New Frontiers in Regional Science: Asian Perspectives 39

Yasuhiro Kawahara
Saburo Saito
Junichi Suzuki *Editors*

The Social City

Space as Collaborative Media to Enhance the Value of the City

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New Frontiers in Regional Science: Asian Perspectives

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Preface

Today, as cities worldwide are equipped with networks to implement the IoT, we can communicate seamlessly between the real and virtual worlds. With such an infrastructure, urban development and evaluation methods are entering a new phase. By grasping the ever-changing situation of the city and the behavior of the people in the city, and by building a CPS (Cyber-Physical System), it will be possible to provide the people in the city with the appropriate information in the right place at the right time. This information is created through a cloud system that interfaces with the city to provide customized information to every individual. Therefore, a city that is both functional and attractive to people would be the one that is equipped with software to create and communicate this kind of information in real-time and hardware to make the most of it.

To provide a concrete perspective in this book, we discuss this new direction of urban development, emphasizing physical and social communication from the perspective of the people involved in the city. For example, we discuss how we can evaluate the city's value as the intangible asset value of its attractiveness that people have embraced in their minds through their experiences. Also, we discuss how we can build a system that enhances the city's value by utilizing communication tools such as IoT technology and social networking services. In this book, we refer to the concept of "The Social City" as a city that uses information and communication technology to promote communication between people and between people and the city in real space to revitalize the city. While elaborating on the conceptual framework of "The Social City," each chapter provides an outlook by introducing specific research cases.

When we reconsider the modern urban development based on this concept, it becomes essential to capture how the physical and the social environments surrounding the people in the real space as the users of the city change and how their changes influence the decision-making of the people in the city. Therefore, we must establish a method for measuring the effects of the physical and social environments on the daily lives of the various users of the city. To do this, we need to conduct a series of trials to see what technologies can be applied to visualize the environmental

changes occurring in the city and to predict what will happen in the environment. Furthermore, by discussing the applicability of these technologies, we can find a way to use them to evaluate the value of the city from a more detailed perspective of each city user.

To maintain the city's functions and increase the city's value, we need to assess the value of the city by understanding how individual users evaluate the city. Until now, how they evaluate the city has been grasped only by using the information obtained from fixed-point observations and questionnaire-based surveys. In today's cities, we can effectively use sensing technology through information communication terminals (mobile and ubiquitous) that have permeated our daily lives in living spaces. With this improved communication infrastructure and the information visualization technology of the city, the provision of individual services to users and the creation of town contents reflecting people's evaluation and decision-making can be accomplished immediately at the right time in the right place. By doing this on a software basis, strategic town management becomes possible at a low cost.

Furthermore, this book covers the role of TMOs (town management organizations) in urban development at present and in the future, where we can utilize those technologies freely. Also, we take up an important topic on how safely we can manage the various information that people interact with the city through IoT. We discuss the use of blockchain for this and its possibility to enhance the brand value of the final product or service by reinforcing the trust of the individuals involved in the supply chain. The social city is one form of the next phase of urban development that will restore social vitality to the modern city, making it smart and vibrant. We want to consider with readers how we can realize such a city.

This book consists of five chapter groups that deal with the following themes: Part I deals with "Activity and Value in Towns," Part II "Activity Visualization in Cities for Urban Development," Part III "Monitoring Methods of Human Activity and Environment in Open Space," Part IV "Utilization of Communication Service and Town Management," and Part V "Social City Development Using Social and Physical Information in Cities." Each chapter group discusses the methods, practices, and technologies for realizing the social city related to each theme from various perspectives.

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Chapter 1
Consumer Behaviors and New Urban Development Trends

Saburo Saito and Yasuhiro Kawahara

This chapter is based on Kawahara and Saito (2017a), "Consumer Behaviors and Urban Development (ShohishaKodo To MachiDukuri)," In: Kawahara and Saito eds. (2017b), Social City (Sosharu ShiThi), pp 10–30, 2017, The Open University of Japan Press (in Japanese), which has been modified for this chapter.

Abstract Much attention has been paid to urban development that focuses on revitalizing the city through human communication. In this chapter, the challenge of new urban development using information and communication technology (ICT) is considered "the social city," and the framework for viewing the city and urban development is outlined. In particular, we elaborate on the relationships between the city and its visitors, consumer behavior and urban development, and urban development mechanisms and ICT. Finally, we provide an overview of the organization of this book.

Keywords City · Town · Consumer behavior · Urban development · City formation system · ICT · Social city

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1.1 New Trends in Urban Development

1.1.1 City Planning at a Major Turning Point

Currently, urban planning and development in Japan are at a significant turning point. First, the decreasing birthrate and an aging population have brought about a declining population.[1] Thus, a significant change is required in conventional urban planning and development. An example is a large housing complex in the suburbs built during rapid economic growth. Second, as the population ages and the number of young residents decreases, the question arises about maintaining and managing extensive facilities and various services, such as nursing care and transportation.

Therefore, while the focus of urban planning and development has been on the development and construction of new facilities, the future of urban planning and development is concerned with reorganizing existing facilities and sustaining and managing them in the future.

On the other hand, globalization is accelerating, the industrial structure that makes up the city is changing significantly, and people's lives are changing vastly. In parallel, an international competition among core cities has begun.[2] Thus, to survive international intercity competition, core cities require urban strategies to attract people from within and outside Japan, establish internationally competitive core industries, and attract and retain the human resources involved in such industries.

In addition to the three major metropolitan areas and regional core cities facing international intercity competition, the mountainous regions also need survival strategies, and regional local cities need strategies to cope with the competition between cities in the country. In particular, these regional local cities require a strategy for wide-area cooperation among local cities, which should be linked to the core cities' strategies to cope with international intercity competition.

To address these issues, we need an original strategy with a unique idea for each town and city, not just a uniform one by the national government and local administration as before. In the past, residents, private companies, and business entities expressed their opinions but only accepted the created public plans. However, nowadays, the government, residents, businesses, and organizations must collaborate in creating urban strategies and their implementation, management, and evaluation to increase their viability.

[1] There are many discussions about the declining birthrate and aging population. For example, refer to Masuda (2014).

[2] As for the international mega-city competition, it has been discussed for some time from the connection with redevelopment in Tokyo. For a recent argument, see Asami et al. (2016).

1.1.2 The Possibility of New City Planning: The Social City

The driving force accelerating globalization is the rapid progress in information technology represented by the Internet. The innovation of mobile information and communication technology (ICT) with mobile terminals such as smartphones and tablets and the new development of big data, machine learning, artificial intelligence (AI), and machine-to-machine (M2M) technology are remarkable. For example, mobile Internet has demonstrated progress in car and pedestrian navigation systems. In big data and machine learning, remarkable advances have been made, including Internet shopping recommendations (e.g., "People who bought this book also bought this"), highly accurate searches, full-text downloads of papers, and high-speed stock trading. We have achieved significant evolution in the implementation of information technology.

Furthermore, the Internet of Things (IoT) and Society 5.0, closely linked to sensing and monitoring technologies, have recently attempted to network production technologies and spark a new industrial revolution. In the deregulation of electricity, there is an attempt to monitor electricity use by smart meters in all households, leading to more efficient energy use.

This progress in information technology also spreads to city planning and has excellent potential as a new direction for urban development.

1.1.3 What Is "The Social City"?

The social city, the title of this book, is defined as follows: In the past, relationships between people and between people and the city were formed only through local ties, kinship relations, and face-to-face communication. However, as suggested, the development of the mobile Internet and social media has made it possible for people to form relationships and communities through communication using these media. In other words, the way the town existed changed drastically with the progress of information technology.

Therefore, in this book, the social city is defined as one that utilizes ICT such as sensing, mobile Internet, and social media such as social networking services (SNS) as information infrastructure to promote communication between people and between people and the city for revitalization. Thus, the discussions in this book can be considered "a challenge to new urban development" through the concept of the social city.

1.2 Viewpoints of the City

Why do we focus on the social city? To answer this, we need to discuss what has been impossible or difficult in the past, how these aspects can be made possible by the social city, and what effects the social city will bring. To do this, it is worth sharing a view of how the city is working and how it is changing.

There are various perspectives to view the city from.

1.2.1 Physical System of the City

First, the real space where the town is established is necessary. We can also deal with the webspace on the Internet as a virtual space. Nevertheless, this book considers only the city existing in real space. The first thing to recall in a real space is hard facilities such as roads, railways, houses, factories, offices, and commercial facilities. Let us call these the "physical system."

Next, note that real spaces and hard facilities do not have a function by themselves. Various entities use them. The entities include residents, companies engaged in production activities, consumers engaged in consumption activities, visitors enjoying sightseeing and leisure, and many others. When these various actors use the spaces and hard facilities and engage in their activities, the real spaces and hard facilities will have functions. The activities of various subjects in the real space and physical system are called the "activity system."

1.2.2 Activity System of the City

In the activity system, the physical system is where various subjects interact to exchange goods, services, money, information, and energy. For example, when a consumer buys clothes in a town, from the consumer's viewpoint, she or he spends transportation costs and time to get to the store and pays the shopkeeper for the goods on display. From the shopkeeper's viewpoint, he purchased the goods; displayed the goods at the shop, a place in a commercial facility; and sold the goods to the consumer at the price the consumer paid. In other words, the shopkeeper and the consumer, the two subjects of the activity system, have conducted an interaction or a transaction between them in which they exchange money and goods.

From a different perspective, the shopkeeper and the consumer can be viewed in a unified framework as the agents who engage in production activities, focusing on what they used as inputs and what they produced as output.[3] In this framework,

[3] For households, this approach is also called the household production approach. See Becker (2009).

consumers are regarded as inputting the transportation cost and time spent traveling to the store, the time spent shopping, the cost of acquiring information, and the price paid for the purchased product, and outputting the desired shopping behavior for clothes. Of course, the shopkeeper carries out the same production activities as ordinary firms. They input the stock of goods purchased and the shop and output the sale of goods.

Thus far, we have looked at the physical and activity systems as those that make up a city, but another viewpoint is necessary from an urban development perspective.

Who constructs new physical systems, and how are they modified and updated? Moreover, who will work on the various actors of the activity system and guide their actions in a new direction, and what procedures will be used?

For example, consider an entity trying to build a shopping complex. Indeed, the entity is one of the various actors in the activity system, and its activity, the construction of the shopping complex, can be viewed as a part of that system if we consider that the entity will make a profit by providing goods and services to visitors to the shopping complex. Thus, the construction of a shopping complex can be considered part of the activity system.

1.2.3 Social Decision-Making System of the City

However, city planning has established rules regarding what kind of building can be built in a given location and what building coverage ratio and volume rate are possible for the site area.[4] Recently, using the form of a special zone, there has been an attempt to remove regulations restricting the range of acceptable activities as a part of the activity system.[5]

On the other hand, public planning, such as determining the use and floor area ratio and road routes, has also established the procedural rules for determining zoning and street plans. Generally, we refer to these rules as the "institution." In the case of city planning, they are called city planning institutions or the city planning system.

In this book, we will not go into the details of this specific institution but rather go back to the starting point and focus on the social decision-making mechanisms that broadly generate such institutions and rules.

Specifically, we refer to the social decision-making system as a mechanism or procedure in which multiple actors involved in the activity system collectively

[4] For an outline of the institutional system for city planning in Japan, such as land-use and building-use regulations, floor-area ratio regulations, city planning law, building standard law, and urban redevelopment law, see for example, Sakamoto (1996) and Taniguchi (2014).

[5] An example in Japan is the special zone designated for Fukuoka City as it being a place for "global entrepreneurship, founding, and job creation."

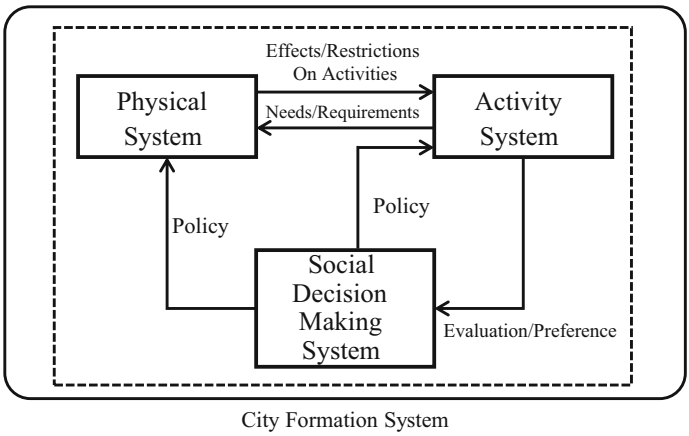

Fig. 1.1 The city as a city formation system. [From Saito (2018), p. 9]

decide to construct or modify the physical system, activity system, and even the social decision-making system while influencing each other.

In summary, we view the city as a complex system consisting of three interrelated systems: the physical system, consisting of hard facilities in real space; the activity system, comprising various actors in the physical system; and the social decision-making system that generates, modifies, maintains, and develops these two systems as well as the social decision-making system itself.

1.2.4 The City as a City Formation System

One reason for adopting this view is that we do not want to consider the city a static system but a self-developing dynamic system that contains a mechanism to change the city by itself. Furthermore, when discussing city planning, one may believe that a single entity, like the national government or the public, decides everything. However, this is not the case, and we contend that a city is formed as a result of the accumulated decisions of the many people involved. In this sense, viewing the city as a complex system of three systems implies that the city is formed by many interrelated actors who cooperate with and influence each other. We refer to this complex system as the "city formation system."

Figure 1.1 shows how this view of the city as a city formation system is utilized to disentangle complex causes, effects, and relationships in the city formation system and employed in the evaluation scheme of various urban development policies.

1.3 Why Focus on the Social City?

The question is why we focus on the social city from the viewpoint of the "city formation system." The answer to this question will be gradually revealed in the following chapters of this book, but it is helpful to summarize it here in advance.

1.3.1 Innovation in the Scientific Evaluation of Urban Development Policies

First, the social city's significance is its contribution to the scientific evaluation of urban development policies. We mentioned the activity system earlier, where diverse actors make various decisions in the urban space. However, it is not easy to understand what information is exchanged when diverse actors make various decisions in the urban space and what activities are brought about as a result. Until now, it has been impossible to measure and record the various actors' diverse decisions in the urban space from the viewpoint of the information transaction of individual actors, reflect this information in predictions, and utilize it to evaluate urban development policies.

However, in the social city, with the advancement of new mobile ICT (information and communication technology) and big data technology, an environment can be created where this is possible. As a result, the evaluation of urban development policies will become more scientific, based on evidence and facts. At the same time, there is an increasing possibility of a micro and accurate evaluation of urban development policies that explicitly describes what kind of effects the urban development policy brings to what kind of subjects.

1.3.2 From Aggregate Data to Micro-Behavioral Data

The previous research stream on city planning and urban development policies can be summarized as follows. Initially, research was mainly based on public statistical data such as population statistics, although most research still follows this thinking.[6] However, these public statistics are typically the aggregate data of the original questionnaires collected in statistical surveys such as the national census. In other words, they are the published data compiled from individual questionnaires in which respondents have written their responses. Because they are aggregate data, extracting

[6] In 1968, the city planning law was enacted in Japan. Until the mid-1970s, since statistical methods to deal with individual questionnaires or votes had not been developed, most studies were based on aggregate official public data.

information on each subject's decision is impossible, which lies in the individual questionnaire before it is aggregated.[7]

Consider a concrete example. Let us consider the purchasing behavior of a consumer visiting a city center. Suppose that a consumer goes from home to the city center, buys a jacket at a select shop on the street, buys a shirt at a commercial complex, and finally goes to a department store to buy a cake before going home. In the official Statistics of Commerce,[8] even in the narrowest geographical area, only the annual sales amount of each shopping street is counted. In another household consumption survey,[9] data on what amount of expenditure households spend on what items are available for each type of household, but there is no information on where they spent it. Therefore, analyzing what amount of expenditure individual consumers spent at what places is impossible with such aggregate data. Besides, statistical methods dealing with such micro-data had not yet been developed.

However, statistical methods that can analyze the choice behaviors of individual consumers have been developed, starting with research on transportation behavior and residential choice.[10]

In the above purchasing behavior case, the current focus is on collecting detailed micro-behavioral data on consumers' purchasing behaviors in a city center commercial district and analyzing the mechanisms by which consumers carry out their purchasing activities in the physical system of the city center. One of the authors' research on *Kaiyu* behaviors based on the on-site surveys of consumers' *Kaiyu* behaviors in the city center is in a stream of such micro-behavioral data analysis.[11]

1.3.3 Consumer Behavior and Information

However, what we recorded as the micro-behavioral data here is the behavior history data individual consumers chose as the results of their decision-making. We want to analyze what kinds of information transactions consumers have made with the urban

[7] Non-aggregated data obtained from the individual questionnaire sheet collected are referred to as micro data.

[8] From the Census of Commerce by the Ministry of Economy, Trade and Industry (METI) https://www.meti.go.jp/statistics/tyo/syougyo/index.html.

[9] From the National Survey of Family Income and Expenditure by the Ministry of Internal Affairs and Communications (MIC) http://www.stat.go.jp/data/zensho/2014/.

[10] McFadden's conditional logit model is a pioneer in this area. This type of model is also called a disaggregate or qualitative response model such as the logit and probit models. Originally written by McFadden are the Refs. (Domencich et al. 1975; (McFadden 1973, 1978). Textbooks are those by Ben-Akiva and Lerman (1985) and Train (2009). Those in Japanese include Nakanishi (1984) and Japan Society of Civil Engineering (JSCE) (1995). Recent textbooks of microeconometrics are Cameron and Trivedi (2005) and Yamamoto (2015). For textbooks on econometrics, refer to Wooldridge (2016), for example.

[11] Refer to Saito et al. (2022), Chapter 2 of this volume and Saito and Yamashiro (2018).

space in their purchasing behaviors and how those transactions have influenced their decision-making behaviors.

To do this, we need micro-history data describing what kinds of information interactions consumers made with the city center commercial environment, which only becomes obtainable through the new mobile ICT and big data technologies. Thus, the capability to access and record the consumers' information transactions with their environment is the most significant possibility the social city provides.

On the other hand, the challenge of new urban planning that the social city will make possible by utilizing the mobile ICT is to obtain micro decision history data of individual consumers based on their interaction with information, which was not possible in the past. Thus the social city significantly advances the scientific evaluation of urban development policies.

1.3.4 Innovation in City Formation System

Besides the points discussed above, the other significance of focusing on the social city exists. That is the possibility of real-time urban development and the multilayered city formation system, where micro-city formation systems can coexist with multilayered networks.

In the past, urban development policies usually presupposed a long planning period, such as 10 or 20 years, from the original plan-devising phase to the completion of the final construction plan, as seen in the development of complex physical facilities. However, in the case of softer urban development policies such as events and marketing, utilizing the new mobile ICT will make it possible to measure the effects of the policies in real time, thus making the urban development process more real-time.

At the same time, we can organize the social decision-making system for urban development and city planning as a network by each interest group utilizing SNS and other mechanisms. Thus, it becomes possible to establish the city formation system as multiple and micro collaborative systems that stand side by side in a multilayered manner. We will discuss these issues in later chapters.

1.4 Utilization of Social Media

1.4.1 Use of Social Media

With the expansion of social media platforms such as Facebook and Twitter, information is exchanged and shared among people everywhere. Social media is a medium or online service that allows individuals to send information and interact with a wide range of people using the Internet. In our daily lives, it is becoming a social infrastructure, an information infrastructure used daily. Nowadays, many

people use this media anytime and anywhere, made possible by the spread of the smartphone.

In urban development, there is an effort to revitalize the city by promoting the communication of a person to another person and the person to the city by installing various mechanisms in the urban space to encourage the use of social media associated with the city's information. Currently, communication using social media in the city is done mainly via information communication terminals such as smartphones.

Mobile information communication terminals enable the transfer of information about the real space, such as location information, leading to face-to-face communication in that real space. The method of transmitting information by using social media from a spot or store in the real space to mobile information communication terminals owned by persons nearby can be said to be one form of social media use. The interactions occurring at the spots and stores among people who decide to visit them by using social media in the real space are considered social media's contribution to enhancing community formation and revitalizing the city.

1.4.2 Effectiveness of Social Media in a City

What kind of communication occurs when residents or visitors spend time in the town? For example, sharing information about valuable places and places they like, talking in stores, and gathering in real space are likely to occur. Moreover, in ICT-based urban development, many consumers recognize the formation of communities as a critical issue and have high expectations for the revitalization of the formation of communities. Thus, they consider that social media serve as a medium that stimulates the formation and activation of communities or as a medium that promotes the formation of communication places in the real space (Ministry of Internal Affairs and Communications (MIC) 2013).

Information exchange through social media often occurs among acquaintances who know each other well, but some may have met only once or only know each other on the web.

Some research empirically shows that the influence of information transmitted and communicated through social media is more significant when the other party is an acquaintance in the real space (Mani et al. 2013). Furthermore, other empirical research reports that the number of direct interactions with another party well indicates the influence of transmitted information (Adjodah 2013).

These empirical facts are significant for the evidence-based urban development policies in the social city. By utilizing these empirical facts, we might devise an effective mechanism such that some influencing person becomes a medium that provokes communication between people, or the city space becomes a medium that activates communication between people.

Therefore, we can see that creating such social mechanisms should become a part of urban development policies in the coming social city. We will present these concrete urban development policy examples in later chapters.

1.5 Composition of this Book

This book consists of the following chapter groups: Part I deals with "Activity and Value in Towns," Part II "Activity Visualization in Cities for City Development," Part III "Methods to Monitor Human Activity and Environment in Open Space," Part IV "Utilization of Communication Services and Town Management," and Part V "Social City Development Using Social and Physical Information in Cities."

In Part I, "Activity and Value in Towns," we provide the evaluation schemes for evaluating urban development policies by viewing a city as a city formation system. We introduce empirical studies based on these evaluation schemes. We define town equity as the asset value of the city's attractiveness embraced in the minds of visitors. We clarify the goal of urban development based on the town equity concept. Also, we discuss the core methodologies to undertake studies for evaluating city development policies.

Part II, "Activity Visualization in Cities for Urban Development," provides an overview of the basic concepts and foundations for visualizing social activities in cities for urban development.

In Part III, "Methods to Monitor Human Activity and Environment in Open Space," the use of ICT and social media in cities and collecting micro-behavioral data are explained, including technical aspects. In addition, to consider the comfortable environments for cities, methods for visualizing the thermal environment by sensing and evaluating the environment based on human factors are explained.

In Part IV, "Utilization of Communication Services and Town Management," we explain how to visualize the "state of the town" using social sensing, a factor affecting human behavior. Also, we discuss the use of town information, referring to the examples of town management.

Finally, in Part V, "Social City Development Using Social and Physical Information in Cities," we comprehensively discuss the essential issues in the construction of the social city by introducing the use of big data accumulated over time for marketing and services and how we utilize social data.

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Part I
Activity and Value in Towns

Chapter 2
The Evaluation of Urban Development Policies: From Activity Effect Approach to Consumer Behavior Approach

Saburo Saito, Kosuke Yamashiro, and Masakuni Iwami

This chapter is based on Saito (2017) Evaluation of a City, Chapter 2 in Kawahara and Saito (eds) (2017) Social City, The Open University of Japan Press, 2017, which is modified for this chapter.

Abstract We discuss the evaluation schemes employed explicitly or implicitly in city planning research. Based on the activity effect evaluation scheme for evaluating urban development policies, we explain how our *Kaiyu* studies have evolved. Furthermore, we discuss why we focus on *Kaiyu* behavior and why consumer behaviors are related to the evaluation of urban development policies while demonstrating the concrete examples of our past studies on urban development policies.

Keywords Evaluation of a city · *Kaiyu* behavior · Activity effect evaluation scheme · Consumer behavior approach

2.1 Viewpoints for Evaluating a City

Urban development intends to change a city into something new. If it intends to change a town from its current state S to a new state S′, it implies that state S′ is preferable to state S. Of course, such an evaluation will differ depending on who

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evaluates it. Therefore, if the tastes and preferences of the evaluators are different, the conclusion that state S′ is preferable to state S will not necessarily be the same among them but will naturally differ.

However, even though the tastes and preferences of individuals differ, it is also true that there is a particular way of thinking—a framework and viewpoint for evaluating a city, that is, a mindset. Here, we discuss the thinking framework or a mindset when evaluating a city, typical in city planning research, as an evaluation scheme.[1]

2.1.1 Three Evaluation Schemes

When considering the thinking framework or the mindset for evaluating a city, what becomes a key point is the viewpoint of a city, as discussed previously.[2] This viewpoint regards a city as a city formation system concerned with urban development. The city formation system is a complex system composed of three systems; a hard physical system in a real space, an activity system on top of that, and a social decision-making system for modifying and maintaining these two systems. We view a city as a complex city formation system because we want to see that a city is formed by many interrelated actors and collectively decides its course of change by itself.

Depending on which of these three systems we focus on and what points we emphasize, we can extract three evaluation schemes when evaluating a city: the ideal city type, the activity effect type, and the city formation system type.

Below, we explain them in order.

2.1.2 Ideal City-Type Evaluation Scheme

The ideal city-type evaluation scheme is still commonly used for evaluating cities. In particular, we implicitly use it when we adopt a method such as selecting a public facility through a design competition.

As shown in Fig. 2.1, in the ideal city-type evaluation scheme, we want to evaluate the physical system, the object of evaluation. Furthermore, in this evaluation scheme, the evaluation criteria, as well as what is described and observed, are all limited to the physical system, such as the shape, color, and design of facilities.

In this scheme, the social decision-making system of the city formation system is referred to as a means of creating a physical system or is ignored. As for the activity

[1] Three evaluation schemes first were presented and discussed in Kumata and Saito (1975) and recently have been elaborated on in Saito (2017, 2018b).

[2] Refer to Saito and Kawahara (2022a), Chapter 1 in this volume.

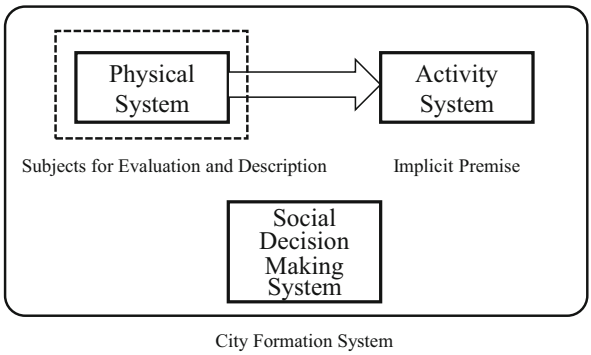

Fig. 2.1 Ideal city-type evaluation scheme. [From Saito (2018a) Fig. 1.1, p. 5]

system, the ideal city-type evaluation scheme implicitly assumes that "optimization of the physical system brings optimization of the activity system." However, this scheme does not explicitly present this assumption's factual basis and this assertion's verification procedures.

The subjects of evaluation and description in the ideal city-type evaluation scheme are the different states of the physical facilities of the physical system, and the physical system itself also describes the criteria for evaluating them.

Regarding the mindset related to the ideal city-type evaluation scheme, there has long been a discussion about the ideal city theory. Even today, land use plans, such as zoning set out without a clear evaluation criterion, can be seen as examples of it. Furthermore, various indicators of cities' status exist, such as "rankings of cities"[3] often reported in the mass media and the recent "evaluation of city structure,"[4] where they have statistically analyzed the interrelationships in a city. Therefore, we know that such an effort to create evaluation indicators is a mindset based on the ideal city-type evaluation scheme.

2.1.3 Activity Effect-Type Evaluation Scheme

Next is the activity effect-type evaluation scheme. Figure 2.2 shows this evaluation scheme. As known from Fig. 2.2, the activity system, which was implicit in the ideal city-type evaluation scheme, becomes a focus in this evaluation scheme. The activity system is explicitly described, and the interaction between the physical and activity systems is also explicitly incorporated and used to evaluate a city. There are several variants of the activity effect-type evaluation scheme.

[3]The City Planning Institute of Japan recently organized special topics on the evaluation and ranking of cities in City Planning Review (City Planning Institute of Japan 2015).

[4]The City Planning Division of MLIT (Ministry of Land, Infrastructure, Transport, and Tourism), Japan, recently published the handbook for evaluating urban structure (City Planning Division, City Bureau, MLIT [Ministry of Land, Infrastructure, Transport and Tourism] 2014).

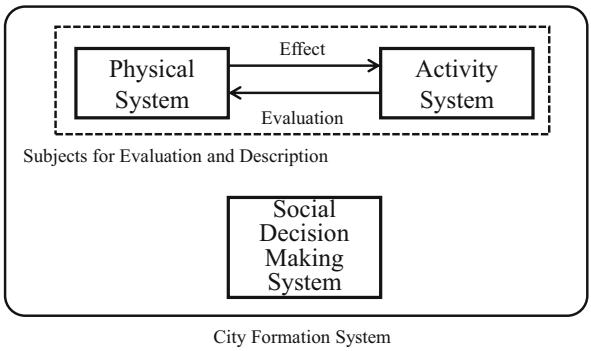

Fig. 2.2 Activity effect-type evaluation scheme. [From Saito (2018a) Fig. 1.2, p. 6]

2.1.3.1 Basic Form

We say the one variant as the basic form of the activity effect-type evaluation scheme. The most crucial premise of the basic form of the activity effect-type evaluation scheme is that the ultimate goal of a city is assumed to be the optimization of the activities carried out in the physical system. Thus, the physical system is regarded as a means to optimize the activity system performed over the physical system. This evaluation scheme is a mindset or a thinking framework often seen in architectural design.

The explicit use of this activity effect-type evaluation scheme in Japan dates back to the 1950s. Then, its first use appeared in the research carried out to evaluate the proto-type house floor plans provided in new towns in suburban areas by the third sector in the age of the deficiency of houses when Japan was at the high economic growth stage.

How that research was carried out can be outlined as follows. First, note that the research needed a scientific factual basis to evaluate which house floor plan is better than the others. Thus, they conducted surveys of how people live in their houses to investigate whether people use the same room for eating and sleeping at different times or use different rooms for eating and sleeping under the condition of the same number of rooms in different house floor plans.

Furthermore, they first assumed that separating eating and sleeping in different rooms were better for living behaviors. Then, utilizing it as an evaluation criterion, they evaluated the house floor plans according to how they are likely to induce the people living there to live in accordance with the living style of the separation of eating and sleeping based on the survey of people's living behaviors.[5]

Note that we defined a policy as a change of the physical system's state in the basic form of the activity effect-type evaluation scheme. Thus, the intervention operated on the physical system becomes a policy. Therefore, this evaluation scheme

[5] Nishiyama originated the methodology of the "survey of how people live in their house," which Kumata and Saito (1975) named the activity effect-type evaluation scheme. For detailed discussions of his methodology, refer to Nishiyama (1967), in particular, vol. 1 "Housing Planning."

is concerned with how the change of the physical system can improve the state of the activity system and evaluates the change of the physical system by the effect that the change of the physical system brings on the activity system. Equivalently, the policy, the physical system's state change, is evaluated by its effects on the activity system.

While we set the evaluation criteria in the state of the activity system, our original aim is to evaluate the physical system's state and the ways the physical system is changed. In this sense, the basic form is an evaluation scheme incorporated into an architectural design. A typical example is the facility planning for an emergency evacuation at a large facility.

2.1.3.2 Physical-Activity Interdependence Extension Form

In the activity effect-type evaluation scheme, the interaction between the physical and activity systems is what we observe and describe. Furthermore, we can regard the entities that make up the activity system as consumers and visitors who decide their activities by themselves. Thinking in this way, we see that also in the physical system, many entities involved in the physical system who supply hard facilities in the real spaces maintain and renovate the physical system in response to the demands and needs of various entities in the activity system. Thus, if this is the case, we are led to the viewpoint that if the physical system changes, the activity system will change, and, conversely, if the activity system changes, the physical system changes, responding to the requirements of the activity system.

Therefore, while the basic form considers a one-way causal effect on the activity system caused by the modification of the physical system, the causal relationship can be seen as two-way such that both the physical and the activity systems affect and are affected by each other. To clarify the difference, we refer to this viewpoint as the physical-activity interdependence extension form of the activity effect-type evaluation scheme.

The physical-activity interdependence extension form extends the basic form by incorporating the interdependent causal relationship between the physical and activity systems. An example based on this evaluation scheme is an integrated model of land use and transportation, which attempts to formulate the process in which transportation behavior, land use, and housing locations have been changing while interdependent and affecting each other.

2.1.3.3 Policy Extension Form

In the activity effect-type evaluation scheme, the policy action or policy intervention target is limited to the physical system. In other words, what is changed or, in modern terminology, the system the interventions are operated on is solely the physical system. However, suppose we expand the target of policy action in this evaluation scheme to include the activity system itself and include promotion such as the provision of information as an instrument of policy. In that case, we can extend

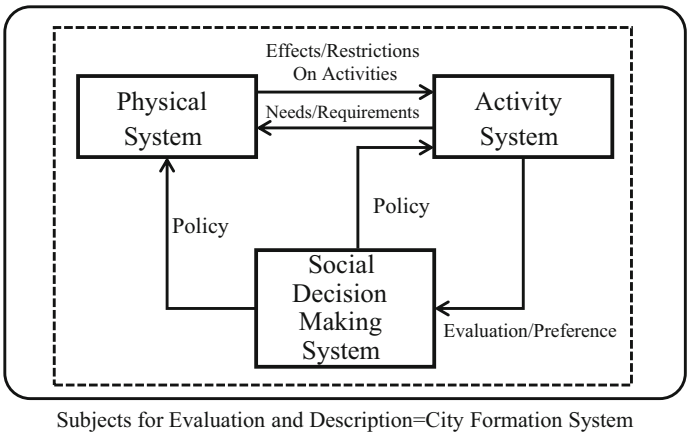

Fig. 2.3 City formation system-type evaluation scheme. [From Saito (2018a) Fig. 1.3, p. 9]

the activity effect-type evaluation scheme to one that can evaluate a wide range of policies from their effects on the activity system, such as community programs, welfare plans, events, regional development policies, and marketing.

We refer to this evaluation scheme as the policy extension form of the activity effect-type evaluation scheme.

2.1.4 City Formation System-Type Evaluation Scheme

The final evaluation scheme is the city formation system-type evaluation scheme, which emphasizes understanding a city as a city formation system, as shown in Fig. 2.3. It is a framework that explicitly describes and evaluates the city formation system that consists of three systems: the physical system, the activity system, and the social decision-making system.

The intention of understanding a city as a city formation system is rooted in the viewpoint that a city contains a built-in mechanism as a social decision-making system, by which the city modifies its physical and activity systems. Therefore, as shown in Fig. 2.3, this evaluation scheme considers that the policies that modify the physical and the activity system are the outputs of the social decision-making system.

In other words, in this evaluation scheme, the social decision-making system introduces policies regarding the physical and the activity system, their effects are feedbacked to the social decision-making system, and policies continue to be created and developed. Therefore, in the city formation system-type evaluation scheme, the physical system is regarded as a product of the social decision-making system from a long-term perspective. Thus, this evaluation scheme considers that, in the long run, a city is formed by an accumulation of decisions made by the people involved.

The concept of urban development planning and policies envisioned by this evaluation scheme is such one as follows: the goal is not a given one but a self-adaptive social process that sets goals, produces policies, evaluates their effects, modifies the goals, and forms and modifies new means, organizations, and decision-making procedures to achieve the goals.

The entities involved in the social decision-making system also constitute the activity system, but the difference lies in whether or not they are involved in the maintenance and development of the mechanisms and systems of urban development.

This concludes the discussion on the evaluation schemes.

2.2 Evaluating a City from Consumer's *Kaiyu* Behavior

This section provides typical examples of our research based on the basic form of the activity effect-type evaluation scheme.

2.2.1 What Is Kaiyu *Behavior?*

Now let us introduce *Kaiyu* behavior research based on the framework of the activity effect-type evaluation scheme.

