User Behavior Information and Diffusion Process for IC-Card System

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Abstract— **The IC-Chip for IC-Cards (contactless smart card) has various field applications (traffic IC-Card, electronic money, mobile IC-Card, identification, credit card, and cash card) and is capable of high-level functions (security, anti-collision algorithm, multi-functionality, reliability, convenience). The IC-Card has larger information storage capacity than that of the existing magnetic stripe card. Japan's IC-Card (Felica: Sony) is a type of a multi–functional card system devised to resolve many payment problems, to improve public payment service, to build advanced transit information system, to encourage reasonable operation of the public transit company, and to obtain basic information for the formulation of public policy. Japan's IC-Card is applied to various kinds of technologies and services in Japan. In this paper, we discuss the diffusion process and user behavior information regarding Japan's IC-Card system. In this study, we hope to contribute to studies in modern means of public payment based on RFID technology and diffusion process study of IC-Card technology.**

Index Terms—**RFID, IC-Card, Management Information System, Trend, Behavior, Network, Diffusion**

I. INTRODUCTION

Kunitaka Arimura of Japan first saw the use of plastic card and cash transactions in the USA and Japan (1969). When he later realized that IC-Card is much more convenient to use, he applied for a patent for the IC-Card in Japan (1970). The IC-Card has undergone several developments and has found usage in various technologies and services [1]. For example, IC-Cards are used in recording sales in the retail business (CRM: customer relationship management), in passports, identification, traffic cards, mileage cards, cash cards, credit cards, membership cards, and point cards. In particular, the IC-Card is used in electronic money (Edy) and traffic IC-Card in Japan.

The expansion of applications of Japan's IC-Card is described in Figure 1, which shows the evolution of Japan's IC-Card from the introduction of the IC-Card system to the present. We can see the multi-functionalities of Japan's IC-Card from the introduction of system to the present in pubic transportation services. At first, Japan's IC-Card (Felica: Sony) was applied to public transportation services. Felica of Sony was applied to Suica Card (JR: East Japan Railway Company), Pasmo Card (Pasmo Co., Ltd.) of Kanto district and Icoca Card (JR: West Japan Railway Company), Pitapa Card (Kansai Thru Pass) of Kansai district in Japan's public transportation services. In Japan, the traffic IC-Card can be used as electronic money (Edy) and the credit card can be used as traffic IC-Card. Japan's IC-Card system is expected to gain much more importance with the expansion of the subway line, monorail, and high-speed rail.

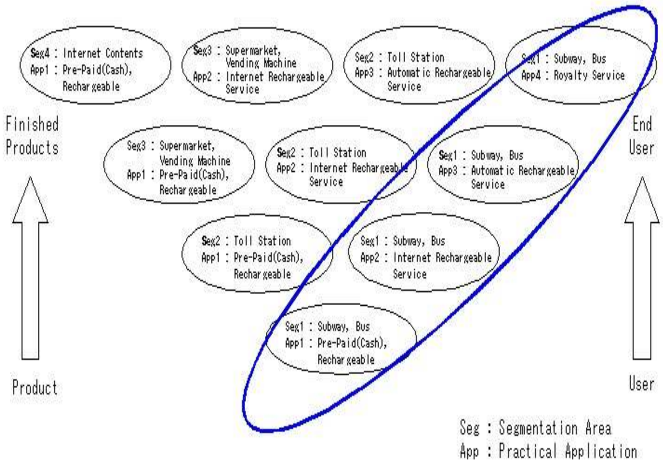

Figure 1. Bowling Alley Model of Japan's IC-Card

The IC-Card system is connected from the IC-Card reader to the main frame of the IC-Card via radio frequency (RF) signals, through which operation is performed, and transaction certification is accomplished by cryptographic algorithm of triple data encryption standard (DES) [2], [3], [4]. The IC-Card system handles payment as well as the prompt processing of off-line transactions [5], [6]. IC-Card (contactless radio frequency) has been used as a new fare payment system implemented to meet the demand of the public for a convenient fare payment process that is faster than magnetic stripe card and cash [7], [8]. IC-Card is contactless and more comfortable to use than the magnetic stripe card. It is widely used throughout the world due to its rapid processing speed, resistance to forgery and physical

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damage, and its potential to create a new business model [9]. In this paper, we discuss Japan’s IC-Card diffusion process and user behavior information in Japan’s IC-Card system. In other similar works, simple demand forecasting had been studied for trend and operation analysis. In this study, we present a demand forecasting model for the accurate study of the diffusion process and user behavior information in order to accurately identify the trend and operation analysis. This study is necessary for the further development of the IC-Card system and RFID technology, formulation of IT policy, studies on public payments, transportation policy, economic policy, and technology marketing.

