Behavior Change Experiment by Congestion Visualization and Coupons in “Shizuoka MaaS”

Yasushi Sugama[1], Daishin Ito[1], Takayuki Kodaira[1], Ryoji Hattori[1], Takenori Iwamoto[2], Akio Oomae[2]

Sugama.Yasushi@bp.MitsubishiElectric.co.jp
[1]Mitsubishi Electric Corporation, 2-7-3, Marunouchi, Chiyoda-Ku, Tokyo, Japan
[2]Shizuoka Railway Co.,Ltd. 1-1-1, Takajyo, Aoi-Ku, Shizuoka-Shi, Shizuoka, Japan
Keywords: Beavior change experiment, Leveling congestion, Signage.

ABSTRACT

We conducted a demonstration experiment for the purpose of reducing congestion and revitalize commerce. In this experiment, we visualized the congestion prediction result through signage and Web application, and distributed coupons according to the congestion degree. In this paper, we show the details of the experiment and the experimental results.

1 Introduction

1.1 Congestion issue in Japanese railway

Railway is most important transportation for commuting in Japanese urban area. But, at the same time, it occurs terrible congestion. Reducing congestion is very important issue for passenger comfort, safe operation, and scheduled operation. Best way to reduce congestion is increasing transportation capacity, but it is sometimes difficult for budget and geographical problem. Actually, railway company has been working on reducing congestion, but it is not improved because transportation capacity has been saturated since 2003 in Tokyo area, since 1998 in Osaka area, and 1993 in Nagoya area [1]. Alternative way to reducing congestion is leveling, that is, changing passenger use from peak time to other. Congestion occurs departure specific time, train line, and certain railroad car, therefore, if many passengers avoid such specific case, we can realize reducing congestion.

In capital area, there are some experiment to level congestion [2]. These experiments prompted passengers to change railway line or railroad car by visualizing congestion. However, in local city area, there are not many trains compared with capital area, therefore we have to prompt users to change time of using railway to avoid congestion.

Therefore, we conducted experiments to level congestion for prompting people to change time of using train in “Shizuoka MaaS”. We visualize not only current congestion, but predicted future congestion in station signage and smart phone app, and we also designed coupon system that people can get better coupon in uncrowded time through QR code displayed in signage.

1.2 Shizuoka MaaS

"Shizuoka MaaS" is a consortium established in 2019 with the aim of providing new mobile services that are easy for everyone to use and sustainable town development, with Shizuoka Railway Co., Ltd. as the representative secretary. it is aiming for a society where people can easily move without being overly dependent on private cars, and for revitalizing the local economy and improving productivity by utilizing ICT technology.

2 Experiment detail for leveling congestion

2.1 Outline

Through November to December 2020, we conducted two experiment as “Shizuoka MaaS”. One is "Congestion visualization experiment" in which visualize predicted future congestion, and another is "Virtual dynamic pricing (DP) experiment" in which good coupons are provided to passengers at uncrowded time. Both of experiments are conducted for the purpose of reducing congestion and activation of the local economy in Shizuoka MaaS.

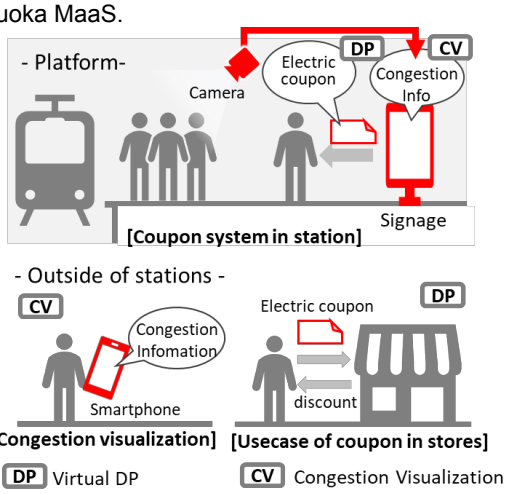

Fig. 1 Outline of experiments

Figure 1 shows the outline of experiments. The main items implemented for these experiments were congestion measurement function from station cameras, train congestion prediction, and distribution system for electronic coupons. We selected five main stations of the Shizuoka-Shimizu Line for this experiment (Shin-shizuoka, Pref. Sports Park, Kusanagi, Kitsunegasaki, and Shin-shimizu).

2.2 Congestion visualization experiment

In the congestion information experiment, we displayed the predicted train congestion up to 1 hour later and congestion of the next day on signage installed at the main station of Shizuoka Railway and on web site of Shizuoka MaaS.

