Application of Pedestrian Flow Simulation to Railway Station Layout Design

—An Approach Based on Collaboration with Customers

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OVERVIEW: Designing the line of flow through railway stations needs to consider not only safety, security, and ease of movement, but also how to encourage people into the shopping areas inside the station and deal with changes in the people using the station resulting from redevelopment of nearby areas. Whereas dealing with changes like these has conventionally drawn on on-site experience, Hitachi is working on establishing communication design methodologies for railway stations that can be used jointly with customers and utilize PDCA based on pedestrian flow simulation. This facilitates collaboration with customers by predicting outcomes and visualizing improvements based on observation and analysis of behavior and pedestrian flow simulation. A field trial of this method has been running since September 2009 at Kintetsu Corporation's Osaka-Uehommachi Station where a redevelopment of the surrounding area is planned.

INTRODUCTION

URBAN developments in Japan including redevelopment projects are creating a large number of multi-purpose spaces that aggregate various different functions including office, residential, and commercial facilities. Meanwhile, the increasing prevalence of commercial areas inside station buildings is transforming the railway station away from simply being a place through which people pass and giving it the characteristics of a place where people also linger and consume. The movement of people in such multi-purpose spaces is no longer a simple matter of going directly toward the desired destination and instead includes a wide range of other behaviors such as browsing through retail areas or lingering around events or other points of interest.

Managing this increasingly complex pedestrian movement appropriately can increase both comfort and profitability and in doing so enhance the value of the multi-purpose space. Against this background, Hitachi has been working on the development of pedestrian flow simulation technology in collaboration with Yokohama National University, East Japan Marketing & Communications, Inc., and MOSAIC Co., Ltd.

This article describes the application of this pedestrian flow simulation technology to the internal design of a railway station in collaboration with customers.

OVERVIEW OF PEDESTRIAN FLOW SIMULATION TECHNOLOGY

Calculation Algorithm

Unlike past fluid-based models which were aimed mainly at analyzing the behavior of people evacuating during an emergency, this work used a mathematical model of a type known as a "cellular automaton" to deal with the complex and diverse movement of people (see Fig. 1).

A cellular automaton model can reproduce the

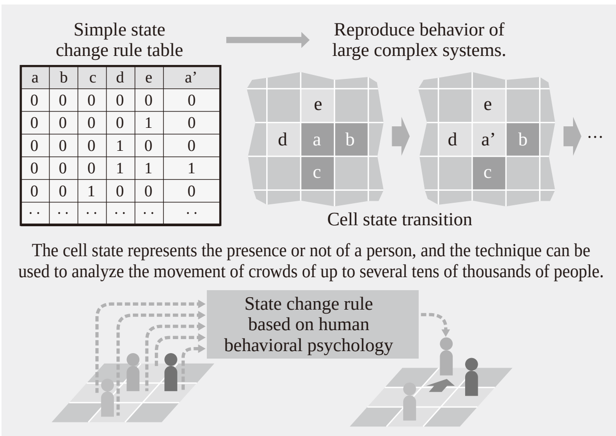

Fig. 1—Computational Model for Pedestrian Flow Simulation.
The movement of people is modeled using a grid of cells in which the cell state, which represents the presence or not of a person in the cell, changes based on the state of adjacent cells.

diverse movements of a crowd using a grid of cells in which the state of each cell changes in response to the state of the adjacent cells. The cell state represents whether or not there is a person in that cell, and where a person in a particular cell will move to next is determined by a state change rule based on the states of the adjacent cells and people's behavioral characteristics. Simplifying individual behavior in this way allows the behavior of crowds of tens of thousands of people to be calculated rapidly.

Simulation Input and Output

The first step in pedestrian flow simulation is to define the spatial layout which includes things like walkways, walls, and stairways, and to augment this with the locations of information signs and other guidance information and also "attractors" (things which draw people to them) such as stores or events. The simulation then reproduces the flow of people when a crowd moves through this defined space, with the crowd being defined by the number of people entering the area. The user can then evaluate the flow of people predicted by the simulation in various ways such as an animation giving an intuitive impression, the level of congestion in each area, or as a numeric indicator indicating how often people cross each other's path.