II. JAPAN’S IC-CARD DIFFUSION PROCESS

A. *Japan’s IC-Card Diffusion Process Model*

Japan's IC-Card was first used as a traffic IC-Card for the subway in 2001. Japan’s traffic IC-Card has been standardized and is compatible with bus and subway. The IC-Card has a very wide range of applications in Japan. In particular, electronic money has become a very popular means of payment since its introduction in 2004.

In this paper, we analyzed the diffusion process of IC-Card (the traffic IC-Card, electronic money) and made a projection of future demand for IC-Card. We studied the demand forecasting model for trend analysis and the future’s demand forecasting of Japan’s IC-Card. The demand forecasting model can accurately analyze future trend for the IC-Card, especially in terms of its monetary value and multi-functionality (the traffic IC-Card, electronic money). We needed to accurately perform a demand forecasting of a multi-functional product as the IC-Card includes the traffic IC-Card diffusion process and electronic money diffusion process. We used the demand forecasting model for Japan’s IC-Card diffusion process analysis. Demand forecasting models are shown in Equations (1), (2), (3), and (4).

y_t = actual value, t = time, α = parameter, e_t = error term

$$y_t = \alpha + \beta\, t + e_t \quad (1)$$

$$y_t = \alpha + \beta_1\, t + \beta_2\, t^2 + e_t \quad (2)$$

$$y_t = \alpha\, \beta^t_1\, t + e_t \quad (3)$$

$$y_t = \frac{10^{\alpha}}{\alpha + \beta_1 (\beta_2{}^t)} \quad (4)$$

We analyzed the diffusion process of the IC-Card (the traffic IC-Card, electronic money) and made a forecast on the future demand for the IC-Card. We analyzed quadratic trend of Japan’s IC-Card by Equations (1), (2), (3), and (4). IC-Card’s quadratic trend and IC-Card’s demand forecasting are described in Figures 2 and 3. We made a forecast on Japan’s IC-Card demand (traffic IC-Card, electronic money) from 2008 to 2009 using Japan’s IC-Card data gathered from the introduction of the IC-Card system to 2007.

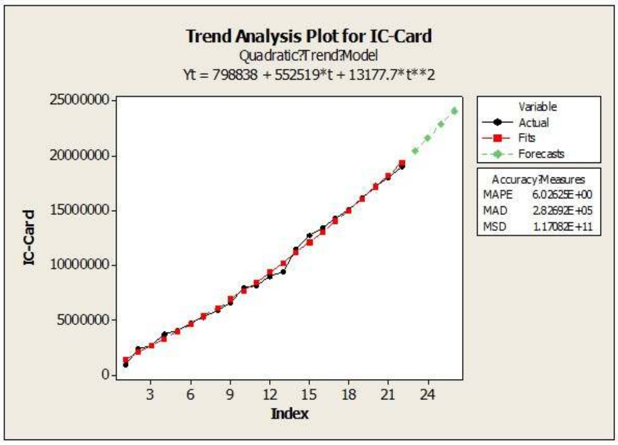

Figure 2. Quadratic Trend Model of Japan’s the traffic IC-Card

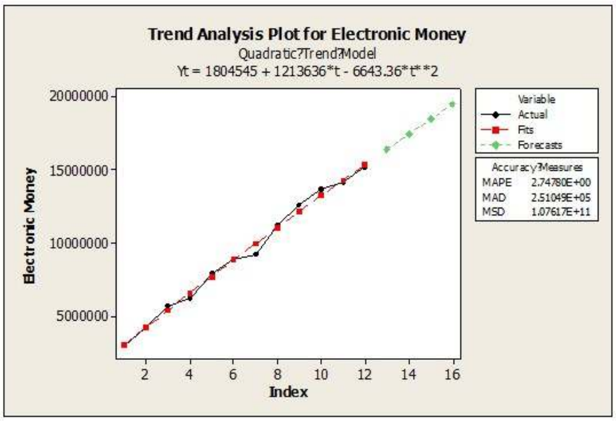

Figure 3. Quadratic Trend Model of Japan’s Electronic Money

Demand forecasting’s result of Japan’s IC-Card (traffic IC-Card, electronic money) by quadratic trend analysis described in Figure 4.