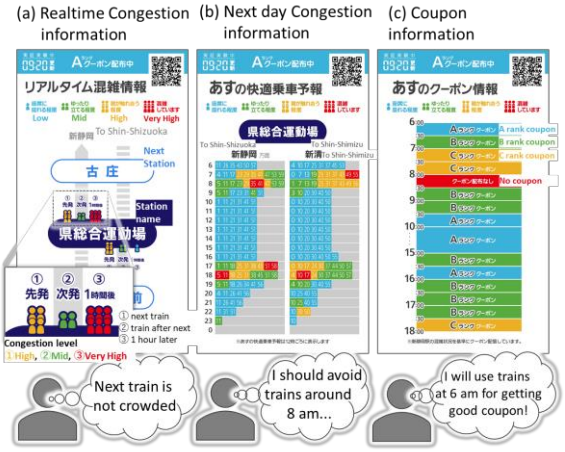

Fig. 2 Displayed contents in signages

Figure 2 shows an example of the content we displayed. As shown in Figure 2 (a) and 2 (b), we aimed to encourage passengers to avoid busy hours by providing congestion information.

In order to provide the congestion information, we considered estimation and prediction algorithm. The algorithm estimates congestion inside train from measuring congestion in platform of station by image analysis of camera. And it predicts future congestion inside train from congestion data derived at each station. By this prediction algorithm, we don't need to derive the congestion inside train directly, therefore the congestion prediction system could be made easily compared with the case where we installed camera inside train.

2.3 Virtual DP experiment

In the virtual DP experiment, electronic coupons were distributed as rewards to passengers. As shown in Figure 2 (c), the purpose of this experiment is to encourage passengers to avoid crowded hours by coupons with a higher discount rate during the vacant hours. By targeting the coupons to stores around the Shizuoka Railway, we also aimed to revitalize commerce along the railway lines.

The electronic coupon can be obtained by reading the QR code displayed on the signage by dedicated app, and when using it at the store, user reads the QR code installed at the store by dedicated app. Because users register the ID of the IC card "LuLuCa" arbitrarily, we can analyze time of coupon acquisition, use history and ticket gate entry history of the user.

2.4 System diagram

Figure 3 shows the system diagram applied in this experiment. Cameras and servers for congestion measurement and signages were installed at each station. Congestion measurement of each station is executed in real time, and the results are sent to the central server via VPN. The central server integrates the congestion measurement results of stations in order to predict in-train congestion, and construct display contents and distributes it to each station signage. In addition, the content is also distributed to the Web server so that the congestion prediction information can be viewed on the Shizuoka MaaS website and dedicated application.

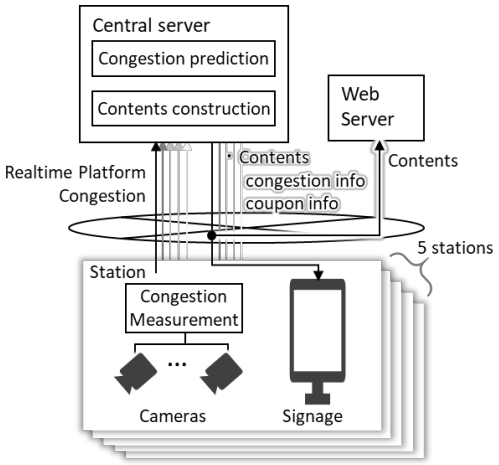

Fig. 3 System diagram

2.5 Congestion measurement from camera images

A general congestion measurement technique is a detection-based method that detects individual people in a crowd and estimates the number of people. Although this method is effective when the degree of congestion is low, it is difficult to estimate the number of people because the accuracy of person detection is reduced by overlap each other when the degree of congestion is high.

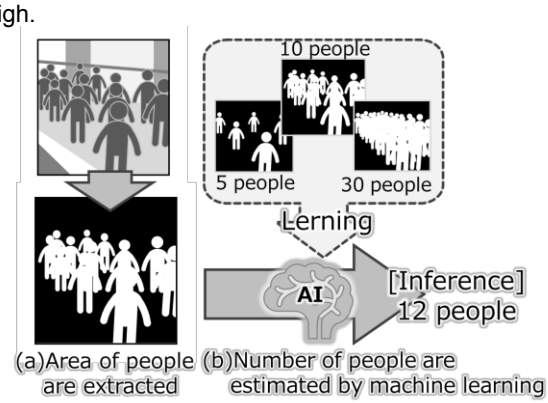

Fig. 4 Outline of congestion measurement algorithm

On the other hand, our technology extracts crowd area from the image by comparing background image taken in advance with the crowd image (Fig. 4(a)) and learns the relationship between the density per area of

the crowd area and the number of people (Fig. 4(b)). Since the crowd area where people overlap each other can be also learned, it is possible to accurately estimate the number of people even during high congestion. By applying the detection-based method during low congestion and by applying this technology during high congestion, we achieved highly accurate estimation for various congestion situations.