Kaiyu behavior refers to the consumer's shop-around behavior, as shown in Fig. 2.4. Specifically, when a consumer arrives at a commercial district, such as a city center commercial district, his or her shop-around behavior from shop A through shop B to shop C, i.e., the movement such as A → B → C for shopping, is referred to as *Kaiyu* behavior. To be precise, after visiting A, visiting B–C is defined as *Kaiyu*.[6]

[6]The *Kaiyu* behavior was clearly defined by Saito (1983) in 1983, and the *Kaiyu* Markov model was formulated, and the *Kaiyu* effects were measured. The survey of *Kaiyu* behavior was first conducted in 1982 as a question item in the home-based questionnaire survey of consumer purchasing behavior conducted and distributed to sampled households in the trade area of *Nobeoka* City, Japan. Specifically, the survey asked the respondents about the commercial places they stopped by before and after the commercial destination place for three items: clothing, shoes and bags, and preserved foods [Cf. Saito (1983), Appendix]. Later, as a question item of the *Saga* Citizen Opinion Survey, a home-based survey (February 1–10, 1985, random sampling, mail method, 3100 questionnaires distributed, 1453 questionnaires collected), the survey of citizen *Kaiyu* behavior at the city center of *Saga* City was conducted in which the entire history of an individual respondent's *Kaiyu* behavior in the city center was recorded as a sequence of pairs of visited places and purposes done there in the order of their occurrence. Saito (1988) presents the result of the analysis of this survey. The first on-site survey of consumer *Kaiyu* behavior was conducted in 1989 in *Tenjin* District of Fukuoka City, Japan. Saito and Ishibashi (1992) estimated a *Kaiyu* Markov model with explanatory variables based on the data. Since 1996, the subject area of the survey has been expanded to include *Tenjin* District, *Hakata* Station District, Canal City *Hakata*, and *Hakata* Riverain, and the survey has been conducted continuously every year. (See Saito 2005).

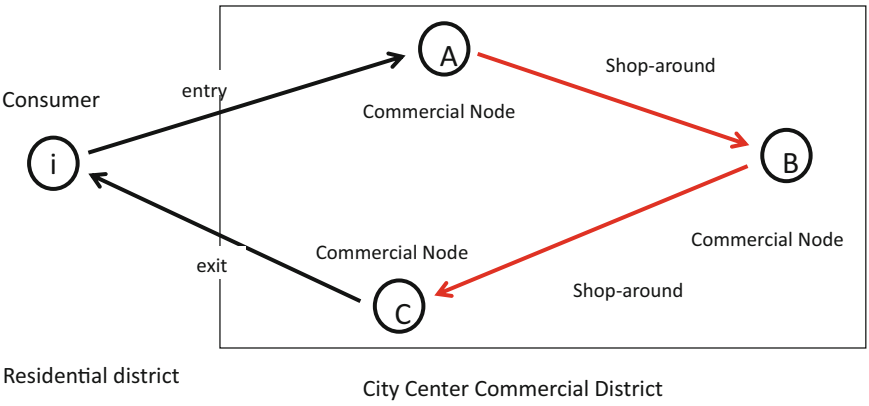

Fig. 2.4 Definition of *Kaiyu* behavior

The reason why we focus on *Kaiyu* is the following. Suppose only one person visits a city center commercial district and moves from shop A through shop B to shop C. Then, if we count the number of visitors from the perspectives of the stores, one person would be counted by shop A, one by shop B, and one by shop C, for a total of three. Thus, while the number of persons who move around is one, the number of visitors to shops becomes three, which can be seen as a multiplier effect that turns one to three.[7]

Kaiyu occurs because commercial facilities are agglomerated nearby and located in close proximity to each other. In this way, we can consider *Kaiyu* to be a concrete phenomenon representing the agglomeration effect of commercial districts.

Therefore, if we create the same city center space, it is more desirable to create a city center space with a more significant agglomeration effect. In other words, we can say that the city center space that induces more *Kaiyu* behavior is desirable.

Recall the discussion in the previous section. We see that this evaluation scheme is a typical activity effect-type evaluation scheme. Thus, we consider facilities and functional placement in a city center space as a physical system and *Kaiyu* behavior as an activity system. Based on this evaluation scheme, for the past 30 years, the authors and their colleagues have been continuously conducting empirical research on *Kaiyu* behavior, mainly in the city center of Fukuoka City, Japan, aiming to create urban spaces with excellent *Kaiyu* inducibility.

[7] The multiplier effect is defined as the economic phenomenon in which a change in one economic quantity spreads to other economic quantities. Eventually, the total of these effects reaches many times the initial change, and that multiple is called a multiplier.

Recently, slogans such as "high *Kaiyu* inducibility urban space" have been often used as one of the goals for urban development.[8]

2.2.2 *How Has Large-Scale Commercial Redevelopment Changed the Flow of People?*[9] *Changes in* Kaiyu *Behavior Due to Large-Scale Commercial Redevelopment at* Tenjin *District in Fukuoka City, Japan*

Let us examine two examples of *Kaiyu* behavior research based on the activity effect-type evaluation scheme. The first is concerned with how large-scale city center commercial redevelopment affects the *Kaiyu* behaviors of consumers, with focus on the experience at *Tenjin* District, the city center commercial district of Fukuoka City, Japan. As far as we know, this is the first research that empirically showed that the redevelopment had affected the visitors' behaviors by conducting surveys before and after the redevelopment.

In the city center commercial district, *Tenjin* District of Fukuoka City, Japan, a large-scale commercial redevelopment took place from 1996 to 1998, in which the shop floor area of department stores increased by 2.7 times, including the opening of two new department stores; *Iwataya* Z-side, *Mitsukoshi* Department Store, and the expansion of the shop floor area of *Hakata Daimaru* Elgala, another existing department store.

We thought this was an excellent opportunity to verify how the large-scale commercial redevelopment affected consumers' *Kaiyu* behaviors within *Tenjin* District. Therefore, we conducted surveys of consumer *Kaiyu* behaviors[10,11] three times in a row between each large-scale commercial redevelopment and obtained empirical evidence that the center of gravity at *Tenjin* District derived from the flow of people moved 105 m south. Figure 2.5 shows these results.

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[8] For example, the "Project for Creating Comfortable and High-Quality City Center Space with High *Kaiyu* Inducibility" in the Policy Promotion Plan of the ninth Master Plan of Fukuoka City, Measure 5–3 "Creation of Hospitable Environment to Visitors including Information Access and Ease of *Kaiyu*." (Cf. (Fukuoka City Government 2013)).

[9] The following analysis is based on Saito et al. (1999). Also refer to Saito and Kakoi (2018), Chapter 2 in Saito and Yamashiro (2018c).

[10] The survey of consumer *Kaiyu* behavior is about a 15-min interview survey with questionnaire sheets. The survey sampling points are set up at about 10 major commercial establishments at the city center of Fukuoka City, and the respondents are randomly selected from the visitors to those survey points. The respondents are asked to record the history of their *Kaiyu* behavior on the day as a sequence of the triple, the places visited, the purposes done there, and the expenditure spent there, if any, in the order of their occurrence.

[11] The first survey of consumer *Kaiyu* behavior at the city center of Fukuoka City Center (September 16–18, 1996), the second (July 18–20, 1997), and the third (January 30–31, and February 1, 1998).

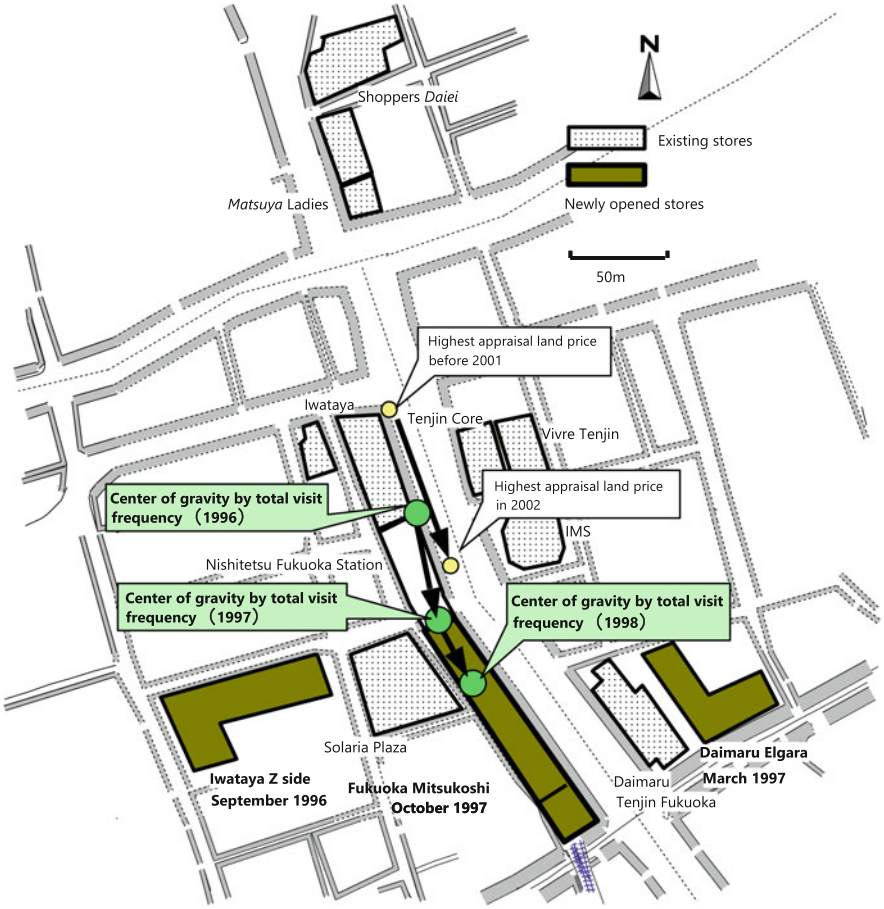

Fig. 2.5 Changes in the center of gravity (1996–1999) derived from the total visit frequency and the highest appraisal land price in Tenjin District. [From Saito and Kakoi (2018) Fig. 2.8, p. 44]

There have been many studies on city planning, but none have empirically studied how the activity system has changed due to changes in the physical system. In particular, studies of redevelopment projects have described how physical facilities have changed, but few have examined how people's behavior has changed. Why this is so is partly because redevelopment projects take a long time, such as 10 years, from planning and construction to completion, and partly because redevelopment projects sometimes involve the development of entirely new areas, but it also indicates that most existing city planning research still relies on the ideal city-type evaluation scheme.

The case of *Tenjin* District in Fukuoka City was blessed with the opportunity of a series of large-scale commercial redevelopment projects in a relatively short period of 3 years.

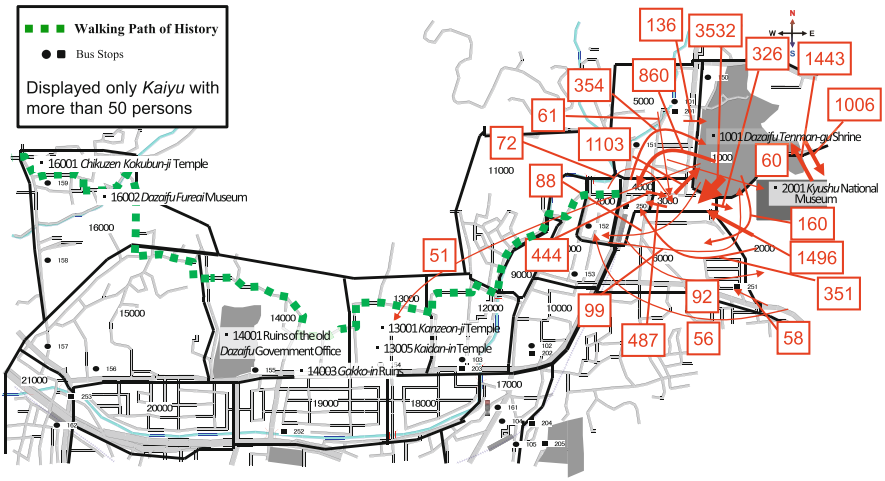

Fig. 2.6 The estimated number of *Kaiyu* movements within *Dazaifu* City. [From Saito et al. (2018a), Fig. 3.4, p. 65]

There is a sequel to this study. Later, it was reported in 2002 that the location of the highest appraisal land price of commercial areas in Fukuoka City, announced every year and never replaced before, was replaced for the first time and moved to the south (Fig. 2.5).

This fact indicates that the highest land prices have been following the changes in the flow of people, with a delay of 4 years.

This study is an excellent example of how the physical system affects the activity system and suggests that we can anticipate the changes in a city by observing changes in people's *Kaiyu* behavior.

2.2.3 *The "Walking Path of History" in* Dazaifu *City*[12]

Next, let us take the example of *Dazaifu* City, near Fukuoka City, in Japan. *Dazaifu* City has an extended history dating back to the seventh century and even earlier, with many historic sites and plans to turn the entire city into a "museum."

The city has established a "walking path of history" around these historic sites as part of its tourism policy to encourage citizens and tourists to walk around them.

Figure 2.6 shows the estimated result that estimates the actual number of people who walk around among districts within the city, that is, the estimated number of visitors' movements between the districts within the city by their *Kaiyu* behaviors.

[12] The following analysis is based on Park et al. (2011). Also refer to Saito et al. (2018a), Chapter 3 in Saito and Yamashiro (2018c).

This estimated number was obtained from the number of net incoming visitors to *Dazaifu* City and the density of visitors' *Kaiyu* movements between the districts within the city. The density is estimated using the consistent estimation method,[13] based on the data obtained from the on-site survey of visitors' *Kaiyu* behaviors in the city.[14,15] The number of net incoming visitors to the city is obtained from the combined use of count data on the number of visitors per day to *Dazaifu Tenmangu* Shrine[16] and the *Kaiyu* density estimate by the consistent estimation.

The broken line in Fig. 2.6 is the route of the "walking path of history." The figure shows that *Kaiyu* is concentrated around the *Kyushu* National Museum, *Dazaifu Tenmangu* Shrine, and *Sando* shopping street. Despite the desire to have many people visit other locations, such as *Kanzeon-Ji* Temple, which holds a national treasure, and the ruins of the ancient *Dazaifu* government office, the "walking path of history" policy has not attained its goal.

This study shows that it is possible to concretely evaluate how tourism resources are connected by the *Kaiyu* behaviors of visitors and to what extent the "walking path of history" policy has achieved its goal by looking at the *Kaiyu* behaviors of visitors.

Besides, why the "walking path of history" is not being used should lead to a succession of ideas such as how we can improve the present situation and how we can implement and verify its improvement plans.

Let us list some of them: Does the walking path start in the vicinity of *Dazaifu Tenmangu* Shrine, *Sando* shopping street, and the *Kyushu* National Museum, where most people gather, to appeal to many visitors? The length of the walking path is 7 km; is there a way for visitors coming by car to return to the starting point? Since it is rather long, shouldn't it be divided into several short sections, with a theme for

[13] As for the brief explanation of the consistent estimation of the *Kaiyu* density from on-site samples, see Saito and Kawahara (2022b), Chap. 19 in this volume. Our *Kaiyu* survey is an on-site random sampling survey in which several sampling points are set up and the samples are selected at random from the visitors to those sampling points. However, in this on-site random sampling survey framework with multiple survey points, if the samples from different survey points are merged and used for analysis, it is known that a statistical bias, or, in technical terminology, a choice-based sampling bias, occurs. A method to remove this bias was devised by Saito et al. (2001) and applied to *Daimyo* District of Fukuoka City, Japan, by Saito and Nakashima (2003).

[14] The survey of visitors' *Kaiyu* behavior in *Dazaifu* City was conducted in the same way as in Fukuoka City. The survey points were set up at the *Sando* Shopping Street, the precincts of *Dazaifu Tenmangu* Shrine, and the Kyushu National Museum, and the respondents were randomly selected from among visitors to the survey points. The respondents were asked to record the history of their *Kaiyu* behavior as a sequence of the triple, the places visited, the purposes done there, and the expenditure spent there, if any, in the order of their occurrence.

[15] The first Survey of Sightseeing *Kaiyu* Behavior in *Dazaifu* City (May 29, 30, 2010).

[16] A people-counting survey was conducted. In this survey, counting surveyors were assigned to all entrances and exits of the precincts of *Dazaifu Tenmangu* Shrine, and the number of people entering and leaving the precincts was measured every 15 min to determine the number of visitors per day to the precincts of *Dazaifu Tenmangu* Shrine. (Conducted on Saturday, May 29, 2010, from 11:00 to 17:00).

each, to increase the value of the walking experience? Of course, we can use mobile ICTs to provide on-site information, such as what one can see and experience at each historic site.[17]

It is essential to understand that these are not just ideas but can be experimentally implemented and evaluated based on the number of people who walked around *Dazaifu* City by *Kaiyu* to see what measures are effective. Essentially, this is the thinking framework of the activity effect-type evaluation scheme.

Finally, we would like to mention the characteristics of these two *Kaiyu* behavior studies. In contrast to previous microdata studies, which are primarily probability-based studies that explain the choice probabilities of decision-making agents, these two studies conduct a frequency-based analysis of how many times people visit a destination and estimate how many people precisely move from one place to another based on actual numbers, which is a new point.

Furthermore, although the results of people-counting surveys are often used for estimating the movements of visitors, the problem of double-counting exists, in which the same person is measured at multiple survey points, making it impossible to estimate precisely how many people are visiting the relevant area on a net basis. On the other hand, to avoid this problem, the *Dazaifu* study used the consistent estimation method to estimate the number of net incoming visitors to *Dazaifu* City from the *Kaiyu* survey on how and where visitors moved around by their *Kaiyu* behaviors and obtained the estimated number of *Kaiyu* movements within *Dazaifu* City shown in Fig. 2.6, which is another new point in our *Kaiyu* studies.[18]

2.3 Evaluation of Urban Development Policies Based on the Consumer Behavior Approach

2.3.1 Kaiyu *and the Economic Effect: From the Activity Effect Type to the Consumer Behavior Approach*

We have discussed thinking frameworks or the mindsets for evaluating a city, implicitly or explicitly contained in the studies concerned with city planning. We have extracted three evaluation schemes: ideal city type, activity effect type, and city formation system-type evaluation schemes. With these discussions, we provided how our research on the evaluation of a city from the perspective of *Kaiyu* behavior

[17] Although *Kanzeon-Ji* Temple has a national treasure, a temple bell which is the oldest Buddhist bell in Japan, made in the late seventh century, and displays in its museum the wooden Buddha statues from the eleventh century that are 5 m high, they are almost unknown to the public.

[18] Specifically, the employed method was as follows: First, the *Kaiyu* movement density was estimated by the consistent estimation based on The first Survey of Sightseeing *Kaiyu* Behavior in *Dazaifu* City. Then, the density was expanded by the number of visitors to *Dazaifu Tenmangu* Shrine from the people-counting survey to obtain the number of net incoming visitors to *Dazaifu* and the number of *Kaiyu* movements between districts within *Dazaifu* City.

has progressed, standing on the viewpoint of the activity effect-type evaluation scheme, taking up our two *Kaiyu* studies.

We have seen that these *Kaiyu* studies have been carried out based on micro-behavior data obtained from surveys of consumer *Kaiyu* behaviors. However, note that the data used in these studies are only *Kaiyu* movement data, that is, the records that describe what places the respondents visited while moving from one place to another based on their *Kaiyu* behaviors. Recall that the *Kaiyu* micro-behavior history data are sequences composed of the triple, the places visited, the purpose performed there, and the expenditure spent there, if any. Suppose the description of *Kaiyu* is limited to the movement of places. In that case, the evaluation of a city is forced to be based on measures like the following: the actual number of movements of people, which may express the "liveliness" of the city, and the ease of *Kaiyu* or *Kaiyu* inducibility of the city, which may be expressed by the average number of places visited by *Kaiyu* per each visitor.

However, it takes cost to promote urban development. Therefore, policy evaluation generally requires a judgment on whether the benefits are commensurate with the costs.[19] Thus, it is desirable to introduce such a concept as the cost-benefit analysis in evaluating urban development policies from *Kaiyu* behaviors. Fortunately, the survey of *Kaiyu* behaviors considers *Kaiyu* behavior as "walk-around behavior" within a city center and defines it as a sequence of the triples, which records how the triple, the place visited, the purpose of the visit, and the expenditure spent there, if any, changes as a result of walk-around behavior.

We refer to the microdata obtained from the survey of *Kaiyu* behaviors as *Kaiyu* micro-behavior history data, which forms the simultaneous choice history data composed of (1) destination choice, (2) purpose choice, and (3) consumption choice by individual consumers while they are undertaking *Kaiyu*. Therefore, we can grasp money flow by analyzing where and how much consumers spend while undertaking *Kaiyu*. In this way, we become able to analyze the relationship between *Kaiyu* and the economic effects by considering the *Kaiyu* agent as a consumer who consumes while moving from place to place rather than as an agent who simply moves from place to place. We call this approach the "consumer behavior approach."

The consumer behavior approach places the consumer as the entity of the activity system, considers his or her consumption behavior as the activity system, and adds the means to influence his or her consumption behavior as policy. Thus it extends the basic form of the activity effect-type evaluation scheme that considers only the modification of the physical system as policy. Thus, this is a policy extension of the activity effect-type evaluation scheme.

[19] As for the policy evaluation based on microeconomic theory, see, for example, Kanemoto et al. (2006).

2.3.2 What Is the Consumer Behavior Approach?

Here let us formulate the concept of the consumer behavior approach.[20]

This approach considers various actions and means that possibly change consumer behavior as policies. Specifically, various policies such as traffic policies, the location of commercial facilities, the construction of expressways, the development of new subway lines, and so on can be regarded as urban development policies.

The consumer behavior approach is a method that measures and predicts the effect of various urban development policies on the increase in consumption expenditure as an effect of those policies, using the following steps. First,

1. Measure or predict how consumer behavior changes before and after the implementation of the urban development policy.
2. Measure or predict whether the change in consumer behavior is linked to an increase in *Kaiyu* or the frequency of city visits.
3. If it does, we measure or predict the effect of the increased expenditure due to the increase in *Kaiyu* or the frequency of visits and define the effect of the increased expenditure as the economic effect of the urban development policy, based on which we measure and predict the size of the economic effect.

In the following, we provide three examples of our *Kaiyu* studies that try to estimate the economic effects caused by urban development policies based on the consumer behavior approach.

2.3.3 Economic Effect of One-Dollar City Center Circuit Buses[21]

In the downtown area of Fukuoka City, *Nishi-Nippon* Railroad (NNR) Co., Ltd. (*Nishitetsu*) introduced the one-dollar city center[22] bus service on a business basis in 2000. When introducing this service, they reduced the fare, which was 180 yen, to 100 yen for all buses within the city center, and they also introduced new 100-yen

[20] Yamashiro (2012) formulated a method for measuring and predicting economic effects using the consumer behavior approach, taking up the one-dollar city center bus and the opening of a new subway line as examples. The following features characterize the consumer behavior approach. First, in contrast to the past efforts for project evaluations, such as the opening of a new subway line, in which a specialized organization predicted the effect on a wide area at great expense, the consumer behavior approach enables one to limit the region to a small area such as a city and conduct the forecast and evaluation of the effect on the small area with a small budget by its own efforts such as by the local city government, and also makes it easy to carry out the ex-post evaluation of the policy.

[21] The following analysis is based on Saito and Yamashiro (2001). Also, refer to Saito and Yamashiro (2018a), Chapter 9 in Saito and Yamashiro (2018c).

[22] Here we set the exchange rate as one dollar USD = 100 yen (JPY).

Table 2.1 Average number of commercial facilities visited by users and nonusers of one-dollar city center buses in the middle of *Kaiyu*

		Average (place)	Number of samples	Standard deviation	Difference in average numbers of steps to stop (a–b)	Significance probability
a	Users of 100-yen bus (in the middle of *Kaiyu*)	6.28	67	2.99	1.72	0.000
b	Nonusers of 100-yen bus	4.56	1178	2.98		

[From Saito and Yamashiro (2018a), adapted from Tables 9.11 and 9.13, pp. 178–179]

circuit buses circulating in the city center every five min. Here, we use the term "one-dollar city center buses" to refer to both the route bus and the circuit bus within the city center area.

They first introduced this city center's one-dollar bus policy in 1999 on an experimental basis for one year and planned to continue on a business basis if the policy attains the goal of increasing the number of passengers by 1.8 times or more. As a result, the one-dollar city center buses attracted passengers more than 1.8 times. Hence, it is still in operation on a business basis.

When measuring the economic effect of the city center's one-dollar bus services, it has been quite difficult for traditional transportation research to measure its economic effect. This is because traditional transportation research usually measures the economic effect of transportation improvements in terms of the economic value of reduced travel time. More specifically, the economic value of the time saved is measured by how much it would be worth if it were devoted to productive activities. However, if one uses the one-dollar city center bus, the travel time will increase, so its economic effect cannot be calculated using the conventional methods.

If we look at the data obtained from our *Kaiyu* behavior survey[23] in detail, we can distinguish between those who used the one-dollar city center bus and those who did not. Comparing these data, we found that the number of commercial facilities visited by those who used the one-dollar city center bus in the middle of their *Kaiyu* was about 1.7 more than those who did not, as shown in Table 2.1.

According to our surveys of consumer *Kaiyu* behavior in the city center commercial district of Fukuoka City, consumers who visit the city center commercial district of Fukuoka City usually visit four or five commercial facilities. When they visit one commercial facility, they spend 1500 yen per visit on average, including those who buy something and those who do not buy anything, that is, the average expenditure per visit including no purchase.

If this is the case, we can think that if consumers used the one-dollar city center bus, they would increase the number of commercial facilities they stop by, and the expenditure they spend at these increased visited facilities can be regarded as an

[23]The fifth Survey of Consumer *Kaiyu* Behavior at City Center of Fukuoka City (conducted on March 17–19, 2000).

increase in the expenditure spent due to the use of the one-dollar city center bus. Thus, this is the effect of increased expenditure attributed to the one-dollar city center bus, and we define it as the economic effect of the one-dollar city center bus on the city center district reflected in the increase in its sales.

Since we want to count the number of visitors to the city center restricted to those who visit the city center for shopping, leisure, and dining, we calculated the number of visitors who use the one-dollar city center bus for shopping, leisure, and dining by checking the NNR's website to obtain the rate of the non-commuting and nonbusiness use of buses by day of the week. Also, from our *Kaiyu* survey, we obtained the percentage of visitors who used the one-dollar city center bus in the middle of their *Kaiyu* and the number of commercial facilities they visited after using the one-dollar city center bus. Consequently, the one-dollar city center bus's economic effect is estimated to be between 10.5 and 11.6 billion yen per year.

In this way, we see that the economic effect of the one-dollar city center bus is caused by the following causal sequence: the use of the one-dollar bus increases the *Kaiyu* visits to commercial facilities, and the increase in *Kaiyu* visits at commercial facilities increases the expenditure spent at the increased number of commercial facilities visited. We also found that in addition to increasing the net incoming number of visitors to the city center, stimulating and enhancing *Kaiyu* behaviors within the city center is also crucial for revitalizing the city center since it has a significant economic effect on the city center.

2.3.4 Economic Effect of City Center Cafés[24]

The factors stimulating *Kaiyu* behaviors are not limited to the one-dollar city center buses. As long as it is a factor that stimulates *Kaiyu*, anything can be used, and the economic effects of various urban development policies such as information provision and city center cafés can be measured and estimated using the same framework.

Until now, there has been no framework for measuring the functions and economic effects of individual facilities located in a city, and there have been no examples of studies that have measured these effects. So, we tried to measure what functions city center cafés such as Starbucks and Doutor provide to the city and what size of the economic effect they provide to the city center.

One interpretation of why city center cafés induce *Kaiyu* is that when consumers stop by a city center café to take a break while shopping, they feel refreshed and continue their *Kaiyu*. Therefore, we estimated the economic effect of city center cafés similarly to the one-dollar city center bus.

We estimated the economic effect of city center cafés in the same way as the one-dollar city center bus.

[24] The following analysis is based on Saito et al. (2002, 2008). Also, refer to Saito et al. (2018b), Chapter 11 in Saito and Yamashiro (2018c).

Table 2.2 Average number of commercial facilities visited by users and nonusers of city center cafes in the middle of *Kaiyu*

		Average (place)	Number of samples	Standard deviation	Difference in average numbers of steps to stop (a–b)	Significance probability
a	Café user (in the middle of *Kaiyu*)	4.26	87	1.73	1.43	0.000
b	Non-café user	2.84	998	1.75		

[From Saito et al. (2018b), Table 11.7, p. 233]

As shown in Table 2.2, according to the results of the analysis of the survey of *Kaiyu* behavior in the city center of Fukuoka City,[25] the number of commercial facilities visited by users of city center cafés in the middle of their *Kaiyu* turns out to be 1.4 more commercial facilities than that by nonusers.

First, we calculated the number of city center café users in the middle of their *Kaiyu* by multiplying the number of incoming visitors to the city center by the ratios of city center café users and those who use city center cafés in the middle of their *Kaiyu.* We then multiplied this by the number of commercial facilities visited by those café users after using the café and the average expenditure spent per visit, including no purchase visits, to obtain the increase in the annual expenditure on the city center due to the use of city center cafés. As a result, the economic effect of the city center cafés was estimated to be 18.9 billion yen per year.[26]

2.3.5 *Economic Effect of the Opening of a Subway in the City Center Commercial District of Fukuoka City*[27]

The last one is a study forecasting the economic effect of opening a new subway in the city center commercial district of Fukuoka City, Japan.

In Fukuoka City, the municipal subway *Nanakuma* Line, connecting the city center of the *Tenjin* district with the southwest suburbs, opened in 2005.

The *Nanakuma* Line connects *Hashimoto* Terminal Station in the southwest suburbs of Fukuoka City to *Tenjin-Minami* Terminal Station in the city center *Tenjin* district in 24 min. For suburban residents, it drastically reduces their travel time to the city center by more than 30 min compared to using buses. As a result, the subway opening connecting the suburbs and the city center is expected to increase the

[25] The sixth Survey of Consumer *Kaiyu* Behavior at City Center of Fukuoka City (conducted on June 15–17, 2001).

[26] The placement of coffee shops on each floor of department stores can be interpreted as an attempt to achieve this effect.

[27] The following analysis is based on Saito et al. (2007). Also, refer to Saito and Yamashiro (2018a), Chapter 12 in Saito and Yamashiro (2018c).

number of visitors to the city center and thus increase its sales, and even before the opening, merchants in the city center commercial district of *Tenjin* had high expectations.

The opening of the *Nanakuma* Line will shorten the travel time to the city center for residents living along the line and improve the convenience of the city center. Assuming that the average expenditure per trip is constant, increasing the frequency of trips will increase the number of visitors to the city center and the amount spent at the city center. We defined this increase in the expenditure spent at the city center as the economic effect of the subway opening on the city center commercial district and forecasted this effect.

Based on several data sources, including Surveys of *Kaiyu* Behavior at the City Center of Fukuoka City[28] conducted before the opening of the subway, Published Public Data, and our GIS distance measurement supplementary data,[29] two models, a logit model for the choice of travel means to the city center *Tenjin* district and a Poisson model[30] for the frequency of visits to the city center *Tenjin* district, were estimated.

Among these, the estimated result of the Poisson model to explain the frequency of visits to the city center *Tenjin* district turns out as follows[31]:

$$\begin{array}{rccccc} \log \lambda_i = & 1.37543 & - & 0.01511 t_{\mathrm{m}}^{*} & - & 0.00062 c_{\mathrm{m}}^{*} \\ & (7.09^{***}) & & (-3.18^{**}) & & (-2.00^{**}) \end{array} . \tag{2.1}$$

Here λ_i is the sample i's average frequency of visits to the city center *Tenjin* district for shopping, leisure, and dining per month (unit: times per month) and t_{m}^{*} and c_{m}^{*}, respectively, travel time (minute) and travel cost (yen) to the city center *Tenjin* district for the travel means which sample i selected on the survey day. Using this formula, we can predict how the visit frequency to the city center *Tenjin* district will change when the travel time and cost change.

Using the estimated models of travel means choice and visit frequency, we predicted the change in travel means choice and the visit frequency in the city center *Tenjin* district due to the opening of the subway *Nanakuma* Line. In addition, we also

[28] The first Survey of Consumer Travel and *Kaiyu* Behavior at City Center of Fukuoka City (conducted on-site on June 28–30, 2002) in which 59 samples were collected and The first Survey of Consumer Travel Behavior at City Center of Fukuoka City (conducted on-site on September 6–7, 2002) in which 240 samples were collected.

[29] In the survey of consumer *Kaiyu* behavior, the respondents were asked to answer the travel time and cost to the city center only for the travel means chosen on the survey day so that we could supplement data on the travel time and cost to the city center for travel means not chosen on the survey day by using GIS.

[30] Actually, a weighted Poisson model was used for estimation to remove the choice-based sampling bias caused by the on-site random sampling survey.

[31] Figures in parentheses are t-values for the estimate of each parameter. ***1% significant, **5% significant.

Table 2.3 Changes in the number of visitors to the city center before and after the subway's opening

	Before		After		
	Bus	Car	Bus	Car	Subway
All residence	255,205	96,865	134,222	51,321	379,490
Total	352,071		565,033		
After–before	212,962				

[From Saito and Yamashiro (2018b), Table 13.8, p. 270]

forecasted the effect of the opening of the subway *Nanakuma* Line on the increase in expenditures spent at the city center commercial district, *Tenjin* District of Fukuoka City, based on the average expenditure per person per visit to the city center commercial district obtained from the survey of *Kaiyu* behavior at the city center of Fukuoka City. The predicted results are shown in Table 2.3.

We see that the frequency of visits to the city center *Tenjin* district will increase before and after the opening of the subway *Nanakuma* Line, and the number of customers who visit the city center commercial district *Tenjin* will increase by 210,000 persons per month.

According to the survey of *Kaiyu* behaviors in the city center of Fukuoka City, the average expenditure per visit per person spent at the city center commercial district, *Tenjin* District of Fukuoka City, is 6925 yen.

We use this amount to estimate the sales increase effect on the city center commercial district, that is, the expenditure increase effect on the city center commercial district due to the increase in the number of visitors. As a result, an estimated economic effect on the city center commercial district, *Tenjin* District of Fukuoka City, turns out to be 17.7 billion yen per year.[32]

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[32] Yamashiro (2012) and Yamashiro and Saito (2018), Chapter 22 in Saito and Yamashiro (2018c), further estimated the stratified CES utility function of residents along the subway *Nanakuma* Line directly using retrospective panel data after the opening of the subway, and estimated the change in welfare level due to the opening of the subway *Nanakuma* Line.

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Chapter 3
The Goal of Urban Development: An Emerging View of Town Equity

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Abstract We introduce the concept of "town equity" to clarify the goal of urban development. The concept of town equity is defined as the asset value of the town's attractiveness fostered in the minds of visitors to the town. Thus, to increase town equity, it is necessary to increase the visit value of an individual visitor to the town. For this purpose, we will discuss the importance of on-site decision support using mobile information and communication technology (ICT) to satisfy the needs of diverse visitors. Furthermore, using our *Kaiyu* studies as examples, we will deepen the understanding of how to scientifically evaluate urban development policies.

Keywords Town equity · Visit value · Value of a city · On-site survey · Choice-based sampling bias · Information evolution · Information interaction

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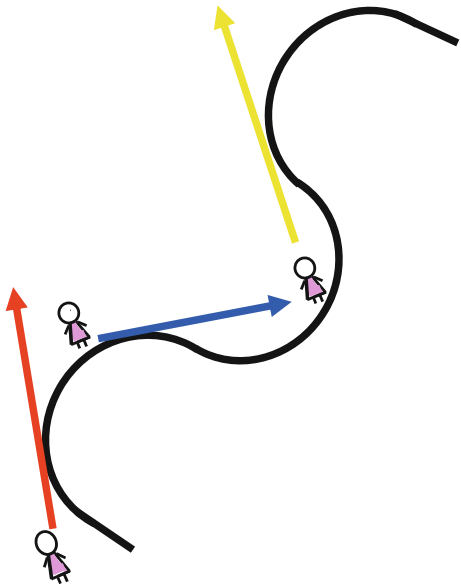

Fig. 3.1 Information evolution through town walking. [From Saito (2018), Fig. 18.1, p. 362]

3.1 Information and Evaluation of a City

3.1.1 Information and the Hypothesis on the Attractiveness of a City: Information Evolution Through Town Walking

3.1.1.1 Hard Tricks: A Case of Canal City *Hakata*

We have a hypothesis on the attractiveness of a city. Canal City *Hakata*, located in Fukuoka City, Japan, is a vibrant commercial complex where people can spend time and stay. Canal City *Hakata* is characterized by its intricate design with many curves throughout the facility. However, then, one may wonder why there are so many curves.