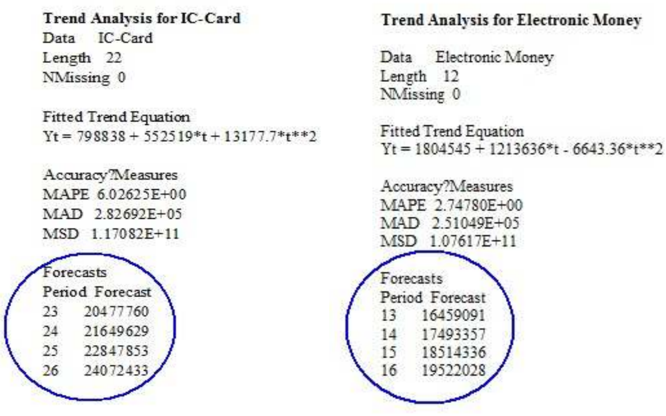

Figure 4. Demand forecasting of Japan’s IC-Card

The accuracy of the quadratic trend model can be measured by mean absolute percent error (MAPE), mean absolute deviation (MAD), and mean squared deviation (MSD). As the value of Equations (5), (6), and (7) decreases, the accuracy of the quadratic trend model increases.

y_t = actual value, $\hat{y}_t$ = forecasting value

$$MAPE = \frac{\sum_{t=1}^{n} |(y_t - \hat{y}_t)/y_t|}{n} \times 100 \quad (5)$$

$$MAD = \frac{\sum_{t=1}^{n} |(y_t - \hat{y}_t)|}{n} \quad (6)$$

$$MSD = \frac{\sum_{t=1}^{n} (y_t - \hat{y}_t)^2}{n} \quad (7)$$

MAPE, MAD, and MSD results of Japan's IC-Card (traffic IC-Card, electronic money) by quadratic trend analysis are described in Figure 5. The analytical result was accurate for trend and demand forecasting. The traffic IC-Card's MAPE value is high because the traffic IC-Card could be used as electronic money and the diffusion process has been changed by external influences.

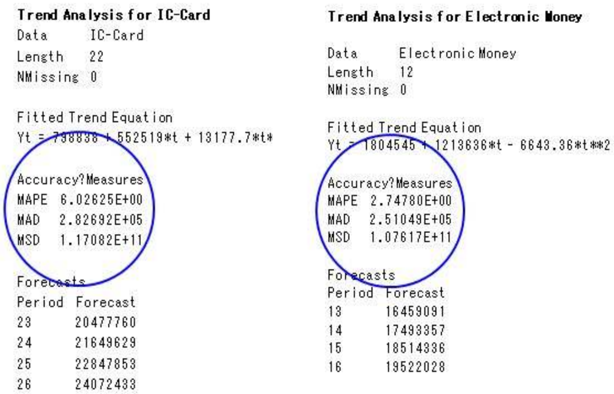

Figure 5. MAPE, MAD, and MSD results of Japan's IC-Card

B. Japan's IC-Card System

The IC-Card is a plastic card embedded with an induction coil and a condenser for the generation of electrical signals. The performance property of the IC-Card is interactive wireless communication between loop antennas in the plastic card [10], [11]. An IC-Card reader can recognize the information on the IC-Card and communicate with it via radio beams [12]. If the distance between card and antenna is 10cm, a radio wave will induce an induction coil in the plastic card and then it will generate enough electricity and save in the condenser [13], [14]. The IC–Card uses this generated electricity and sends the IC–Card's memory chip information to the IC-Card reader by radio wave. Then the IC-Card reader with embedded micro-processor confirms the information [15], [16]. The configuration of Japan's IC-Card is described in Figures 6 and 7.