EFFECTIVENESS OF RAILWAY STATION PEDESTRIAN SIMULATION AND POTENTIAL ISSUES

Diverse Requirements for Railway Station Spaces

Railway stations have traditionally been spaces that value functionality so that people can get to where they are going. Accordingly, major considerations in the design of pedestrian routes' line of flow and the provision of guidance information have included the efficiency and comfort of this movement and ensuring it can be done safely and with confidence.

However, against the background of an aging society with shrinking population and falling demand, railway operators are, in addition to providing transport services, becoming increasingly active in the fields of distribution and real estate where they can take advantage of their superior location, existing assets, and other attributes. With social changes such as people's values becoming more diverse and growing demand for leisure travel (travel for personal reasons such as tourism, shopping, or other interests), there is an increasing expectation from users that railway stations will engage them at a more emotional level rather than just being a place one passes through.

Also, because railway stations are an important venue for the activities people undertake in their daily lives, they need to adapt in a timely way to changes in expectations and other aspects of how they are used brought about by redevelopment or other changes in surrounding precincts.

Effectiveness of Pedestrian Flow Simulation

Responding to this growing diversity and other changes requires meticulous preplanning. For example, ease of movement is a top priority for station users and it is necessary to avoid making the addition of new shops to an existing concourse a cause of disorientation, confusion, and people crossing paths. Similarly, the location of new signage needs to consider how to avoid its being a cause of people being bunched together, lingering, or crossing routes.

However, when one considers the wide range of relevant factors mentioned above, there is a limit to how far on-site experience can be used to estimate the ultimate effect that changes like the addition of new shops or the installation of new signage on will have on the flow of people.

Using pedestrian flow simulation technology to take a scientific and quantitative approach to this planning opens up new possibilities for using the space in railway stations by making it possible to predict the actual changes in the flow of people that will occur in response to changes to the station environment, which may include its signage or spatial layout, or changes to the number and nature of station users resulting from nearby redevelopments (see Fig. 2).

Challenges for Implementing Technology

The application of pedestrian flow simulation requires an analysis of the current situation to be conducted from a range of perspectives. Specific examples include profiling and other behavioral analysis of station users, determining the current pedestrian flow and use of space at the station, and identifying what is happening in the surrounding environment together with analysis of its impact on station use. This not only obtains the pedestrian flow, pedestrian numbers, future changes, and other base data required by pedestrian flow simulation, it also helps clarify what it is that needs to be investigated using the technology.

What is also essential when considering potential measures identified by this work is to conduct joint investigations by working closely with the railway

