Consumers’ Activities for Brand Selection
— Questionnaire Investigation to Automobile Purchasing Case—

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Abstract

Consumers often buy higher ranked brand after they are bored using current brand goods. This may be analyzed utilizing matrix. Suppose past purchasing data are set input and current purchasing data are set output, then transition matrix is identified using past and current data. If all brand selections are composed by the upper shifts, then the transition matrix becomes an upper triangular matrix. Questionnaire investigation to automobile purchasing case is executed and above structure is confirmed. If transition matrix is identified, S-step forecasting can be executed. Generalized forecasting matrix components’ equations are introduced. We have made a questionnaire investigation concern automobile purchase before (Takeyasu et al.,(2007)). In that paper, questionnaire was executed mainly on an urban area. In this paper, we make investigation on a rural area and make comparison for both of them. Planners for products need to know whether their brand is higher or lower than other products. Matrix structure makes it possible to

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ascertain this by calculating consumers’ activities for brand selection. Thus, this proposed approach makes it possible to execute an effective marketing plan and/or establish a new brand.

Keywords: brand selection, matrix structure, brand position, automobile industry

1 Introduction

It is often observed that consumers select upper class brand when they buy next time.

Suppose that former buying data and current buying data are gathered. Also suppose that upper brand is located upper in the variable array. Then transition matrix becomes upper triangular matrix under the supposition that former buying variables are set input and current buying variables are set output. If the top brand were selected from lower brand in jumping way, corresponding part in upper triangular matrix would be 0. These are verified in numerical examples with simple models.

If transition matrix is identified, S-step forecasting can be executed. Generalized forecasting matrix components’ equations are introduced. Planners for products need to know whether their brand is higher or lower than other products. Matrix structure makes it possible to ascertain this by calculating consumers’ activities for brand selection. Thus, this proposed approach makes it possible to execute an effective marketing plan and/or establish a new brand.

We have made a questionnaire investigation concern automobile purchase before (Takeyasu et al.,(2007)). In that paper, questionnaire was executed mainly on an urban area. In this paper, we make investigation on a rural area and make comparison for both of them. It is expected that somewhat different trend will be extracted.

Hereinafter, matrix structure is clarified for the selection of brand in section 2. Block matrix structure is analyzed when brands are handled in group and s-step forecasting is formulated in section 3. Questionnaire investigation to Automobile Purchasing case is examined and its Numerical calculation is executed in section 4. Application of this method is extended in section 5.

2 Brand selection and its matrix structure

(1) Upper shift of Brand selection

It is often observed that consumers select upper class brand when they buy next time.

Now, suppose that $x$ is the most upper class brand, $y$ is the second upper brand, and $z$ is the lowest brand. Consumer’s behavior of selecting brand would be $z \rightarrow y$, $y \rightarrow x$, $z \rightarrow x$ etc. $x \rightarrow z$ might be few.

Suppose that $x$ is current buying variable, and $x_b$ is previous buying variable. Shift to $x$ is executed from $x_b$, $y_b$, or $z_b$.

Therefore, $x$ is stated in the following equation.

\[ x = a_{11}x_b + a_{12}y_b + a_{13}z_b \]

Similarly,

\[ y = a_{22}y_b + a_{23}z_b \quad \text{and} \quad z = a_{33}z_b \]

These are re-written as follows.
\[
\begin{pmatrix}
x \\
y \\
z
\end{pmatrix}
= 
\begin{pmatrix}
a_{11} & a_{12} & a_{13} \\
0 & a_{22} & a_{23} \\
0 & 0 & a_{33}
\end{pmatrix}
\begin{pmatrix}
x_b \\
y_b \\
z_b
\end{pmatrix}
\]  
(1)

Set

\[
X = 
\begin{pmatrix}
x \\
y \\
z
\end{pmatrix}
\]

\[
A = 
\begin{pmatrix}
a_{11} & a_{12} & a_{13} \\
0 & a_{22} & a_{23} \\
0 & 0 & a_{33}
\end{pmatrix}
\]

\[
X_b = 
\begin{pmatrix}
x_b \\
y_b \\
z_b
\end{pmatrix}
\]

then, \( X \) is represented as follows.

\[
X = AX_b
\]  
(2)

Here,

\[
X \in \mathbb{R}^3, A \in \mathbb{R}^{3 \times 3}, X_b \in \mathbb{R}^3
\]

\( A \) is an upper triangular matrix.