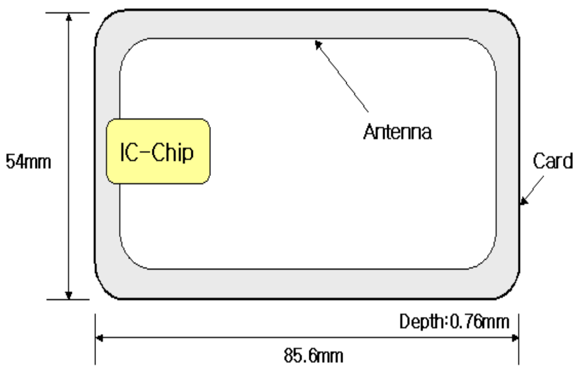

Figure 6. Japan's IC-Card

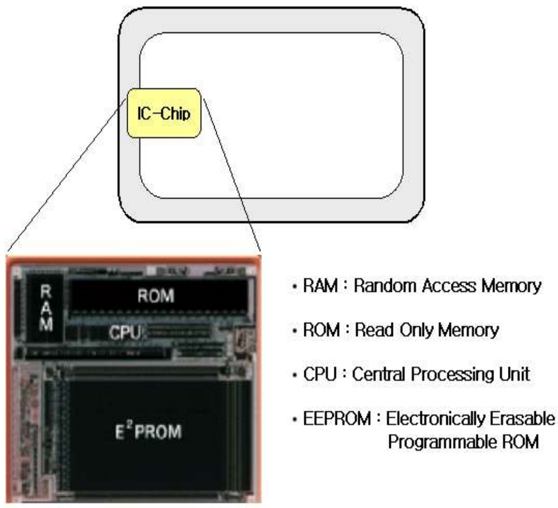

Figure 7. Configuration of Japan's IC-Card

TABLE I.
COMPARISON BETWEEN THE IC-CARD AND THE MAGNETIC STRIPE CARD

Feature	IC-Card	Magnetic stripe card
Configuration	Plastic card, IC-Chip, Antenna	Plastic card, Magnetic type
Memory capacity	Large	Small
Data record	IC-Chip	Magnetic tape
Computing power	○	×
Secret number combination	Writer and IC-Card	Magnetic stripe card reader and central center
Security	Encrypted data used by IC-Card and reader	Lost card and stolen card's confirmation
Eavesdropping	Impossible	Possible
Multi-functionality	A variety of services and practical applications by IC-Card memory	Safety and memory capacity's limitation
Cost	High	Low

Both terminal system and relay station system are connected by the communication network in the IC-Card system. The IC-Card system is connected to all areas and provides services by value-added network (VAN) [17], [18], [19]. The IC-Card system is described in Figure 8.

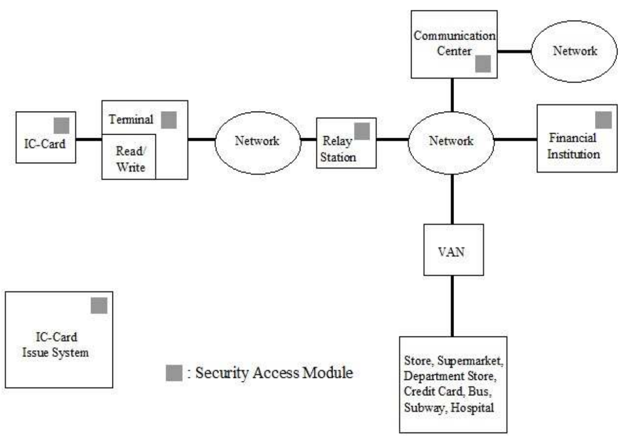

Figure 8. IC-Card System

III. JAPAN'S IC-CARD USER BEHAVIOR INFORMATION

At present, Suica (JR: East Japan Railway Company) is a very popular traffic IC-Card in Tokyo, Japan. The types of Suica cards include the Suica (bus ticket, subway ticket, and commuter pass), Electronics Money Suica (bus ticket, subway ticket, and electronics money), and View Suica (bus ticket, subway ticket, electronics money, and credit card). Mobile Suica has been used in Tokyo, Japan from 2005.