We interpreted it as shown in Fig. 3.1. When people walk in a curve valley, the view is limited, but when they gradually walk towards the curve mountain, the view opens up, and the next valley appears for the first time. The interpretation is that this may be linked to "a feeling of excitement" when walking inside the facility, which then becomes an element of attractiveness. We refer to such a trick, where new information is introduced one after another during town walking, as the "information evolution" through town walking.

This hypothesis considers that the attractiveness of a city lies in the information evolution during walking in the city. In other words, we hypothesize that the attractiveness of a city lies in the fact that one can discover unexpected and new information while walking around a city.

If this is the case, there would be no attractiveness in a facility with many straight lines and good visibility, such as a straight corridor, where what one can see at the end of the corridor becomes more visible as one walks along. Therefore, the hypothesis is that Canal City *Hakata*'s use of many curved lines throughout the facility, rather than many straight lines with good visibility, can be interpreted as having been one of the tricks among various means available to the hard facility that effectively generates the information evolution during walking around the facility[1,2]

3.1.1.2 Soft Tricks: The Concept of Hypertext City

Thinking in this way, we come to the idea that to make the information evolution richer through walking around the city, various soft mechanisms can also be utilized in addition to hard mechanisms. Events in the city and street performances such as street art, musical performances, and singing throughout the town can be seen as examples of these mechanisms.

In the early days of the Internet, hypertext, where WWW URL links are embedded in plain text, had a tremendous impact and appeal. One of the authors named the city that allows visitors to have semantic information interaction with the city through intelligent mobile terminals "Hypertext City" and advocated the realization of the "Hypertext City Concept."[3]

Since then, we have assumed that the actual link in the city would be an intelligent agent. However, with the rapid technological innovation of smartphones, mobile ICT, IoT, and wearables, the feasibility of the environment envisioned by the hypertext city is increasing.

Nevertheless, systematically recording and analyzing how consumers coming to the city interact with the information provided by the city is a new attempt that has just started. It is still a future challenge to verify whether or not the attractiveness of the city or, more precisely, the evaluation of the city by individual visitors has increased as they had experienced the "information evolution through walking around the city" based on the individual's micro-behavioral history data that records how individual visitors interact with the information provided by the city. In any case, the hypothesis of "information evolution while walking through the city" is our current working hypothesis.[4]

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[1] As for the information evolution through town walking, refer to Saito (2005, 2018, 2017).

[2] It is allegedly said that the new spot in Shanghai, *Xintiandi*, made extensive use of the right-angle intersections of *hutongs*, following the idea of the curves of Canal City *Hakata*.

[3] As for the concept of Hypertext City, refer to Saito (2001, 2005). Also, see Saito et al. (2008a).

[4] An indirect corroboration is a result of measuring the time value of consumer shopping [Cf. Saito et al. (2003), and Saito and Yamashiro (2018a), Chapter 10 in Saito and Yamashiro (2018b)]. They measured the time value of consumers who come to the city for shopping while classifying their purchasing attitudes into three purchasing attitudes, "I definitely intend to buy the desired product," "I intend to look around," and "Willing to buy if there is a good product." Among the three, the consumer having the purchasing attitude, "willing to buy if there is a good product," shows the

3.2 Town Walking and Information Interaction[5]

3.2.1 Social Experiment Investigating Consumers' Information Processing Behavior Using Smartphones

Here, we set up a social experiment to measure the effect of providing information during the year-end sale in the city center commercial district, *Tenmonkan* District of *Kagoshima* City, Japan. This study is a research example that tries to measure the effect of information provision on the year-end sale by recording how consumers who came to *Tenmonkan* District interacted with the information on the year-end sales provided by shops in the district using the smartphone app.

FQBIC[6] is developing a smartphone-based information provision system to accelerate visitors' *Kaiyu*, aiming to enhance the value of a city by providing real-time on-site decision support to visitors to increase their visit value to the city. For 2 years, starting in 2012, the Ministry of Internal Affairs and Communications (MIC) selected us as a recipient of the Strategic Information and Communications R & D Promotion Program (SCOPE). Under the adopted research project,[7] we conducted a social experiment in *Tenmonkan* District, the city center commercial district of *Kagoshima* City, to explore how the consumers who came to the city center district interacted with the information provided by the shops in the district on the year-end sale by recording their interactions as the log of their use of the smartphone app.

Figure 3.2 shows the screen of the smartphone app. The app displays a map of the current location, and by simply shaking the smartphone, multiple icons randomly appear with information on stores in the vicinity. Tapping on the icon will bring up detailed information about the store, and one can learn more about the store and the year-end sale at the store. On the other hand, in the background of the app, the user's location, the information provided, and the information selected by the user are collected and sent to the server.

The social experiment in the *Tenmonkan* district was conducted for 3 days, from December 13 to 15, 2013, in conjunction with the year-end sale. On the day of the social experiment, we asked visitors with Android-based smartphones to volunteer to participate in the social experiment. As a result, we recruited 89 people from visitors who participated in the experiment on the day they came to shop during the

highest time value, followed by "I intend to look around," and the lowest was "definitely intend to buy." This counter-intuitive result suggests that discovering and excavating new products during the shopping process is of great value.

[5] For a more detailed analysis of this section, refer to Imanishi et al. (2018).

[6] Fukuoka University Institute for Quantitative Behavioral Informatics for City and Space Economy.

[7] Our research project title is "A Development Study on the System for Measuring Tourist Movements around Wide Area using Auto GPS (Global Positioning System) and IMES (Indoor MEssaging System), and for an Effective Information Provision to Trigger *Kaiyu* (Trip Chaining)." For the outline of the research result, see Saito (2014).

Fig. 3.2 Screen of smartphone app "FuriFuri Tenmonkan"

3-day experiment. Finally, the collected log data amounted to 50,000 records.[8] Figure 3.3 shows a visualization of the collected log data of the user behavior log.

3.2.2 *Consumer's Information Processing Micro-Behavior History Data*

Most research has been limited to visualizing location information log data using GIS, such as *Kaiyu* behavior logs, as shown in Fig. 3.3. However, visualization alone

[8] Assuming that we accumulate eight h of data on the *Kaiyu* behaviors of visitors to the city center of Fukuoka City, it would amount to about 0.09 peta per year. The rationale for this is that the net number of visitors entering the city center of Fukuoka: 300,000 people/day × 8 h × 60 min × 60 s × 365 days × (location information: 30 bytes) = 0.09 petabytes. If we assume that this is the entire country of Japan and recorded 24 h a day, the amount of data is comparable to the estimate due to Beyea (2010) that if the electricity consumption of all households in the US were recorded in units of 1 s, it would be about 50 peta (10^{15}) bytes.

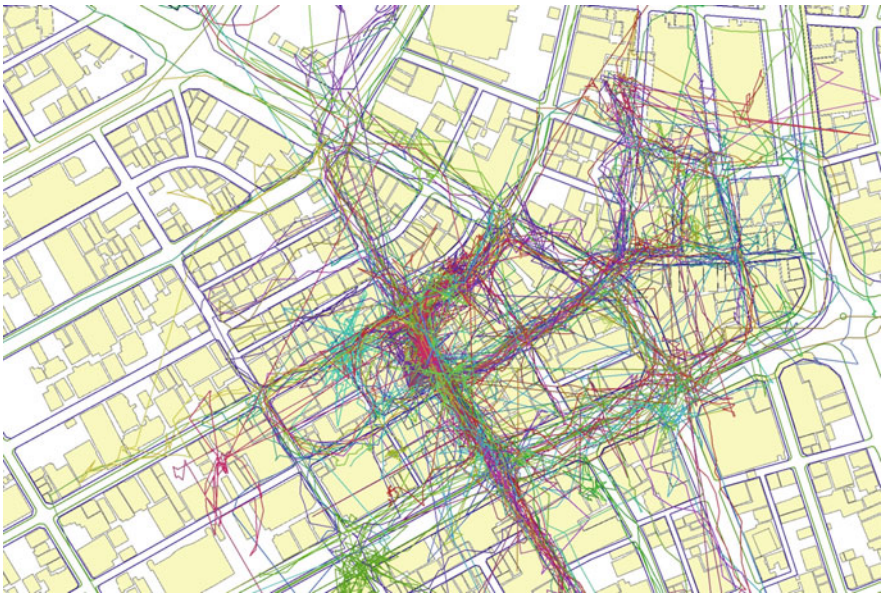

Fig. 3.3 Visualization *Kaiyu* behavior logs of all participants within *Tenmonkan* District. [From Imanishi et al. (2018), Fig. 20.6, p. 406]

only describes the results of *Kaiyu* behavior and does not explain why such *Kaiyu* behavior was chosen. Therefore, to perform urban development rooted in scientific evidence utilizing big data, it is indispensable that the big micro-behavioral data should enable one to analyze how and why individual consumers have made such *Kaiyu* behaviors.

For this reason, at this time, the system is designed to enable one to statistically verify what kind of information was provided and how it affected the *Kaiyu* behavior of the app users. Figure 3.4 shows the data obtained from this system and its structure. More specifically, the system records a log of the information presented in addition to the selected information. Thus, it enables one to statistically analyze why the selected information was chosen among the set of information presented, that is, the set of alternatives.

Integrating these data makes it possible to explore how the individual visitor has carried out information interactions with the city center commercial environment. In Fig. 3.5, we provide the information processing micro-behavior history data obtained from one sample. The figure describes how the sample undertook *Kaiyu* while transacting with the information environment by integrating the sample's log histories of movement logs, search logs, and information browsing logs.

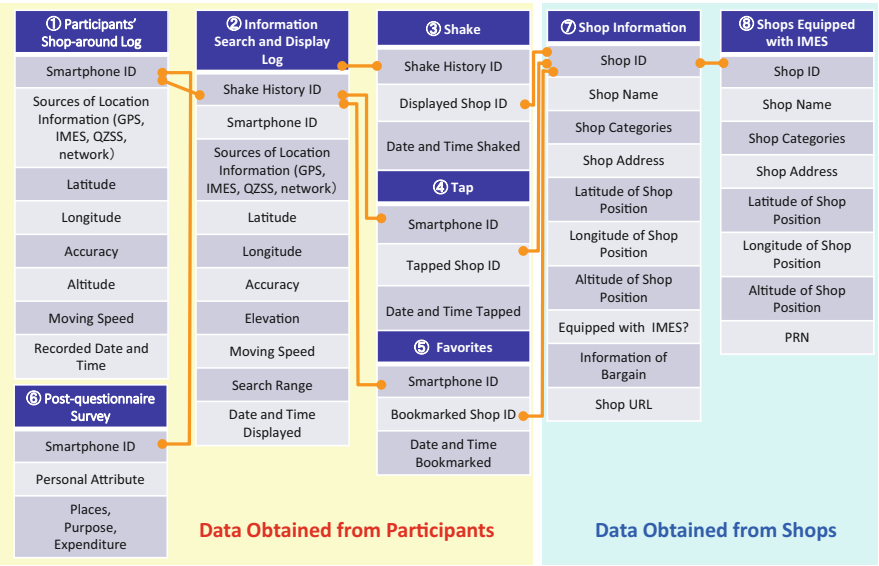

Fig. 3.4 Interrelationship among various log history data. [From Imanishi et al. (2018), Fig. 20.3, p. 401]

3.2.3 *Information Easily Chosen and Highly* Kaiyu-*Inducing Information*

Let us take a look at some of the results of the analysis. We examined to what extent people tapped the information provided by shaking their smartphone and whether or not they visited the store after viewing the shop's information by tapping. The results show that the percentage of how often icons were tapped to the number of shakes for searching was 43%. Of the stores tapped, 15.6% actually were visited [Cf. (Imanishi et al. 2014 2018), Yamashiro et al. (2015)].

In addition, we analyzed the factors that led consumers to tap the genre-specific icons displayed in the app by building a logit model to explain icon selection. We found that the farther the distance to the shop the icon shows, the less likely the icon is to be tapped. Furthermore, if the shop the icon shows is located in the same direction as the participant is walking, the icon is more likely to be tapped [Cf. (Imanishi et al. 2014, 2018)].

We further found that the likelihood that participants visit the specific shop is related to how the information content of that shop is provided to them. More specifically, we found that when a banner is contained in the information content of the shop, the rate of the visit to that shop becomes higher than when there is no banner. Also, when a store's description is contained in this store's information content, the visit rate to this store is higher than when there is no description [Cf. (Imanishi et al. 2018; Yamashiro et al. 2015)].

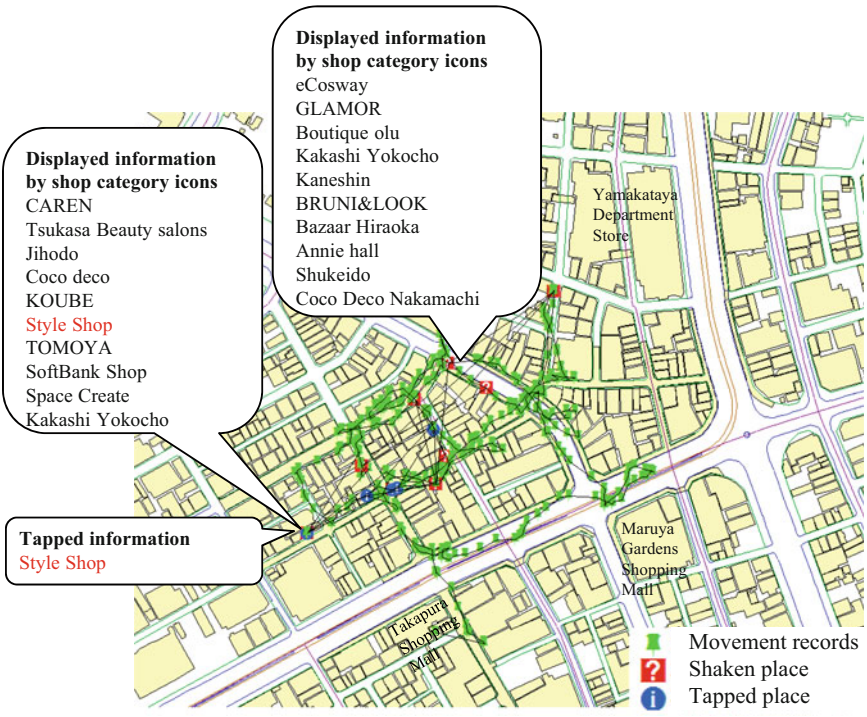

Fig. 3.5 History of information transactions by one sample. [From Imanishi et al. (2018), Fig. 20.4, p. 404]

As described above, by using mobile ICT, we can obtain consumers' information processing micro-behavior history data which describes how individual consumers have interacted with the information environment in a city and what kind of decisions they have made while undertaking *Kaiyu*.

Thus, this kind of microdata enables us to analyze how individual consumers perform information transactions with the city environment while they are doing *Kaiyu*, which is impossible so far. If this becomes possible, the analysis of this kind of data can effectively be fed back and utilized to enhance our understanding of urban development policies, which is our concept of the social city.

3.3 Consumer Behavior as Revealed Evaluation of a City

In the following, we introduce two examples of *Kaiyu* studies that investigate how the renewal of commercial facilities and the opening of new stores, that is, the changes in the state of the city environment, have affected the behaviors of individual consumers.

One feature common to these two studies is the effort to extract the effect specific to each different individual consumer. In other words, these two studies take the individualistic viewpoint to evaluate the effects caused by urban development policies. Here, note that while traditionally the changes such as the renewal of the department store and the store opening of new shop category are not thought of as urban development policies, these two studies treat them as urban development policies since they change the behaviors of the consumers who visit the city. Further, we are concerned with how these urban policies have different effects on different individual consumers.

The second feature of these two studies is that they share the following viewpoint. The changes in behaviors of individual consumers, equivalent to the effects of policies, are regarded as the reflection of the evaluation of the policies those individual consumers implicitly perform as their behaviors.

In other words, these two studies consider that individual consumers' evaluation of a city is reflected in their behaviors that respond to the changes in the city's state or urban development policies.

Therefore, these two studies take up urban development policies such as the renewal of commercial facilities and the opening of the new stores to investigate how they change the behaviors of the individual consumers who visit the city.

However, the focus is on the analysis from the perspective of how these policies are evaluated differently by various individual consumers, to what extent they increase the value of the visit for individual consumers, and whether they increase the value of the city for visiting consumers.

Hence, the central purpose of the two studies is to empirically verify how individual consumers have changed their behaviors or evaluated the policies before and after they are implemented. Thus, we must have some statistical methodology that enables us to identify the behavioral change of each consumer.

For this purpose, both studies employed the data that we call "retrospective panel data," in which, after the implementation of an urban development policy, we ask the same individuals how their evaluation of the city has changed before and after the implementation of that urban development policy.

3.3.1 Did the Grand Renewal Opening of the Department Store Increase the Value of the City?[9]

This case study is about the grand renewal opening of *Iwataya*, a long-established local department store in the city center of Fukuoka City, Japan.[10]

[9] For a more detailed analysis and the background of the renewal, refer to Saito et al. (2018a). Also, see Saito et al. (2006), which first introduced the retrospective panel data in our *Kaiyu* studies.

[10] *Iwataya*, which had the characteristics of a terminal department store at *Nishitetsu Tenjin* Railway Station, had the main building and the new building at the location where *Parco* is now located. Initially, in conjunction with the redevelopment of the *Nishitetsu* Terminal Building, *Iwataya* was

Iwataya, a long-established local department store that had been operating in the main and new buildings adjacent to *Nishitetsu Tenjin* Station since 1936, closed these buildings and reopened them on March 2, 2004, as a completely new two-building system, with the former Z-Side as the main building and the new store built adjacent to it across *Kirameki-Dori* street as the new building. The renewal opening was a large-scale renewal, limited to not only the physical renovation but also the strategic changes in their marketing. While the core customers for the previous two-building system were older people, the store configuration for the new two-building system was strategically changed to target working women in their late twenties and thirties.

To take this opportunity, we decided to measure the evaluation of visitors to *Iwataya* before and after the renewal on an individual basis to see what kind of customers have changed their evaluation and how and why they have changed their evaluation.

To capture the changes on an individual basis, a simple way we can employ would be to conduct a survey of visitors to the store twice, before and after the renewal. However, in a standard on-site survey of visitors, the respondents are randomly selected from among the visitors to the store. Therefore, even if we conduct the survey twice before and after the renewal, no chance exists that the same respondent will be selected. Thus, while conducting the on-site survey twice, it is almost impossible to measure how individual customers have changed their evaluation before and after the renewal.

Survey data collected at a single point in time is referred to as cross-section data. On the other hand, data observing changes multiple times, such as before and after the renewal for the same individual, is referred to as panel data.

To capture the changes on an individual basis, we need panel data. However, it takes cost and time to secure a panel[11] before the renewal and maintain it until after completion.[12]

Therefore, we devised the following method. In the Survey of Consumer *Kaiyu* Behavior at the City Center of Fukuoka City conducted after the renewal,[13] we asked the respondents about their behavior before and after the renewal. Thus, we obtained the panel data for the two-time points for each respondent before and after the renewal. We call the panel data obtained in this way "retrospective panel data."

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scheduled to expand its floor space in a part of the redevelopment building connected to the main building. However, the plan was changed, and a new department store, Z-Side, was opened in 1996, but it fell into financial difficulties in 2000. With the support of the local business community, the company secured the former NHK site adjacent to Z-Side as a site for a new building and attempted to rebuild itself. However, the business deteriorated further, and the store became part of *Isetan*, and on March 2, 2004, the former Z-Side became the main store, and the new store on the adjacent NHK site became the new building. For the background and history of this period, refer to the statement given in Saito et al. (2018a). For general information about Iwataya, see Wikipedia (2018).

[11] The group of subjects followed by a panel survey is referred to as a panel.

[12] At this time, Internet surveys were not yet widespread.

[13] The ninth Survey of Consumer *Kaiyu* Behaviors at the City Center of Fukuoka City conducted on July 10 (Sat.) and 11 (Sun.), 2004.

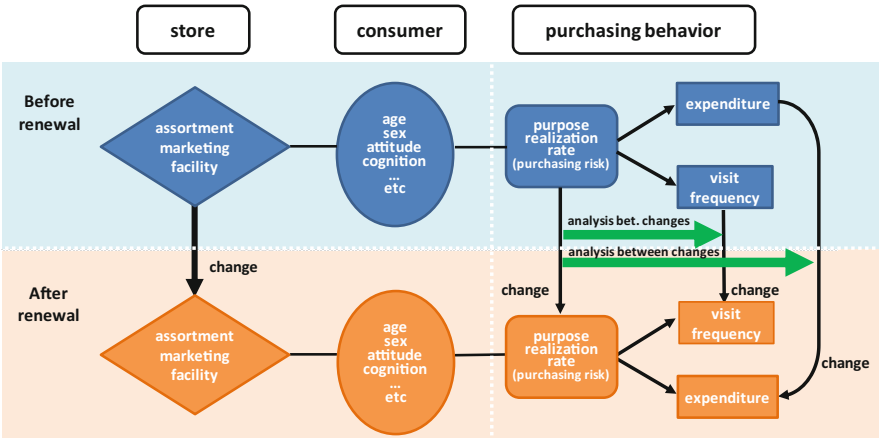

Fig. 3.6 Framework for analyzing changes in purchasing behaviors before and after *Iwataya*'s renewal. [From Saito et al. (2018a), Fig. 16.2, p. 323]

Now, consumer behaviors change before and after *Iwataya*'s renewal. This is so because the renewal changes its product lineup, sales floor configuration, and store image.

Here, we will focus on the changes in the purpose realization rate and the frequency of visits. The hypothesis is shown in Fig. 3.6. The renewal has affected consumers' opportunities to decide whether they can buy their desired products. Thus, the renewal changes consumers' purpose realization rates of shopping at that store. Furthermore, we hypothesize that if the purpose realization rate at the store increased, the frequency of shopping visits to that shop and the amount of expenditure at that shop also would increase.

Usually, in cross-section data, it is possible to analyze the correlation between the higher purpose realization rate and the higher frequency of visits, but it is not possible to strictly analyze the relationship between these changes. In contrast, we can identify whether the frequency of visits increases as the purpose realization rate increases for the same individual in retrospective panel data. Thus, the retrospective panel data makes it possible to analyze the relationship between these changes. Specifically, the retrospective panel data makes it possible to analyze the causal relationship between the purpose realization rate and the frequency of visits and the causal relationship between the purpose realization rate and the amount of expenditure, as shown in Fig. 3.6.

First, let us look at changes in the purpose realization rate. In Fig. 3.7, we show two cumulative distribution functions corresponding to before and after the renewal for each age group. In this figure, if the cumulative distribution function shifts to the left, i.e., the closer to the vertical axis through the origin, the lower the average purpose realization rate becomes.

From Fig. 3.7, we see that, except for the targeted 25–29 age group, the purpose realization rate at the new *Iwataya* after the renewal is lower than before the renewal for all age groups.

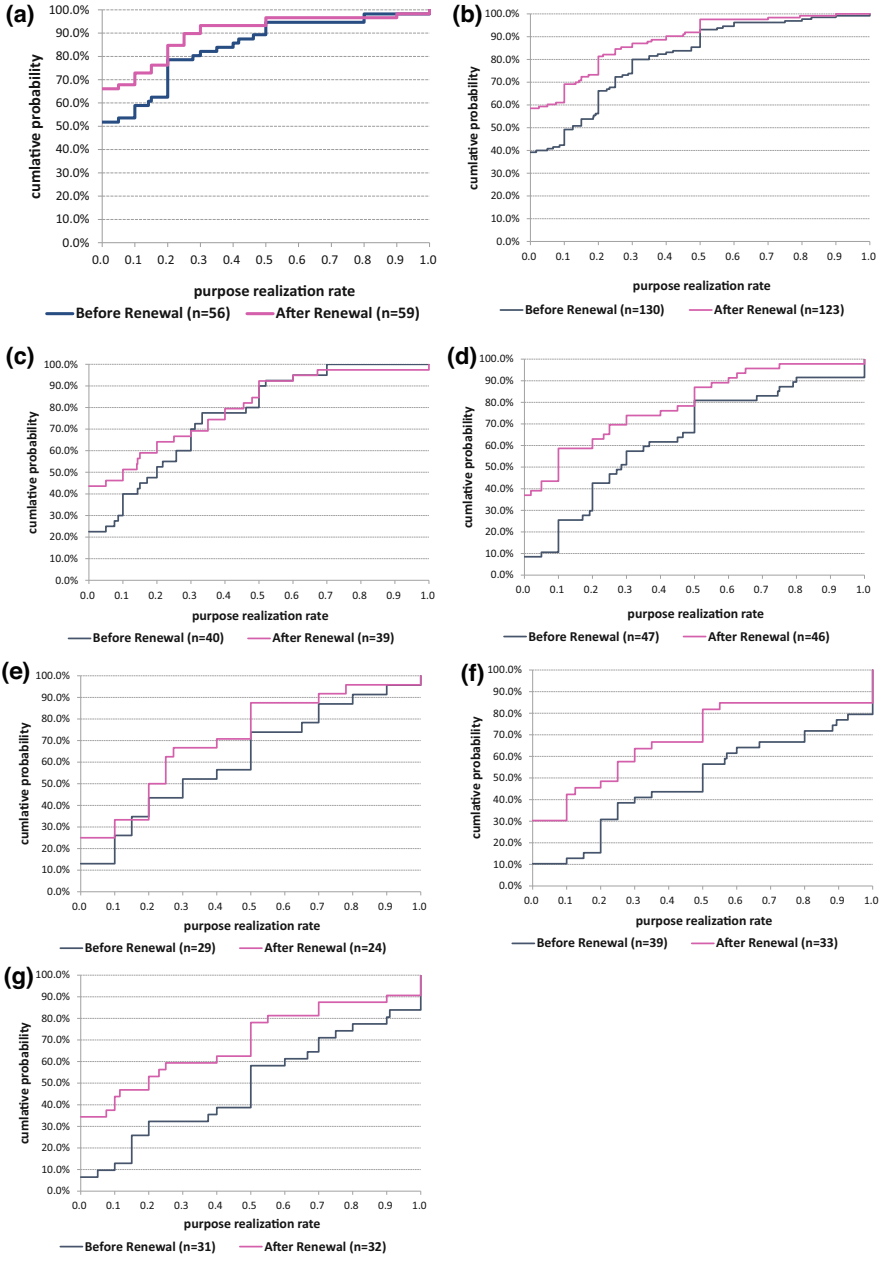

Fig. 3.7 Changes in the purpose realization rate before and after the renewal by age groups: (**a**) teenagers (**b**) 20–24 years old (**c**) 25–29 years old (**d**) 30–39 years old (**e**) 40–49 years old (**f**) 50–59 years old (**g**) 60 years old and over [from Saito et al. (2018a), Fig. 16.4, p. 328]

Table 3.1 The higher the purpose realization rate, the higher the frequency of visits

			Changes in visit freqency before and after the renewal (ratio: after/before)		
			Visit frequency decreased group after/before <1	Visit frequency increased group after/before ≥1	Total
Changes in purpose realization rate before and after the renewal	Purpose realization rate decreased group after/before <1	%	**40.5**	**59.5**	100.0
		Obs	64	94	158
	Purpose realization rate increased group after/before ≥1	%	**30.0**	**70.0**	100.0
		Obs	27	63	90
Total		%	**36.7**	**63.3**	100.0
		Obs	91	157	248

$\chi^2 = 2.7247$, $p = 0.0988$

Changes in purpose realization rate by changes in visit frequency [from Saito et al. (2018a), Table 16.3, p. 337]

Furthermore, Table 3.1 provides the results of the division ratio cross-tabulation[14] analysis of whether the frequency of visits increases if the purpose realization rate increases for the same individual before and after the renewal.

For the customer group whose purpose realization rate had increased, the percentage of the visit frequency increased group increased by 10.5% from 59.5% to 70.0% compared to those who had decreased their purpose realization rate, as shown in bold numbers at the rightmost except the last column. This result suggests a relationship between increasing the purpose realization rate and increasing the frequency of visits.

Similarly, Table 3.2 shows the division ratio cross-tabulation analysis results of whether the expenditure increases if the purpose realization rate increases for the same individual before and after the renewal.

From Table 3.2, for the customer group who had increased the purpose realization rate, the share of the expenditure per month increased group increased by 33.7% from 31.4% to 65.1% compared to those who had decreased their purpose realization rate, as shown in bold numbers at the rightmost except the last column. Conversely,

[14]The division ratio cross-tabulation method proceeds as follows. First, suppose we want to analyze the relationship between the changes in two variables, causal and outcome variables. Also, suppose each variable is measured at two points in time, before and after the policy implementation. Then, we make two ratio variables corresponding to causal and outcome variables by taking the ratio of after to before for each variable. Further, by dichotomizing the ratio variables according to whether or not their values are greater than 1, we obtain two categorical variables corresponding to changes in causal and outcome variables. Finally, we perform a cross-tabulation analysis between these two categorical variables and analyze whether there are some relations between the change of the causal variable and that of the outcome variable.

Table 3.2 The higher the purpose realization rate, the more the expenditure per month

			Changes in expenditure per month per cconsumer before and after the renewal (ratio: after/before)		
			Expenditure per month decreased group after/before <1	Expenditure per month increased group after/before ≥1	Total
Changes in purpose realization rate before and after the renewal	Purpose realization rate decreased group after/before <1	%	**68.6**	**31.4**	100.0
		Obs	105	48	153
	Purpose realization rate increased group after/before ≥1	%	**34.9**	**65.1**	100.0
		Obs	30	56	86
Total		%	**56.5**	**43.5**	100.0
		Obs	135	104	239
$\chi^2 = 25.504$, $p < 0.000$					

Changes in purpose realization rate by changes in expenditure per month [from Saito et al. (2018a), Table 16.4, p. 338]

for the customer group who had decreased the purpose realization rate, the share of the expenditure per month decreased group increased by 33.7% from 34.9% to 68.6% compared to those who had increased their purpose realization rate, as shown in bold numbers at the column next to the previous column. These results also suggest a relationship between increasing the purpose realization rate and increasing the amount of expenditure.

3.3.2 *A New Entry of a Large Variety Shop Increased the Value of the City Center?*[15]

The following example is *Tenjin* Loft, a large-scale variety shop or general merchandise store that opened in November 2007 in the city center district, *Tenjin* District of Fukuoka City. At that time, INCUBE, a large-scale variety shop, was already located in *Solaria* Stage in the Tenjin District, but *Tenjin* Loft opened in a building about 200 m south of INCUBE.

There has not been much research on the implication of a large-scale variety shop's opening in a city center commercial district. This study sets up the hypothesis that the value of the city center commercial district, *Tenjinn* District of Fukuoka City, will be enhanced since the large-scale variety shop opening expands the choices available for consumers visiting the city center.

[15] The following analysis is based on Saito et al. (2009). For a more detailed analysis, see Saito et al. (2018b).

Table 3.3 Changes in shopping destinations before and after the opening of *Tenjin* Loft (stationery)

		After opening				
Before opening		INCUBE	Tenjin Loft	Department stores	Other stores in the city center of Fukuoka	All
INCUBE	Obs	196	43	0	3	242
	%	81.0%	17.8%	0.0%	1.2%	100.0%
Department stores	Obs	0	12	77	1	90
	%	0.0%	13.3%	85.6%	1.1%	100.0%
Other stores in the city center of Fukuoka	Obs	2	20	1	197	220
	%	0.9%	9.1%	0.5%	89.5%	100.0%
All	Obs	198	75	78	201	552
	%	35.9%	13.6%	14.1%	36.4%	100.0%

[From Saito et al. (2018b), Table 17.2, p. 345]

Therefore, we analyze how consumers' shopping behaviors have changed before and after the opening of *Tenjin* Loft and how these changes enhanced the value of the city center of Fukuoka City from the viewpoints of the consumers who come shopping in the city center, focusing on their switches in the shopping destination choices and the changes in the purpose realization rate.

The data used in this study is the retrospective panel data obtained from the Survey of Consumer *Kaiyu* Behavior at the City Center of Fukuoka City[16] conducted after the opening of *Tenjin* Loft. Specifically, we used the responses to the question items, in which, for each of the six items (stationery, interior goods, variety goods, household goods, health goods, and accessories), we asked the respondents about the change in their shopping destination and the purpose realization rate before and after the opening of *Tenjin* Loft.

In Table 3.3, we show the analysis results on how consumers have changed their shopping destination for stationery goods before and after the opening of *Tenjin* Loft. From Table 3.3, we see that 17.8% of the respondents who used to shop at INCUBE, 13.3% from department stores, and 9.1% from other stores have switched their shopping destination to *Tenjin* Loft.

In Table 3.4, we provide the analysis results of whether the consumers who switched their shopping destination for stationary goods to *Tenjin* Loft have increased their purpose realization rate for shopping the stationary goods or not. From Table 3.4, it is statistically significant that the percentage of the increase in the purpose realization rate for those who changed their shopping destination to *Tenjin* Loft for the stationery category is higher than that for those who did not change. Furthermore, from similar analyses for the other five category items, the change of shopping destination to *Tenjin* Loft increases the purpose realization rate for all six items.

[16] The 13th Survey of Consumer *Kaiyu* Behaviors at the City Center of Fukuoka City conducted on June 28 (Sat.) and 29 (Sun.), 2008.

Table 3.4 Switches to *Tenjin* Loft and the purpose realization rate (stationery)

Purchase destination switch		Purpose realization rate Not increased (after/before ≤1)	Purpose realization rate Increased (after/before >1)	All
Not changed to Tenjin Loft	Obs	442	3	445
	%	99.3%	0.7%	100.0%
Changed to Tenjin Loft	Obs	48	24	72
	%	66.7%	33.3%	100.0%
All	Obs	490	27	517
	%	94.8%	5.2%	100.0%
$p < 0.001$				

[From Saito et al. (2018b), Table 17.7, p. 352]

3.4 The Concept of Town Equity

3.4.1 Dynamics of Hotspot Changes in City Centers

We now discuss the case of the city center of Fukuoka City.

The city changes dynamically, but the causes of this change are not limited to the renewal of physical systems such as the development and redevelopment of physical facilities. The value of a city changes drastically when the evaluation by visitors changes.

In the city center of Fukuoka City, before 2000, *Oyafuko-Dori* Street in the north of the city center was a hotspot where young people from all over *Kyushu* Island flocked, especially on weekends nights, and it was quite a popular district with significant momentum. However, due to the worsening security of *Oyafuko-Dori* and the opening of adult entertainment establishments, it has declined, and the popular spot has shifted from *Oyafuko-Dori* to the *Daimyo* District, another near hotspot in the city center of Fukuoka City.

This case demonstrates that hotspots in the city center can change dynamically and drastically depending on the popularity among visitors. If the district is not popular and does not attract people, the real estate value of the town will drop sharply.

In other words, the change in the visitors' evaluation of *Oyafuko-Dori* has drastically changed the town's value. To put it another way, people's evaluation of the city dramatically determines its value.

Therefore, in a town that is aware of this, people's evaluation of the town is considered a "town brand," which should be maintained, nurtured, and managed.[17]

[17] An example is *Marunouchi* District, Tokyo. Refer to Saito (2007). Also note the title of the open symposium held by JARES (The Japan Association for Real Estate Sciences).

3.4.2 Brand Equity

It is easy to extend from the concept of "town brand" or "brand" to the concept of "brand equity."