To examine this, generating following data, which are all consisted by upper brand shift data,

\[
X^i = 
\begin{pmatrix}
1 \\
0 \\
0 \\
\end{pmatrix}
\begin{pmatrix}
1 \\
0 \\
0 \\
\end{pmatrix}
\ldots
\begin{pmatrix}
0 \\
0 \\
0 \\
\end{pmatrix}
\]  
(3)

\[
X^i_b = 
\begin{pmatrix}
1 \\
0 \\
0 \\
\end{pmatrix}
\begin{pmatrix}
0 \\
1 \\
0 \\
\end{pmatrix}
\ldots
\begin{pmatrix}
0 \\
0 \\
1 \\
\end{pmatrix}
\]  
(4)

\[ i = 1, 2, \ldots, N \]

parameter can be estimated using least square method.
Suppose
\[ X' = AX'_b + \varepsilon^i \]  
and
\[ J = \sum_{i=1}^{N} \varepsilon^{iT} \varepsilon^i \rightarrow Min \]
\[ \hat{A} \] which is an estimated value of \( A \) is obtained as follows.
\[ \hat{A} = \left( \sum_{i=1}^{N} X'_b X'^{iT}_b \right)^{-1} \left( \sum_{i=1}^{N} X' X'^{iT}_b \right) \]
In the data group of upper shift brand, estimated value \( \hat{A} \) should be upper triangular matrix.
If following data that have lower shift brand are added only a few in equation (3) and (4),
\[ X' = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} \]
\[ X'_b = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \]
\( \hat{A} \) would contain minute items in the lower part triangle.

(2) Sorting brand ranking by re-arranging row
In a general data, variables may not be in order as \( x, y, z \). In that case, large and small value lie scattered in \( \hat{A} \). But re-arranging this, we can set in order by shifting row. The large value parts are gathered in upper triangular matrix, and the small value parts are gathered in lower triangular matrix.
(3) **In the case that brand selection shifts in jump**

It is often observed that some consumers select the most upper class brand from the most lower class brand and skip selecting the middle class brand.

We suppose \( v, w, x, y, z \) brands (suppose they are laid from upper position to lower position as \( v > w > x > y > z \)).

In the above case, selection shifts would be

\[
\begin{align*}
    v &\leftarrow z \\
    v &\leftarrow y \\
\end{align*}
\]

Suppose they do not shift to \( y, x, w \) from \( z \), to \( x, w \) from \( y \), and to \( w \) from \( x \), then Matrix structure would be as follows.

\[
\begin{bmatrix}
    v \\
    w \\
    x \\
    y \\
    z
\end{bmatrix}
= \begin{bmatrix}
a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\
0 & a_{22} & 0 & 0 & 0 \\
0 & 0 & a_{33} & 0 & 0 \\
0 & 0 & 0 & a_{44} & 0 \\
0 & 0 & 0 & 0 & a_{55}
\end{bmatrix}
\begin{bmatrix}
v_b \\
w_b \\
x_b \\
y_b \\
z_b
\end{bmatrix}
\]

(9)

3. **Block matrix structure in brand groups and s-step forecasting**

Next, we examine the case in brand groups. Matrices are composed by Block Matrix.

[1] **Brand shift group — in the case of two groups**

Suppose brand selection shifts from Corolla class to Mark II class in car. In
In this case, it does not matter which company’s car they choose. Thus, selection of cars are executed in a group and brand shift is considered to be done from group to group. Suppose brand groups at time $n$ are as follows.

$X$ consists of $p$ varieties of goods, and $Y$ consists of $q$ varieties of goods.

$$
X_n = \begin{pmatrix}
    x_1^n \\
    x_2^n \\
    \vdots \\
    x_p^n
\end{pmatrix}
$$

$$
Y_n = \begin{pmatrix}
    y_1^n \\
    y_2^n \\
    \vdots \\
    y_q^n
\end{pmatrix}
$$

$$
\begin{pmatrix}
    X_n \\
    Y_n
\end{pmatrix} = \begin{pmatrix} A_{11}, & A_{12} \\ 0, & A_{22} \end{pmatrix} \begin{pmatrix}
    X_{n-1} \\
    Y_{n-1}
\end{pmatrix}
$$

(10)

Here,

$$X_n \in \mathbb{R}^p \ (n = 1, 2, \ldots), \quad Y_n \in \mathbb{R}^q \ (n = 1, 2, \ldots), \quad A_{11} \in \mathbb{R}^{p \times p},$$

$$A_{12} \in \mathbb{R}^{p \times q}, \quad A_{22} \in \mathbb{R}^{q \times q}$$

Make one more step of shift, then we obtain following equation.

$$
\begin{pmatrix}
    X_n \\
    Y_n
\end{pmatrix} = \begin{pmatrix} A_{11}^2, & A_{11}A_{12} + A_{12}A_{22} \\ 0, & A_{22}^2 \end{pmatrix} \begin{pmatrix}
    X_{n-2} \\
    Y_{n-2}
\end{pmatrix}
$$

(11)

Make one more step of shift again, then we obtain following equation.

$$
\begin{pmatrix}
    X_n \\
    Y_n
\end{pmatrix} = \begin{pmatrix} A_{11}^3, & A_{11}^2A_{12} + A_{11}A_{12}A_{22} + A_{12}A_{22}^2 \\ 0, & A_{22}^3 \end{pmatrix} \begin{pmatrix}
    X_{n-3} \\
    Y_{n-3}
\end{pmatrix}
$$

(12)

Similarly,

$$
\begin{pmatrix}
    X_n \\
    Y_n
\end{pmatrix} = \begin{pmatrix} A_{11}^4, & A_{11}^3A_{12} + A_{11}^2A_{12}A_{22} + A_{11}A_{12}A_{22}^2 + A_{12}A_{22}^2A_{22}^3 \\ 0, & A_{22}^4 \end{pmatrix} \begin{pmatrix}
    X_{n-4} \\
    Y_{n-4}
\end{pmatrix}
$$