We surveyed users of Japan's IC-Card system and analyzed the behavior of IC-Card users in 2008. We selected Tokyo's Minatoku for the survey on IC-Card users and studied the behavior information of IC-Card users. The IC-Card (bus, subway, and tollgate) is the most frequently used public means of payment in Tokyo, Japan. In particular, Minatoku is a center of Tokyo and it includes the Ginza district. The surveyed IC-Card system is Suica Card (bus, subway) and ETC Card (electronic toll collection system). We surveyed the all-time number of IC-Card users and classified IC-Card users's number on weekday and holiday. Normal distribution was studied for weekday users and holiday users in this data.

We analyzed IC-Card users's number and IC-Card's usage according to various influences, such as traffic, time, infra, social phenomenon, and economic phenomenon. We studied the mutual influence and correlation between weekday users and holiday users by variance. Normal test and variance analysis were used for analysis. Equation (8) is null hypothesis. Equations (9), (10), and (11) are alternative hypotheses. It is necessary to select one for users's analysis.

$$H_0 : \mu_1 = \mu_2 \quad (8)$$

$$H_1 : \mu_1 \neq \mu_2 \quad (9)$$

$$H_1 : \mu_1 > \mu_2 \quad (10)$$

$$H_1 : \mu_1 < \mu_2 \quad (11)$$

We used Equations (12) and (13) for analysis of test's statistic because we could not know σ_1, σ_2 and could know $\sigma_2^2 = \sigma_1^2$. In this case, test's statistic can analyze accurately by Equations (12) and (13).

$$T = \frac{(\overline{X_1} - \overline{X_1}) - (\mu_1 - \mu_2)}{S_P\sqrt{1/n_1 + 1/n_2}} \quad (12)$$

$$S_P^2 = \frac{(n_1 - 1)\, S_1^2 - (n_2 - 1)\, S_2^2}{n_1 + n_2 - 2} \quad (13)$$

In case of Equations (14), (15), and (16), H_0 is rejected and H_1 is selected.

$$\left| T \right| > t_{\frac{e}{2}}\,(n_1 + n_2 \text{-}2) \qquad (14)$$

$$T > t_{\alpha}\,(n_1 + n_2 \text{-}2) \qquad (15)$$

$$T < -t_{\alpha}(n_1 + n_2 \text{-}2) \qquad (16)$$

A. User Behavior Information Analysis of Japan's BusIC-Card

We analyzed bus IC-Card's user behavior information and could see research result by normality test and variance analysis.

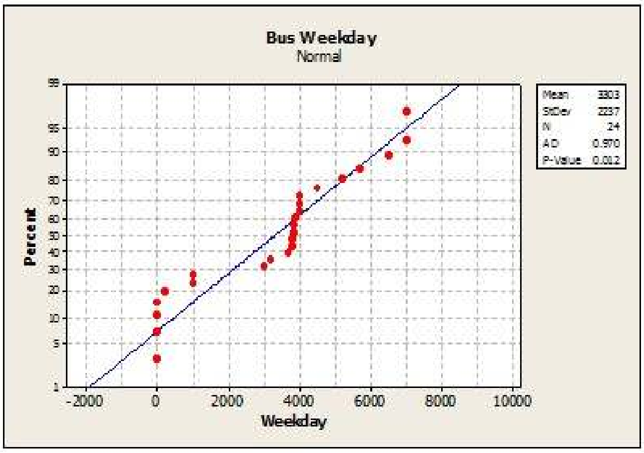

Figure 9. User Analysis of Japan's Bus IC-Card(Weekday)

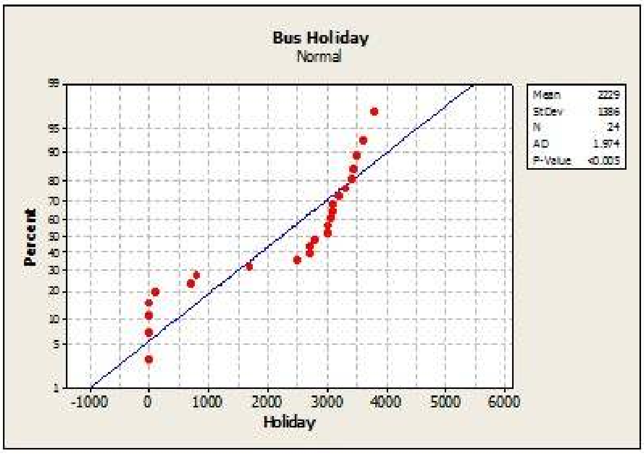

Figure 10. User Analysis of Japan's Bus IC-Card (Holiday)