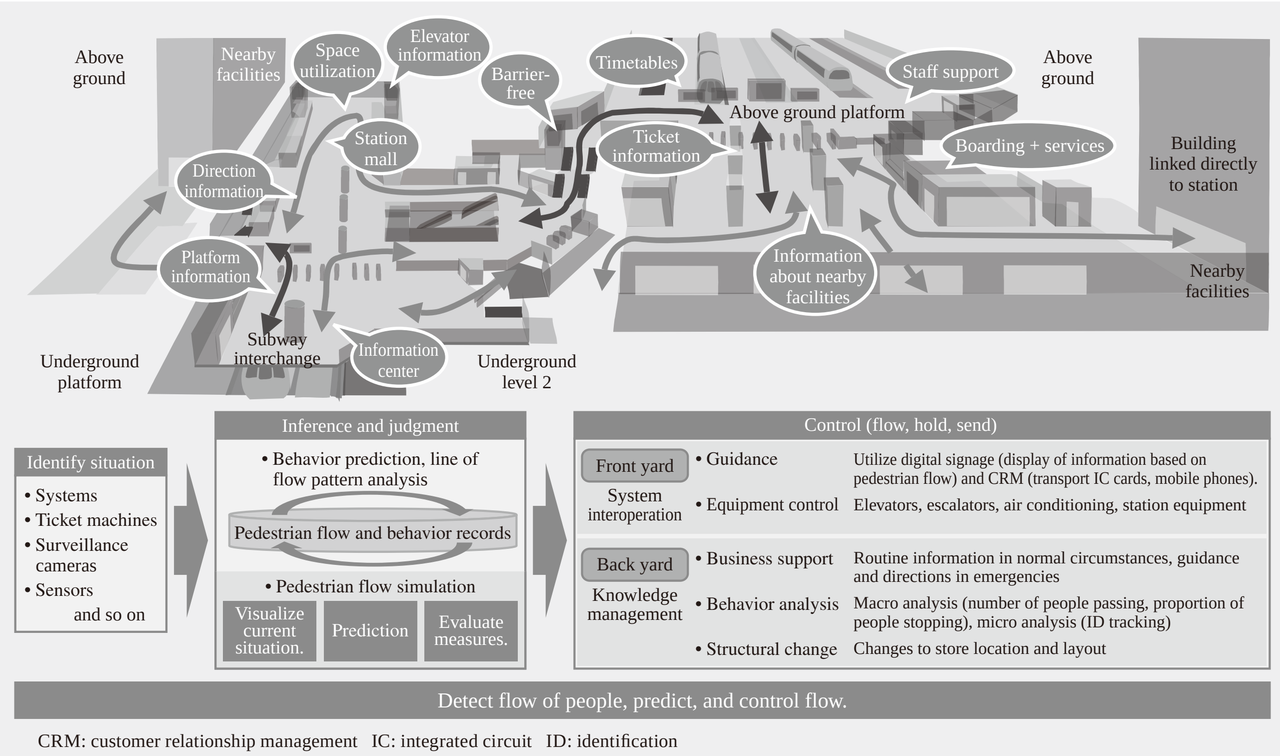

Fig. 2—Communication Design for Railway Station Utilizing Pedestrian Flow Simulation.
Techniques such as behavior sensing, behavior surveillance, and interviews with people can be used to identify changes in requirements for the station and how it is used, and can also be a source of ideas for potential improvements. By combining this with pedestrian flow simulation, it becomes possible not only to predict people's behavior but also to progress toward a spatial communication design in which the layout of pedestrian routes can adapt dynamically.

operator responsible for the station, in other words, to have a framework for customer collaboration.

USE OF PEDESTRIAN FLOW SIMULATION FOR STATION SPACE COMMUNICATION DESIGN

PDCA-based Approach in Collaboration with Customers

The PDCA (plan, do, check, act) cycle is a problem solving technique that transforms implicit knowledge into formal knowledge and Hitachi has adopted an approach that combines PDCA with customer collaboration. Specifically this is a creative process that involves (1) "sharing of site information" obtained through interviews and surveys of actual use, (2) "utilization of knowledge from within the organization" obtained through brainstorming sessions, (3) "visualization, externalization, and formalization" through prototyping technology and making the situation visible, and (4) "product commercialization" through creative thinking.

The "station space communication design" affects numerous different businesses and users and it is important to adopt an approach that involves collaboration with the customer and can deliver value creation while at the same time utilizing the above process to engage these groups and convince them of the value to be delivered with respect to their various perspectives.

Combination of Pedestrian Flow Simulation Technology and Design Capabilities

A typical way of gaining a customer's perspective is to undertake a qualitative analysis to define the problems in a systematic way and identify the issues through an analysis of written and oral records, photographs, video, and other recordings together with visual observation of user behavior.

A deeper commonality of view and creation of value in collaboration with the customer can be anticipated by combining the insights provided by pedestrian flow simulation with those obtained from this qualitative analysis and then working through the PDCA cycle while also undertaking comparative studies involving the use of simulation to perform quantitative evaluations of the different potential solutions to the issues identified by qualitative surveys and analysis.