(13)
Consumers’ Activities for Brand Selection

\[
\begin{pmatrix}
X_n \\
Y_n \\
Z_n
\end{pmatrix}
= 
\begin{pmatrix}
A_{11}^5, & A_{11}^4A_{12} + A_{11}^3A_{12}A_{22} + A_{11}^2A_{12}A_{22}^2 + A_{11}A_{12}A_{22}^3 + A_{12}A_{22}^4 & 0 \\
0, & 0, & 0
\end{pmatrix}
\begin{pmatrix}
X_{n-5} \\
Y_{n-5} \\
Z_{n-5}
\end{pmatrix}
\tag{14}
\]

Finally, we get generalized equation for \(s\)-step shift as follows.

\[
\begin{pmatrix}
X_n \\
Y_n \\
Z_n
\end{pmatrix}
= 
\begin{pmatrix}
A_{11}^s, & A_{11}^{s-1}A_{12} + \sum_{k=2}^{s-1} A_{11}^{s-k}A_{12}A_{22}^{k-1} + A_{12}A_{22}^{s-1} & A_{22}^s & 0 \\
0, & 0, & 0, & 0
\end{pmatrix}
\begin{pmatrix}
X_{n-s} \\
Y_{n-s} \\
Z_{n-s}
\end{pmatrix}
\tag{15}
\]

If we replace \(n-s \to n, n \to n+s\) in equation (15), we can make \(s\)-step forecast.

[2] **Brand shift group — in the case of three groups**

Suppose brand selection is executed in the same group or to the upper group, and also suppose that brand position is \(x > y > z\) (\(x\) is upper position). Then brand selection transition matrix would be expressed as

\[
\begin{pmatrix}
X_n \\
Y_n \\
Z_n
\end{pmatrix}
= 
\begin{pmatrix}
A_{11}, & A_{12}, & A_{13} & 0 \\
0, & A_{22}, & A_{23} & 0 \\
0, & 0, & A_{33} & 0
\end{pmatrix}
\begin{pmatrix}
X_{n-1} \\
Y_{n-1} \\
Z_{n-1}
\end{pmatrix}
\tag{16}
\]

Where

\[
X_n = \begin{pmatrix}
x_1^n \\
x_2^n \\
\vdots \\
x_p^n
\end{pmatrix},
Y_n = \begin{pmatrix}
y_1^n \\
y_2^n \\
\vdots \\
y_q^n
\end{pmatrix},
Z_n = \begin{pmatrix}
z_1^n \\
z_2^n \\
\vdots \\
z_r^n
\end{pmatrix}
\]

Here,

\(X_n \in \mathbb{R}^p (n = 1, 2, \ldots), \ Y_n \in \mathbb{R}^q (n = 1, 2, \ldots), \ Z_n \in \mathbb{R}^r (n = 1, 2, \ldots), \ A_{11} \in \mathbb{R}^{p \times p}, \ A_{12} \in \mathbb{R}^{p \times q}, \ A_{13} \in \mathbb{R}^{p \times r}, \ A_{22} \in \mathbb{R}^{q \times q}, \ A_{23} \in \mathbb{R}^{q \times r}, \ A_{33} \in \mathbb{R}^{r \times r}\)

These are re-stated as

\[
W_n = AW_{n-1}
\tag{17}
\]

where,
Hereinafter, we shift steps as is done in previous section. In the general description, we state as

\[ W_n = A^{(s)} W_{n-s} \]  

Here,

\[
A^{(s)} = \begin{pmatrix}
A_{11}^{(s)}, & A_{12}^{(s)}, & A_{13}^{(s)} \\
0, & A_{22}^{(s)}, & A_{23}^{(s)} \\
0, & 0, & A_{33}^{(s)}
\end{pmatrix}
\]

\[ W_{n-s} = \begin{pmatrix}
X_{n-s} \\
Y_{n-s} \\
Z_{n-s}
\end{pmatrix}
\]

From definition,

\[
A^{(1)} = A
\]

In the case \( s = 2 \), we obtain

\[
A^{(2)} = \begin{pmatrix}
A_{11}, & A_{12}, & A_{13} \\
0, & A_{22}, & A_{23} \\
0, & 0, & A_{33}
\end{pmatrix}
\begin{pmatrix}
A_{11}, & A_{12}, & A_{13} \\
0, & A_{22}, & A_{23} \\
0, & 0, & A_{33}
\end{pmatrix}
\]

\[
= \begin{pmatrix}
A_{11}^2, & A_{11}A_{12} + A_{12}A_{22}, & A_{11}A_{13} + A_{12}A_{23} + A_{13}A_{33} \\
0, & A_{22}^2, & A_{22}A_{23} + A_{23}A_{33} \\
0, & 0, & A_{33}^2
\end{pmatrix}
\]