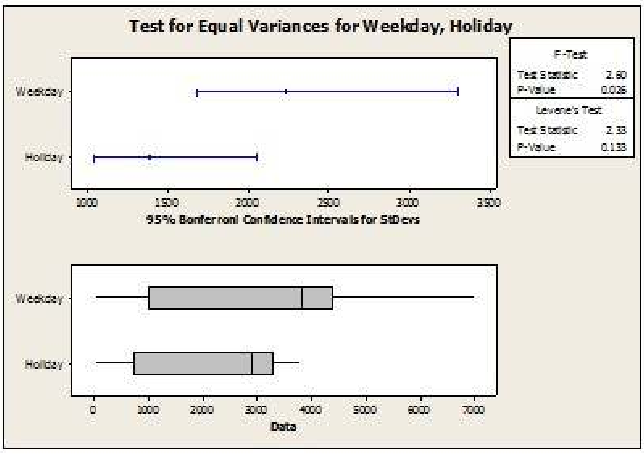

Figure 11. User Analysis of Japan's Bus IC-Card (Variance)

We could see bus IC-Card users's normal distribution by the result of the normality test. Figures 9 and 10 are nonnormal distribution (P-Value<0.05). The result of the analysis shows that bus IC-Card users are concentrated in regular hours on weekday and holiday. It means that IC-Card user behaviors have been influenced by traffic, time, infra, social phenomenon, and economic phenomenon. IC-Card is useful than bus tickets, cash, and card for bus use and applied effectively to the bus operation system.

We could see the normal distribution and variance of weekday and holiday in the result of variance analysis. Figure 11 is nonnormal distribution (P-Value<0.05). We can see IC-Card users's mutual influence and correlation between weekday users and holiday users in the analysis result. Both weekday and holiday are of different variances. Bus IC-Card users are concentrated regular hours but distributional patterns are different in weekday and holiday. It means that user behaviors are different in weekday and holiday. We can see that user behaviors of the bus IC-Card are of a different pattern on weekday and holiday.

B. User Behavior Information Analysis of Japan's Subway IC-Card

We analyzed the subway IC-Card's user behavior information and could see research result by normality test and variance analysis.

We could see subway IC-Card users's normal distribution by normality test's analysis result. Figure 12 is normal distribution (P-Value>0.05). Figure 13 is nonnormal distribution (P-Value<0.05). Analysis result is that subway IC-Card users are distrbuted all times in weekday and concentrated regular hours in holiday. We could see that IC-Card users always use IC-Card in the subway and subway has been the most used public transportation in weekday. IC-Card is useful than subway ticket, cash, and card for subway use and effective public payment for subway use.

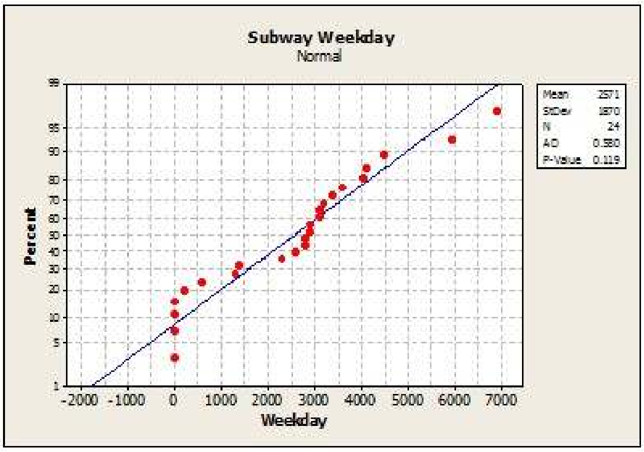

Figure 12. User Analysis of Japan's Subway IC-Card (Weekday)

We could see the normal distribution and variance of weekday and holiday in the result of the variance analysis. Figure 14 shows the nonnormal distribution (P-Value<0.05). We can see IC-Card users' mutual influence and correlation between weekday users and holiday users in the analysis result. Weekday and holiday users are of a different variance. Subway IC-Card users are distrbuted at all times on weekdays and concentrated in regular hours on holidays. The difference in distributional patterns between weekday and holiday reflect the difference in user behaviors on weekdays and holidays. We can see that the behaviors of subway IC-Card users reveal a different pattern in weekday and holiday.