To clarify the goal of urban development, we will introduce the concept of "town equity" in the next section. "Town equity" is a term coined by one of the authors of "brand equity."

Brand equity means, for example, that 10,000 people are willing to spend 10,000 yen (100 USD) more for a famous brand product than a nonbrand product. If these people buy the famous brand product 100 times a year, there will be an annual increase of 10 billion yen (100 million USD) in sales. In other words, just by being a famous brand, there would be an increase in sales of 10 billion yen per year, i.e., an additional cash flow. If this is discounted by a 5% discount rate, it would have an asset value of 200 billion yen (2 billion USD). In other words, if one has a deposit asset of 200 billion yen (2 billion USD), if it earns 5% interest every year forever, one will have an annual interest income of 10 billion yen (100 million USD), which is the same amount as the cash flow generated by the "intangible asset" of a famous brand,[18] which is what we call brand equity.[19]

What is important to note about the concept of brand equity is that it is an asset of the company that owns the famous brand, but it is not an asset such as a building or land that the company owns, but rather the value of the company's asset that is fostered in the minds of the consumers who are the customers of the company.[20]

3.4.3 Definition of Town Equity[21]

Thinking this way, we realize that the same is true for towns. Based on brand equity, we define "town equity" as "the asset value of the attractiveness of the town fostered in the minds of visitors who visit the city."[22]

The most crucial point worth noting about the concept of town equity is that the asset value of the attractiveness fostered in the mind of each individual at the micro-

[18] For ease of understanding, we also give the calculation in terms of US dollars with the following rate: 100 JPY = 1 USD.

[19] As for brand equity, see the well-known reference, Aaker (1991).

[20] In short, it refers to intangible assets such as "goodwill." The concept of brand equity has recently come to be used in a common way as our concept of town equity, which we will introduce below, such as place branding and tourism destination brand equity. For example, see Ref. Gomez et al. (2015).

[21] The term "town equity" was used for the first time in the 20th anniversary symposium "Urban Renewal and Town Equity," held at the 20th Annual Meeting of the Japan Association for Real Estate Sciences (JARES). The workshop "Consumer Behavior and Town Equity I, II" was held at this conference. See Refs. (Ishibashi et al. 2005; Kakoi et al. 2005; Saito 2005).

[22] The term "town equity" was first defined by Saito in Ref. (Kakoi et al. 2005). Also, a detailed discussion is given recently in Saito (2017) and Saito (2018). See also Saito (2005, 2010).

level is first defined as a disaggregated concept, and then the aggregated value is defined as town equity.

Moreover, the "asset value of the town's attractiveness fostered in the minds of visitors" may refer to a district in the city center such as *Daimyo* or the entire city of Fukuoka City, just as a brand may refer to the product itself or a super brand that includes a line of products.[23] Furthermore, it is equally applicable to sightseeing spots and *Satoyama* (undeveloped woodlands near a populated area) with unique products.

When we have constructed the concept of town equity, defined as the value perceived by individual visitors, we notice that the goal of urban development, which has not been considered clearly in the past, is to maximize "the asset value of the attractiveness of the town fostered in the minds of people visiting the town.

If the goal of urban development is understood as maximizing town equity, the tremendous research field on the evaluation of various urban development policies would be opened by taking the viewpoint of what functions, services, and facilities in a city will provide the highest visit value to individual visitors. Among the vast examples of questions, some are the following. What configuration of stores in a commercial complex would maximize the commercial complex's equity, and what functional configuration would maximize the city's equity.[24]

3.5 The Goal of Urban Development

3.5.1 Clarifying the Goal of Urban Development

Town equity is nothing other than the value of a city from the perspective of individual consumers. If we take the view of the city formation system that a city is not formed by a single entity but by various entities and businesses, we can redefine the goal of urban development as "maximizing town equity by regarding the city as if it were a single entity," as Saito (2017, 2018) advocated.

To put it in another way, by emphasizing the concept of the city formation system, maximizing the visit values of visitors becomes equivalent to maximizing the value of the town, and the goal of urban development can be reduced to the question, "What kind of visit values can be maximized for what kind of visitors by providing what kind of functions and facilities to constitute the town?"

The significance of the concept of "town equity" is that it clarifies the goal of urban development, which was ambiguous in the past, and makes the value of the

[23] Our study [Cf. Saito et al. (2007)] attempted to concretely measure the town equity of the *Daimyo* district from the perspective of what additional expenditures people are willing to make in the *Daimyo* district compared to the *Tenjin* district as a whole. See also Saito (2007).

[24] The first author advocated the concept of "town equity" and "town equity research" at the annual meeting of the Japan Association of Real Estate Sciences (JARES) held at Fukuoka University in 2004. To promote this concept, he has held four open public symposia sponsored by JARES.

town a measurable concept. Also, it shows that we can concretely measure the value of the town based on *Kaiyu* behavior microdata.[25]

Furthermore, town equity is measured in monetary terms as an asset value. Therefore, it is possible to compare the cost of implementing an urban development policy with the increase in the value of the town equity brought about by this urban development policy in monetary terms. Thus, more cost-effective urban development policies can be explicitly chosen.[26]

Moreover, it should be noted that the attractiveness of a city is not uniform for visitors but varies from visitor to visitor. Hence, to determine what urban development policy will increase the value of the town, we should examine in detail what urban development policy will increase what kind of visit values for what kind of visitors in what way.

The perspective of evaluating urban development policies focusing on the value to individual visitors and consumers with diverse preferences and motivations can be called "consumer-oriented urban development.[27]

We defined the goal of urban development as maximizing town equity by looking at the town as a single entity. The following section discusses a case study that examined parking lot policies in the city center district while regarding a city as one business entity.

3.5.2 *The City Center Parking Lot Policy: Regarding the Town as One Entity*[28]

As an example of how individual policies contribute to the value of the town, we consider the case of the parking lot policy in *Tenjin* District, the city center district of Fukuoka City.

Fringe parking, park-and-ride, vehicle regulation in the downtown area, and traffic congestion tax, among others, have been studied to solve traffic congestion in the downtown area. However, few studies examined the city center transport policy from the viewpoint of increasing the value of the city center and considering the city center district as one business entity.

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[25] An example of the measurement of town equity for a specific area is the *Daimyo* district by Saito et al. (2007).

[26] Saito et al. (2001a) measured the monetary value of the *Murasaki* River, which runs through *Kokura* District, the city center commercial district of *Kitakyushu* City, and divides the district into the east and west from the perspective of consumer *Kaiyu* behaviors. For this purpose, they used a disaggregated Markov model to determine the amount of decrease in commercial sales caused by the existence of the *Murasaki* River.

[27] The "consumer-oriented approach" is a broader framework than the "consumer behavior approach," as it focuses on the value of visits to the city for consumers.

[28] The original analysis is based on Saito et al. (2008b). For a more detailed analysis, see Saito et al. (2018c).

Here, the purpose is to determine the parking lot policies while regarding the city center district as one business entity and increase its business value based on evidence obtained from analyzing consumer *Kaiyu* behavior microdata.[29]

The idea is simple. First, we note that our survey of consumer *Kaiyu* behaviors shows that visitors to the city center spend an average of 54.4 yen per minute in the city center, including those who bought and those who did not purchase. Then, we attempt to induce visitors by car to park at the parking lot where their time spent in *Tenjin* District becomes the longest by offering a half-price discount for the parking fee. Thus, we expect to have visitors by car extend their staying time in *Tenjin* District and increase the city center's overall sales.

The following equation is the estimated result of the staying time spent in *Tenjin* District by car visitors.[30]

$$\mathrm{St}T_i = \underset{(6.24***)}{224.4} + \underset{(0.34)}{0.102}T\mathrm{Dist}_i + \underset{(2.56**)}{0.248}\mathrm{Dest}_i - \underset{(-1.84*)}{0.00017}(\mathrm{Dest}_i)^2 - \underset{(-2.80***)}{0.260}\mathrm{Fare}_i. \tag{3.1}$$

Here, $\mathrm{St}T_i$ is the length of stay (in minutes) in the city center district, $T\mathrm{Dist}_i$ is the time distance (in minutes) from the residential area to *Tenjin* District, Dest_i is the distance (in meters) from the parking lot to the destination in *Tenjin* District, and Fare_i is the parking fee per hour (in yen).

From Eq. (3.1), we see that since the coefficient of the second-order term of Dest_i is negative, the distance from fringe parking to the destination in *Tenjin* District that maximizes staying time is 731 m. Therefore, the staying time for this case is 269 min (Fig. 3.8). This result means that if the parking lot were moved to this distance, the staying time could be increased by 19.6 min, compared to the current average staying time of 250 min. Furthermore, if the parking fee is reduced by half, the staying time can be extended by 44 min compared to the present situation.

If this policy were enforced, the revenue of *Tenjin* District would increase by 18.6 billion yen a year because of the increase in staying time. On the other hand, if the parking fee were reduced by half, the income of parking lot operators in *Tenjin* District would decrease by 2.8 billion yen annually. However, even after compensating parking lot operators for this loss, the revenue increase of *Tenjin* District due

[29]The analysis here uses data from The 12th Survey of Consumer *Kaiyu* Behaviors at the City Center of Fukuoka City conducted on June 30 (Sat.) and July 1 (Sun), 2007; and The first Survey of Behaviors of Shoppers Using Parking Lots at the City Center of Fukuoka City conducted on May 24 (Sat.) and 25 (Sun), 2008.

[30]The figure in parentheses is the *t* value of each estimate. ***Significant at 1%, **Significant at 5%, *Significant at 10%.

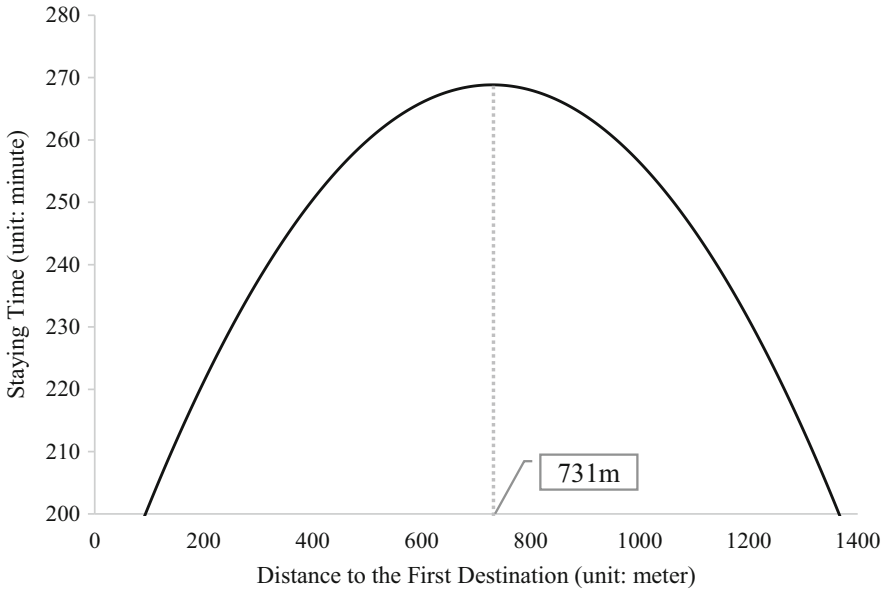


Fig. 3.8 Distance from the parking lot parked to the first destination visited in *Tenjin* District that maximizes the staying time for car-use shoppers. [From Saito et al. (2018c), Fig. 19.1, p. 381]

to this parking policy would become 15.7 billion yen[31] (Fig. 3.9), which would increase the business value of the city center district.

3.6 Scientific Evaluation of Urban Development Policy

3.6.1 Models and Statistical Methods Used in Kaiyu *Studies*

The examples of *Kaiyu* studies discussed so far are studies that attempted to evaluate urban development policies based on actual data and evidence from the perspective of what effects they had on individual visitors and consumers, regarding the goal of urban development as maximizing town equity.

Here, let us review the characteristics of the models and statistical methods that formed the basis of these studies.

[31] Since the increased revenue is attributed to various business entities in the city center, a mechanism is needed to determine who will pay discounts on the parking fees and how they will be compensated. In *Miyazaki* City, Japan, TMO sells discount parking tickets (30 min) to commercial business entities, mainly retailers, and the retailers distribute the discount tickets to shoppers. The parking lot operators ask the TMO to redeem the discount coupons they collect, and the TMO uses the commission to operate the business. See Deguchi et al. (2008).

Economic Effect of Halving the Parking Fee Price
(Discount from 195 yen/hour to 100 yen/hour)

Increase in Retail Sales due to the Increase In Staying Time

Sales Increase = Number of Car-Use Shoppers to Tenjin ×
Increase in Staying Time (minute) × 365 days ×
Expenditure per minute

21,150 (persons) × 44.29 (minute) × 365 (days) × 54.4 (yen/mimute)
=18.6397 billion (yen)

Decrease in Parking Sales

Sales Decrease = Parking Sales per year × Discount Rate
- Sales Increase by the Increase in Staying Time
6.93 billion (yen) × 0.487 - 21,150 (persons/day) × (44.29/60) ×
100 (yen/person) × 365 (days)
=2.8607 billion (yen)

15.7979 billion (yen) = 18.6397 billion (yen) - 2.8607 billion (yen)

Fig. 3.9 Economic effect of the half-price parking policy in the *Tenjin* district

3.6.1.1 Choice-Based Sampling Bias in the On-Site Survey[32]

The surveys of consumer *Kaiyu* behavior at the city centers are conducted as on-site surveys. This method means that the samples, that is, the respondents to the surveys, are sampled or selected at the place they visited.

More specifically, in our surveys of consumer *Kaiyu* behaviors, several survey points are set up in the city center, and the respondents are randomly selected from among visitors to the survey points, and questionnaire surveys are conducted through interviews.

The obtained data is the consumers' *Kaiyu* micro-behavior history data, which records the respondents' behavior history of their walking around within the city center as a sequence of the triples: the place they visited, the purpose performed there, and the expenditure spent there if any in the order of occurrence. That is, we record the progression of *Kaiyu* in terms of how these three pairs change.

Since our surveys are based on the on-site random sampling survey, people who come to the city center ten times a month are ten times more likely to be selected as a sample than those who come to the city center once a month.

If we ignore this fact and analyze the obtained data, a bias, a deviation from the true value, necessarily occurs. This bias is well-known and called choice-based sampling bias. We used a weighted method to remove this bias in the studies cited above. This method uses the reciprocal of each sample's frequency of visits to the

[32]The weighted Poisson model for the on-site surveys was developed by Saito et al. (1995) and extended by Saito et al. (1999).

city center as the weight attached to the sample, employed in the models to estimate and forecast the number of visitors to the city center.

3.6.1.2 Consistent Method to Estimate *Kaiyu* Density[33]

In the case of *Kaiyu* micro-behavior history data obtained by the above on-site random sampling survey, a choice-based sampling bias occurs when data obtained from different survey points are combined and used. The choice-based sampling bias occurs because samples have different frequencies of visits to the different survey points, so the likelihoods that the respondents are selected as a sample are different depending on where they are sampled. Therefore, we constructed a consistent estimation method to obtain a consistent estimate of *Kaiyu* density, that is, the distribution over the whole *Kaiyu* paths within the city center area, from the on-site survey data, removing the bias.

3.6.1.3 *Kaiyu* Markov Model with Explanatory Variables[34]

The study on the changes in consumer *Kaiyu* behaviors due to the large-scale commercial redevelopment discussed in the previous chapter is an ex-post measurement of the changes in *Kaiyu* behaviors before and after the redevelopment.

Of course, we want to predict how consumer *Kaiyu* behaviors would change due to what kind of redevelopment. To do this, we formulated the consumer's *Kaiyu* choice probability in the *Kaiyu* Markov model as a conditional logit model with covariates and estimated this logit model based on the consumer's *Kaiyu* micro-behavior history data obtained from *Kaiyu* surveys. Thus, the consumer's *Kaiyu* behavior after the redevelopment was made to be predictable by expressing the redevelopment as the changes in covariates of the *Kaiyu* Markov model.

3.6.1.4 Retrospective Panel Data[35]

For an individualistic evidence-based policy study, verifying what behavioral changes occurred in the same consumer before and after implementing a policy must be indispensable. Thus, we need to observe the consumer's behavior twice

[33] The consistent estimation method was developed by Saito et al. (2001b) and applied to *Daimyo* District by Saito and Nakashima (2003). As for the elementary introduction to the method, see Saito (2008). Also, see Saito and Kawahara (2022), Chapter 19 in this volume.

[34] The *Kaiyu* Markov model was developed in Saito and Ishibashi (1992a) and reported in Saito and Ishibashi (1992b).

[35] The retrospective panel data analysis was first introduced in Saito et al. (2006), became a core method to identify the changes at an individual consumer level, and was employed by several studies. For example, see Saito et al. (2008c) and Yamashiro and Saito (2012).

before and after implementing the policy. Such data obtained by observing the same subject at multiple subsequent time points is called panel data. As for obtaining panel data, we must maintain and manage a group of subjects, a panel, which takes cost and time.

Therefore, in our *Kaiyu* studies, we devised a method to obtain panel data at two points in time before and after the policy implementation. The method is that, in the survey conducted after the policy implementation, we asked the respondents retrospectively about their behavior before the policy implementation and their present behavior. Thus, we refer to the panel data obtained by this method as "retrospective panel data."

The ex-post studies of how individual consumers' evaluations of the city changed after the renewal of a department store and the new entry of a large-scale variety shop discussed in the previous section were made possible by obtaining and using retrospective panel data.

More specifically, in those studies, we have analyzed the relationship between changes over two-time points in two variables by reducing it to the analysis between two ratios, each obtained by taking the ratio of after to before for each variable. We refer to this method as "division ratio cross-tabulation," closely related to the fixed effect model in econometrics and statistics and broadly to causal inferences.

The causal inferences in statistics and econometrics have made remarkable progress in recent years. For more details, readers are required to refer to the literature (Angrist and Pischke 2009; Pearl et al. 2016).

3.6.2 New Possibilities for Urban Development Policy Evaluation

The above studies focusing on the city center *Tenjin* district have been carried out based on *Kaiyu* micro-behavior history data and retrospective panel data of the individual consumers, all obtained from the on-site surveys of *Kaiyu* behaviors. These studies have gradually expanded, first from the analysis of the destination choice, then through the analysis of the choice of expenditure, to the analysis of the individual consumers' evaluations of the renewal of the store and the opening of the new category shop. Studies have evolved from *Kaiyu* spatial movement behavior to town equity research.

To further elaborate, as anticipated in the social experiment at *Tenmonkan* District, the data collected in the future would include the one involved with the information interaction that individual consumers transact with the city and other consumers while undertaking their *Kaiyu*. Thus, the possibility of obtaining *Kaiyu* micro-behavior history data on destinations, purposes, and consumption choices in real time would be opened rather than just one shot per day as at present. This situation will require new algorithms and statistical methods to analyze the big data

involved with the micro-behavioral history data. The prospects for such a situation will be discussed in a later chapter.[36]

In the next section, we provide an example of the study on the integrated model that simultaneously forecasts the increased number of incoming visitors to the city center and the changes in *Kaiyu* movements among shopping sites within the city center due to the redevelopment of the railway station building at the city center, which utilizes the methods and models stated above.

3.6.3 *Forecasting Changes Due to Urban Development Policies*[37]

While the ex-post evaluation of policies is essential, ex-ante forecasting is also essential. In this section, we will present a case study of forecasting the impact of the opening of JR *Oita* City in the city center commercial district of *Oita* City, Japan.

This case is characterized by the fact that the city center shopping street with arcades in *Oita* City, as in other local cities in Japan, is in competition with two large suburban shopping malls, and although the long-established local department store remains, the city center shopping street is in decline as large stores in the shopping street withdrew. On the other hand, JR *Oita* City, a new station building with a large commercial complex and a hotel, was constructed there along with the elevation of JR *Oita* Station and opened in March 2015.

The purpose of the forecast is to predict how many visitors to the city center commercial district of *Oita* City would increase with the opening of JR *Oita* City, and how visitors' *Kaiyu* among the commercial facilities of JR *Oita* City, the existing city center shopping street, and the department store would change, and how the annual retail sales of each would change.[38]

In particular, the city center shopping street had a strong doomed perception because of the emergence of a new dominant commercial complex competitor at the station neighboring their shopping street. On the contrary, we thought opening a

[36] As for new algorithms needed, for example, algorithms for HEMS (Home Energy Management System), see Saito (2012). As for the prospect of new possibilities, see Saito et al. (2022), Chapter 5 in this volume.

[37] The following analysis is based on FQBIC (2015) and Yamashiro et al. (2014).

[38] National Route 10 runs east to west between the city center shopping street and *Tokiwa* Department Store, and JR *Oita* Station dividing the city center commercial district of Oita City into the north part, the existing shopping districts, and the south part, JR Oita Station. The existing shopping districts, the city center shopping street on the west side and *Tokiwa* on the east side, face each other across the road running north to south. The only passage from JR *Oita* Station to *Tokiwa* on the east side was an underpass under Route 10, which has been a barrier for accelerating *Kaiyu* between the station and the department store. At the time of the opening of JR *Oita* City, the pedestrian crossing on Route 10 was set up on the east side to accelerate *Kaiyu* between *Tokiwa* and JR *Oita* Station. We also estimated the impact of the pedestrian crossing on the retail sales at the city center commercial district as 2 billion yen per year [Cf. (FQBIC 2015)]

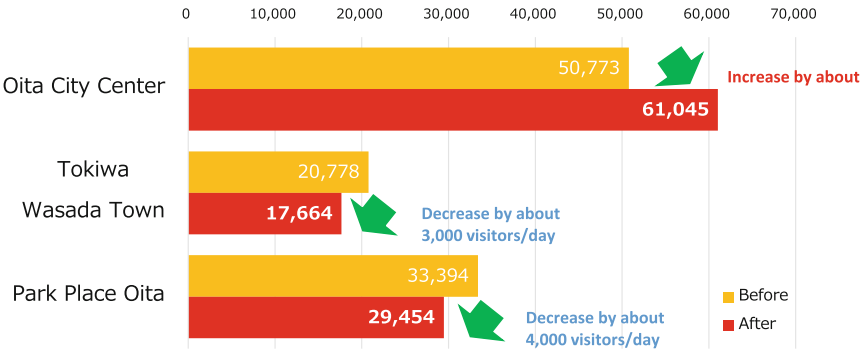


Fig. 3.10 Forecast of the number of net incoming visitors to the city center commercial district of *Oita* City, *Tokiwa Wasada* Town Shopping Mall, and Park Place Shopping Mall before and after the opening of JR *Oita* City (unit: person/day)

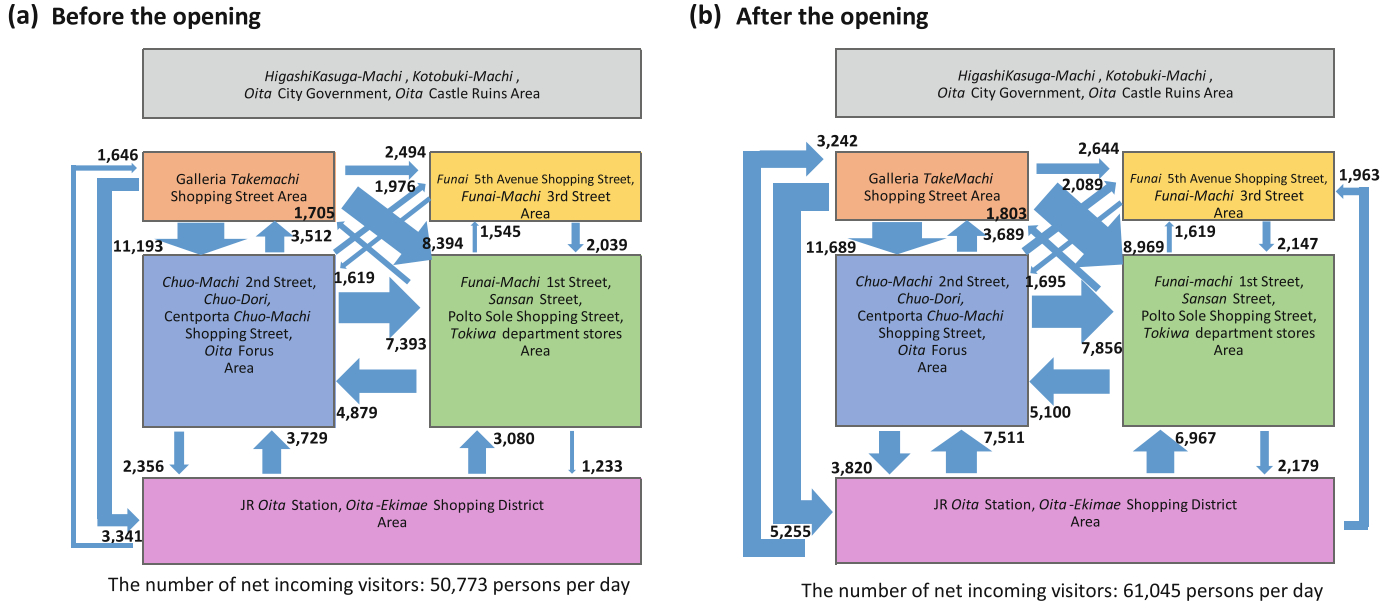
large commercial complex would provide a significant opportunity for the city center because it could bring back the fled customers from the suburbs to the city center commercial district.

Hence, to verify this thought, we developed a model for forecasting the number of customers attracted to the city center commercial district while considering the competition with the suburbs. The results are shown in Fig. 3.10.

The main results are as follows: First, in the city center commercial district of *Oita* City, the number of incoming visitors to the city center commercial district for shopping, leisure, and dining purposes increases by about 10,000 persons per day on a net basis, of which 7000 persons per day are brought back from suburban malls, resulting in a net increase of 3000 persons per day.

As for the *Kaiyu* pattern within the city center commercial district, the *Kaiyu* pattern will change due to increased visitors to the city center and the emergence of a commercial core at the JR *Oita* station. The number of people who undertake *Kaiyu* and move among shopping sites within the city center commercial district before and after the opening of JR *Oita* City on the actual number of persons per day is shown in Fig. 3.11.

Numbers in the table under Fig. 3.11 show the changes in the number of people who move between the city center shopping street and JR *Oita* City, which increases by 13,588 persons per day.



(c)

Kaiyu movements more than 1,000 people/day are displayed

Area	before	after	difference (before - after)
The total number of *Kaiyu* movements between the West side (*TakeMachi* and *Chuo-Machi* area) and JR *Oita* Station areas	11,073	19,828	8,755
The total number of *Kaiyu* movements between the East side (*Tokiwa* Department Store) and JR *Oita* Station areas	4,313	9,146	4,833

Total on both sides increases by 13,588 persons/day

Fig. 3.11 Changes in *Kaiyu* movements within the city center commercial district of *Oita* City before and after the opening of JR *Oita* City. (**a**) Before the opening, (**b**) after the opening, (**c**) total *Kaiyu* movements between the East and West sides of the city center commercial district and JR *Oita* City (unit: person/day)

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Chapter 4
City Marketing

Junichi Suzuki

Abstract With the widespread use of the Internet, customers' choices in making purchasing decisions have expanded not only across physical stores but also to the web. By making it easy to purchase products from anywhere at any time and at lower prices, online stores have considerably reduced consumption at physical stores, especially by the younger generation. An increasing number of consumers use the Internet exclusively to purchase their requirements. Furthermore, people also visit physical stores to compare products and prices and then make their purchases at online shops that sell them at a lower price, effectively using physical stores as showrooms for online stores.

It is difficult to implement the idea of comfort merely as a service from the viewpoint of hardware functionality and system rationality and apply it to a wide range of users; this also requires user experience (UX) design. In this chapter, we introduce a UX-driven approach to increase loyalty and encourage visitors to become enthusiasts of the town, thereby stopping the outflow of customers to the Internet and neighboring cities, by creating a space that is valuable for each visitor.

Keywords Design thinking · Human-centered design (HCD) · User experience (UX) · Ethical consumption · Blockchain

4.1 A New Kind of Consumer

4.1.1 Real Space Homogenization and Showrooming

Because brands that existed in exclusive fashion stores have moved into shopping centers and tenants and products have become more homogenous, it is difficult for customers to make a purchase by merely examining and comparing products at

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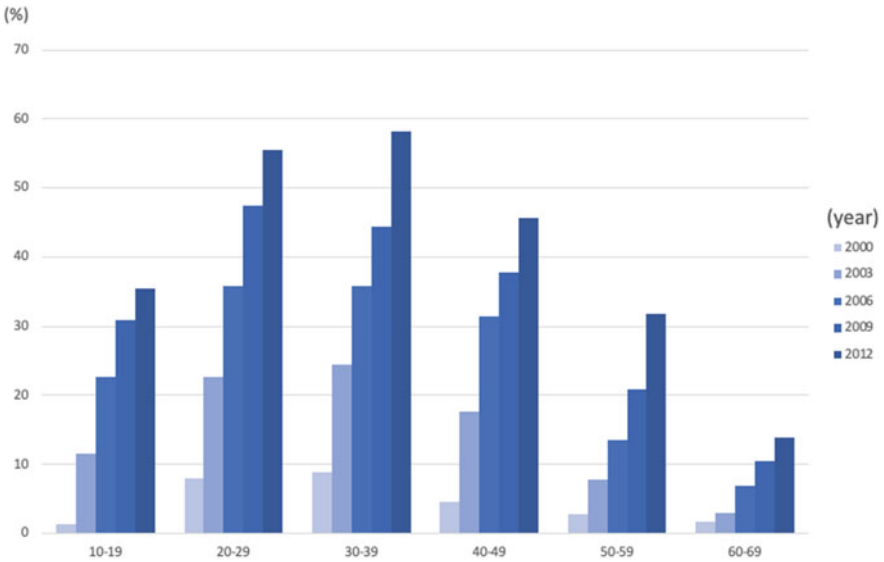

Fig. 4.1 Transition of the percentage of Internet shopping users (by age)

various stores. Consequently, the phenomenon of "showrooming," a behavior in which customers purchase online at electronic commerce (EC) sites after checking items at physical stores, is on the rise. Originally considered a problem in the American retail industry, it is called showrooming because the actual store is used as a showroom for online stores. Showrooming has a significant impact on the purchase of items and specialty products, and this trend is particularly noticeable for household electrical appliances and branded products. However, the rise in showrooming is also considered an opportunity for retailers and manufacturers, because information on products is available through websites and apps for product comparison. Several EC sites now offer product comparison information, and applications that can read the bar code of a product and search for the lowest price across thousands of stores are available.

In Japan, there has been an annual increase in the number of customers who compare product prices and spec information from actual store floors using Internet-connected devices, such as smartphones, and some customers even place online orders on the spot. As shown in Fig. 4.1, the number of Japanese Internet shoppers has been steadily rising among all generations in recent years, especially among those in their 1930s, who are considered the primary purchasers of the products. Furthermore, according to the data (Kelly and Littman 2002), 70% of online purchasers check products at actual stores in advance. Many consumers, familiar with EC sites, believe that online stores are priced more affordably and also provide points as a reward for shopping. Some desirous of purchasing a product from an EC site may find it difficult to do so without looking at the actual product, such as by showrooming. Thus, there are behaviors in which consumer purchases are never

completed in real space. Consequently, sales of retail stores have become sluggish, except for sections that benefit from inbound consumption, and there is a growing sense of crisis among town operators who have leased their stores to such tenants.

4.1.2 Changes in Japanese Values and Consumption Behavior in NRI Consumer Questionnaires

Owing to an increase in consumption patterns such as searching for prices on comparison sites and buying online, if a cheaper price is found for a product on the Internet than in an actual store, the consumer behavior among those that lack loyalty to the place and seek low-cost products is to readily favor the EC. Regardless of how real estate companies and commercial facilities devise ways to make towns and stores attractive, traditional methods such as interior and exterior improvements and seasonal event promotions can only attract customers to visit them. They do not foster loyalty for the city, and it is difficult to stop the flow of showrooming where consumption behavior is not completed in real space.

The president of Aquabit Spirals Ltd., Toshihiro Sugawara, spoke about his showrooming service as follows: "When you hold your smartphone over a product in our store, an online shopping page opens, and heavy and bulky items can be placed into an online basket. In other words, the user can shop by hand. This method is particularly useful for products such as tools that cannot easily be compared without using the online page. This means that the store becomes a "space to experience." The essence of shopping is "contact with products" and "experience," not payment or taking them home. This is not a story of the future, but can be achieved with existing technology. Using these technologies, shops that allow, instead of inhibit, showrooming are soon to be established."

Therefore, instead of conventional town planning that focuses on the occupancy rate and the unit price of customers, a town can attract consumers based on thorough town management in which the emotional characteristics of each visitor can be addressed, leaving a positive impression on the visitor's mind. There is also a need for community development from the perspective of user experience (UX), or "visitor experience," by which a visitor becomes a "fan." In an era when consumers' communication modes are free, with the advent of mobile phones and the Internet, the functioning of organizations and companies, and the ways of working and consumption, have all changed. These have led to the creation of "personally driven consumption," in which individual opinions are strongly reflected. Given the rise in such consumers, who are, in a sense, self-centered and driven by personal needs and choices, a space that enables each person to take their own lead while simultaneously promoting communication would be most suited for the times. The definition of UX design (UXD) for impacting a user's experience and notions related to UXD are summarized next.

4.2 Human-Centered Design (HCD) and User Experience (UX)

4.2.1 HCD and International Standard ISO9241-210

In the context of the current work, the aim of UXD is to create visitor experiences. Related to UXD are development processes such as human-centered design (HCD), participatory design (both focusing on humans, i.e., users), and the concept of design thinking.

In system development, HCD refers to a design policy that puts usability first. It is characterized by the analysis of requirements based on user trends and the design of screens and interactions before the program design. The program is modeled to realize the design, and usability evaluation is performed several times before the completion of the project. The concept of HCD originated from the idea of using knowledge and information about human beings to recognize that manufacturing based on a system-oriented approach does not provide sufficient satisfaction to users and cannot enable a system that accommodates people smoothly and effectively. As inferred from the name, HCD is a systematic process for creating products and services that meet people's needs. It focuses primarily on the people who use them, rather than the tools and technology. The basic process of HCD is illustrated in Fig. 4.2. As shown in the figure, if the user's requirements are not satisfied at the evaluation stage, the process is repeated.

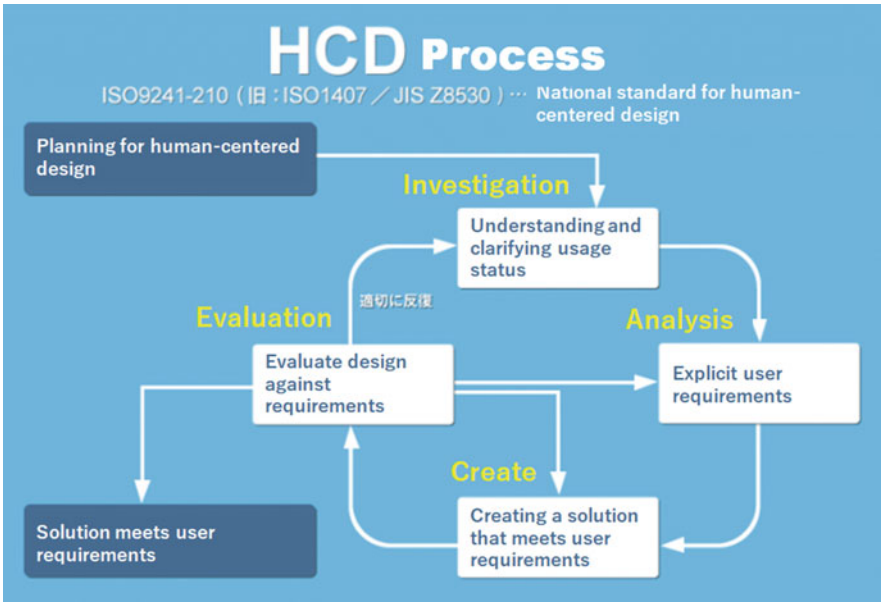

Fig. 4.2 HCD process according to ISO9241-210

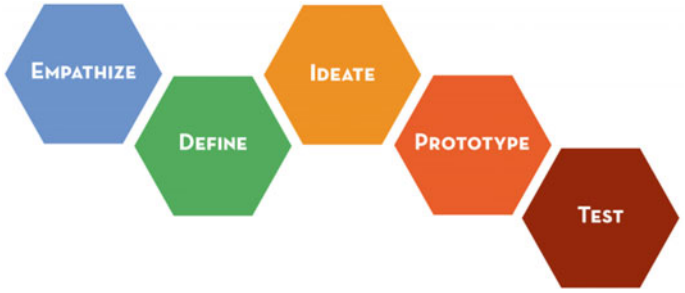

Fig. 4.3 Five stages of design thinking (Tim 2009)

In the basic process of HCD, the beginning stage of "planning for human-centered design" is important. Defining the reason for introducing the objectives and the process involved and sharing it with relevant parties in advance enhance the success of a project.