2.6 Congestion prediction

Measuring the degree of congestion in train vehicle directly is difficult problem because we must install cameras in each train vehicle. Furthermore, even if the current congestion status is measured and provided, it is useless information for passengers already waiting in station so does not lead to behavioral change.

Therefore, we considered a prediction algorithm which predicts future congestion of train vehicle from the real-time congestion measurement result by the camera of the station platform. In order to realize this method, it is necessary to make prediction model learn a large amount of the relationship between the degree of congestion in the platform and the degree of congestion in the train vehicle. There for, we constructed the prediction model by generating a pseudo-congestion degree in the past platform and train from the past ticket gate entry and exit data and using this as learning data, as shown in Figure 5.

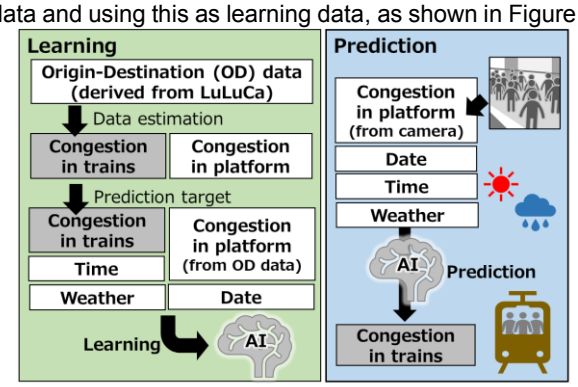

Fig. 5 Outline of congestion prediction algorithm

Table 1 shows the results of evaluating the congestion prediction accuracy during this experiment. In this experiment, the degree of congestion is presented in 4 ranks (0 to 76 people / vehicle, 77 to 187 people / vehicle, 188 to 256 people / vehicle, 257 people / vehicle or more). We used classification accuracy of the rank and average absolute error of the number of passengers as evaluation index. In both of the prediction result (on the next day and next train), we achieved over 90% accuracy.

Table. 1 Prediction accuracy of next day prediction and next train prediction

	4 rank accuracy	Mean absolute error
Next day	90.9%	15.0/ car
Next train	94.0%	11.0 /car

3 Experimental results

3.1 Effect of visualizing congestion

At first, we explain analyzation results of passengers' behavior change in the "congestion visualization experiment". We had to consider the impact of the spread of COVID-19. From the end of October to the end of January, the number of weekday users of the Shizuoka Railway decreased in line with the spread of infection (decreased by 9.2% from October 26th to January 25th). In analyzing the effect of this experiment on congestion leveling, it was necessary to exclude the effect of this natural decrease in the number of users. Figure 6 shows the congestion level of trains departing from and arriving at Shin-shizuoka from October to January. From this data, it is difficult to determine whether the morning peak has leveled congestion or simply the number of users has decreased.

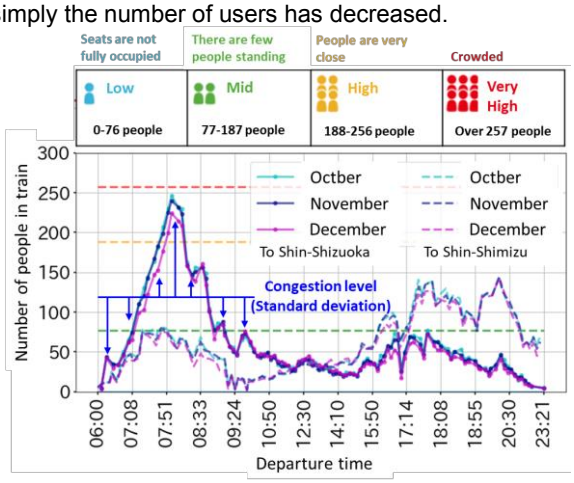

Fig. 6 Number of arrival / departure passengers in Shin-shizuoka station

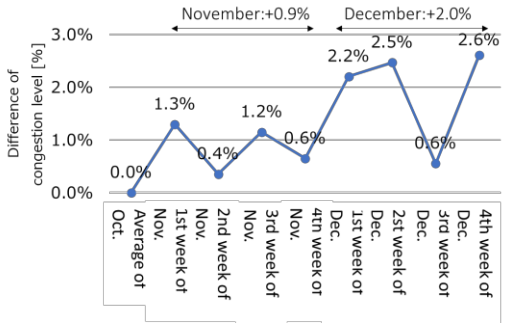

Fig. 7 Difference of congestion level

Therefore, we defined an index of congestion level and evaluated the effect in this experiment. The congestion level is a value obtained by normalizing the number of passengers in the morning and calculating the standard deviation of the distribution of passengers in trains arriving at Shin-shizuoka Station on weekdays from 6:00 to 10:00 AM. By using the congestion level, the influence of the natural decrease in users was excluded, and how the morning peak changed before and after the

demonstration experiment was quantitatively measured.