C. User Behavior Information Analysis of Japan's ETC IC-Card

We analyzed ETC IC-Card's user behavior information and could see research result by normality test and variance analysis.

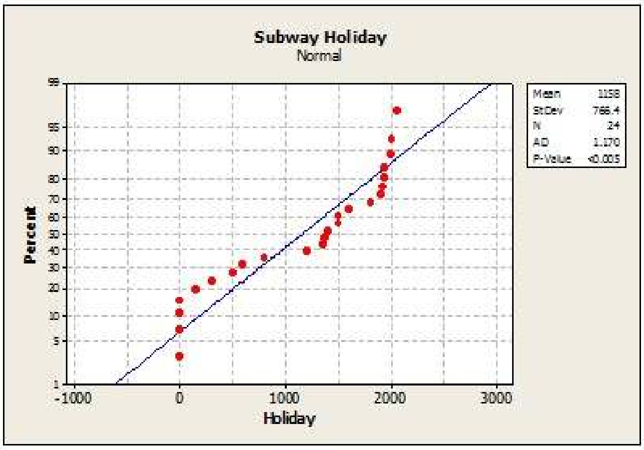

Figure 13. User Analysis of Japan's Subway IC-Card (Holiday)

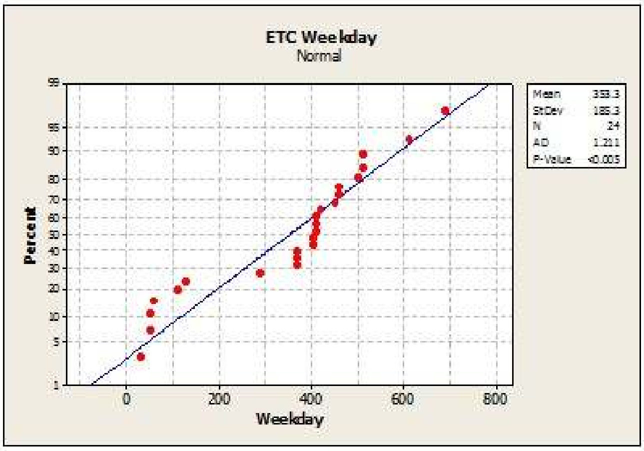

Figure 15. User Analysis of Japan's ETC IC-Card (Weekday)

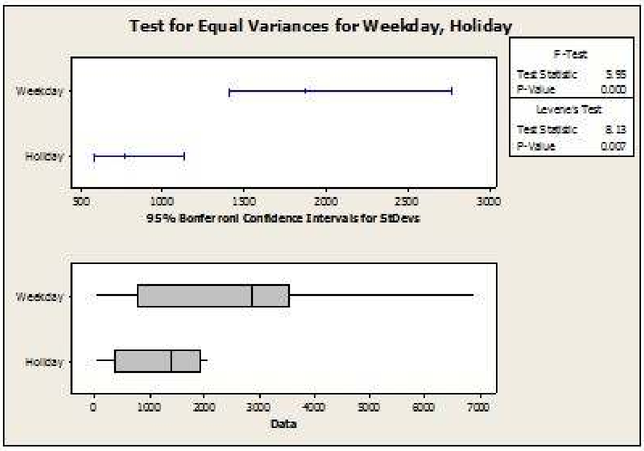

Figure 14. User Analysis of Japan's Subway IC-Card (Variance)

