughness	**Rough** > Smooth
x_{12}	Softness	**Soft** > Hard

Conclusion

- Satisfaction survey of vehicle interior materials
  - 6 interior parts of 30 passenger cars
  - Identified 8 to 15 material design variables for the interior parts
- Variable screening method
  - Stable and significant models from statistical and practical aspects
  - 3 aspects (statistical significance, technical trend, and practical significance)
- Satisfaction model development and application
  - Generalized linear model (quantification I method)
    - Relatively important design variables for satisfaction
    - Preferred material design characteristics

Q & A