We would like to touch on participatory design in relation to community development. Although Schuler and Namioka (1993) introduced the activities and methodologies involved in participatory design, it was originally started as a movement to involve users in the design process, especially in Scandinavian countries. For example, before an IT system is introduced into a company, the person in charge of the IT department of the company usually meets with the IT company's system engineer to design the system. However, in a participatory design, representatives of teams participate in the meeting and express their opinions on the usefulness of the system for employees. In product design, a user may create a prototype, draw a sketch, or write a scenario. These tasks are performed in collaboration with designers, and specialist designers can further adjust the design if required.

This concept was later introduced in Japan and is now firmly established in the form of community participation, mainly in community revitalization and community development activities. Further, in the development of devices and systems in the manufacturing industry, the process of participatory design exists in practice in the form of user surveys and usability tests.

In addition, the design thinking methodology is important in town planning. Design thinking is an approach to resolving problems, and "design" here does not exclusively refer to a specialized design created by designers. Rather, people who are not designers can provide ideas for design. This is a systematic problem-solving process. In terms of its history, design thinking is the conceptualization of a unique approach towards innovation coined by the design consulting company IDEO in the United States. One of the founders of IDEO founded the "d. school" at Stanford University in the United States in 2005, and the method has become widely popular.

As shown in Fig. 4.3, there are five stages in design thinking: empathize, define, ideate, prototype, and test. Design thinking is a basic process, and although it is expressed differently, it is similar to HCD. With a quick process based on the ideas of failing early and repeating improvements, the amount of rework required to make major corrections after creation is reduced, and the overall efficiency is improved.

A characteristic of IDEO is that innovation begins with seeing (Nomura Research Institute 2012), and it is often said in Japan that seeing outweighs hearing. Since there is a big difference between the two, the "empathize" in step 1 is considered important. In design thinking, designers and engineers are required to conduct surveys, observe, and obtain awareness and understanding of someone's feelings and thoughts through dialog. This approach seeks to elucidate potential needs that are not expressed in words by adding background and context to objective facts, such as survey results.

4.2.2 User Experience (UX)

"User experience" is an expression that is also used in a general sense, apart from its use as a technical term in the IT industry. It is no exaggeration to say that UX is all about customer experience and shopping experiences, such as at Disneyland. In this context, it refers to all experiences at the venue. In addition to the actual "experience," experiences such as fantasies and imagination are also included. For example, looking at a product name or package design, imagining the product, or fantasizing about one's life with the product, are all aspects of UX. The methodology for realizing a user experience is called UX design.

UX is emphasized because the conventional concept of "usability" refers to only creating a product that is easy to use. In addition to usability, UX reveals the importance of capturing system usage from a long-term perspective.

The purpose of UX design in a real space is to differentiate the real space from EC sites on the Internet or neighboring towns, as a special place, by increasing the attractiveness of the whole city, and not by not fitting the specifications of each function, such as offices and commercial facilities that comprise the city. Experiences occur in every aspect of a person's visit to a city, and hence, to design such an experience, it is not sufficient to simply create a high-spec building with excellent heating and cooling efficiency. It is also necessary to create a novel experience and add new values by including all hardware, software, systems, and services.

A famous example of intentional design and the provisioning of UX is Starbucks Corporation, which operates under the theme of "human business." Human business emphasizes the importance of all related parties in the business, including the customer. In typical consumer electronics retail stores in Japan, salesclerks are often desperate to sell products and have customers obtain points cards, and this does not feel like human business for a customer. However, this is absent at Starbucks, and one can expect to receive a friendly "hello." Being a human business consequently enables it to be a successful business. The company's chairman and CEO, Howard Schultz (as of February 24, 2015), said, "Starbucks is not selling coffee. It is selling an experience." The company has adopted the concept of "the third place" as a UX strategy. The following are some of the characteristics of the UX adopted in Starbucks stores:

- The staff, called "baristas," take orders for coffee at the counter.
- The customer waits and receives coffee under a stylish lamp.
- A customer can choose from a range of coffee options such as latte, mocha, and espresso, and decide how they want to drink their coffee.
- Stylishly designed store space [ARCHECO "App Strategy University" (ARCHECO Inc. 2015)].

Although these are now common styles, they were rare when Starbucks began operations and were then pioneering ideas.

Even in Japan, many people use cafes like Starbucks as "the third place." There are people who sit and read at a cafe on holidays, people who work on their computers at a cafe, and people who come looking for a place that is neither home nor work, and a café is such a place.

By properly designing the UX in this manner, it is possible to increase the attractiveness of a place by providing a user with an experience in the space of the café, rather than merely a product, namely coffee. This is a marketing approach that not only has customers visit repeatedly but also potentially sublimates them as "evangelists," as fans, who enhance the value of the store and its brand in the surroundings.

4.2.3 UX Evaluation of a Town Space

What kind of evaluation axis can be provided for the UXD of a town? Long-term monitoring is necessary to evaluate UX. A method that is often used is to conduct a survey or interview after 9 months of product use. Such surveys involve describing the user's experience when a product is bought and used, the relationship between the product and the user, and the user's impression of the product. The change in the user experience over the time series of product use can be captured. If the purchased product is equipped with a logging device, for example, the usage status after purchase can be captured by constantly recording whenever the user uses the product to collect data. If the product is a communication device and it allows the user to transmit the usage status, data from many users can be collected, and the information necessary for UX evaluation can be easily obtained. By simultaneously viewing the usage data along the time axis and the change in the level of satisfaction obtained, UX evaluation can be used to identify the kind of user experience of the product that will lead to further user satisfaction.

If a user's behavior when using the product is captured directly in the environment of its use, more effective UX evaluation is possible. This is because the actual context in which the user is embedded at the time of use can be gleaned from such information. By grasping the relationship between the user's behavioral context and changes in user psychology, it is possible to see which elements of the user experience in the product are valuable. The behavior context refers to the flow and background of the user's behavior when using a product or service. It includes the

influence of the environment, the usage form of the service, and the psychological changes at events along the time axis.

UX can be evaluated in the same way when it is used in a town space. For this, we need to capture various aspects such as actions taken by a user, changes in the user's surrounding environment (physical or social), and changes in the user's psychology. Presently, studies have been conducted on how the behavioral context and user psychology can be converted into data using information communication devices embedded in the city space and smartphones carried by users. If an environmental measurement logger is installed in the town space, changes in the physical environment of the space can be determined. By logging information that can be measured from a user's smartphone, the user's location and context can be estimated. Furthermore, by using social network services (SNS) usage histories, it is possible to estimate the degree of satisfaction with the space used by the user and the social environment at the time of use from the user's information sharing status. This can provide a picture of the behavioral context. Various methods have been devised to capture the daily behavior of users of a town and the environment of the town space, along with the development of behavior and environment logging technology. Using these methods, data collection for UX evaluation of a town space from a user's viewpoint can also be conducted.

4.3 Diversifying Values and Approaches to New Consumers

In today's world, where consumers have gained a means to confirm the relevance of products and services to their own values, people's values are also diversifying. For example, while many consumers have focused on product specifications and prices, some consumers have started to evaluate products based on how environmentally friendly and ethical the product is. This is a niche market that is becoming popular, and it is possible that this market will soon become comparable to the mass market.

Until recently, in the mass market, a centralized contact that served as an intermediary for information between the consumers and the producers sufficed. However, the niche market involves "direct" and "borderless" information contact, in which consumers' cooperation is required. Therefore, empathy is important in this context. When people sympathize with a product's philosophy and values, they tend to like the product and become fans of it.

Although the aforementioned ideas in town management state that UX is required to turn a visitor into an enthusiast and fan of the town, products and content are also required to draw fans and engage them, by gaining sympathy from the consumers and increasing their engagement in the market. These are keys to the success and the expansion of the market share of a product or service.

On the other hand, if the philosophy or content of a product does not make consumers sympathize with it, new consumption behavior will not arise. Information Services International-Dentsu, Ltd. (ISID)'s Open Innovation Lab (hereinafter referred to as InoLab) focused on this aspect. Utilizing the scheme of blockchain

technology, InoLab researched a mechanism to deliver products that meet the philosophy and values of diversifying consumers and has conducted numerous experiments to demonstrate this mechanism. Two of these experiments are described next.

4.3.1 Collecting Data

InoLab launched a research project titled Internet of Value by Blockchain (IoVB), which supports regional revitalization using blockchain technology in collaboration with Osaka blockchain venture Sivira Inc. in September 2016. This was a novel approach to realize a social system that meets the nonhierarchical and open value evaluation standards of users from the SNS generations, who prefer an interactive trust-building process, using blockchain technology that achieves technological development based on the same philosophy. The first IoVB project was based on a proposal from the coalition "The most beautiful village in Japan" of nonprofit organizations (NPOs) to cooperate with Aya city, the NPO member local government in Miyazaki Prefecture, Japan.

The official announcement of the cooperation with Aya city was announced on October 19th. Through the course of about a month, InoLab built partnerships with industry leaders and creators. Thus, a globally challenging project was initiated. It was a demonstration experiment aimed at realizing a reasonable and convincing price for products for the generation of SNS users, by building a system to fairly evaluate the value of organic agricultural products using blockchain technology.

The town of Aya city, the site of the demonstration experiment, has conducted strict agricultural production management for consumers seeking food safety under the "Ordinance on Promotion of Natural Ecosystem Agriculture" established in 1988. Agricultural products are sold according to their own farmland standards and production management standards with the ranks of "gold," "silver," and "copper," and these are displayed on the label of each product (Fig. 4.4). However, the town faced a challenge in that the process involved in the production and the value of the products were not easily conveyed to consumers. Aya city's organic farming method, which requires overwhelming effort compared to conventional farming methods to maximize taste and safety, is realized by the strong beliefs of the producers and the voluntary labor system. It is essentially a premium that should be reflected in the price, but products are shipped to the suburban market without any added value. Aya city participated in this demonstration experiment to further appeal to consumers, educating them about the strictness of Aya city's unique efforts and the high quality of their organic agricultural products.

There are two main points of verification in this experiment. The first is the effect of implementing the production management information on a blockchain. Each farmer in Aya city has been planting, harvesting, using fertilizers and pesticides, and checking the quality of soil and agricultural products under Aya city's certification. In this demonstration experiment, all these histories are recorded in the database built

Fig. 4.4 Vegetables that meet strict standards are given a “gold” mark, but their value is difficult to convey (at Aya sales offices)

using the blockchain product called Broof by Sivira Inc., which has excellent robustness, performance, and data traceability. Aya city gives a unique ID to agricultural products that are shipped through this process to support certification according to its own standards. By verifying this unique ID, consumers can verify that the agricultural product is indeed the product of Aya city, which is produced based on Aya city’s strict certification standards, and that it has not been altered. Consumers can check the history of the product on the Internet using the product’s ID. An overview of this blockchain system is illustrated in Fig. 4.5. InoLab examined whether this notarization system using blockchain could affect consumer purchasing behavior and brand loyalty and whether the operation of the system is at a level that is reasonable for local governments.

The second point is the reliability guarantee of the blockchain. The blockchain that registers production management information in this experiment is a “private” blockchain on a decentralized platform, which is operated and managed by Aya city. By combining this blockchain with the blockchain Keyless Signature Infrastructure (KSI) provided by Guard Time Inc., an IT enterprise in Estonia, we created a mechanism that further increases the reliability of information. The project IoVB defined the mechanism that guarantees the validity of two blockchains in this manner as proof of proof (PoP) and verified its effectiveness. This mechanism is illustrated in Fig. 4.6.

Seven companies and organizations participated in this study. Sivira Inc. and Guard Time Inc. provided the blockchain system and collaborated with InoLab to

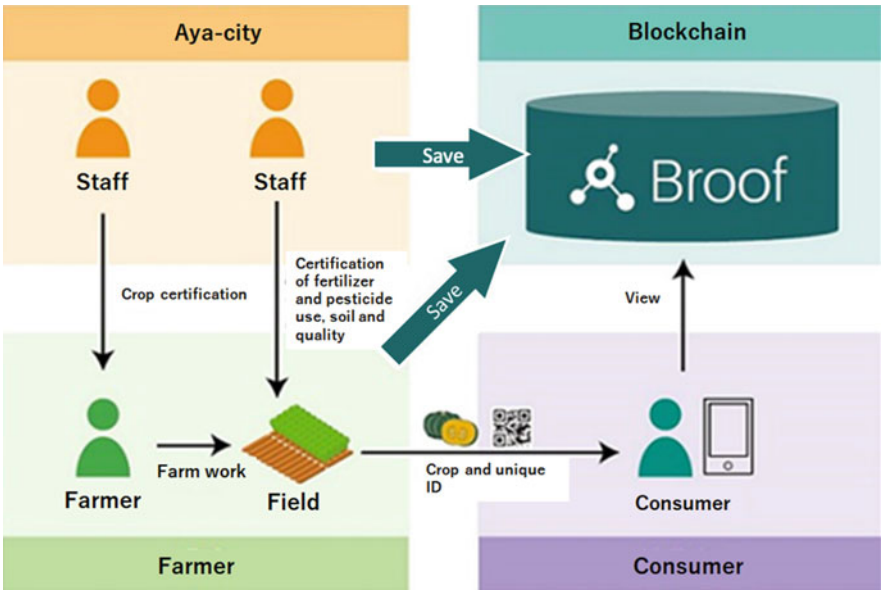

Fig. 4.5 Overview of the blockchain operated and managed by Aya city

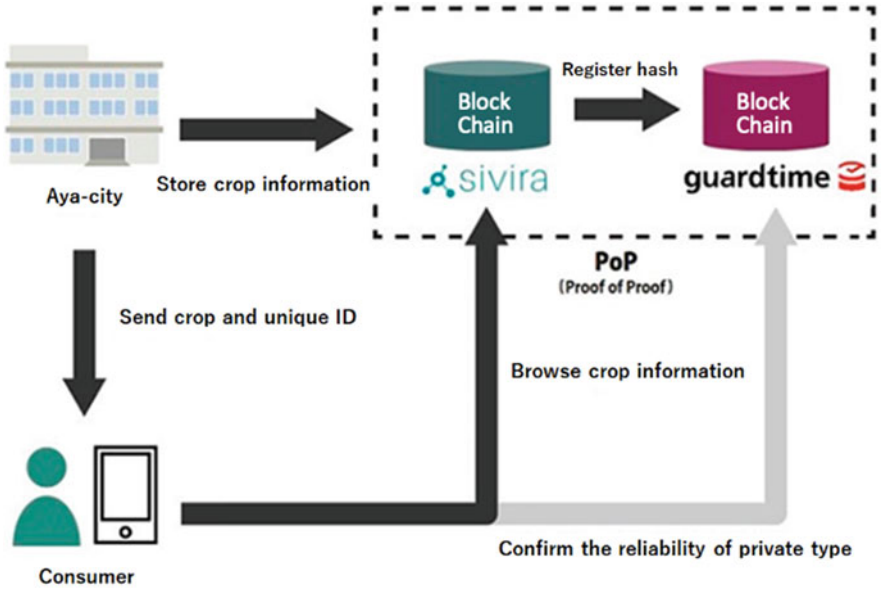

Fig. 4.6 Mechanism for validity guarantee (PoP) using two blockchains

Fig. 4.7 Product package with an NFC-tagged QR code and a unified design (example of brand direction by a designer, Norichika Yokota)

verify the effectiveness of PoP in a scheme of Blockchain 2.0. The NPO "The most beautiful village in Japan" and Mori Building Co., Ltd. chose and offered a place (the Hills Marche held at ARK Hills, Minato Ward, Tokyo) to examine the possibility of the creation of a new market brought about by human and material communication between the local areas and the city center. Sumitomo Bakelite Co., Ltd. offered its freshness-preserving packaging technology "P-Plus" for its logistics resistance to transportation between Aya city, Miyazaki, and Tokyo. Aquabit Spirals Inc. offered its NFC technology combined with product packing and cooperated with InoLab to verify the UX improvement using the technology. An example of a product package is shown in Fig. 4.7. In addition, Daikanyama Salad (a restaurant in Tokyo), which has long recognized the quality value of Aya city vegetables, specially provided cold press juice and dressing, demonstrating the potential of Aya city vegetables for tasting when opening the Marche store.

In this manner, InoLab was able to build cooperative relationships with multiple companies and organizations. Owing to these relationships, the experimental design was solidified, and the verification points were expanded from the initial scope. By attaching QR codes with NFC tags to all vegetables sold at the Hills Marche, without being asked to install apps, consumers could hold smartphones and read QR codes to verify the production history of individual products recorded daily by the farmers and the organic farming development center in Aya city. Individual authentication (ID authentication) is required to prevent spoofing when registering the data. However, a simple login method that simply holds a card over an exclusive terminal was

introduced to reduce the burden on workers. A "FeliCa Lite-S card" (a contactless IC card) was distributed to each worker to record their work.

4.3.2 Influencers and Creators

When opening a store in Hills Marche, which was positioned as the climax in the consumer UX verification phase, consumer UX demonstration was not the only important objective. Target items, shipment quantities, and pricing to serve as marketing for Aya city's continued store openings in the future were carefully planned. In particular, the prices included the cost of adopting QR codes with NFC tags (link URLs are all different) in individual packaging units, transportation costs between Miyazaki and Tokyo, and the value of all the efforts made by the farmers and other workers involved in producing the products. Consequently, the target selling price of the products in these stores is double of that in the Aya city suburban market. Therefore, it is important to cultivate a brand image of Aya city vegetables for consumers who have a correct understanding of high-quality vegetables, to identify influencers supported by them, and to practice a creative initiative, called social communication initiative (SCI), that will attract highly conscious consumers.

The Hills Marche is sometimes referred to as a "customer-chosen" type marche, which is held on weekends. Thus, to attract customers, an effective approach is to spread information via influencers who would talk about the quality of Aya city vegetables with people in their influence base, rather than to simply and unilaterally provide information about the marche store opening. Mori Building, which has long operated the Marche business, the NPO "Japan's most beautiful village," which led the Japanese Lohas culture, and Daikanyama Salad, which leads a fan community with a high awareness of beauty and health, developed information communication through each influencer.

In addition, we requested the cooperation of two leading creators in the industry to communicate to urban residents about the high quality and safety of Aya city vegetables with the power of design. This was done by a designer, Yoshiya Yokota, who has a reputation for brand visual design and creatives for stores, and by a video artist, Suzuki Kenta, who is familiar with the way SNS generations interact with information. Yokota was asked to provide an exterior package specification and logo design that captured the characteristics of Aya city vegetables, and a product display method that would affect the sensibility of the target consumer under a unified consumer UX strategy. Suzuki Kenta was in charge of social communication design and video content production (Fig. 4.8) via SNS with target consumers, such as users of Instagram, Facebook, and Twitter, to build trust in Aya city vegetables.

Fig. 4.8 Aya vegetable CM for SNS "Let's Meet at Ark Hills Marche". (SCI Art Direction by video artist Kenta Suzuki/Model: Kaoru Gamo)

Fig. 4.9 Screenshots of production area information and production process that can be verified on a smartphone

4.3.3 Impact of the Experiment

The results were revealed shortly after the marche began. We were able to sell all the vegetables at the planned price without waiting for the closing time of the marche. A

customer looking at the production area and production management history (Fig. 4.9) by holding a smartphone over a vegetable package appeared strange in 2017, but this would be a precursor to store behavior in future fresh produce sections at shopping stores. Following the success of this store's opening, Aya city has begun to consider opening a regular store. In addition, reasonable results were obtained for the workload on the Aya-city side, where production management history was registered daily. By adopting a simple authentication method using a contactless IC card and a dedicated terminal for ID authentication at the time of data registration, the wallet issuance process by the Aya-city government office, soil inspection result registration by the organic farming development center, and work done daily by each producer were recorded. The workloads involved in registering production records were not as high as they had initially been concerned they would be. On the other hand, the additional work at the time of shipment, during which a QR code with an NFC tag is placed on an external package in individual packaging units, exceeded the expected workload; therefore, staff members were sent to Aya city from InoLab.

In addition, good results were obtained from the technical verification. In this demonstration experiment, PoP was established as a mechanism for distributing and storing data in multiple blockchains, guaranteeing the reliability of the data in each blockchain and the order of the distributed and stored data. Guard Time Inc.'s KSI was used as the operating blockchain. The good results demonstrated that PoP can compensate for the weaknesses of privately operated blockchains. At the same time, it was confirmed that it is possible to save a large amount of data by distributing and storing data on multiple blockchains, and it is theoretically possible to save all the data in the world on blockchains.

Furthermore, in this demonstration experiment, the implementation was completed in about 1 month, which is significantly shorter than the implementation period (assuming 3 months) when using the relational database (RDB). It can be an incentive for local governments to implement learning in a short period of time while keeping learning costs low because developers can easily access, store, and search the blockchain through the REST API (a type of program specifying conventions for using a web system from the outside) without any special knowledge. In addition, Broof, a blockchain implemented on the premise of search and analysis, confirmed in this demonstration that all information browsed by the user can be searched and displayed from the blockchain, and its searchability is also strongly proven. Verifications linked with Hadoop (an open-source software framework for distributed processing of large data) and Spark (an open-source cluster computing framework) are also implemented, and even if a large amount of data (big data) is accumulated in the future, the blockchain can, theoretically, be analyzed.

4.3.4 Demonstration Experiment at Restaurant "Realta"

In the above-mentioned demonstration experiment in Aya city, a system was created in which farmers' philosophy and values were transmitted to consumers in the

Fig. 4.10 Customers view information on menus and ingredients offered for the day and information on ethical consumption on their smartphones

process of the distribution of crops grown by organic farming to consumption areas. In the next demonstration experiment, the objective was to record not only the behind-the-scenes details of products from production to distribution for the information of consumers but also the consumption history of selecting and consuming them. By recording this information on the blockchain, we can enable consumers to participate in the so-called "ethical consumption." This can be applied for marketing purposes, such as providing customers with benefits via discount services when visiting other affiliated stores.

The experiment was conducted in the Italian restaurant "Realta" in Chiyoda Ward, Tokyo. Agricultural products produced in Aya city were added to an ethical menu. The flow of the experiment is as follows.

1. Restaurants participating in the experiment purchased ingredients from farmers in Aya city. As described previously, the status from production to distribution is recorded on the blockchain, and the "reliability" of the agricultural products is secured.
2. Consumers who visit the restaurant check the menu (contents and ingredients used) of the dishes to be served on smartphone screens or printed paper (Figs. 4.10 and 4.11). The state of the production area can also be viewed using

Fig. 4.11 The ethical menu, which shows the amount of environmental considerations in the graph, rather than the price

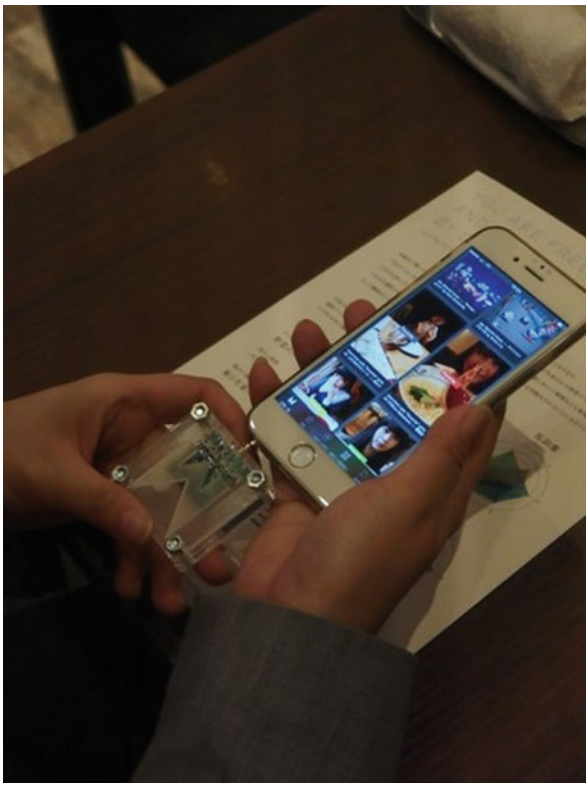

Fig. 4.12 Customers order from an ethical menu on a smartphone

video. At the time of browsing, the dongle (adapter) installed at the store is attached to the smartphone, and the consumer's SNS account is registered with the recording system. Using this procedure, a record of the information on the ethical menu browsed by the consumer is recorded in the blockchain.

3. The consumer learns about the details of the contents of the menu, and when placing an order (Fig. 4.12), replaces the dongle on the smartphone, and the order is recorded on the blockchain.
4. Each time an ethical ingredient is selected (consumed), a token called "ethical points" is issued and can be received by each account (wallet). Depending on the number of accumulated tokens, one can obtain discounts and other services at other restaurants that offer dishes with the same ethical ingredients.

The results of the experiment confirmed that users were able to understand the contents of the ethical menu containing environmentally friendly ingredients by using the dongle interface. Most of the customers that watched the video chose the ethical menu, which was about 1.5 times as expensive as the regular menu.

In this experiment, a system was constructed to induce ethical consumption behavior using a dongle interface and blockchain. This system has (1) a function

to appeal to consumers to opt for ethical consumption at the store using the dongle interface, and (2) a function to encourage consumers to continue ethical consumption activities by checking their history of consumption activities. Function (1) was tested in restaurants. By observing users operating the system, we verified that the system can be easily introduced in restaurants, and it encourages ethical consumption behavior in consumers. However, the potential changes in ethical consumption behavior in daily life catalyzed by the visualization of prior ethical behavior have not been verified, and it remains an open issue for future work to address.

4.4 In Closing

An interesting aspect of the second experiment mentioned above was the customer group that visited the restaurant. Despite being a restaurant with a large number of customers in their 1950s, the average age of the general participants dropped significantly to 28.9 years during the experiment. In the ordinary mass market, young people tend to prefer low prices, but most participants chose an ethical menu that was more than twice the price of the regular menu. While on the one hand, it is likely that they cannot afford to spend on products that cost more owing to their financial limitations, on the other hand, their questionnaire responses revealed that they also participate in volunteer activities such as picking up garbage on weekends and donate to organizations such as NPOs and NGOs once a year. In other words, it is probable that they found meaning in the fact that they contributed to the environment.

In addition, it was found that a device for facilitating UX is indispensable for promoting ethical consumption. The UX of ethical consumption can be refined by combining technologies such as a dongle and blockchains as mentioned above, leading to new consumption behaviors. The evolution of these latest technologies will not only change the ethical consumer market but also usher in wider changes in the future.

Looking back 10 years ago, the value of the collective knowledge accumulated on social networking services and rating sites appeared to be far behind the value of the information provided by authoritative individuals and sources such as critics and restaurant guides. Ten years later, consumers today have gradually shifted towards collective knowledge to facilitate their own evaluation of value, whether in their search for books and movies to spend their holidays with or for information on restaurants with a good atmosphere. Further, consumers have themselves become sources of information in an increasingly nonhierarchical and interactive information communication ecosystem. However, problems such as the emergence of unreliable "summary sites" and public opinion manipulation through "fake news" have underlined the potentially harmful effects of personal media. Therefore, services that guarantee the legitimacy of information will become increasingly necessary in the future.

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Chapter 5
Kaiyu Analytics Enhances the Value of the City: The Town Equity and Big Data

Saburo Saito, Kosuke Yamashiro, and Masakuni Iwami

Abstract We discuss the significance of big data to urban studies from the perspective of *Kaiyu* analytics. *Kaiyu* refers to consumers' shop-around or walk-around behaviors within the city center commercial district. *Kaiyu* analytics first defines *Kaiyu* as the sequence of individual consumers' simultaneous decisions about which destinations they choose, for what purposes, and how much they spend, if any, in the order of the occurrence, records and collects *Kaiyu* micro-behavior history data, and analyzes and utilizes them to evaluate urban development policies and ultimately to enhance the value of the city. To see how *Kaiyu* analytics works, we review our *Kaiyu* studies and describe how they lead us to the concept of town equity, which defines the value of the city as the asset value of the attractiveness of the city the visitors to the city embrace in their minds. We explain how the concept of town equity drastically changes our traditional goal and scope of urban development. Once we noticed the goal of urban development as maximizing the town equity, urban policies begin to include all interventions to change visitors' behaviors and minds not restricted to the traditional physical facilities constructions. Nevertheless, we can keep the framework of evaluating urban policies by verifying their effects on consumers' behaviors and minds, which becomes the town equity research we seek. The most challenging theme in town equity research now is to explore how the information affects people. The enormous significance of big data for town equity

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research is that we can observe and record how individuals interact with information to make their choices, and even we can intervene with these individuals to support their on-site decision-making. If this becomes possible, excellent research frontiers will open. The town equity management system is the apparatus that accumulates this kind of big data and utilizes it for strategic town management to enhance the value of the city.

Keywords *Kaiyu* · *Kaiyu* analytics · Value of city · Town equity · Visit value · Hypertext city · Goal of urban development · Evaluation of urban development policies · City center commercial district · Consumer behavior · Urban development marketing · Strategic town management · Activity effect evaluation scheme · On-site *Kaiyu* survey · Consistent estimation of *Kaiyu* Pattern

5.1 Introduction

Looking at the recent tendencies in the industrial world, one realizes that the interest in big data is rapidly expanding in various fields. For example, just recently, we wrote, "It might come as quite a surprise to you, but the wave of big data is just around the corner for urban planning as well" (Saito 2012b). The wave of big data has now reached urban development, as featured in newspapers (Nikkei 2013b).

However, even though "big data" is advocated, in many cases, there is no explicit mention of what is involved and how it relates to one's core business. Nor is there a clear strategy for linking big data to the transformation of one's core business.

The Fukuoka University Institute of Quantitative Behavioral Informatics for City and Space Economy (FQBIC) (FQBIC (Fukuoka University Institute of Quantitative Behavioral Informatics for City and Space Economy 2021) has conducted various studies on urban development, focusing on *Kaiyu* behavior and establishing a field, so to call, *Kaiyu* analytics. Here, we refer to the *Kaiyu* behavior as the behavior of consumers who walk around in the city center commercial district.

We also believe that the "big data" trend will bring about a fundamental paradigm shift in how we think about urban planning research and development and will open the door to an era of significant change (Saito 2012a).

So why do we think this way? In this chapter, we address why "big data" is relevant for *Kaiyu* studies and why *Kaiyu* analytics can enhance the value of the city.

5.2 What Is *Kaiyu* Analytics?

FQBIC has focused on the *Kaiyu* behavior of consumers in the city center commercial district and has conducted various studies on urban development policy evaluation. The core activities of these studies are on-site surveys of consumer *Kaiyu*

behaviors. These are conducted continuously at the city center commercial district of Fukuoka City and include the implementation at other city centers of Asian megacities such as Beijing, Shanghai, Hanoi, Seoul, and recently at those districts of *Kagoshima*, *Kumamoto*, *Miyazaki*, *Oita*, and *Nagasaki*, prefectural capitals in the *Kyushu* region.

The most significant characteristic of our *Kaiyu* behavior surveys is that we have developed a theoretical method that can estimate the net incoming number of visitors to the city center district, which could not have been estimated before. Using this *Kaiyu* analytics method, we have clarified the net incoming number of visitors to the city center commercial districts of prefectural capital cities in the *Kyushu* region.

Usually, they utilize pedestrian traffic count surveys to obtain the net incoming number of visitors to the city center commercial district. However, the problem of double-counting the same pedestrian at multiple measurement points is inherent in pedestrian traffic count surveys, making it impossible to estimate the net number of visitors accurately. Therefore, despite implementing various policies for revitalizing city center districts, it is almost impossible to scientifically evaluate the effect of such policies without these figures. As a result, we cannot assess how the net incoming number of visitors to a city center increased by what kind of revitalization measures when the net incoming number of visitors to a city center remains unknown.

Let us illustrate *Kaiyu* analytics using an example.

The morning edition of the Nikkei on April 9, 2013 (Nikkei 2013a), reported that the 2012 sales for "Amu Plaza *Kagoshima*" (a commercial complex located at JR *Kagoshima Chuo* Station, the Southend terminal station of *Kyushu Shinkansen*) were approximately 23.2 billion yen, an increase of 1.7% compared with 2011. It also reported that the number of visitors had increased by 3.4% to 13.33 million people, a record for three consecutive years.

How would people read this article? Typically, they would not be impressed by such numbers and skip reading them.

Let us look at Figs. 5.1 and 5.2. Five days before this news, FQBIC reported the results of the analysis obtained from the Survey of Consumer *Kaiyu* Behaviors at the City Center of *Kagoshima* City conducted on November 10 and 11, 2012, at a meeting with people involved in the *Tenmonkan* district, the largest city center commercial district of *Kagoshima* City. According to the estimated results, the net incoming number of visitors per day on average per year to the city center commercial district of *Kagoshima* City for shopping, leisure, and meals on November 10 and 11 was 88,000 people. (Cf. Fig. 5.1) On the other hand, the share of the net incoming number of visitors to the surrounding district of *Kagoshima* Chuo Station was about 19.2%. (Cf. Fig. 5.2) However, during the survey days, the Great Exhibition of Hokkaido Products was held at the *Yamagataya* department store. Thus, the number of visitors on an ordinary weekend was estimated to be 78,000 people, after deducting the 10,000 people who gathered for the exhibition. We also reported that compared with 2011, the net incoming number of visitors increased by approx-

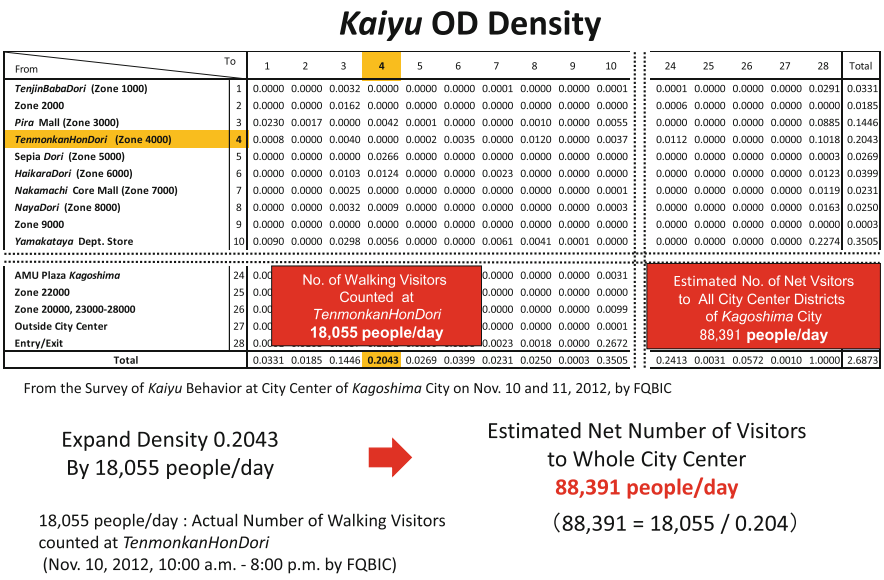

Fig. 5.1 The net incoming number of visitors to the whole city. Estimation and expansion of *Kaiyu* density by the consistent estimation method: The *Kaiyu* density, 0.204 at *TenmonkanHonDori,* the central passage in the arcaded shopping streets, is obtained from the surveyed *Kaiyu* micro-behavior data by applying the consistent estimation method. The net number of incoming visitors to the whole city center, 88,391 people/day, is obtained from expanding its density by the actual number of walking visitors measured at the central passage, 18,055 people/day

imately 10,000 people, and the effect of the full opening of the JR (Japan Railways) *Kyushu Shinkansen*, the *Kyushu* express railway,[1] is continuing.