Next, in the case \( s = 3 \), we obtain

\[
A^{(3)} = \begin{pmatrix}
A_{11}^3, & A_{11}^2A_{12} + A_{11}A_{12}A_{22} + A_{12}A_{22}^2, & A_{11}^2A_{13} + A_{11}A_{12}A_{23} + A_{12}A_{23}A_{33} + A_{13}A_{33} + A_{12}A_{23}A_{33} + A_{13}A_{33} + A_{12}A_{23}A_{33} + A_{13}A_{33} \\
0, & A_{22}^3, & A_{22}^2A_{23} + A_{23}^2A_{33} + A_{22}A_{23}A_{33} + A_{23}A_{33} + A_{22}A_{23}A_{33} + A_{23}A_{33} + A_{22}A_{23}A_{33} + A_{23}A_{33} \\
0, & 0, & A_{33}^3
\end{pmatrix}
\]

In the case \( s = 4 \), equations become wide-spread, so we express each Block
Matrix as follows.

\[
\begin{align*}
\mathbf{A}^{(4)}_{11} &= \mathbf{A}^4_{11} \\
\mathbf{A}^{(4)}_{12} &= \mathbf{A}^3_{12} + \mathbf{A}^2_{11}\mathbf{A}_{12} + \mathbf{A}_{11}\mathbf{A}^2_{12} + \mathbf{A}_{12}\mathbf{A}^3_{12} \\
\mathbf{A}^{(4)}_{13} &= \mathbf{A}^3_{13} + \mathbf{A}^2_{11}\mathbf{A}_{12}\mathbf{A}_{13} + \mathbf{A}^2_{11}\mathbf{A}_{12}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} \\
&+ \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{13}\mathbf{A}^2_{22} \\
\mathbf{A}^{(4)}_{22} &= \mathbf{A}^4_{22} \\
\mathbf{A}^{(4)}_{23} &= \mathbf{A}^3_{22}\mathbf{A}_{23} + \mathbf{A}^2_{22}\mathbf{A}_{23}\mathbf{A}_{33} + \mathbf{A}_{22}\mathbf{A}_{33}\mathbf{A}_{33} + \mathbf{A}_{23}\mathbf{A}^2_{33} \\
\mathbf{A}^{(4)}_{33} &= \mathbf{A}^4_{33}
\end{align*}
\]

(22)

In the case \( s = 5 \), we obtain the following equations similarly.

\[
\begin{align*}
\mathbf{A}^{(5)}_{11} &= \mathbf{A}^5_{11} \\
\mathbf{A}^{(5)}_{12} &= \mathbf{A}^4_{12} + \mathbf{A}^3_{11}\mathbf{A}_{12} + \mathbf{A}^2_{11}\mathbf{A}_{12} + \mathbf{A}_{11}\mathbf{A}^2_{12} + \mathbf{A}_{12}\mathbf{A}^3_{12} \\
\mathbf{A}^{(5)}_{13} &= \mathbf{A}^4_{13} + \mathbf{A}^3_{11}\mathbf{A}_{12}\mathbf{A}_{13} + \mathbf{A}^2_{11}\mathbf{A}_{12}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} \\
&+ \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{13}\mathbf{A}^2_{22} \\
\mathbf{A}^{(5)}_{22} &= \mathbf{A}^5_{22} \\
\mathbf{A}^{(5)}_{23} &= \mathbf{A}^4_{22}\mathbf{A}_{23} + \mathbf{A}^3_{22}\mathbf{A}_{23}\mathbf{A}_{33} + \mathbf{A}^2_{22}\mathbf{A}_{23}\mathbf{A}_{33} + \mathbf{A}_{22}\mathbf{A}_{33}\mathbf{A}_{33} + \mathbf{A}_{23}\mathbf{A}^2_{33} \\
\mathbf{A}^{(5)}_{33} &= \mathbf{A}^5_{33}
\end{align*}
\]

(23)

In the case \( s = 6 \), we obtain

\[
\begin{align*}
\mathbf{A}^{(6)}_{11} &= \mathbf{A}^6_{11} \\
\mathbf{A}^{(6)}_{12} &= \mathbf{A}^5_{12} + \mathbf{A}^4_{11}\mathbf{A}_{12} + \mathbf{A}^3_{11}\mathbf{A}_{12} + \mathbf{A}^2_{11}\mathbf{A}_{12} + \mathbf{A}_{11}\mathbf{A}^2_{12} + \mathbf{A}_{12}\mathbf{A}^3_{12} \\
\mathbf{A}^{(6)}_{13} &= \mathbf{A}^5_{13} + \mathbf{A}^4_{11}\mathbf{A}_{12}\mathbf{A}_{13} + \mathbf{A}^3_{11}\mathbf{A}_{12}\mathbf{A}_{13} + \mathbf{A}^2_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}^2_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} + \mathbf{A}_{11}\mathbf{A}_{12}\mathbf{A}_{22}\mathbf{A}_{13} \\
&+ \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{12}\mathbf{A}^2_{22}\mathbf{A}_{13} + \mathbf{A}_{13}\mathbf{A}^2_{22} \\
\mathbf{A}^{(6)}_{22} &= \mathbf{A}^6_{22} \\
\mathbf{A}^{(6)}_{23} &= \mathbf{A}^5_{22}\mathbf{A}_{23} + \mathbf{A}^4_{22}\mathbf{A}_{23}\mathbf{A}_{33} + \mathbf{A}^3_{22}\mathbf{A}_{23}\mathbf{A}_{33} + \mathbf{A}_{22}\mathbf{A}_{33}\mathbf{A}_{33} + \mathbf{A}_{23}\mathbf{A}^2_{33} \\
\mathbf{A}^{(6)}_{33} &= \mathbf{A}^6_{33}
\end{align*}
\]