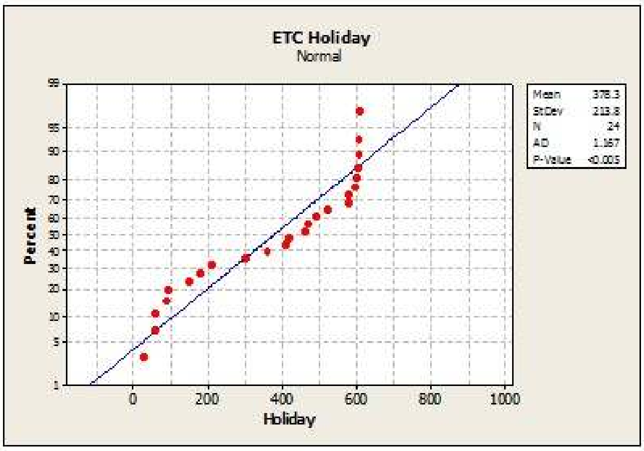

Figure 16. User Analysis of Japan's ETC IC-Card (Holiday)

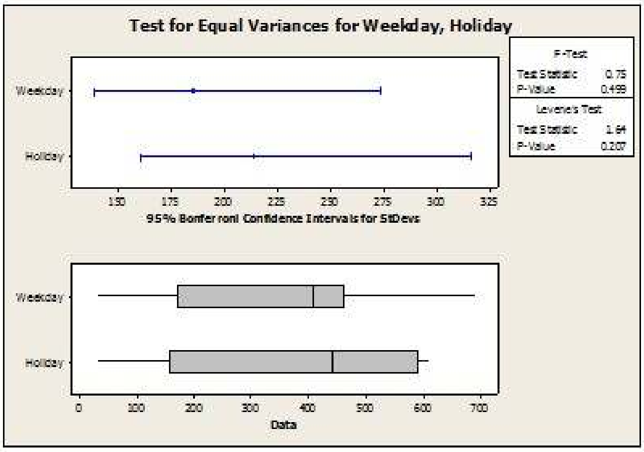

Figure 17. User Analysis of Japan's ETC IC-Card (Variance)

We could see bus IC-Card users's normal distribution by the analytical result of the normality test. Figures 15 and 16 are nonnormal distribution (P-Value<0.05). ETC IC-Card users are concentrated in regular hours on weekday and holiday in the analysis result. It means that IC-Card user behaviors are influenced by traffic, time, infra, social phenomenon, and economic phenomenon. The IC-Card is useful than tollgate ticket, cash, and card for tollgate use and applied effectively to the ETC operation system.

We could see the normal distribution and variance of weekday and holiday in the result of variance analysis. Figure 17 shows the normal distribution (P-Value>0.05). We can see IC-Card users's mutual influence and correlation between weekday users and holiday users in the analysis result. Both weekday and holiday are of the same variance. ETC IC-Card users are concentrated in regular hours and distributional patterns are the same on weekday and holiday. It means that user behaviors are the same on weekday and holiday. We can see that user behaviors of ETC IC-Card users are similar in pattern on weekday and holiday.

IV. CONCLUSION

The IC-Card can be used anywhere, and it is projected to have even more convenient services in the future with further developments in RFID and IC-Chip technologies [20], [21]. As IC-Card started as a payment system, it has contributed to the rationalization of management. It means that a user does not need to pay cash or use magnetic card, thereby reducing payment time and number of workers involved in the operation [22], [23], [24]. In this paper, we studied Japan's IC-Card user behavior information and diffusion process regarding the IC-Card system (bus, subway, ETC). Japan's IC-Card diffusion process was analyzed by quadratic trend, whereas normality test and variance analysis were used in analyzing user behavior. As a result, we could forecast the IC-Card's future demand and analyze the behavior of IC-Card users. This study's analysis result can be used as information for the IC-Card system's further development, multi-functional development, public payments policy decision-making, and technology marketing. In other similar works, simple demand forecasting had been studied for trend and operation analysis. In this study, we studied demand forecasting model for the accurate study of the diffusion process and user behavior information study for accurate trend and operation analysis. This study is necessary for further developments in the IC-Card system and RFID technologies, IT policy, transportation policy, economic policy, and technology marketing.

With this study's findings, we hope to contribute to studies on modern public means of payment based on RFID technology and diffusion process study of IC-Card technology. Future studies should include new means of payment based on mobile RFID system and network information technology.

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