Figure 7 shows results of the congestion level during the experiment period based on the congestion level in October. The congestion level until December was improving, and it can be inferred that this experiment was effective. Furthermore, in order to verify the certainty of this congestion level improvement, we performed a significant difference test on the distribution of departure times of users in October and December (6: 00-10: 00 AM). We defined behavior change as user meet both of following conditions. (1) there is a significant difference in the student's t-test[4]. (2) Average departure time of each user during this experiment is away more than 5 minutes from the peak time (7:40) compared with the time before the experiment. Table 2 shows the analysis results of congestion avoidance behaviors. We could find that 7.1% of users were avoiding congestion by this analysis.

Table. 2 Result of behavior change

	Number	Ratio
Users which used train in both of Oct and Dec	6958	—
They did not avoid congestion	6465	92.9%
They avoided congestion	493	7.1%

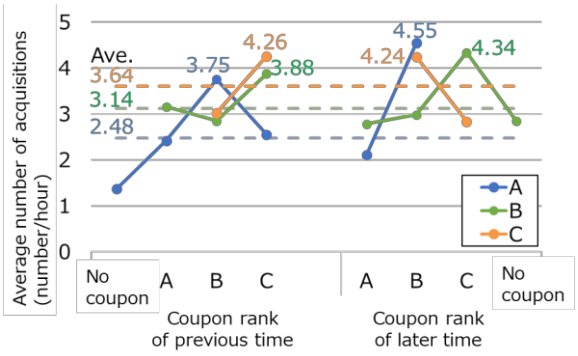

Fig. 8 Factor-effect diagram of coupon

3.2 Effect of coupons

We analyzed how much the behavior change of users were promoted by the "virtual DP experiment". Figure 8 shows the factor-effect diagram. From diagram, we can see that "A rank coupon before B rank coupon" was the most acquired (4.55), and "B rank coupon after the C rank coupon" was also acquired (4.34). That is, we found that there were users who avoid the peak time to get the better coupon.

3.3 Effects on commercial revitalization

At last we explain the effect of "virtual DP experiment" on commercial revitalization. The index of commercial revitalization was defined as the effect of sending customers to the city area by coupons, and we measured the effect of sending customers by comparing the behaviors of users with and without coupon acquisition from ticket gate history.

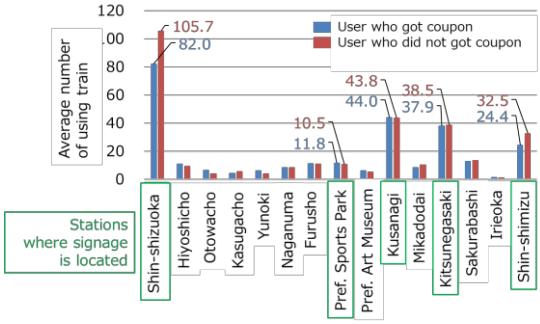

Fig. 9 Coupon effect for number of using train

Figure 9 shows the results of extracting the entry and exit history of the days with and without coupon acquisition. As a result, Average number of using train in the case where people obtain coupon was higher than the case where people did not obtain coupon in Shin-shizuoka and Shin-shimizu. In this analysis, there is a problem that it is not possible to distinguish between "whether the movement increased due to the coupon" or "whether the person who originally planned to shop acquired the coupon". In the future, it will be necessary to verify the coupon effect in a form that eliminates such bias by methods like RCT[5].

4 Conclusions

We conducted a congestion visualization experiment and a virtual DP experiment for the purpose of leveling train congestion and revitalizing commerce. We found 7.1% users avoided congestion by these experiments. In the questionnaire after experiment, 7.8% of users answered that they avoided congestion. We think this result also guaranteed the effect of our experiment. About commercial revitalization, it was confirmed that visits to Shin-shizuoka was increased by 29.0% (82 to 105.7) when the coupon was obtained. Shizuoka MaaS will continue to conduct experiments that can contribute to public transportation and revitalization of the local economy.

References

[1] "Changes of average congestion ratio and transport capacity of major railway sections in three major metropolitan areas" (Japanese) https://www.mlit.go.jp/common/001382427.pdf

[2] Inoue, Kodaira, Hattori, and Harada, "銀座線渋谷駅「混雑度の見える化」実証実験", (Japanese) JREA 63(8), 44300-44304, (2020)

[3] "群集解析技術", (Japanese) Mitsubishi Electric technical journal ,Vol.95,No.1, p.77 (2021)

[4] "The t-test and Basic Inference Principles" https://www.stat.cmu.edu/~hseltman/309/Book/chapter6.pdf

[5] "Randomized Controlled Trials" https://www.unicef-irc.org/publications/pdf/brief_7_randomized_controlled_trials_eng.pdf