(24)
We get generalized equations for the $s$-step shift as follows.

\[
\begin{align*}
A^{(s)}_{11} &= A^{s}_{11} \\
A^{(s)}_{12} &= A^{s-1}_{11} A_{12} + \sum_{k=2}^{s-1} A^{s-k}_{11} A_{12} A^{k-1}_{22} + A_{12} A^{s-k}_{22} \\
A^{(s)}_{13} &= A^{s-1}_{11} A_{13} + A^{s-2}_{11} \left( \sum_{k=1}^{2} A^{s-3}_{11} A_{1(k+1)} A_{1(k+1)} \right) + \sum_{j=1}^{s-3} \left[ A^{s-j-2}_{11} \left( \sum_{k=1}^{j+1} A^{j+1-k}_{j} A_{j+1} A^{k-1}_{23} A_{23} A^{k-1}_{33} \right) + A_{13} A^{s-j}_{33} \right] \\
A^{(s)}_{22} &= A^{s}_{22} \\
A^{(s)}_{23} &= \sum_{k=1}^{s} A^{s-k}_{22} A_{23} A^{k-1}_{33} \\
A^{(s)}_{33} &= A^{s}_{33}
\end{align*}
\]

Expressing them in matrix, it follows.

\[
A^{(s)} =
\begin{pmatrix}
A_{11}, & A^{s-1}_{11} A_{12} + \sum_{k=2}^{s-1} A^{s-k}_{11} A_{12} A^{k-1}_{22} + A_{12} A^{s-k}_{22} \\
0, & A^{s-1}_{11} A_{13} + A^{s-2}_{11} \left( \sum_{k=1}^{2} A^{s-3}_{11} A_{1(k+1)} A_{1(k+1)} \right) + \sum_{j=1}^{s-3} \left[ A^{s-j-2}_{11} \left( \sum_{k=1}^{j+1} A^{j+1-k}_{j} A_{j+1} A^{k-1}_{23} A_{23} A^{k-1}_{33} \right) + A_{13} A^{s-j}_{33} \right] \\
\end{pmatrix}
\]

Generalizing them to $m$ groups, they are expressed as

\[
\begin{pmatrix}
X^{(1)}_n \\
X^{(2)}_n \\
\vdots \\
X^{(m)}_n
\end{pmatrix} =
\begin{pmatrix}
A_{11} & A_{12} & \cdots & A_{1m} \\
A_{21} & A_{22} & \cdots & A_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
A_{m1} & A_{m2} & \cdots & A_{mm}
\end{pmatrix}
\begin{pmatrix}
X^{(1)}_{n-1} \\
X^{(2)}_{n-1} \\
\vdots \\
X^{(m)}_{n-1}
\end{pmatrix}
\]

\[
X^{(1)}_n \in R^{k_1}, \quad X^{(2)}_n \in R^{k_2}, \quad \cdots, \quad X^{(m)}_n \in R^{k_m}, \quad A_{ij} \in R^{k_i \times k_j} \quad (i = 1, \cdots, m)(j = 1, \cdots, m)
\]
4 Questionnaire investigation and numerical calculation

Questionnaire Investigation to Automobile Purchasing case is executed.

<Delivery of Questionnaire Sheets>

- Questionnaire sheet: Appendix 1
- Delivery Term: July to September/2012
- Delivery Place: Shizuoka, Mie Prefecture in Japan
- Number of Delivered Questionnaire sheets: 300

<Result of collected Questionnaire Sheets>

- Collected Questionnaire Sheets: 98 (male: 47, female: 51)
- Collected sheets for Sedan Typed Automobile: 41

<Fundamental Statistical Result>

Table 1: Summary for 98 sheets

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Occupation</th>
<th>Annual income (Japanese Yen)</th>
<th>Marriage</th>
<th>Kids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teens 10</td>
<td>Male 47</td>
<td>Student 16</td>
<td>0-3 million</td>
<td>Single 46</td>
<td>0 55</td>
</tr>
<tr>
<td>Twenties 20</td>
<td>Female 51</td>
<td>Officer 48</td>
<td>3-5 million</td>
<td>Married 51</td>
<td>1 11</td>
</tr>
<tr>
<td>Thirties 18</td>
<td></td>
<td>Company employee 6</td>
<td>5-7.5 million</td>
<td>Not filled in</td>
<td>1 23</td>
</tr>
<tr>
<td>Forties 20</td>
<td></td>
<td>Clerk of Organization 1</td>
<td>7.5-10 million</td>
<td>2</td>
<td>3 9</td>
</tr>
<tr>
<td>Fifties 15</td>
<td></td>
<td>Independents 25</td>
<td>10-15 million</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sixties 15 and over</td>
<td></td>
<td>Miscellaneous 0</td>
<td>15 million or more</td>
<td>0</td>
<td>5 0</td>
</tr>
<tr>
<td>Not filled in</td>
<td></td>
<td>Not filled in 2</td>
<td>Not filled in</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Sum</strong> 98</td>
<td></td>
<td><strong>98</strong></td>
<td></td>
<td><strong>98</strong></td>
<td><strong>98</strong></td>
</tr>
</tbody>
</table>
Table 2: Sedan Typed Summary for 41 Sheets