The issue is how these results are related to the news the newspaper reported. Since the number of visitors is 78,000 people per day and the share of the surrounding district of *Kagoshima Chuo* Station is 19.2%, the net number of visitors to Amu Plaza *Kagoshima* is about 15,000 people per day, 5.47 million annually. On the other hand, according to another aggregated result of this *Kaiyu* survey, the expenditure per visitor at the city center commercial district of *Kagoshima* City is 4500 yen. From these results, we can forecast the annual sales of Amu Plaza *Kagoshima* at 24.6 billion yen. This value is very close to the 23.2 billion reported.

In addition, according to the *Kaiyu* survey results, each visitor stops at an average of 2.68 places in the commercial facilities in the city center commercial district of *Kagoshima* City. Therefore, if we consider each net visitor visits 2.68 commercial facilities as visitors to those facilities, Amu Plaza *Kagoshima* will have 14.66 million visitors, that is, 5.47 million people multiplied by 2.68 places. Furthermore, considering that 78,000 people/day is the net number of incoming visitors on the weekends,

[1] The full line of JR *Kyushu Shinkansen* connecting JR *Hakata* Station, the north end terminal in Fukuoka City, and JR *Kagoshima-Chuo* Station, the south end terminal in *Kagoshima* City, started operation on March 12th, 2011.

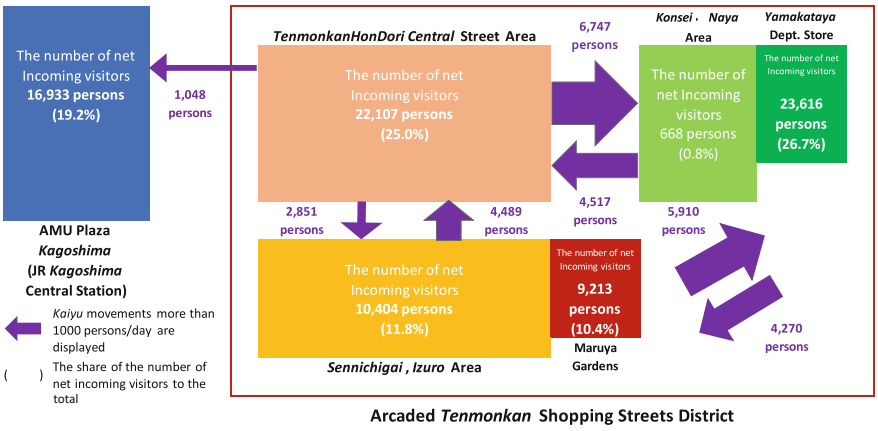

Fig. 5.2 The net incoming number of visitors and *Kaiyu* movements within the city center commercial district of *Kagoshima* City

we know why our estimate is a little overestimated. Thus, if renewed, the estimate should be closer to the reported 13.33 million people in the news.

Why was it possible to estimate the number of visitors coming into the city center commercial district in this way? First, we use the consistent estimation method, the core of *Kaiyu* analytics. We will explain it in the next section.

5.3 The Consistent Estimation Method to Accurately Measure the Flow of People

In the *Kaiyu* survey, we set up multiple sampling points in the city center commercial district and randomly selected the respondents from among the visitors to the sampling points. Thus, the *Kaiyu* survey is an on-site random sampling survey for a 15-min interview survey with questionnaire sheets. It records the history of consumers' *Kaiyu* behaviors that occurred during the course of their *Kaiyu* as a sequence of three choices, namely, the place they visited, the purpose of going there, and the expenditure spent there, if any; in other words, it records as a sequence how the triples of three simultaneous choices, place, purpose, and expenditure, have changed over the time axis. Thus, we call the data obtained from the *Kaiyu* survey the *Kaiyu* micro-behavior history data.

It is worth noting that we can consider the *Kaiyu* micro-behavior history data as comprehensive POS data (Saito 2005) since it contains consumer behaviors at multiple shops, at different kinds of shop-category stores, while including visits with no purchase. Furthermore, from another angle, its characteristics can be seen as the records of consumers' simultaneous choices among destination, purpose, and

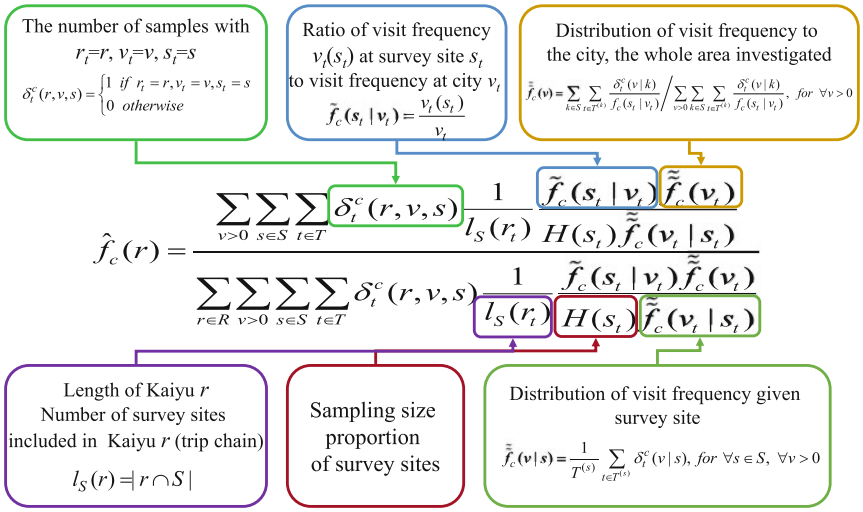

Fig. 5.3 On-site consistent estimation method for estimating *Kaiyu* pattern (JP No. 3793447)

consumption. In other words, we defined *Kaiyu* behavior and recorded the *Kaiyu* micro-behavior history data as a sequence of consumers' joint decisions of which destinations they chose, for what purposes, and how much they spent, if any, in the order of their occurrence. Unfortunately, these *Kaiyu* micro-behavior history data have never been systematically collected.

On the other hand, by profoundly considering the feature of the *Kaiyu* survey as the on-site random sampling survey, we obtained the new development of establishing a theoretical method to estimate the flows of people accurately in the *Kaiyu* analytics. We refer to it as the on-site consistent estimation method for estimating the *Kaiyu* pattern, granted as a Japanese algorithmic patent [Cf. (Saito 2010; Saito et al. 2001b; Saito and Nakashima 2003)].

Figure 5.3 shows the equation employed in the on-site consistent estimation method. We explain its meaning by using the analogy of noise-canceling headphones.

First, note that the *Kaiyu* survey is an on-site random sampling survey in which a sample is randomly selected not at home but at the place the sample visited. Therefore, a person who makes ten visits a month to the city center commercial district is likely to be selected as a sample ten times more than a person who makes one visit a month. Similarly, there are other differences in the likelihood of being chosen as a sample. For example, people frequently visit some sampling points while they do not frequently visit some other sampling points. Furthermore, young people visit more places in their *Kaiyu* than others. A choice-based bias occurs if we ignore these and collapse the data obtained from different sampling points to apply simple analysis.

Our consistent estimation method can remove the choice-based sampling bias as if we selected samples equally likely. Why the consistent method can remove

choice-based bias can be interpreted from the analogy of noise-canceling headphones. We consider visitors to the city center to have their own unique waves (or noises), which reflect the likelihoods that they are selected as a sample. The noise-canceling headphones extract clear sound from noises by emitting opposite phase waves to the noises. In the same way, we give visitors the weights to cancel their unique waves and make it possible to extract the true *Kaiyu* pattern of visitors by aggregating their *Kaiyu* behaviors with those weights. The equation in Fig. 5.3 shows those weights used.

Recently, an unexpected development arose from this patent. The consistent estimation method estimates the *Kaiyu* pattern of visitors or the density. Therefore, if one knows how many visitors come to one place in a town in an actual number, we can estimate the number of people coming into the whole town by expanding this number by the density ratio. Furthermore, besides the total number of incoming visitors to the whole town, even we know how visitors move within the city center district by their *Kaiyu* on an actual number basis.

In Fig. 5.1, we exemplify this development. First, we counted the actual number of walking visitors traffic at one place, at one section of the central passage, *TenmonkanHonDori,* in the arcaded *Tenmonkan* shopping streets. Next, we applied the consistent estimation method to the *Kaiyu* micro-behavior history data to get the *Kaiyu* density from the on-site survey of *Kaiyu* behaviors at the city center commercial district of *Kagoshima* City. Finally, we expanded the actual number counted by the density estimated to obtain the number of net incoming visitors to the whole district.

We should note that until now, we have yet to have a theoretical tool to grasp how many people visit the city center district for shopping, leisure, and meals, as well as the flow of these visitors within the city center district. The situation is the same for big cities that millions of people visit daily and even for regional core cities. Thus the formulation and its application of the consistent estimation method were revolutionary. Because, for example, if one knows the number of visitors to the *Marunouchi* Building, it becomes possible to estimate the net incoming number of visitors to the whole *Marunouchi* district and how they move around within the *Marunouchi* district (Saito 2010). In this way, we can expect to carry out highly accurate evaluations of urban development policies by establishing a theoretical method to estimate the number of visitors coming into the whole town from the number of visitors coming to one place.

In fact, for the Castle Festival held in *Toricho-Suji*, *Kumamoto* City, it has become possible to estimate how many participants the festival had attracted and how its spill-over effects spread over to the entire town through the participants' *Kaiyu* behaviors within the city center district (The Japan Association for Real Estate Sciences 2010; Saito et al. 2010).

It is becoming more evident that the consistent estimation method is also effective in developing countries with little published data, such as Vietnam (Saito et al. 2012; Tran Ngoc 2012).

5.4 *Kaiyu* Analytics and Big Data

Measuring the actual number of *Kaiyu* movements using the consistent estimation method was a significant theoretical development. In the future, we must advance it to real-time estimations. However, the estimation of the number of people is not the only reason why *Kaiyu* behavior studies have focused on *Kaiyu* micro-behavior history data. The purpose of advancing the *Kaiyu* studies also includes clarifying why people choose such destinations, why they continue *Kaiyu*, and why they make such consumption selections. The purpose also contains the decision-making mechanism of people's behavior choices. We believe that "information" is extensively involved in this decision-making mechanism.

Since its establishment in 2000, the FQBIC has been aiming to build a theory of semantic interaction between urban spatial information and behavioral entities. However, verifying how "information" had affected consumer behavior choices has been difficult since we could not fully prepare the means and the environment for verification. Currently, however, with information and communications technology (ICT) progress, this environment has drastically changed.

We focus on the potential possibilities of "big data" that can be obtained and accumulated by intervening with interactions between information and people's behaviors through smartphones.

There are two meanings. The first is the possibility of bringing a more scientific and objective method to urban planning and development research. The second is the possibility of becoming a new means to increase the value of a town.

In the next section, we further consider these issues while connecting them to the past *Kaiyu* behavior research and the recent smart city research.

5.5 Focusing on *Kaiyu* Behavior

5.5.1 Agglomeration Effect

To explain the reasons for focusing on *Kaiyu* behaviors, we must refer to the agglomeration effect. For example, if one consumer visits three commercial facilities downtown, there are three visitors to commercial facilities, which implies a multiplier effect that turns one into three. On the other hand, consumer *Kaiyu* behaviors occur because commercial facilities are accumulated and located close to each other. Also, we note that the city center commercial district is where the commercial facilities form a proximate agglomeration of the retail sector. Thinking this way, we realize that the consumer *Kaiyu* behaviors are concrete and specific manifestations of the agglomeration effects of the retail sector in that area. Therefore, if we were to develop a city center urban space with proximately agglomerated retail facilities, the city center urban space must be more desirable if it can induce higher

agglomeration effects. In other words. The city center urban space should be more desirable if it induces higher consumer *Kaiyu* behaviors.

Kaiyu behavior research began in the 1980s with this simple evaluation framework. Fortunately, *Kaiyu* has recently become a policy objective in many activities for downtown improvement and revitalization policies.

5.5.2 Metatheory of City Planning Research

Another aspect of focusing on *Kaiyu* behavior relates to the metatheory of city planning research. Metatheory is a theory or framework that researchers implicitly rely on when evaluating what research is desirable. More specifically, Kumata and Saito (1975) first proposed a metatheory for city planning research, which consequently extracted three evaluation schemes in city planning research.[2]

They conceptualized the urban system as a complex system consisting of three systems: the physical system, the activity system, and the social decision-making system. From this, Kumata and Saito presented the activity effect evaluation scheme in contrast to the ideal city evaluation scheme, which confines the description and evaluation of the urban system only to the physical system, such as facility design. In contrast to the ideal city evaluation scheme, the activity effects evaluation scheme considers that city planning aims to optimize the activity systems of people in the urban system. Thus the activity effects evaluation scheme supposes that we should evaluate the physical system by assessing its effects on activity systems. However, even now, many policies exist based on the ideal city evaluation scheme that emphasizes design centered on physical facility development in regional commercial revitalization or revitalization of the city center district.

Most of *Kaiyu* behavior research stands on the activity effects evaluation scheme. However, due to the possibilities of big data, which can record the micro-behavior history of interactions between people and information, it has become necessary to reconsider this scheme.

Under the catchphrase of "city planning with big data," the recent trends show many ideas insisting that one can do this using ICT technology and car navigation (Nikkei 2013b), which is just an ideal city evaluation scheme that only replaces the physical system with information technology.

Instead, it is necessary to have a genuine understanding based on grasping the purpose of urban development as the optimization of people's behavior and change the evaluation scheme by considering the possibilities of big data.

There are three axes of changes we should focus on, (1) the type of data, (2) the scope of urban development policies, and (3) the time cycle of policy evaluation feedback.

[2]Recently, Saito discussed again three evaluation schemes in Saito (2017a, 2018a), Chapter 1 in Saito and Yamashiro (2018c). Also see Chapter 2 by Saito et al. (2022a) in this volume.

The first axis concerns changing the data types from aggregate to disaggregate ones. Some urban development research has already put this change into practice. Most of our *Kaiyu* behavior research could not have been carried out without this change. The data we deal with should be the records of each individual's micro-behavior decisions, like the *Kaiyu* micro-behavior history data discussed above, not the aggregate ones like public statistics.

The second axis of change is concerned with changing the scope of urban development policies from optimizing the aggregated activity systems by hard facility improvement to supporting the individual actor's on-site decision-making through the platform combining ICT and hardware. For example, a typical system is a system for providing bus approach information. From the supplier side of the city function, this system maximizes the value of the place, and from the visitor's side, it maximizes the visit value for visitors.

In addition, the third axis concerns the time cycle of policy evaluation feedback and changes it from long-time feedback to real-time feedback through the platform combining ICT and hardware. The traditional evaluation feedback cycle takes a long time since it must provide the supplier with information about the aggregated impact of hard improvements on the activity system.

Since this is a little abstract, we look at concrete examples and consider their implications for urban development policies in the next section.

5.6 Smart Cities and Computational Social Sciences

In recent years, using smartphones as sensors, various forms of big data have become available, so they have attracted much attention from fields such as smart cities, indoor positioning measurement, and complex networks. What is interesting is that since these big data are obtained and accumulated through people's movements, calls, purchasing behavior, web browsing, and social networking services (SNS), which are deeply involved with interactions between people and their locational movements and between their behaviors and information, these big data triggered the interest in social science and human behavior again.

Next, we provide a few examples.

First, the Behavioral Initiatives for Energy Efficiency Project by Stanford University is fascinating regarding smart grids [Cf. (Advanced Research Project Agency-Energy (ARPA-E) 2010; Armel et al. 2013)]. Also, there is a study on mobile phones by Gonzalez et al. (2008). This research is the first study to clarify the movement patterns of people using the location data of a base station (cell) from the anonymized usage data of 100,000 mobile phone users for 6 months. The study (Brockmann et al. 2006) attempted to show whether the movement of people follows the power law from the movement of banknotes. As a result of these studies, complex network system research [Cf. (Dorogovtsev 2010)] has been actively featured in magazines such as Nature and Science. In addition, various smartphone sensing methods have been used in ubiquitous computing and sensing research. In

urban research, there is also a movement to understand the activities of people in cities in real time, as exemplified by "Real Time Rome" by the SensableCity Lab of MIT, and active research is being carried out (Calabrese and Ratti 2006).

Similar trends in Japan are "Pedestrian Context Recognition" of the Ubiquitous Sakamura-Koshizuka Laboratory, the "Human Flow Project" by Shibazaki Laboratory at the Center for Spatial Information Science at the University of Tokyo, and wide-area tourism behavior analysis using auto GPS (Zenrin Datacom, Jalan Research Center 2011). Also, in 2012–2013, under the SCOPE project of the Ministry of Internal Affairs and Communications, FQBIC implemented the research project (Kyushu Regional Bureau of Telecommunications MIC (Ministry of Internal Affairs and Communications, Japan) 2012), attempting to estimate the visitors' information evaluation function that changes in real time according to the visitors' contexts while integrating the visitors' movements in wide and small areas.

In particular, hot topics in the business and research domain of location positioning are seamless location positioning in indoor and outdoor spaces. As for indoor location positioning, the related entities established the Indoor Messaging System (IMES) consortium in 2011 to promote seamless positioning. The IMES is an indoor position measurement technology developed in Japan by JAXA (Japan Aerospace Exploration Agency). On the other hand, Google introduced the Indoor Maps service. As of 2014, a commercial complex in Tokyo, *Futago-Tamagawa* Rise, and a commercial establishment in *Sapporo* both experimentally installed IMES. The efforts to measure people's indoor movements are actively conducted. FQBIC also implemented social experiments using IMES at the city center commercial district, *Tenmonkan* in *Kagoshima* City, and participated in social experiments in *Tanegashima* Island, where Softbank, SPAC (Satellite Positioning Research and Application Center), and JAXA have also participated in verifying the accuracy of the measurement of the Quasi-Zenith Satellite System (QZSS) (FQBIC (Fukuoka University Institute of Quantitative Behavioral Informatics for City and Space Economy 2013; Satellite Positioning Research and Application Center, General Incorporated Foundation, SoftBank Telecom Corp. 2013).

What is distinctive about the interest in human behavior is that all of them are thinking about what we can do with "big data" obtained through sensors such as mobile phones and smart meters.

Indeed, the most exciting point of the Stanford project is the following. In a typical smart grid, systems such as HEMS (Home Energy Management System) and BEMS (Building Energy Management System) are emphasized in order to improve the efficiency of energy use in homes and buildings while integrating ICT (Kato 2010) and utilizing renewable energy sources such as photovoltaic (PV) power generation.

In contrast to this traditional thinking, the idea of the Stanford project is to redefine the technical system of electricity as one that includes human behavior as a part of it and use real-time pricing and information feedback to induce people to change their behavior to curb the electricity demand.

Inspired by the Stanford project, Japan also implemented a project to induce behavioral change as the demonstration project of the energy system at Huis Ten

Bosch, *Nagasaki*, (Sojitz Corp. 2011), in which FQBIC participated as a behavioral analysis expert.

According to Beyea (2010), in the next 4–5 years, 40 million smart meters will be introduced in the United States by the Green New Deal of the Obama administration, and 245 million smart meters will be introduced in Europe over the next 10 years. Further, to store the electricity usage data of all households in the United States every second will need approximately 50 Peta (1 Peta = 1,000,000 Giga) bytes of data per year. These trends are called "computational social science" by Lazer et al. (2009).

Up to now, there have been many attempts to model the interactions of many entities, such as agent simulation, but the big difference between agent simulation and "big data" is that "big data" can directly observe, record, and even intervene in real time to give feedback to the interactions of many entities. Furthermore, we know that "big data" are usually digitized, so they are likely to be linked with control. Thus, we can see many possibilities for significant innovations in existing technologies, such as the electricity demand forecast and control.

5.7 *Kaiyu* Micro-Behavior History Data and Economic Effects

These trends, which resonate with the behavioral initiatives for energy efficiency by Stanford University, are also closely related to the systematic, extensive collection of *Kaiyu* micro-behavior history data FQBIC has carried out, as well as town equity research, the idea of hypertext cities, and the concept of urban development marketing [Cf. (Saito 2005, 2007, 2008b; Saito et al. 2008b)].

More specifically, the following points are major synchronizing points. First, they include collecting many households' micro-behavior data, recording their information environment (such as power usage status provided by visualization and feedback), and the transaction process itself (what kind of interactions each household engaged in). Furthermore, they also include interventions involving interactions between households and their information environment and triggering behavioral changes in the households.

Significantly, the point of effecting a change in people's behavior and trying to tie it to efficient energy use is precisely the same philosophy of *Kaiyu* behavior analytics, which aims at revitalizing the local economy by activating *Kaiyu* behaviors.

Our one big discovery in *Kaiyu* analytics is that inducing *Kaiyu* produces a large economic effect. This discovery occurred in *Kaiyu* behavior research because the *Kaiyu* micro-behavioral history data is the simultaneous records of consumers' choices of destination and consumption. The 10.9 billion yen per year of the city center circuit 100-yen bus (Saito and Yamashiro 2001, 2018a), the 18.7 billion yen per year of city center cafés (Saito et al. 2008a, 2018a), and the 17.7 billion yen per year of the opening of the *Nanakuma* new subway line (Saito and Yamashiro 2018b;

Saito et al. 2007) are examples of the economic effect of these urban policies on the local economy of the city center commercial district of Fukuoka City.

We verified that people who used these services increased their visit frequency to the city center or their *Kaiyu* visits to other commercial facilities. From this verification, we consider the amount of money they spent on the increased frequency of visits to the city center or the increased *Kaiyu* visits to other commercial facilities in the city center as the effect of increased spending at the city center commercial district. We calculate this increased spending in the city center commercial district annually as the economic effect of these services on the local economy of the city center commercial district[3] (Yamashiro 2012).

Roughly 100 million visitors annually visit the city center commercial district of Fukuoka City for shopping, leisure, and dining purposes. According to our past surveys of consumer *Kaiyu* behavior at the city center of Fukuoka City, when people come to the city center, they visit 4–5 commercial facilities as *Kaiyu* on average and spend 1500 yen or 15 US dollar per *Kaiyu* visit on average, including not buying. From this fact, if we could have visitors extend their *Kaiyu* visits by just one visit by some means, such as the information provided through smartphones, we can expect to obtain a 150 billion yen or 1.5 billion US dollar spending increase effect on the local economy, a tremendous amount of economic effect on the local economy of the city center of Fukuoka City.

5.8 Town Equity, Urban Development Marketing, and the Idea of the Hypertext City

The critical concept of "town equity" was born from these *Kaiyu* studies. The first author of this chapter coined "town equity" from the term "brand equity." Its definition is "the asset value of the attractiveness of a city embraced in the minds of visitors to the city.[4]"

The concept of "town equity" and town equity research was first proposed at the Japan Association for Real Estate Sciences (JARES) meeting held at Fukuoka University in 2004. Furthermore, we held public symposiums sponsored by JARES four times to disseminate them [Cf. (The Japan Association for Real Estate Sciences 2005, 2007, 2008, 2010, 2012)].

[3] We can also apply the *Kaiyu* micro-behavor approach to the estimation of the economic effects of the event held at some place that spread over other places in the city center district. [See Saito et al. (2018b), Chapter 15 in Saito and Yamashiro (2018c), as an example.]

[4] Inspired by the concept of brand equity, Saito first created the new term "Town Equity" in Kakoi et al. (2005). Relating the concept of "Town Equity" to the goal of urban development, Saito renewed the notion of "goals of urban development" as the maximization of "Town Equity." While this conceptual evolvement occurred around 2008, Saito discussed recently the relationship between "Town Equity" and the goal of urban development in Saito (2017b, 2018b) and Chapter 3 by Saito et al. (2022b) of this volume. While the goals of city planning were discussed head-on in the early literature on city planning, they are rarely mentioned these days.

To state the conclusion, first, "town equity" is nothing but the "value of the city" from the consumers' perspective. If this is the case, we can rethink the goal of urban development as "maximizing town equity by looking at the city as a single business entity."

In other words, maximizing the visit value for visitors is maximizing the value of the town, and the goal of urban development is reduced to the question, "What kind of functions and facilities should the city have to maximize the visit value for visitors?"

The significance of the concept of "town equity" is that it clarifies the purpose of urban development, which has been ambiguous until now, makes the value of a town a measurable concept, and shows that it is possible to attempt to measure the value of a town based on *Kaiyu* micro-behavior history data (Saito 2007; Saito et al. 2001a).

We should note that the attractiveness of a town is not uniform for visitors but is different for each visitor. Therefore, to see what urban development policies increase the value of a town, we must clarify what kind of measures would enhance what kind of visit value for what kind of visitors in what ways. Further, we should accumulate these as knowledge for effective urban development policies. This way to accumulate the knowledge for effective urban development policies through their verification is what we advocate as "urban development marketing."

Therefore, to increase the value of a town, we must increase the different visit values of the diverse visitors. To do this, we must satisfy the different needs of diverse individual visitors when they come to the town. Thus it becomes indispensable for a town or a city to have a mechanism for assisting individual visitors in attaining their visit purposes by supporting their decisions while considering what they want to do while they are in the town or the city in real time. Here, we believe that the information plays a critical role. Hence, we seek some apparatus for providing on-site, real-time decision support by offering customized information to individual visitors.

Since its establishment in 2000, the FQBIC has defined a "hypertext city" as "a city where visitors can make semantic information transactions with the city through intelligent mobile terminals." Also, the FQBIC aims to realize the hypertext city concept, and along with various proposals, it has researched mechanisms for providing intelligent information to visitors (Saito 2005; Saito et al. 2008b).

The hypertext city concept intends to realize an urban development marketing method systematically utilizing ICT, collecting the consumers' information interactions micro-behavior history data by recording their semantic information interactions with city space information and clarifying their behavioral grammar. At the same time, the concept aimed at maximizing the visit value for each visitor by providing accurate information feedback and effectively supporting visitors' decision-making on site.

In order to actualize such a hypertext city in a city center, it is necessary to have at least one place to count the number of visitors, as well as a platform to trigger interaction between visitors with smartphones or tablets and city space information using air tags or NFC tags linked to GPS, IMES, and Wi-Fi location information. Furthermore, we need a mechanism that makes individual visitors' interactions

through this platform valuable by supporting their on-site decision-making to enhance their visit value to the city and thereby maximize the value of the city. We will call this the Town Equity Management System (TEMS).

TEMS will be an indispensable device for strategic urban development to maximize the value of the city.

5.9 Town Equity Management System (TEMS)

From this viewpoint, we can see that the trends of HEMS and BEMS in smart grids and the aim of town equity research closely intersect.

Various measures for revitalizing the city center commercial districts, including events, have been implemented up to the present. However, it can be said that there are no city center commercial districts that know how many people are visiting their town. Without knowing the number of visitors to each city, how can we evaluate the effectiveness of the various revitalization measures? Therefore, it can be said that FQBIC's research, based on *Kaiyu* micro-behavior history data, has attempted to develop a scientific method for evaluating urban development policies.

In particular, the aim has been to provide information to promote *Kaiyu* behaviors and link *Kaiyu* behaviors to the city's revitalization.

However, it has been quite challenging to measure and verify what kind of information provision causes what kind of behavioral changes in consumers and how the information provision induces *Kaiyu* behaviors in the traditional information technology environment.

However, this situation is about to change drastically. We enter an era where it is possible to track what kind of information was provided to what kind of visitors and what effect occurred.

These consumers' information transactions are the domain that the town equity research should focus on in the future to develop scientific methods to measure and evaluate how various urban development policies contribute to enhancing the value of the city, based on a proper understanding of the goal of urban development as maximizing town equity.

5.10 Real-Time City Through *Kaiyu* Analytics

The estimated number of incoming visitors at the city center commercial district of *Kagoshima* City presented in Sect. 5.2 is our result obtained by applying the consistent estimation method to our *Kaiyu* micro-behavior history data to obtain the *Kaiyu* density and expanding the density with the actual data of visitors' walking traffic counted by us at one cross-section of a central passage, *TenmonkanHonDori,* in the arcaded *Tenmonkan* shopping streets.

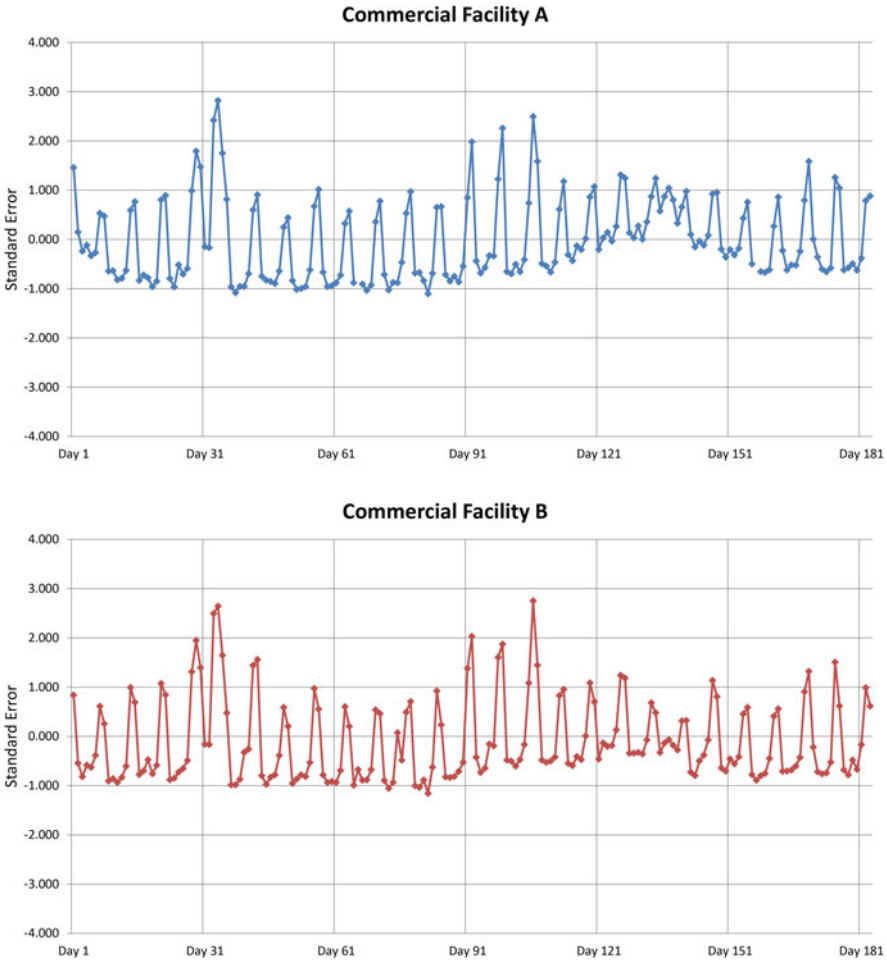

Fig. 5.4 Daily variations of the number of visitors to large-scale commercial facilities (normalized by annual average and standard deviation)

However, many extensive commercial facilities automatically measure how many people visit their facilities per minute or second through a people counting system. For example, Fig. 5.4 shows two of the four measurement results for the large-scale commercial facilities, including three department stores and one commercial complex, in the city center commercial district, *Tenjin* District, of Fukuoka City. Here, Fig. 5.4 visualizes the measurement results as the two time series of the number of visitors per day for a certain period of 2012 for two commercial facilities. We normalized these time series respectively by their annual average and standard deviation.

Looking at Fig. 5.4, we see apparent periodicity with peaks on weekends and that the linkage between facilities seems to be also high, making it possible to find exciting characteristics.

We can expect a revolutionary change in *Kaiy*u analytics if we utilize these existing automatically-collected data while combining them with our on-site consistent estimation method, enabling one to estimate the number of incoming visitors and the *Kaiyu* movements simultaneously in real time.

It will significantly impact advertising and promotion in real space if we can estimate or predict precisely how many people will gather at specific places in a city in real time. Moreover, if we compose respective town equity indices for local cities and create a distribution market to provide town equity indices with a wide range of investors, we can expect a more open investment environment for local cities (Saito 2013).

The following is the driving force for such a transformation, starting with big data. First, from consumers' point of view, various environmental information is coming in real time. Thus, consumers have incentives to extract the maximum value from the environment by utilizing various information resources and motivations to maximize the value of the time and places of their activities.

Second, from city planning and urban development perspectives, they have incentives to maximize the value of places and spaces. Here, we should note that the value of places and spaces in the new era changes minute by minute and hour by hour with the composition of visitors and the events held there. Thus, by considering the motivations and preferences of visitors, they develop and modify their places and spaces to maximize their value while assisting visitors in maximizing their visit values by supporting their on-site decision-making.

Then, we need a platform that fuses ICT and hardware to connect these two types of incentives and activate their interactions. We can create new business opportunities if we implement *Kaiyu* analytics using big data as the TEMS package on this platform.

Recently, there has been a trend of selling renewable/energy-saving technology in Japan, such as infrastructure and smart grid technology, from Japan to Asia as packages. However, Japanese companies only sell smart grid technology, and there are reports that they are losing to foreign companies because they do not provide a vision of what cities they are aiming at as the purpose of urban development (Nakajima et al. 2011).

In Asia, many medium-sized cities have a population of 1–10 million. Therefore, the Japanese experience and knowledge of forming city center commercial districts are invaluable to them. Therefore, instead of simply stating experiences, examples, and techniques, Japan should scientifically put forward an urban development theory based on *Kaiyu* as the Asian urban development theory.

Furthermore, providing the urban development theory as the package of TEMS that implements *Kaiyu* analytics must have global competitiveness and significance (Saito 2008a).

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Part II
Activity Visualization in Cities for Urban Development

Chapter 6
Use of Social Graphs and Social Networking Sites

Junichi Suzuki

Abstract Current consumers do not favor unilaterally delivered advertising information via the mass media. Consumer behavior models are evolving and diversifying because the Internet has rendered communication between consumers interactive. Thus, new information transmission methods targeting consumers already interested in products are examined. Targeting such consumers changes expression methods and a product's appeal points, and product information is transmitted via multiple social networking services (SNS).

Alongside the direct transmission of information, there is the indirect delivery of information through influencers, who serve as a node of information dissemination among target consumers and relevant audiences. Here, we analyze the history of SNS such as Facebook and Twitter, which are new media that complement conventional mass media and are used by the majority of the population via the Internet. We explain the use status of "social graphs," which show the correlation and connection of people on the Internet. Moreover, regarding city planning, we consider Grand Front Osaka, a commercial complex in Osaka, Japan, which is planning to use information and communication technology to formulate the city's redevelopment. To attract customers in real space, Grand Front Osaka is working on using social graphs and forming an SNS community beyond the Internet space.

Keywords Town management organization (TMO) · Social graphs · Social community · Blockchain

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6.1 Social Community Formation

6.1.1 Delivering Information as "Advice from Acquaintances" and not as Advertisement

According to Nielsen's (Adweek Media/Harris Poll 2010) global advertisement reliability survey, more than 80% of people trust advertisements when recommended by friends and family. Therefore, conveying information about products and services as favorable reviews through target consumers' acquaintances is more advantageous than delivering the same information through mass media advertisements. Acquaintances with such influence are called influencers, who deliver information to target consumers through their credit and thus, strengthen their interest.

A social graph represents the connections and correlations between users based on comments and shared information in social communities such as SNS. The speed of information dissemination and diffusion in SNS depends on each person's social graph. Based on the social graph, it is possible to find an acquaintance that influences the target population.

The trend of ignoring online advertisements on websites and skipping commercials when recording and watching television has been prominent in recent years. According to Adweek Media/Harris Interactive (Twitter Investor Relations 2015), a survey conducted with 2100 adults in the United States showed that more than 6 out of 10 respondents ignored Internet advertisements. Moreover, two out of five people (43%) responded that they did not see banner ads, and one in five (20%) ignored search engine ads.