PRACTICAL TRIAL

Overview of Osaka-Uehommachi Station

Kintetsu Corporation's Osaka-Uehommachi Station consists of an above-ground rail terminal building and an underground interchange station and is used as a through-station or transfer point by many passengers. The movement of users within the station is complicated by the location of ticket gates both above and below ground. Also, a plan to open a cultural and commercial center constructed at the station site as part of a redevelopment project is anticipated to result in a dramatic increase in the number of train passengers using the station and major changes in user behavior.

Survey of User Behavior

The first step was to undertake qualitative and quantitative surveys based on on-site observation in order to conduct profiling and other behavioral analysis of station users and to determine actual pedestrian flows.

Survey personnel were positioned at 10 locations inside the ticket gates to collect traffic counts and records of pedestrian routes. The survey was split into three time periods consisting respectively of a morning period starting after the end of the weekday morning commuter rush, an afternoon period when the number of users is low, and an evening period when large numbers of commuters are returning home. The survey of pedestrian routes recorded information such as the path they took past eight designated points and places where they paused their journey. This data was collected for a total of 706 people. Also, detailed visual observations were collected on the subjects' age bracket, gender, activity at places where they paused their journey, what they did after moving on, and so on.

This survey provided an understanding of the flow of passengers and the pattern of their movements inside the ticket gates and was also used to determine "wandering," "pooling," "coordinated," and "mixing" behavior patterns (see Fig. 3).

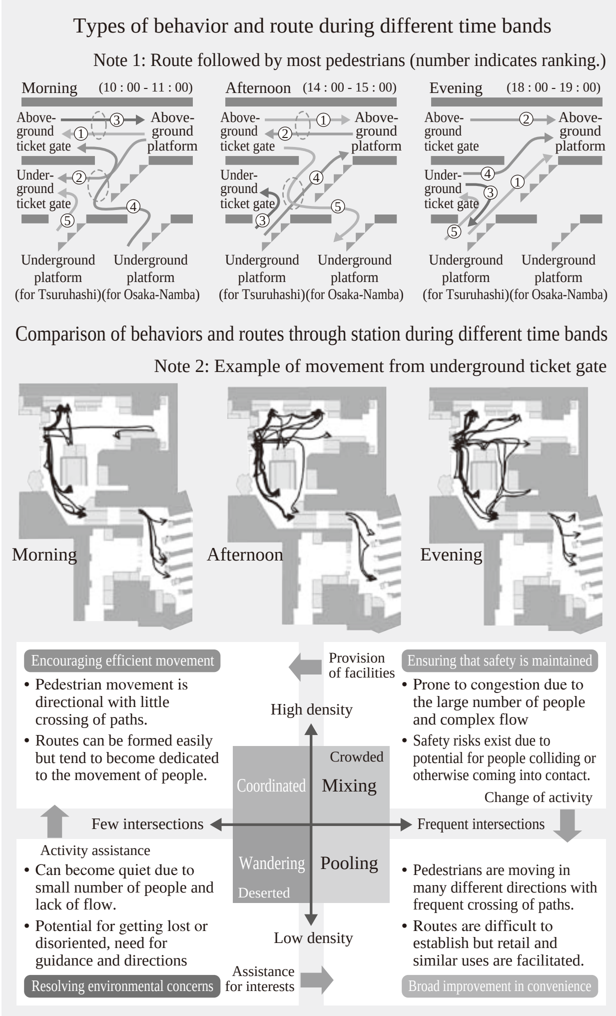

Fig. 3—Pedestrian Routes and Patterns of Behavior inside Ticket Gates Identified by Behavior Survey.
Pedestrian routes were markedly different depending on the time period and characteristic behaviors were evident. It is necessary to set targets for the solutions of the problems associated with the behavior patterns at each location.

Consultation with Station Stakeholders

To determine the views of station users which could not be ascertained by visual observation, vox pop interviews were conducted with 233 people both inside and outside the ticket gates and on both weekends and weekdays during the three time periods. The interviews selected station users who had exhibited "lost or disoriented," "restricted or burdened," "group rendezvous," or "comparison shopping" behavior and asked questions such as the purpose of their visit and whether they had any suggestions or comments about the station.