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Occupation</th>
<th>Annual income (Japanese Yen)</th>
<th>Marriage</th>
<th>Kids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teens</td>
<td>0</td>
<td>Male</td>
<td>14</td>
<td>Student</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0-3 million</td>
<td>Single</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Married</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Twenties</td>
<td>9</td>
<td>Female</td>
<td>27</td>
<td>Officer</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3-5 million</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Married</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Thirties</td>
<td>7</td>
<td></td>
<td>Company employee</td>
<td>0</td>
<td>5-7.5 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Not filled in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Forties</td>
<td>12</td>
<td></td>
<td>Clerk of Organization</td>
<td>0</td>
<td>7.5-10 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Fifties</td>
<td>6</td>
<td></td>
<td>Independents</td>
<td>3</td>
<td>10-15 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Sixties</td>
<td>7</td>
<td></td>
<td>Miscellaneous</td>
<td>0</td>
<td>15 million or more</td>
</tr>
<tr>
<td>and over</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>5</td>
</tr>
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<td></td>
<td></td>
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<td>0</td>
<td>0</td>
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<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Not filled in</td>
<td>0</td>
<td></td>
<td>Not filled in</td>
<td>0</td>
<td>Not filled in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>41</td>
<td>41</td>
</tr>
</tbody>
</table>

The questionnaire includes the question of the past. Therefore plural date may be gathered from one sheet. For example, we can get two data such as (Third ahead, before former automobile)(before former automobile, former automobile ),( former automobile, current automobile ),( current automobile, next automobile),( current automobile, future automobile).

Analyzing these sheets based on Model ranked Table (Appendix2, Appendix3), we obtained the following 201 data sets. Appendix2 shows total ranking Table and Appendix3 shows the ranking Table for sedan type.

① Number of shift from 5th position to 5th position : 87
② Number of shift from 5th position to 4th position : 10
③ Number of shift from 5th position to 3rd position : 11
④ Number of shift from 5th position to 2nd position : 3
⑤ Number of shift from 5th position to 1st position : 1
⑥ Number of shift from 4th position to 5th position : 15
⑦ Number of shift from 4th position to 4th position : 17
⑧ Number of shift from 4th position to 3rd position : 3
⑨ Number of shift from 4th position to 2nd position : 6
⑩ Number of shift from 3rd position to 5th position : 5
⑪ Number of shift from 3rd position to 4th position : 3
⑫ Number of shift from 3rd position to 3rd position : 8
⑬ Number of shift from 3rd position to 2nd position : 6
⑭ Number of shift from 2nd position to 5th position : 3
⑮ Number of shift from 2nd position to 4th position : 4
⑯ Number of shift from 2nd position to 3rd position : 4
⑰ Number of shift from 2nd position to 2nd position : 10
⑱ Number of shift from 1st position to 2nd position : 2
⑲ Number of shift from 1st position to 1st position : 2

Total: 201

The vector $X, X_b$ in these cases are expressed as follows.

$$
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix}
= 
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix}
$$

$$
\begin{bmatrix}
0 \\
0 \\
0 \\
1 \\
0
\end{bmatrix}
= 
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix}
$$
\[
\begin{align*}
\begin{bmatrix}
0 \\
0 \\
1 \\
0 \\
0
\end{bmatrix} &= X \\
\begin{bmatrix}
0 \\
0 \\
1 \\
0 \\
0
\end{bmatrix} &= X_b
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
0 \\
1 \\
0 \\
0 \\
0
\end{bmatrix} &= X \\
\begin{bmatrix}
0 \\
0 \\
0 \\
1 \\
0
\end{bmatrix} &= X_b
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
0 \\
1 \\
0 \\
0 \\
0
\end{bmatrix} &= X \\
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix} &= X_b
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
0 \\
1 \\
0 \\
0 \\
0
\end{bmatrix} &= X \\
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix} &= X_b
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
0 \\
0 \\
0 \\
1 \\
0
\end{bmatrix} &= X \\
\begin{bmatrix}
0 \\
0 \\
0 \\
1 \\
0
\end{bmatrix} &= X_b
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix} &= X \\
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix} &= X_b
\end{align*}
\]
\[
\begin{align*}
\mathbf{X} &= \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}, & \quad \mathbf{X}_b &= \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \\
\mathbf{X} &= \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}, & \quad \mathbf{X}_b &= \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \\
\mathbf{X} &= \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}, & \quad \mathbf{X}_b &= \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \\
\mathbf{X} &= \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}, & \quad \mathbf{X}_b &= \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \\
\mathbf{X} &= \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}, & \quad \mathbf{X}_b &= \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \\
\mathbf{X} &= \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}, & \quad \mathbf{X}_b &= \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}
\end{align*}
\]
\[
X = \begin{pmatrix}
0 \\
0 \\
1 \\
0
\end{pmatrix}, \quad X_b = \begin{pmatrix}
0 \\
1 \\
0 \\
0
\end{pmatrix}
\]