According to the Reuters Institute Digital Report 2015 and reports by Shaun Austin (YouGov) and Nic Newman (Reuters Institute), the majority of online news media readers in the United States and the United Kingdom use adblockers, which eliminate advertisements and prevent tracking during web browsing. Add-on programs with adblocking functions, such as Adblock Plus, are generally used. The aforementioned survey by Adweek Media/Harris Interactive targeted people who did not use such programs to eliminate advertisements; however, 63% of the respondents stated that they still did not see advertisements. In Japan, such adblocking functions are not well recognized, and thus, the results of the survey reflect the situation in Europe and the United States. However, a greater percentage of consumers in Japan have been ignoring advertisements in recent years.

In an era where information is delivered through advertisements, which are automatically blocked before reaching consumers, delivering information on products and services to them has become increasingly difficult. Therefore, a new method that can effectively yield consumer recognition without relying on conventional information transmission methods is proposed. By directly approaching influencers to disseminate product and service information, friendly word-of-mouth information will be induced and delivered to target consumers in the form of influencer credit.

6.1.2 Interactive Communication in the Webspace

Why have consumers become disinterested in information delivered through conventional advertisements in recent years? Since its inception, the Internet has undergone major changes, including becoming a form of media. The Internet will continue to change in various ways. For example, the expansion of two-way communication on the Internet because of SNS has changed the communication environment.

Because of the widespread use of SNS, such as Facebook, Twitter, and Internet blogs, the distance between the senders and receivers of information has now disappeared, and anyone can easily send and relay information (information sharing). From the era when products and services were recognized through one-way information provision via the four forms of mass media—television, radio, newspapers, and magazines—individuals have become the subject of information dissemination and received opinions from friends and acquaintances. The communication environment for consumers has considerably changed into an interactive form in which consumer opinion is integrated by obtaining the approval of friends or acquaintances.

Individual consumers have acquired means of transmitting information to disseminate their candid individual evaluations (user reviews) for products and services that may have remained unknown when receiving information from the conventional media. Therefore, acquiring consumer recognition through the unilateral delivery of advertising content with appealing words and phrases via mass media, which leads to a favorable evaluation of the product or service and induces consumption behavior, has become a thing of the past. If an evaluation gap exists between the advertised content about products/services and consumer reviews in the interactive social community on the Internet, which are sometimes negative reviews, it will be difficult to induce consumption behavior by gaining approval from mass consumers. Two-way communication is one feature of SNS. In this environment, as a member of the social community, product and service companies must sincerely listen to user reviews and improve as necessary, which requires a response with accurate information.

The progress of interactive communication technology on the Internet is symbolized by the expression "Web 2.0," which indicates the change in web platform usage and user customization. This signifies the shift from a communication environment centered on the company and consisting of information transmission and reception at a hub (company) to a communication environment centered on consumers (i.e., people). The conventional information communication approach, namely a centralized model with information asymmetry as the source of business, must be transformed because of the emergence and popularization of SNS. Companies can connect with numerous consumers, and consumers can connect with each other. Therefore, companies are changing their business models.

Therefore, some businesses termed "democratic models" create information channels and eliminate the conventional asymmetry. With overwhelming support

from consumers of the younger generation, companies can now expand their business domain.

6.1.3 Establishing SNS and Social Graphs

We now review the history of SNS and analyze the introduction of social graphs. When SNS were first proposed is debated, however, no established theory is available. The interoperable architecture using the distributed hyperlink of information management on the Web is a characteristic of SNS. Thus, the Web itself can be considered an SNS. However, in a narrower sense, Friendster, launched in 2002, is reportedly the first platform to obtain numerous users by consciously adopting the basic style of SNS we are now familiar with. In around 2004, LinkedIn, Orkut, MySpace, GREE, and Mixi entered this domain, increasing the popularity of SNS. Facebook was established in 2004; however, it was initially aimed at networking within a university and was not open to the public.

In the initial stage of SNS, users could only create their own pages, create their profiles, and associate with acquaintances. Differences between SNS and regular Web pages include inviting the participation of existing members and acquiring mutual approval to create associations with other users. The invitation system and mutual recognition were merely devices to obtain participants through word-of-mouth; however, services that used social networks (social graphs) for communication grew rapidly. In these services, an acquaintance-related network can be used as an access control method. For example, showing a diary, commenting, and messaging can only be done for direct acquaintances or, in some cases, acquaintances of acquaintances. In 2008, a trial for a search service named "Ano Hito Search SPYSEE," which automatically collected and organized personal acquaintance information published on the Internet and displayed it on a single page, was launched. Following this, the momentum for using full-fledged social graphs has increased.

SNS that can easily realize private information sharing on the Web, which is based on the premise that all information is open and accessible worldwide, are widely supported by ordinary users. With the popularization of blogs as a tool to easily build and maintain websites, SNS have attracted attention as a representative example of Web 2.0. Furthermore, the information-sharing mechanism based on a social graph can be applied to communication and other fields. Around the same time, platforms such as Flicker for photo sharing, Delicious for bookmark sharing, Digg for news sharing, and YouTube for video sharing were established, each attracting many users.

In addition, the single sign-on function provided by SNS that unifies user accounts can be realized by proxying the authentication process when users log in to various SNS services. For example, Facebook offers a function that enables users to log in to many other web services. Furthermore, based on the user's consent, an authorization mechanism to access information in SNS from other services is provided.

The social graph, which extracts only network information related to acquaintances from SNS, continues to evolve across various services. In SNS, users construct social graphs to activate their communication; however, this information can be used for other purposes, such as game invites or to attract more customers. Therefore, companies need not reconstruct the graph. In this case, a social graph is provided based on the authorization framework described above.

Facebook started providing these functions in 2007, and Twitter in 2006, the year it launched, allowing various external companies to implement the functions. The number of SNS users operating the platform has further increased because of the development of various services and applications that utilize games, news sharing, and single sign-on. Likewise, the number of businesses targeting these users is increasing.

6.2 Visualizing Human Relationships

6.2.1 Appearance of Facebook/Twitter and Social Community

Considering the establishment process of Facebook, which is representative of a large SNS that provides comprehensive communication functions, and Twitter, representative of an SNS specializing in simple communication, we overview the crucial role of social graphs and their use in modern SNS-type communication.

Facebook started registering nonstudent users in September 2006. Facebook provides not only text communication such as diaries and comments but also multimedia and multi-functionality communication like pictures, audio, and video-sharing functions. In May 2009, Facebook was the largest SNS worldwide, surpassing MySpace. In 2010, the number of monthly active users exceeded 500 million, and in 2012, totaled 1 billion. By July 2014, Facebook was the most commonly used SNS worldwide, excluding Russia and China. It exceeded the 1.5 billion mark in 2015, and in April 2016, the number of users was 1.65 billion (Facebook Investor Relations 2016).

Twitter has attracted attention as a service specializing in simpler communication services than Facebook and is becoming increasingly multifunctional. Established in 2006, Twitter emerged as a simple service that does not require two-way approval for associating with acquaintances. It only publishes tweets with up to 140 characters or less for Japanese characters. The simplicity of functions and restrictions on the number of characters have a high affinity with widely used mobile phones and smartphones, and the number of users has rapidly increased to share personal events and emotions with acquaintances in real time. In 2011, the number of monthly active users exceeded 100 million, and at the end of 2015, there were 320 million users (Global Trust 2015). With these two services, SNS continue to propose community styles specific to the Internet. The collapse of the administrations in North Africa and the Middle East in the early 2010s—the Arab Spring—had a major impact on the

real world. Facebook and Twitter were crucial in large-scale demonstrations and were used as a means of expanding support by young people during the presidential election in the United States. Even in Japan, these platforms provided a communication infrastructure equivalent to or better than the mobile phone network during the Great East Japan Earthquake in 2011.

Services that match an individual's resources are also considered broad SNS. Flea market-type buying and selling brokerage applications use social graphs to enhance communication orientation. Furthermore, Uber matches private car drivers and taxi entrants, and Airbnb connects lodging providers with real-time users who require these services. In the city planning context, which is the theme of this book, we focus on ICT utilization measures when formulating a redevelopment plan for the city. Grand Front Osaka is a redevelopment project in front of Osaka Station that opened in 2013, which has actively worked to develop an SNS community and use its social graph across the fence.

6.2.2 Interactive Communication Approaches in Real Space

As a social city with a two-way communication environment for visitors, Grand Front Osaka has successfully increased visitors' interest by enabling communication between them and various people involved in the city, such as shop clerks, buskers, and street musicians. Opened in 2013, this large complex facility is located in front of the north exit of the Japanese Railway Osaka Station. Since its opening, Grand Front Osaka has attracted attention as the world's first social city. By implementing a cafe and sidewalk space along the public road and thus eliminating the boundary between the public and private zones, the town has an ornate and lively pedestrian space similar to the cafe area on the Champs-Elysees in Paris. Furthermore, through the widespread use of SNS and smartphones, the town has unique features, including a "Compass Service," that foster new exchanges between the townspeople. It also has a social system called "socio-activities" that supports regional circle activities and helps diverse people.

The compass service was developed as a large-scale infrastructure in the city. It serves as an "entrance" function for Grand Front Osaka and as a communication interface of the city with 36 digital signage terminals.

6.2.3 Features of the Compass Service Provided by Grand Front Osaka

Grand Front Osaka's compass service fosters new exchanges with the townspeople and visitors, providing a place where they can enjoy mutual exchanges and create new connections. The characteristics of the compass service are as follows:

In addition to access through a smartphone application, user authentication is performed anonymously by holding commercial point cards and handheld radiofrequency identification (RFID) cards (noncontact integrated-circuit cards) over 36 interactive digital signage terminals installed in the city.

Visitors can provide their reactions through smartphone apps and compass touches (e.g., "check-in" by touching the RFID card on the terminal and "Like" for town content). The compass service collects information and analyzes the attributes and fondness of each visitor so that other visitors can acquire suitable information.

Furthermore, rather than delivering conventional advertising content, the information delivered includes "content that allows visitors to enjoy understanding the city and content that allows townspeople to understand visitors." The use of "intra-town social graphs" is to realize organic exchanges among the people in the town by delivering information through users with similar interests and behavioral characteristics, which provides enjoyment and fun when walking around the area.

For people who want to further enjoy the city, the point-of-sale card "GFO OSAMPO CARD" and one's SNS account are linked to the compass service with the individual's permission. The data for the service have accumulated since its opening. Furthermore, a friend, who directly communicates with a nickname based on mutual permission called "Machi Tomo," provides an important clue for the user to know an acquaintance with influence. The compass service has a recommendation function and menu that provides information on the recommended content each day for each user; however, a mechanism allows people to connect with the city through acquaintances such as "Machi Tomo."

In addition, communication measures that reduce the distance between the towns called "socio-activities" are attracting attention. This system is based on the notion that "buildings and other facilities will depreciate over time, and the relationship between people and the city and among people will strengthen." It is an effort to support community formation among people gathering in the city and aims to increase the value of activities in the town. Circle activities are performed primarily by the leaders of the socio-activities, and people's loyalty toward the city increases when they consider it "their city." Information on socio-activities is delivered via the compass service, and visitors to the city participate in the community through these events and become familiar with the city. The combination of human-centered socio-activities and the "Compass Service" is a mechanism for information circulation.

A framework is available for evaluating the attractiveness of an experience using ethnography. In this framework, pre-experience, experience, and post-experience processes are divided into five phases: attraction, participation, involvement, exit, and extension. For each phase, six attributes (cleanliness, freshness, immersion, access, importance, and transformation) are evaluated to define attractive experiences. Considering Grand Front Osaka from an ethnographic perspective, the road leading to the Grand Front square and buildings represents the "participation" phase. Elements crucial to the participation phase are cleanliness, freshness, and access. The large square of Grand Front and the fresh environment that changes depending on the event have a positive impact on the people who come and go.

From a marketing perspective, if Grand Front Osaka is considered the target market, delivering appropriate content to each potential customer through appropriate mediators to visitors with various preferences will be an effective approach to encourage customers to be interested in the city. The provision of information in social cities requires a cross-media communication strategy that yields favorable user reviews by intermediaries and influencers who influence target visitors. The key to the implementation of this strategy is the "social graph of the city," which is formed and updated every day.

In addition to providing information through conventional mass media, we explained the changes occurring in the purchasing behavior process by examining an environment in which individuals are the primary source of information with the widespread use of SNS. This chapter discussed influencers in the social community and effective information transmission methods with examples of the social graphs used at Grand Front Osaka.

From the Perspective of Operating Companies—Kenichi Hirono, Former Secretary General of TMO, Grand Front Osaka

Grand Front Osaka created a system in which hardware and software work together to motivate people to visit the town repeatedly. For example, the large staircase at the front attracts numerous people when utilized as a spectator seat and sometimes as a stage. In addition, mist is regularly ejected from the ground of the plaza. This design considers the heat island phenomenon, as well as art. Moreover, because power supply and communication lines can be stored in the basement of the plaza, they can sometimes be used as concert venues and Marchés. The plaza includes various implementations that attract many people.

A rental cycle service is also available. Although the rental cycle service is widely used overseas, it is not yet that common in Japan. As a private company, I would like to lead the rental cycle service and would like the government to get involved and implement it. The hall can be used for experiments as part of area management. For example, artificial turf is placed over half the square, and benches and chairs are on the other side. We are examining new technologies that can be used in the town's infrastructure to help people gather and relax.

Grand Front Osaka considers visitors' precious experiences, and all facilities cooperate to provide the best services. The town management organization (TMO) specializes in this initiative. The TMO is an organization with the theme of regional revitalization and conducts research on community development. It proposes initiatives such as supporting street performers' activities. They audited street musicians and selected some of them to act as performers on the street. In addition, the Umekita Ship Hall facility provides a platform for privately sponsored activities such as providing free space to universities to conduct workshops on cardiopulmonary resuscitation training and connecting people and towns. We are working every day to realize the development vision of Grand Front, "a town where diverse encounters and excitement nurture new ideas."

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Chapter 7
Mobile Communications in Japan

Yasuhiro Kawahara and Hiroshi Yoshida

Abstract The fostering of active communication on social networking services to revitalize the local community requires the proliferation of mobile communication terminals (MCTs) and the improvement of the communication environment. In this chapter, we outline the configuration and usage of mobile communication networks that are necessary for obtaining and sharing information in real space. We begin by revisiting the history of mobile communication terminals and mobile networks, primarily focusing on the history of Japan. Next, we introduce cloud networks and mobile sensing, which are feasible mainly because of the development of MCTs and mobile networks. Subsequently, we introduce certain recent applications enabled by MCTs and mobile networks that revitalize the local community.

Keywords Mobile communication terminal · Mobile sensing · Lifelog · Recommendation · Real space · Indoor positioning

7.1 Use of Mobile Information Communication Terminals

7.1.1 Mobile Communication Terminal

A mobile communications terminal (MCT) is a terminal composed of communication, information processing, and interface parts, as shown in Fig. 7.1. Such terminals are pervasive in everyday life in the form of mobile phones and smartphones.

Most MCTs that people carry with them daily can display information through built-in displays. In addition, it is possible for the MCT to sense the environment surrounding the user with built-in sensors. Whereas mobile phones realize

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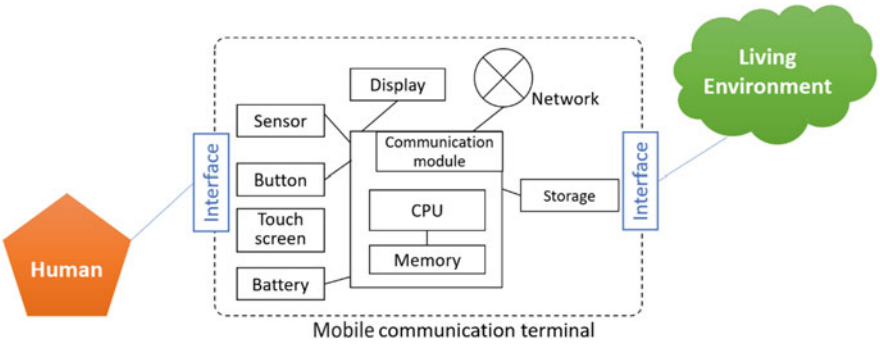

Fig. 7.1 Composition of a mobile communication terminal

communication by exchanging audio between users, most of today's MCTs can transmit other types of communication media such as videos and text messages.

7.1.2 History of the Popularization of MCTs in Japan

First, we outline the history of the popularization of MCTs, focusing primarily on the case of Japan. Mobile phone sales in Japan began with the introduction of a shawl-style radiotelephone in 1985. In the 1990s, mobile phones that could be carried around by hand began to spread, and with the development of digital communication networks, the short message service began in 1997. In 1999, Internet connection services from cellular phones began, and it became possible to send and receive images.

In 2000, mobile phones equipped with cameras were released, with increasing diversification in the information that could be communicated using them, such as the sending of images by e-mail. In 2004, mobile phones capable of handling electronic money appeared, and in 2006, it became possible to use mobile phones at automatic ticket gates. In 2007, it became obligatory for manufacturers to install GPS on mobile phones, and various services linked with location information also appeared.

In addition, since 2000, mobile data communication cards have become available at fixed data charges, and the number of people using laptop computers or personal digital assistants (PDAs) connected to the Internet in the cities began to increase. In 2005, a PDA with a call function and a touch panel, which is now called a smartphone, was launched. As a consequence of the evolution of terminals, combined with the development of communication infrastructure, many people now carry MCTs, typified by smartphones, daily. The changes in the form of MCTs leading to today's smartphones are shown in Fig. 7.2. Figure 7.3 shows the adoption rates of internet usage in Japan. The ownership rate for ICT devices among households in 2019 was 83.4% for smartphones, which are included in the category of

Fig. 7.2 Tht changes in the form of mobile communications terminals (MCTs)

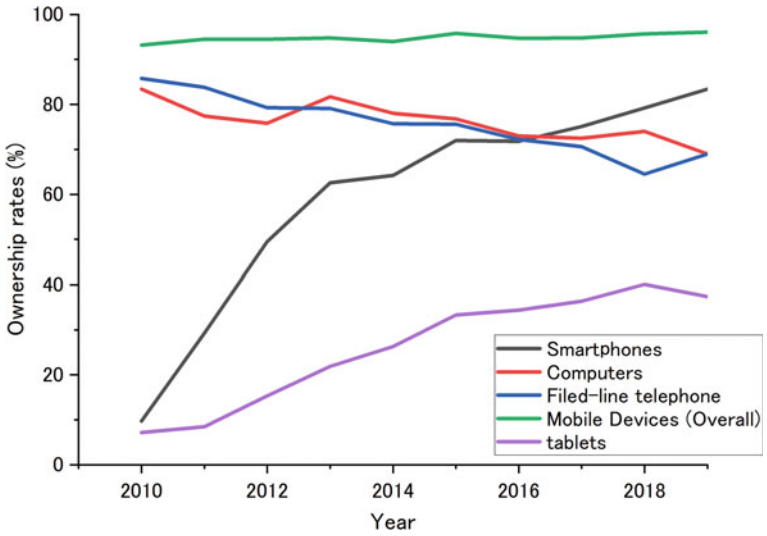

Fig. 7.3 Internet usage rates by devices in Japan (Ministry of Internal Affairs and Communications, Japan 2019)

"mobile devices" (96.1%) and exceed 80% of the devices in this category (Ministry of Internal Affairs and Communications, Japan 2019).

7.1.3 History of Mobile Communication

Wireless communication began with an experiment conducted by G. Marconi in Italy in 1895, when he succeeded in receiving Morse code from a distance of 18 m using an antenna with a height of 8 m (Goldsmith 2005). Subsequently, the Titanic accident in 1912 led many large ships to be equipped with a radio system to ensure the safety of the ship, thus wireless communication in practice began in the ocean. In

the early period of wireless communication, terminals communicated directly with each other. By contrast, modern wireless communication, such as with mobile phones, is typically realized through communication between a terminal and a base station.

In wireless communication between a mobile terminal and a base station, many terminals must be able to communicate large amounts of information at high speeds, and mobile communication has been evolving steadily in this regard (Raychaudhuri and Mandayam 2012). In Japan, cell phone services using analog communication began in 1979. For multiple people to communicate simultaneously using the same radio waves, it is necessary to separate communication channels for each communicating terminal so that they do not interfere with each other. In analog communication, a communication method was adopted in which the frequency was shifted slightly for each channel to avoid interference. This communication method, in which division is achieved by frequency, is called frequency division multiple access (FDMA), and the form of this mobile communication is called first-generation mobile communication (1G). The first 1G service began in Japan in 1979, followed by Denmark, Finland, Norway, and Sweden in 1981. Motorola DynaTAC, the world's first handheld (as opposed to car-mounted) mobile phone, was launched by Motorola in 1984. Shoulder-type radiotelephones were announced in Japan in 1985, as mentioned previously.

Digital communication began in Europe in 1990, and data communication became possible in addition to conventional voice communication. In the initial stages of digital communication, a communication method called time-division multiple access (TDMA) was used. The communication technology used at this stage is called second-generation mobile communication (2G), and in particular, a communication system called the global system for mobile communication (GSM) was adopted in many countries, with the exception of a few countries such as Japan.

Third-generation mobile communication (3G) was introduced for practical use in the 2000s, and digital communication was speeded up to support multimedia, such as video. Code division multiple access (CDMA), which was the mainstream communication method in this generation, does not divide the frequency. Instead, it performs modulation with a unique code for each communication terminal, and then performs inverse modulation with the same code on the receiving side, thereby enabling multiple access at the same frequency. Service of the fourth-generation mobile communication (4G) based on the Long-Term Evolution (LTE) communication standard was launched in Japan in December 2010. With 4G, the communication speed initially increased from the several Mbps of 3G to ten-odd Mbps, but subsequently, the communication speed further increased to several tens to several hundred Mbps.

In 4G, several technological elements have been adopted for increasing communication speeds. For example, a carrier aggregation technique (CA) that bundles a plurality of communication frequency bands, and a multiple-input multiple-output (MIMO) technology that simultaneously transmits data using a plurality of antennas, have been adopted to increase communication speeds. In the 4G system, to alleviate the concentration of communication and enable mobile communication in daily

scenarios, small-scale cells are introduced. Enhanced inter-cell interference coordination (eECIC), which reduces radio interference in communication between cells of different sizes, is also an element technology in 4G. In the fifth-generation mobile communications (5G), which began commercial service in March 2020 in Japan, communications will be provided with wide bandwidths using high-frequency bands in the 6 GHz and millimeter wave bands to achieve even higher speeds and wider bandwidth (up to 20 Gbps is the target), lower latency, and simultaneous multiple terminal connections. High-speed, large-capacity communications require an increase in communication bandwidth, and the use of high-frequency bands is necessary to utilize frequency bands that are not being used for other purposes. Since radio waves in the high-frequency band are susceptible to attenuation and stable communication is difficult in some situations, 5G achieves stable communication by using methods such as Massive MIMO, which increases the number of antennas.

7.1.4 Cloud Networks and Mobile Sensing

With the development of mobile networks described above, consumers can now routinely connect with each other and access various computers and databases via the network. This has also changed the relationship between the user and the computer, notably through the proliferation of "cloud networks." Before the spread of mobile networks, the main role of networks was to connect computers. Users were always aware of the physical location of the computer and had to be in physical proximity to the computer to access it.

However, with the increased speed and connectivity of mobile networks, users can access servers (computers that process and manage data) from anywhere on the network. Consequently, regardless of the physical location of servers, they can connect to the servers as if the servers existed in a metaphorical cloud above. This form of usage of servers is called "cloud computing."

A network that enables cloud computing is called a cloud network. In today's cloud networks, not only computers and MCTs but also various other information communication terminals are connected to the cloud network, ranging from street cameras, bulletin boards, bus stops, and ticket gates to home appliances. Through the interface (external contact) of the terminal connected to the cloud network, the surrounding environment of the MCTs can be monitored, and neighboring devices can be controlled from the terminal. For example, a server on a cloud network can monitor (mobile sensing) user behavior using a human interface such as a screen as a point of contact with the user of the MCT. Thus, servers can provide specialized information to users through MCTs. In the next section, we will introduce two services in town spaces, realized by the progress of mobile communication.

7.2 Newly Enabled Applications by MCTs and Mobile Networks

7.2.1 Mobile Sensing in Town Spaces

A record of an individual's activities in everyday life as digital data for preservation and retrieval is called a "lifelog." "MyLifeBits" is an early and famous project that studied lifelogs (Gemmell et al. 2006; Bell and Gemmell 2007). This project was implemented by Gordon Bell at Microsoft in 2001. The project constructed a database of digital artifacts pertaining to an individual's activities, such as pictures photographed, music played, videos watched, web pages viewed, e-mails sent, telephone calls received or dialed, and invoices received, to freely search for information on various parts of the individual's life.

By improving the information communication terminal and the communication network explained in the previous section, it becomes possible to accumulate data pertaining to individual activities on a remote server in real time within the daily living space. In addition, the development of individual monitoring technologies (small built-in sensors and high-speed information processing technology) enables the accumulation of new types of life data.

Furthermore, the interconnection between the real space and the cloud network provides useful information pertaining to the "virtual space" for the person living in "real space." In other words, with the development of information and communication technologies, it is possible to cross-reference information existing in real space and virtual space instantaneously, regardless of location.

7.2.2 Behavior Recognition in Town Spaces

In some facilities, many sensors are installed on floors and walls and are connected with information technologies. Such a facility is called a "smart city". A "smart city" attempts to provide personalized information to a person who visits a town. For example, attempts may be made to obtain biometric information of users of wearable sensor modules embedded in MCTs. To obtain biologically relevant information, acceleration sensors are frequently used. An acceleration sensor can be used to identify the user's state of activity (such as whether they are walking or stationary) and estimate the amount of activity, and this information can be utilized for service provision and health management.

An example of the estimation of behavior information from acceleration is shown in Fig. 7.4. The composite acceleration waveform in the vertical direction during rest, walking, and running, measured by a three-axis accelerometer worn on the waist and wrist, and the movement state estimated by the amplitude of the waveform are shown. Because the acceleration waveforms of the lumbar region and the wrist exhibit characteristics of almost the same movement form, it is suggested that

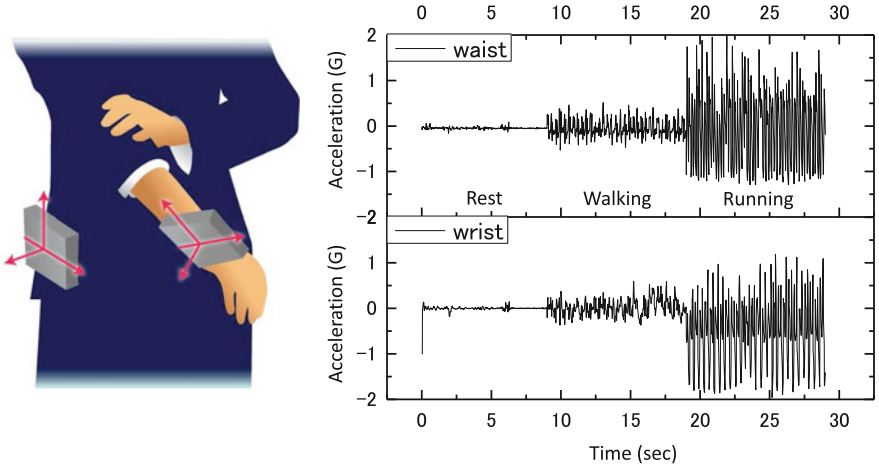

Fig. 7.4 Gravitational acceleration of the wrist and waist at rest, while walking, and while running

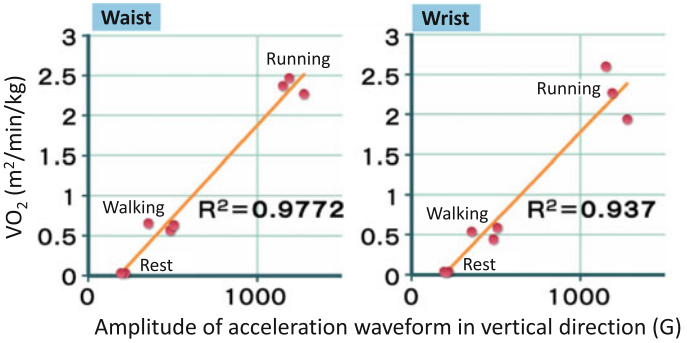

Fig. 7.5 Correlation between the amplitude of acceleration and oxygen uptake (VO_2)

discrimination between movement states is possible even with wrist-worn information communication equipment such as a smartwatch (Kawahara et al. 2013).

Figure 7.5 illustrates the relationship between the acceleration amplitude and the oxygen consumption in the respective states of Fig. 7.4. This figure shows that the oxygen consumption can be estimated by the acceleration amplitude.

Figure 7.6 shows an example of the acceleration and pressure measured with a mobile sensor while walking inside a commercial building. The waveform with finely vibrating parts represents the acceleration, and the thick line with a linearly increasing part represents the atmospheric pressure. There have been attempts to estimate behaviors in the community using data from such mobile sensors, to capture the movement of people in a specific area and provide personalized information.

Similarly, by attaching the sensor module of a wearable information terminal to a specific part of the body, it is possible to sense a wide range of biologically relevant

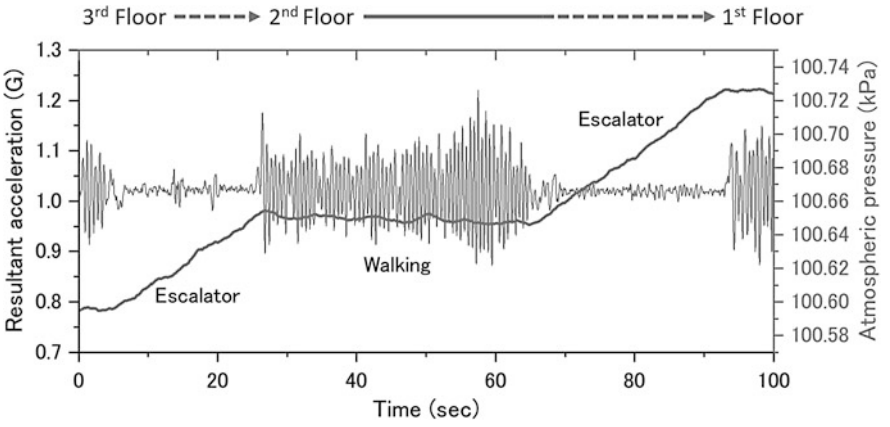

Fig. 7.6 Behavior recognition using barometric pressure and acceleration

information. For example, it is also possible to estimate the activity state of the autonomic nervous system by calculating the heartbeat interval based on the electrocardiogram waveform continuously sensed by a 15 g sensor attached to the chest.

Therefore, mobile sensing can be used to estimate useful information for health management, thereby facilitating useful experiences for those living in the town and those visiting the town, as well as providing feedback on the operation of the town.

7.2.3 Indoor Positioning

Indoor maps have been primarily used in the past to identify one's relative position in an indoor space. However, in some public spaces and commercial buildings, indoor positioning services are provided to help users verify their relative position in the space and provide them with information. Radio transmission equipment (known as beacons), such as access points for wireless local area networks (LANs) and Bluetooth (wireless communication technology for short-distance data communication), are used for indoor positioning.

Using the wireless LAN function of MCTs, the position of the terminal can be estimated based on the radio field intensity and the unique address from a nearby wireless LAN access point. In this positioning service, the service system (server) must know the unique address and location of the access point or learn the access point-specific address receivable at the positioning point. If this is satisfied, the position of the terminal can be estimated with an accuracy as high as the interval between the installations of the access points or higher. Further, by embedding a near-field communication (NFC) chip in the mobile terminal and periodically communicating with a reader/writer terminal, it is possible to estimate the position of the mobile terminal from the installation position of each reader/writer terminal. The NFC reader/writer terminal is installed in the digital signage and automatic ticket

gate of a station. This is similar to the method of distributing goods and capturing inventory using electronic tags such as radio frequency identification (RFID) tags, and by installing NFC reader/writer terminals at specific locations to be used daily, such as an automatic ticket gate of a station, it is possible to continuously capture the trajectory of the user.

We introduce an actual service trial using mobile sensing in a town space (Suzuki et al. 2014). In this town space, indoor positioning using smartphones is possible. There are also 36 digital signages in the facility. In addition, using a dedicated smartphone application, the information registered in the database of the facility can be accessed anytime and anywhere. The time at which a user accesses the digital signage, the search history of the application, and the history of check-ins recorded by the NFC reader at the shop front are accumulated in the server through the network. In this trial, by using the check-in information of a user at a certain spot as a trigger, the user's activity history was acquired from indoor wireless LAN positioning data, and those users acting together could be identified separately among numerous unspecified users.

7.2.4 Human Probing

Various sensors can be connected to portable information communication terminals. Conventionally, these sensors have been used to obtain aspects of the user's state, such as position and acceleration, and to gather more detailed information on the user's behavior.

On the other hand, using these sensors, it is possible to sense information about not only the user but also the environment around the user, such as light, sound, and thermal information. The environmental condition of a specific point can be determined by combining positional data with the acquisition of such information. In addition, by using a large number of portable information communication terminals and combining ambient environment information and position information, a wide range of environmental information can be acquired when a person is within the vicinity of the environment. Such a method of monitoring and scanning environment information based on human movement is called a "human probe" (Thepvilojanapong et al. (2010). This method is not suitable for investigating changes at a specific point in time. However, because this method can acquire a large amount of information at a low cost, it is useful for easily obtaining information that does not change significantly over time, such as radiation dose and topography.

In addition, environmental conditions can be summarized based on information actively provided by a large number of users, and a wide range of environmental information can be visualized by exploiting the low cost and the potential for multiple samplings. For example, a weather information service that collects and publishes weather condition reports based on users' information communication terminals can acquire a collection of detailed weather conditions. This cannot be easily achieved with conventional sparsely constructed fixed weather observations.

7.3 Recommendation Using Real-Space Information

Figure 7.7 illustrates that the potential for understanding human behavior and providing recommendations on the conventional web can be significantly expanded by using real-space information obtained by mobile sensing. Human behavior can be understood in greater depth with information obtained from real space. For example, it is possible to derive information on connections between people and identify those that are unknown on the social networking service by using position information, and to derive information on the mood of the individual by using environmental information. In addition, by using such information in combination with the capability to direct the actions of people, such as through digital signage and smartphones, new possibilities can be created to expand recommendations on the traditional web into real space.

As an example of a recommendation in real space, consider recommending a place that is comfortable for each visitor in a large commercial facility. Studies at commercial facilities by Otsuka et al. (2016) show that changes in the micro weather across places, such as the plaza, waterside, and café, in the same commercial facility have a major influence on the mood of people visiting there. It is also suggested that the mood of people is greatly influenced by the compatibility of companions.

Consequently, by sensing the environmental information in each space and gathering preference information of the user and the surrounding people, it may be possible to gauge the comfort level of the individual and to recommend a destination that can provide greater comfort. Therefore, by collecting environmental information using appropriate sensors, it is possible to provide recommendations not only in the

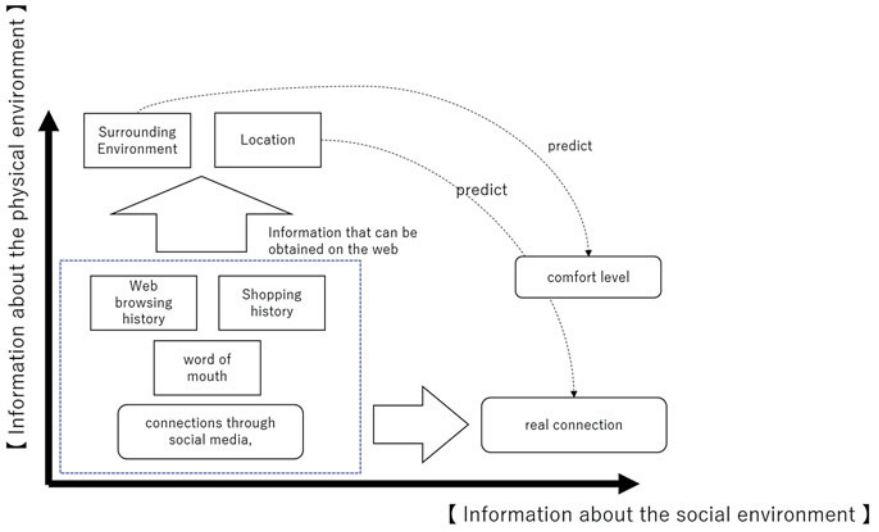

Fig. 7.7 Model for estimating human behavior using both information on the web and physical conditions

web space but also in real space. In this book, we explain these initiatives with concrete examples.