Profiling of station user behavior and an analysis of the effect that opening the redeveloped building would have on the station surroundings were performed based on the results of this survey to understand the problems and identify the issues. The results of this analysis showed that the "lost or disoriented" and "comparison shopping" categories had characteristic behaviors.

Station Space Communication Design

Brainstorming and idea exploration sessions were held to review the analysis results and one idea in particular that was investigated was the installation of mobile digital signage in the area inside the ticket gates which was seen as a problem solution by both station users and station stakeholders. The aim was to reduce the number of station users who become “lost or disoriented” and improve “comparison shopping” by using the signage primarily to provide directions and guidance to station users or, when used by retail staff from the station mall or station personnel, as a way of providing information.

To provide a visual representation of how the positioning of the mobile digital signage would change pedestrian routes, the pedestrian flow simulation was used for prototyping. The results showed how changing the location of the signage could encourage people toward shops in the station mall that were not easy to notice and so unlikely to attract visits from passers-by, and could also solve problems with the congestion of passageways in the vicinity (see Fig. 4).

Providing a visual representation of numerous problems and potential solutions achieves value creation and a common understanding among the people concerned and discussions continue aimed at practical application at the site.

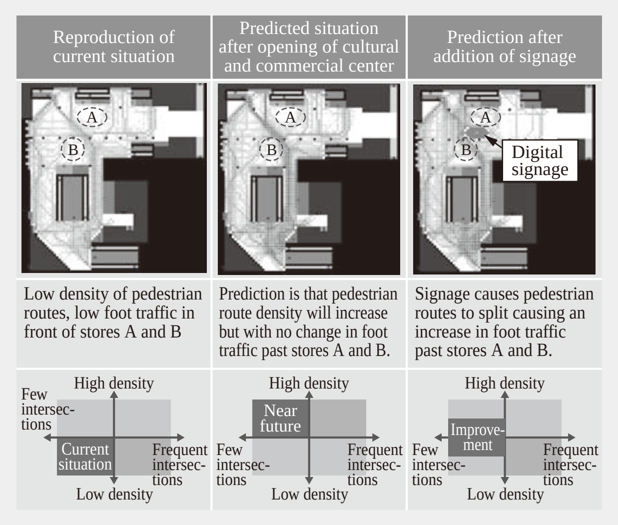

Fig. 4—Changes in Pedestrian Routes Predicted by Simulation.
Use of mobile digital signage to disperse the increased foot traffic caused by the opening of the cultural and commercial center is expected to increase foot traffic past the stores (A and B).

CHALLENGES AND FUTURE APPLICATIONS

The pedestrian flow simulation works by specifying the factors such as attractors that affect people’s behavior and then presenting the consequent calculation results. Determining which elements of the actual space should be set as attractors and the extent to which they affect behavior requires measures such as observing behavior or conducting interviews at actual sites as described above. Creative measures are also required to apply in practice the potential improvements and other ideas obtained from the simulation. Using trials like this to accumulate know-how on the identification and embodiment of attractors is one of the challenges for the future.

On the other hand, real-world sensing techniques that use various types of sensor to detect people’s behavior and digital signage that can present various different types of information depending on time, location, and circumstance are increasingly practical technologies and are entering wider use. Combining this technology with technology for pedestrian flow simulation opens up the prospect of new types of space communication design that incorporate prediction of people’s behavior and in which the layout of pathways through the space can change dynamically.

CONCLUSIONS

This article has described the application of pedestrian flow simulation technology to the internal design of a railway station in collaboration with customers.

Against a background of demand for the creation of new value as society matures, Hitachi will continue to contribute to value creation in railway stations and a wide range of other public spaces from the specific perspective of pedestrian flow design.

Hitachi would also like to express its deep thanks to everyone involved at Kintetsu Corporation who not only willingly provided a site for trialing the pedestrian flow simulation technology but also offered valuable input from an on-site perspective.

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