\[
X = \begin{pmatrix}
0 \\
0 \\
1 \\
0
\end{pmatrix}, \quad X_b = \begin{pmatrix}
0 \\
1 \\
0 \\
0
\end{pmatrix}
\]

\[
X = \begin{pmatrix}
0 \\
1 \\
0 \\
0
\end{pmatrix}, \quad X_b = \begin{pmatrix}
0 \\
1 \\
0 \\
0
\end{pmatrix}
\]

\[
X = \begin{pmatrix}
1 \\
0 \\
0 \\
0
\end{pmatrix}, \quad X_b = \begin{pmatrix}
0 \\
1 \\
0 \\
0
\end{pmatrix}
\]

\[
X = \begin{pmatrix}
0 \\
1 \\
0 \\
0
\end{pmatrix}, \quad X_b = \begin{pmatrix}
1 \\
0 \\
0 \\
0
\end{pmatrix}
\]

\[
X = \begin{pmatrix}
1 \\
0 \\
0 \\
0
\end{pmatrix}, \quad X_b = \begin{pmatrix}
1 \\
0 \\
0 \\
0
\end{pmatrix}
\]
Substituting these to equation (7), we obtain

$$\hat{A} = \begin{pmatrix} 2 & 0 & 0 & 0 & 1 \\ 1 & 10 & 6 & 6 & 3 \\ 0 & 4 & 8 & 3 & 11 \\ 0 & 4 & 3 & 17 & 10 \\ 0 & 3 & 5 & 15 & 87 \end{pmatrix} \begin{pmatrix} 3 & 0 & 0 & 0 & 0 \\ 0 & 3 & 23 & 0 & 0 \\ 0 & 0 & 23 & 0 & 0 \\ 0 & 0 & 0 & 22 & 0 \\ 0 & 0 & 0 & 0 & 112 \end{pmatrix}^{-1} = \begin{pmatrix} \frac{2}{3} & \frac{2}{23} & 0 & 0 & \frac{1}{112} \\ \frac{1}{10} & \frac{3}{6} & \frac{3}{11} & 0 & 0 \\ 0 & \frac{3}{23} & \frac{11}{41} & \frac{112}{3} & 0 \\ 0 & \frac{4}{4} & \frac{3}{4} & 0 & \frac{112}{3} \\ 0 & \frac{23}{23} & \frac{22}{41} & \frac{56}{5} & \frac{112}{3} \end{pmatrix}$$

Questionnaire investigation to automobile purchasing case is executed and matrix structure stated in 2.(1) can be confirmed. This is rather a slight upper shift on the whole compared with the former research. We make comparison for both of them in Table 3 and 4.

<table>
<thead>
<tr>
<th>Rank</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>Summary</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper shift</td>
<td>-</td>
<td>3</td>
<td>7</td>
<td>5</td>
<td>23</td>
<td>38</td>
<td>38.8</td>
</tr>
<tr>
<td>Same Rank movement</td>
<td>2</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>44</td>
<td>44.9</td>
</tr>
<tr>
<td>Lower shift</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>-</td>
<td>16</td>
<td>16.3</td>
</tr>
<tr>
<td>Summary</td>
<td>4</td>
<td>10</td>
<td>19</td>
<td>24</td>
<td>41</td>
<td>98</td>
<td>-</td>
</tr>
<tr>
<td>Share (%)</td>
<td>4.1</td>
<td>10.2</td>
<td>19.4</td>
<td>24.5</td>
<td>41.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4: The results of this research

<table>
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<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>Summary</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper shift</td>
<td>-</td>
<td>2</td>
<td>6</td>
<td>9</td>
<td>25</td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Same Rank</td>
<td>2</td>
<td>10</td>
<td>8</td>
<td>17</td>
<td>87</td>
<td>124</td>
<td>61.7</td>
</tr>
<tr>
<td>movement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower shift</td>
<td>1</td>
<td>11</td>
<td>8</td>
<td>15</td>
<td>-</td>
<td>35</td>
<td>17.4</td>
</tr>
<tr>
<td>Summary</td>
<td>3</td>
<td>23</td>
<td>22</td>
<td>41</td>
<td>112</td>
<td>201</td>
<td></td>
</tr>
<tr>
<td>Share (%)</td>
<td>1.5</td>
<td>11.4</td>
<td>10.9</td>
<td>20.4</td>
<td>55.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Apparently, the former one has a clear upper shift. To clarify this reason, we have made an interview to the car dealers.

Hearing results from the car dealers are as follows. There is a tendency to the shift to the upper brands. But some of them have each feature such as
a. When young, they ride on high ranked automobile. But when married, they ride on ordinary level automobile.
b. Office workers are apt to buy higher ranked automobile as they promote.
c. Recently interior of automobile became upgraded. Therefore user can enjoy higher ranked automobile in a rather lower grade automobile, which cause less need to upgrade.

In this research, residents are in rural area therefore that may affect the behavior for the purchase. Anyway we have obtained interesting results. This should be expanded in many areas.

5 Application of this method

Consumers’ behavior may converge by repeating forecast with above
method and total sales of all brands may be reduced. Therefore, the analysis results suggest when and what to put new brand into the market which contribute the expansion of the market.

There may arise following case. Consumers and producers do not recognize brand position clearly. But analysis of consumers’ behavior let them know their brand position in the market. In such a case, strategic marketing guidance to select brand would be introduced.

Setting in order the brand position of various goods and taking suitable marketing policy, enhancement of sales would be enabled. Setting higher ranked brand, consumption would be promoted.

6 Conclusion

It is often observed that consumers select upper class brand when they buy next time. Suppose that former buying data and current buying data are gathered. Also suppose that upper brand is located upper in the variable array. Then transition matrix become upper triangle matrix under the supposition that former buying variables are set input and current buying variables are set output. If the top brand is selected from lower brand in jumping way, corresponding part in upper triangle matrix would be 0.

Questionnaire investigation to automobile purchasing case was executed and above structure was confirmed. We have made a questionnaire investigation concern automobile purchase before. In that paper, questionnaire was executed mainly on an urban area. In this paper, we have made investigation on a rural area and made comparison for both of them. Interesting results were obtained. Various fields should be examined hereafter. In the end, we appreciate Ms. Kurumi Kawamura for her helpful support of work.
References


Appendix 1 Questionnaire Sheet

1. Age
<teens · twenties · thirties · forties · fifties · more than sixties >

2. Sex
< Woman · Man >

3. Occupation
< Company employee · public official · Independent · Housewife · Miscellaneous >

4. Official position
< Chairman · President · Officer · General manager · Deputy general manager · Section chief · Deputy Section chief · Chief · Employee · Miscellaneous >

5. Annual Income
< Less than 3 million · 5-3 million · 7.5-5 million · 10-7.5 million · 15-10 million · 15 million or more >

6. Address. (City · Town · Village)

7. Marriage
< Single · Married >

8. Number of children
Working ( ) , University student ( ) , High school student ( ) , Junior high school student ( ) , School child ( )
child before entering school ( )

9. Please write the car that you own.
Manufacturer Name: A. Toyota Motor  B. Honda Motor  C. Nissan Motor  D. Mitsubishi Motors  
E. Mazda  F. Subaru  G. Isuzu  H. Daihatsu Kogyo  I. Suzuki  J. Benz  K. BMW  
L. Audi  M. Miscellaneous

Model Name: a. Sedan  b. Coupe (Sports car)  c. One box • Minivan  d. Wagon  
e. RV  f. Compact car • Light car  g. Recreational vehicle  h. Miscellaneous

Purchase Reason or Reason why you want to buy.: 1. Design  2. Structure (It is possible to load with a lot of luggage.)  3. Performance (It is flexible., The engine is good.) 4. Sales price  5. Family structure  6. Favorite Manufacturer  7. According to the lifestyle (Hobby etc.)  8. It is good for the environment. (Fuel cost etc.)  9. Area of garage 10. Present (You are presented used car.) 11. Interest rate 12. Maintenance expense (The tax is cheap.) 13. Miscellaneous (Please write in the frame.)
## Appendix 2  Model Ranking Table (Total classification) (CC)

<table>
<thead>
<tr>
<th>Toyota</th>
<th>Nissan</th>
<th>Honda</th>
<th>Subaru</th>
<th>Suzuki</th>
<th>Mitsubishi</th>
<th>Mazda</th>
<th>Daihatsu</th>
<th>Benz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opa</td>
<td>Infiniti Q</td>
<td>CR-X</td>
<td>Impreza</td>
<td>SX4 sedan</td>
<td>Aspire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WILL</td>
<td>Auster</td>
<td>Accord</td>
<td>Impreza-anesis</td>
<td>Aero</td>
<td>Eterna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avalon</td>
<td>Gloria</td>
<td>Ascot</td>
<td>Leone</td>
<td>Cultus</td>
<td>Emeraude</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Sunny</td>
<td>Insight</td>
<td>Legacy</td>
<td>Chevrolet-optra</td>
<td>Carisma</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allion</td>
<td>Cima</td>
<td>Inspire</td>
<td>B4</td>
<td>Chevrolet-cruze</td>
<td>Galant</td>
<td></td>
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<td></td>
</tr>
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<td>Stanza</td>
<td>Integra</td>
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<td>Concerto</td>
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<td></td>
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<td>Saber</td>
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<td>Mirage</td>
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<td>Today</td>
<td></td>
<td></td>
<td>Lancer-evolution</td>
<td></td>
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<td>Crown- comfort</td>
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<td>Torneo</td>
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Consumers’ Activities for Brand Selection