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Part III
Monitoring Methods of Human Activity and Environment in Open Space

Chapter 8
Mobile Sensing Technologies and Their Diverse Potentials

Masakatsu Kourogi

Abstract Since billions of people around the globe are now always carrying high-performance computers with various kinds of sensors and communication capabilities such as smartphones, smartwatches, and other wearable devices, the potentials of mobile sensing technologies (MSTs) have emerged. However, satellite-based localization technologies such as the Global Positioning Systems (GPS) have difficulties expanding to indoor environments where people spend most of their lifetime, and that limits the potentials of MSTs. In this section, localization methods which can be applicable to GPS-denied environments are introduced and their real-world applications are described.

Keywords Dead reckoning · Mobile sensing · GPS-denied environment · Vibration analysis

8.1 Potentials of Mobile Sensing Technologies

With the rapid proliferation of smartphones globally, most people now carry high-performance computers with them practically all the time. Further, smartphones are equipped with mobile sensing technologies (MSTs), which are the collection of sensing hardware, such as cameras, motion sensors, wireless communication devices, and GPS receivers, and also advanced data processing software. This enables context-aware applications, which can be aware of both the users and their surroundings.

On-board motion sensors, such as accelerometers, gyroscopes, magnetometers, and barometers in smartphones, can be used to analyze motion patterns and identify and measure users' daily physical activities, such as walking, jogging, and lying down. For example, a pedometer is a simple mobile application (referred to simply as an app) that can measure daily physical activities such as the number of steps

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taken by a person. As walking step counts can serve as a good indicator of health, this app demonstrates the significant potential of context awareness in daily human activities. Further, it also indicates the possibility that an advanced app can track the location of users carrying smartphones while in motion, even when they are in a moving vehicle, such as a car, bus, or train.

Because all moving objects inevitably generate unique patterns of vibration owing to their characteristics, speed, and the conditions of pathways, vibration analyzing techniques can infer a significant amount of information that can be used to detect whether a user is travelling in a vehicle and monitor their contextual conditions. As a smartphone carried by a user can pick up the vibration of the transportation vehicle propagated through the human body, it is possible to track users across all mobilities based on vibration analysis.

When personal mobilities such as cars, forklifts, and wheelchairs are used, by attaching smartphones with proper dedicated cradles to the mobilities, vibration analysis can be further facilitated because the vibration is directly delivered to the motion sensors from the source. This can also be used for monitoring transportation conditions, which can facilitate the detection of early warning signs of mechanical malfunction and failure. Additionally, as vibrations are also dependent on transportation pathways such as roads and rails, vibration analysis can also be used to detect the degradation of road surfaces, occurrences of bumps, and slopes. Maps can then be enhanced and updated to include real-time road conditions by labeling the corresponding locations with such information.

In addition to various sensors, smartphones are also equipped with Bluetooth wireless capabilities that can find and connect to other Bluetooth devices. This can be used to detect fixed Bluetooth locating devices nearby. Such locating devices are called “beacons,” and they emit wireless signals so that the location of smartphones that receive the signals can be estimated. Smartphones with wireless features can also be utilized to determine the social distance between users and identify close contacts, and thus can be used to evaluate the risk of exposure to infected persons.

In this chapter, MSTs, mostly based on smartphones with motion sensors, and their applications, are described.

8.2 Localization and Tracking Based on MSTs

Location information is particularly useful and is widely utilized by applications based on MSTs. Not only can it be used to provide navigation services to general users, even in the absence of the global navigation satellite system (GNSS)-based positioning systems, but also it can direct first responders swiftly to an exact location from where an emergency call is made. For example, by combining health monitoring and fall detection with locating features, mobile monitoring systems can be programmed to automatically make emergency calls to report a user’s current contextual conditions and location when a fall is detected and no movement occurs subsequently.

Today, because smartphones have locating capabilities (with precision in the range of 2–50 m) based on the Global Positioning System (GPS) services, which use satellites orbiting in the sky, and these services are available without additional fees, most locating services are dependent on GNSS in the form of GPS. However, GNSS-based locating services are unavailable in locations where the satellite signals are obstructed, such as in underground locations and indoor environments, including buildings, where many office workers and pedestrians may be located. In such scenarios, MSTs can serve as an alternative solution for location services.

One well-known technology for identifying relative location is called dead reckoning and can be executed by integrating data from motion sensors. Unlike GNSS-based services, this technology is not dependent on external sources of information and is therefore available both indoors and outdoors. The basic method has been known since the Middle Ages for marine navigation and is used for the navigation of rockets, ships, aircraft, and submarines even in the modern age. However, because dead-reckoning navigation generally uses double integration of acceleration to estimate and update the location, it can be challenging to realize based on MST because the motion sensors in smartphones are not accurate enough. Consequently, the error-growing curve is steep when sensors in smartphones are used for general dead reckoning, because estimation errors accumulate in proportion to the square of elapsed time and the proportionality factor is dependent on the accuracy of the motion sensors.

Many researchers have attempted to implement dead reckoning by pre-determining the target moving objects, to reduce calculations from double to single integration (Foxlin 2005). We refer to this approach as dead reckoning for "x" (xDR) (Ichikari et al. 2018), where x refers to the target moving object. In this sense, dead reckoning specifically targeted at pedestrians can be called pedestrian dead reckoning (PDR). By targeting specific moving objects and exploiting the nature of their movement, it is possible to estimate their velocity without integration of acceleration by using motion features strongly correlated with the velocity, and thus location can be estimated from single integration based on the xDR approach.

In this section, we first describe the four fundamental technologies comprising xDR, and then introduce dead reckoning specialized for pedestrians and vehicles.

8.2.1 Basic Components of Localization Based on xDR

The realization of xDR localization requires the following four components, with accelerometers, gyroscopes, and magnetometers (three-axis) as measurement sensors.

1. Attitude estimation.
2. Earth magnetic field (EMF)-assisted attitude adjustment.
3. Speed estimation.
4. Moving direction estimation.

In the process for 1, the 3D pose/attitude is estimated and updated from the data of accelerometers and gyroscopes (angular velocity sensors). However, the estimated 3D pose/attitude in this process is degraded and drifts, primarily because tiny errors in angular velocity accumulate over time. Therefore, process two corrects the estimated 3D pose/attitude by observing the magnetic north direction based on data from the magnetometers. Attitude estimation and EMF-assisted attitude adjustment are universally applicable to any moving object, given the knowledge of the EMF. Several pose estimation algorithms with EMF enhancement have been developed, some of which are open-source software (Madgwick 2010).

Process 3 uses speed-correlated motion features calculated from acceleration and angular velocity to estimate the speed of the measurement sensor. Process 4 estimates the moving direction (heading). The heading direction of many vehicles, such as cars, forklifts, and carts, is fixed, and the process can therefore be simplified. Processes 3 and 4 fully exploit the nature of the moving object and thus are intrinsically only applicable to specifically targeted objects.

8.2.2 Localization with Pedestrian Dead Reckoning (PDR)

As described in the previous section, speed estimation and moving direction estimation are inherently necessary for the xDR process in general. In this section, the details of the methods that constitute PDR are described.

8.2.2.1 Speed Estimation for Pedestrians

The speed (i.e., walking speed) of a pedestrian can be estimated without using integrals of acceleration based on empirical rules. For example, Kourogi et al. proposed a method of estimating the speed from the linear correlation between the speed and the amplitude of acceleration in the vertical direction (Kourogi and Kurata 2003). In addition, Weinberg proposed a linear correlation between the walking step length and the fourth root of the amplitude of the acceleration vector in a walking cycle (Weinberg 2002). We proposed another method of estimating speed by using the correlation between the speed and motion feature called the Frequency Normalized Power or FNP, described in the following equation:

$$\mathrm{FNP}(f, p) = \sum\nolimits_i p(f_i)^2 / f_i^2,$$

where f_i is the i-th frequency in the power spectrum and $p(f_i)$ is the i-th power of the frequency. The digital Fourier transform, or DFT, easily computes the power spectrum from which the FNP motion feature strength can be derived. Figure 8.1 shows a correlation between the FNP motion feature strength and the speed of pedestrians.

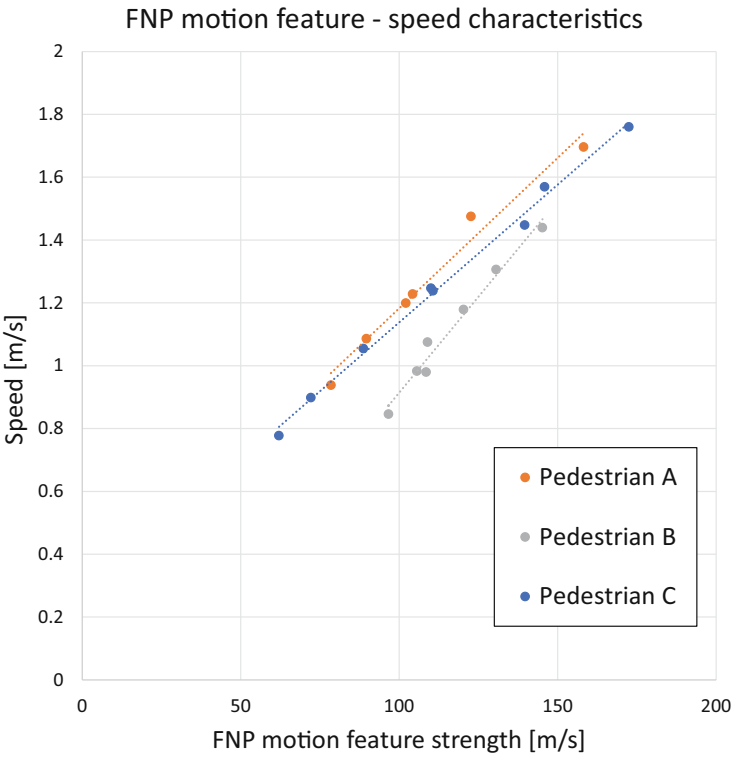

Fig. 8.1 The correlation between the FNP motion feature strength and the speed of pedestrians

8.2.2.2 Direction Estimation for Pedestrians

Because the measurement sensors are not fixed to the pedestrians in most cases, the moving direction needs to be constantly estimated. This is especially so because smartphones can be used for various purposes such as talking and texting. They are also subject to being carried in many ways such as in pockets, handbags, shoulder bags, or just the hand. Nevertheless, acceleration patterns of pedestrians during walking can be classified into forward and sideways patterns, even if the smartphones are worn or held in different ways. Figure 8.2 shows an example of the patterns of acceleration in the motion of pedestrians.

8.2.3 Localization Based on Dead Reckoning for Vehicles (VDR)

In this section, a method of speed estimation for xDR specialized for vehicles (VDR) is described. The method incorporates the vibration that occurs during the motion of

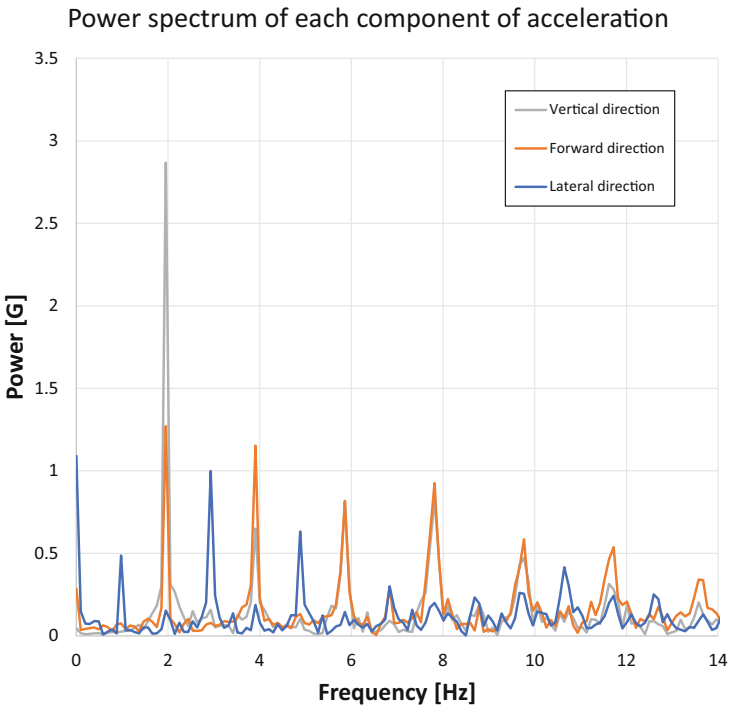

Fig. 8.2 The power spectrum of the forward/vertical/lateral component of acceleration

a vehicle and uses the correlation between the speed of the vehicle and motion features, and can therefore avoid the need for the integration of acceleration, which can cause a significant accumulation of errors.

8.2.3.1 Speed Estimation for Vehicles

Vibrations caused when a vehicle is in motion are thought to be undesirable and to be controlled and minimized in general. However, vibrations carry information about the vehicle and its surrounding environment, which noise analysis methods can retrieve.

The root-mean-square (RMS) of acceleration or angular rate is a good motion feature that exhibits a strong linear correlation with the speed of the vehicle when the road conditions are uniform. Figure 8.3 shows the correlation between the RMS and the speed of the vehicle. The FNP motion feature strength also exhibits a strong correlation with the speed of the vehicle (Fig. 8.4).

However, road conditions might not be uniform even if they are maintained regularly owing to degradation caused by heavy traffic and aging. Figure 8.5

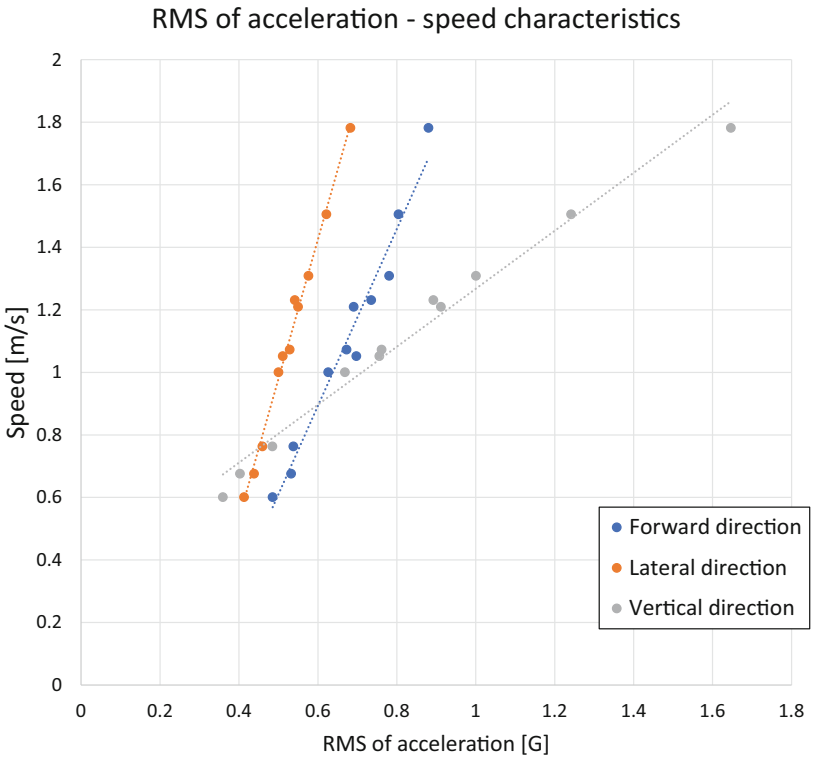

Fig. 8.3 The correlation between RMS and the speed of the vehicles

shows the effect of differences in road conditions on the correlation between RMS and the speed of a wheelchair.

8.2.4 Towards Universal Dead Reckoning (UDR)

Because smartphones are carried by people almost all the time, machine learning-based technologies can be used to identify whether users are walking or on a bus or train. By using a combination of VDR and such recognition methods, universal dead reckoning (UDR) can be developed, implying that locations and states of people can be tracked irrespective of the form of mobility they are using.

In business-to-business (B2B) scenarios, for example, a UDR solution can contribute to the seamless localization of forklift operators using the smartphones they carry. In the business-to-consumer (B2C) scenarios, users of railways can be informed by navigation software incorporating UDR on smartphones to switch train lines at a station.

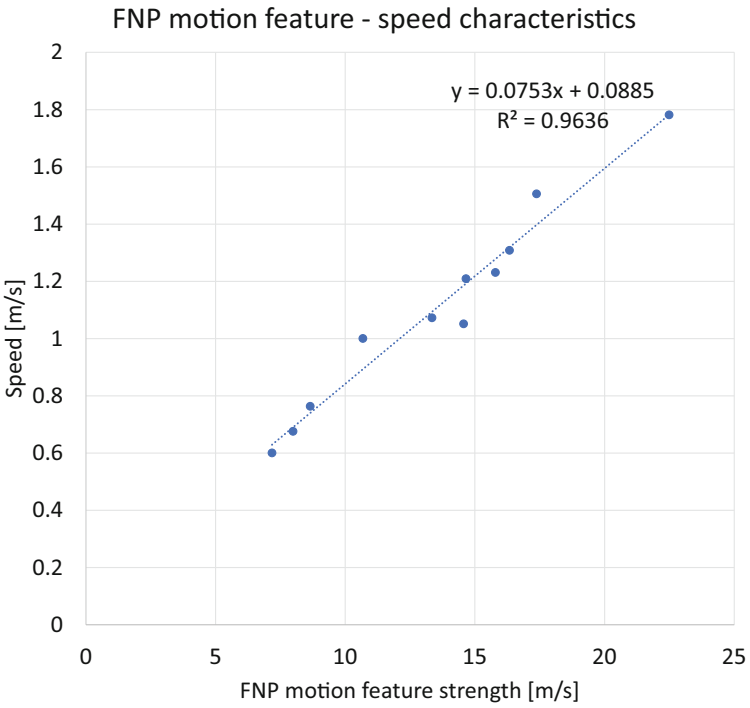

Fig. 8.4 The correlation between the FNP motion feature strength and the speed of the vehicle

8.3 Status Sensing Technologies for Human and Mobile Platforms

Motion sensors can be used to diagnose abnormal internal operations and failures of mobility platforms such as cars, buses, forklifts, and railway cars, based on machine learning methods (Tsypkin 2011; Goundar et al. 2015). Because various abnormalities and failures are likely to cause different patterns of vibration, these technologies can also provide clues to identify the parts involved in the failures.

However, as machine learning-based methods require a large amount of data for training, in B2C scenarios, crowd-sourcing methods are used to collect data from users. In such data collection methods, the users must be motivated to provide their data. One of the motivations can be self-health monitoring benefits. For example, a smartphone app developed for road maintenance can be used to detect and collect locations of abnormalities on roads while also providing the user with self-health functionalities on the cars they drive in return.

This section illustrates the potentials for self-monitoring (for humans and mobilities) based on MST.

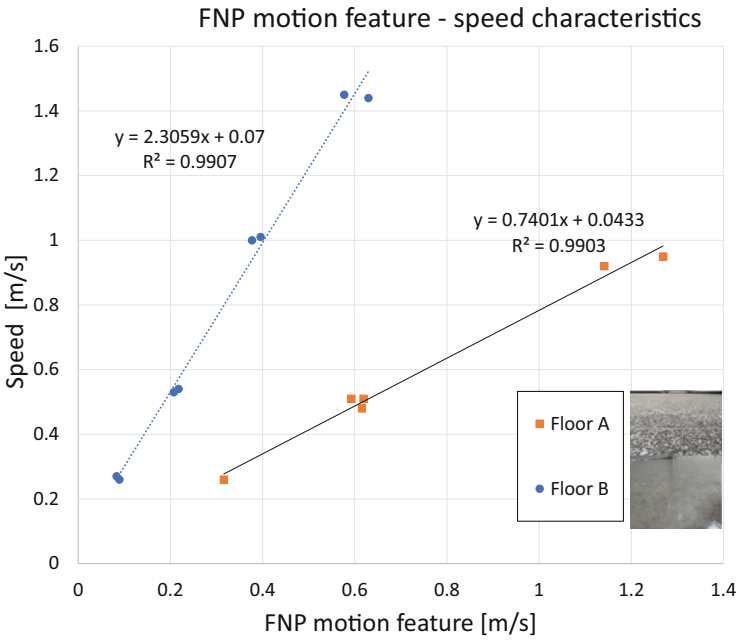

Fig. 8.5 The effect of road (floor) conditions on the correlation between the FNP motion feature and the speed of the same vehicle

8.3.1 Self-Health Monitoring for Humans

Certain health problems and risks for humans are expressed in gait patterns, and thus smartphones can be used to monitor users' gait to detect these problems. Human walking locomotion can be characterized by a cyclic motion, whose patterns show several differences from person to person. Therefore, by constantly monitoring these characteristics in a person, their change or disturbance can be linked to health problems, and thereby used as predictors of health problems or risks. For example, locomotive syndromes have been detected by monitoring gait changes in research studies (Park et al. 2020; Hahm et al. 2021).

8.3.2 Self-Monitoring on Mobile Platforms

Inertial sensors (accelerometers and gyroscopes) attached to rotary machineries can be used to monitor the health of the machines and predict and diagnose failure and abnormalities. While pumps and power generators have hitherto been the main targets of health monitoring, research is now being conducted on mobility platforms such as cars and forklifts (Tsypkin 2011; Goundar et al. 2015).

8.4 Surrounding Environment Surveying Technologies with MST

Because road conditions affect vibration-speed characteristics as depicted in Sect. 8.2.3, if the speed can be measured using GNSS and odometers, the road condition can be conversely estimated from the characteristic curves of VDR. Smartphones carried by pedestrians can also sense slopes and steps through the PDR-based MSTs.

Further, as described in Sect. 8.1, most smartphones are equipped with Bluetooth functionalities to discover and connect to other Bluetooth devices. Companies such as Google and Apple utilize these functionalities on Bluetooth-enabled smartphones to detect and trace contact between people and evaluate the transmissibility risks of contagious viruses such as COVID-19 (Google and Apple 2022).

The following subsections describe the potentials of MST to estimate the surrounding environments of smartphones.

8.4.1 Estimation of Road Conditions, Unevenness, and Degradation

Most smartphones have the GNSS functionality to estimate absolute location and speed in outdoor environments. Therefore, the speed can be estimated using a smartphone from both the VDR-based method and the GNSS-based method. On roads with standard conditions, these methods provide identical estimates of speed, whereas on roads with rough conditions, the VDR-based outputs surpass the GNSS-based outputs. This implies that the ratio or the discrepancy between the estimates of the VDR-based method and those of the GNSS-based method can represent the goodness of road conditions. This idea has been partially implemented for estimating the road conditions for the handicapped by installing smartphones on wheelchairs to evaluate road accessibility.

8.4.2 Smart Contact Tracing Applications

As the Bluetooth Low Energy (BLE) standard provides functions for discovery and connection between proximate BLE devices, smartphones with the BLE functions can be used to find and estimate the distance to nearby devices, including smartphones. Because the risk of infection by infectious diseases such as COVID-19 significantly increases if the duration of proximate contact with infected persons lasts for more than 20 min, the BLE proximity discovery function can enable the automatic detection of high-risk events with dedicated apps installed on users' smartphones.

In the context of B2C, smartphones with BLE functionalities are now partially used globally to prevent outbreaks of contagious diseases such as COVID-19 while securing the anonymity and privacy of users. In applications for B2B scenarios, because manufacturing factories and warehouses with many densely collocated workers pose grave risks that may force them to shut down for several days if such contagious diseases spread among workers, contact tracing of each worker along with the trajectories of their movement provides valuable information to evaluate these risks. MST-based localization combined with social distance detection functionalities provides greater value because they can not only be used to evaluate transmissibility risks but also provide clues to pinpoint areas to be sterilized. Additionally, even though workers are prohibited from carrying their private smartphones in certain factories or warehouses for confidentiality reasons, they can instead be equipped with MST-enabled devices with B2C applications such as those for COVID-19 tracing.

8.5 Conclusion

This chapter describes MST-based localization and technologies derived from it, along with important applications.

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Chapter 9
Visualization of the Urban Thermal Environment Using Thermography

Akira Hoyano and Hiroki Takahashi

The original text of this chapter was written in Japanese by Akira Hoyano and translated by Hiroki Takahashi.

Abstract In addition to the physical cityscape, a unique thermal environment is present in every city that is not directly visible but exerts considerable influence on the daily lives of urban residents. The spatial and temporal distributions of surface temperatures across the urban environment are related to the spatial form and constituent materials of the city and can be visualized using thermal infrared cameras to observe and investigate the resulting urban thermal environment.

Keywords Urban living space · Thermal environment · Thermal infrared camera · Spherical thermography · Mean radiant temperature (MRT) · Thermal comfort

9.1 Focus on the Urban Thermal Environment

9.1.1 Cityscape and Thermal Environment

Residents perceive the environment of a city through five senses: sight (vision), hearing (audition), touch (somatosensation, including thermal radiation), taste (gustation), and smell (olfaction). Visual information is said to account for 90% of the sensory information collected by human beings, but there are many aspects of the urban environment that are not directly visible. In this chapter, we focus on the

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thermal environment of the city, which dictates the experience of heat and cold, and a method for visualizing it.

The most important factors in shaping a cityscape are the local climate and geography. Because the characteristics of the climate in Japan differ considerably between summer and winter, the thermal cityscape is highly dependent on the season. This is common in many regions of the world, but the particular manifestation of this dependance varies according to the region. For example, as Western Europe is located at higher latitudes than Japan, the summer temperatures there are relatively lower, so it is typically dry and comfortable, and the daytime is long, allowing urban residents to enjoy a great deal of outdoor living. During the autumn, the duration of daylight decreases day by day. In winter, cities are often covered by a leaden sky, creating a monotone urban environment colored by lights during the long nights. Even within Japan, which spans an approximately 20° range in latitude from Okinawa, the southernmost prefecture, to Hokkaido, the northernmost prefecture, the cityscapes associated with each season are entirely different according to region.

Residents tend to take the cityscape where they live for granted, even though it heavily influences everyday life. This cityscape includes a unique thermal environment resulting from the properties of the urban landscape. For example, the prevailing wind direction can align with or blow crossways relative to the road system, and residents can experience discomfort owing to thermal radiation from heated pavement surfaces when walking on roads that are exposed to solar radiation in summer. Thus, the urban thermal environment is influenced by the space composition, material usage, and heat energy emitted by human activities in the city.

The elements that define the urban thermal environment include temperature, humidity, airflow, and thermal radiation, which is emitted from the sun as well as the surrounding surfaces. As mentioned above, these elements are not directly visible, so they are not familiar aspects in the discussion of the cityscape, despite exerting a considerable influence on everyday life. However, each of these elements is closely related to urban planning, comfort, and lifestyle.

A future approach to urban planning that accounts for the thermal environment can be envisioned as follows: in a snowy region, airflow planning to prevent the drifting of snow could accommodate residents' enjoyment of snow while minimizing inconvenience, providing sun exposure, and sheltering pedestrians from the wind; in a hot and muggy region, airflow planning could provide comfortable conditions with a gentle breeze passing down the road. The realization of efficient and comfortable urban environments thus requires positive thinking to create a favorable thermal environment according to the unique characteristics of each city.

9.1.2 Thermal Radiation and Comfort

9.1.2.1 Relationship Between Elements of the Thermal Environment and the Thermal Comfort of the Human Body

The thermal sensations experienced by human beings depend on the balance of thermal energy between the body and the environment. This balance is defined by two body factors (heat production and clothing condition) and five environmental factors (temperature, humidity, airflow, and thermal radiation, including solar radiation and surface temperature). Thermal energy flows between the human body and the environment through radiation, convection, evaporation, and conduction. When the amount of energy transferred between the human body and the environment is zero, the neutral state is experienced, which is neither hot nor cold (Fig. 9.1).

The energy transfer between the human body and the environment is influenced by the surface temperatures across the cityscape, which are determined by the specific characteristics of the city such as spatial configuration and material composition. The spatial distribution of surface temperatures can be captured by thermography using a thermal infrared camera. Importantly, the captured temperature data represent the radiation temperatures experienced by a human body in the environment rather than the specific temperatures of the surfaces around them. Thus, it is possible to observe the actual condition of the thermal environment using thermography and thereby discuss the thermal comfort of the human body. However, as stated in Sect. 9.2, not all of the thermal environment can be understood through the surface (radiation) temperature.

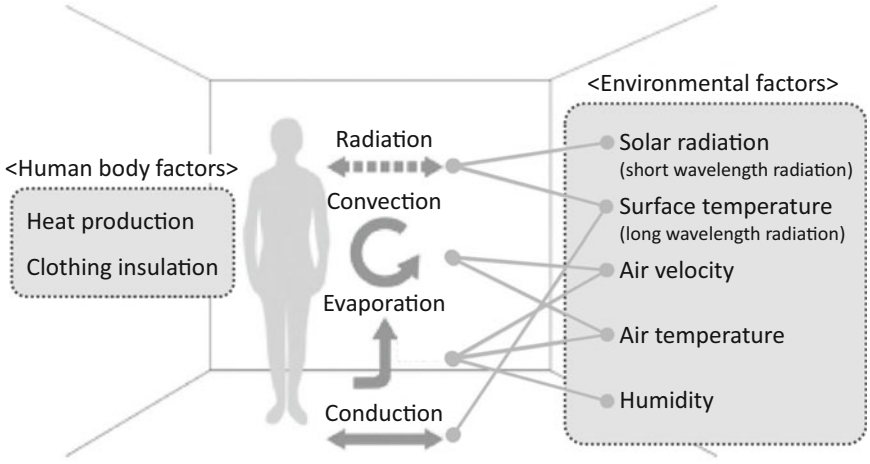

Fig. 9.1 Factors involved in heat exchange between the human body and its environment

9.1.2.2 Thermal Radiation Evaluation Index

The quantification of thermal radiation—including solar radiation and surface temperature—is less familiar than that of temperature, humidity, or airflow. The thermal radiation received by the human body includes solar radiation, which comprises direct solar radiation, diffuse sky radiation, and reflected solar radiation from surrounding objects, as well as thermal radiation emitted by surrounding surfaces according to their temperature and properties (emissivity). Solar radiation consists of electromagnetic waves with wavelengths of 0.4 to several μm, including ultraviolet rays, visible rays, near-infrared rays, and short-wavelength infrared rays. Visible rays constitute approximately 50% of the total energy contained in solar radiation. Thermal radiation consists of electromagnetic waves with wavelengths of about 10 μm in the thermal infrared band, which is invisible to the eyes. Only thermal radiation is considered in this discussion.

A human body inside a room will receive different quantities of thermal radiation from different directions if the temperatures of the surrounding surfaces are different. This condition can result from the presence of a radiator, floor heating, or a cold window surface in winter. Therefore, the state of thermal radiation from the surroundings is expressed as the sum of the products of the form factor of each surface, whose shape is modeled by various methods, and its temperature acting on the human body. This is called the mean radiant temperature (MRT) [°C] and can be expressed as follows:

$$\mathrm{MRT}\,[^\circ\mathrm{C}] = \sqrt[4]{\sum_{i=1}^{N} F_i \cdot {T_{\mathrm{si}}}^4} - 273.2, \tag{9.1}$$

where F_i is the form factor of surface i as observed from the position of the human body. T_{si} is the radiation temperature [K] of surface i (typically, the surface temperature is used by regarding the surface as a blackbody except in cases of metal surfaces with low emissivity), and N is the number of surfaces.

The MRT value provided by Eq. (9.1) can be calculated using spherical thermography obtained by the system developed by the authors, which will be introduced in Sect. 9.3.

9.1.2.3 Influence of Thermal Radiation on the Thermal Comfort of the Human Body

The physical sensations of hot and cold depend on temperature, humidity, airflow, and thermal radiation, as discussed in Sect. 9.1.2.1. When there is almost no wind, the temperature and MRT will have the same effect on the thermal sensation. This condition is experienced indoors on a daily basis owing to floor heating in the winter and solar radiation on the ceiling surface in the summer. To consider the influence of

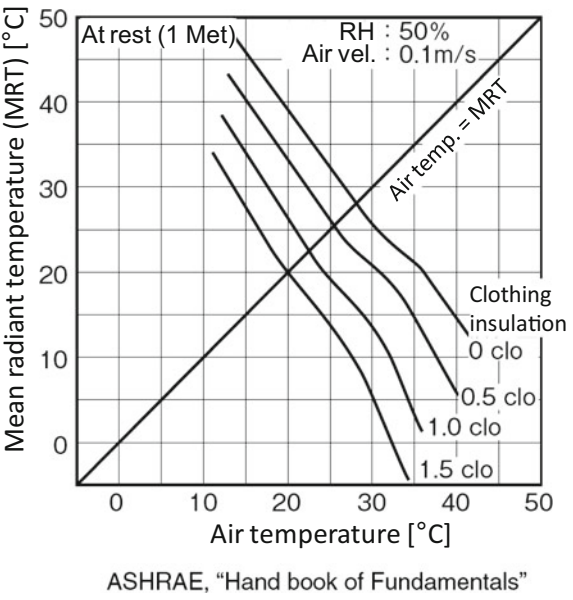

Fig. 9.2 Relationship between MRT and air temperature showing comfortable conditions for the human body (according to clothing insulation) (ASHRAE, XXXX)

thermal radiation on sensation, Fig. 9.2 shows the relationship between temperature and MRT in the neutral condition (neither hot nor cold) according to clothing condition. In the figure, 0 clo indicates the naked state with no clothing insulation and 1.0 clo indicates the clothing insulation state when wearing a suit or similar garment. The curves in the figure show a comfortable condition at rest (1 Met) when the relative humidity is 50% and the airflow velocity (wind velocity) is 0.1 m/s or less. The gradient of the nearly straight portion of each curve is −45° for any clothing condition. This indicates that approximately the same sensation is obtained given a 1 °C change in MRT as with a 1 °C change in room temperature. Thus, thermal radiation considerably affects thermal comfort in a city because the surface temperatures of the ground and walls that receive solar radiation can increase by tens of degrees Celsius above the air temperature. This increase can be observed in thermography collected by a thermal infrared camera.

Although Fig. 9.2 shows results for the nearly windless condition (wind velocity of 0.1 m/s), it is necessary to keep in mind that the air velocity outdoors is typically about 0.5 m/s even when "windless," which contributes to a sensation of coolness. Furthermore, when the clothing insulation is 1.5 clo, it is comfortable when both the air temperature and MRT are approximately 20 °C; however, when the MRT induced by floor heating is 25 °C, it is comfortable at an air temperature of 17 °C. Thus, comfort can be obtained at a lower room temperature with radiant floor heating than with forced air heating. In an urban area, there are significant differences between the temperatures of surfaces exposed to and shaded from the sun. For example, in the summer daytime, the temperature of a sunny asphalt pavement surface can be in excess of 20 °C greater than the air temperature, but in the shade, the temperature of an asphalt surface will be nearly equal to the air

temperature. This phenomenon dominates the sensation of heat in the urban environment, indicating that the surface temperature distribution exerts a considerable influence on activities in the city because the resulting MRT is much greater than the air temperature.

9.1.2.4 Calculation of MRT

If the temperatures of all the surfaces surrounding a human body are known, the MRT value can be obtained by multiplying the form factors of the respective surfaces by their temperatures as described in Eq. (9.1).

However, the thermal radiation experienced by urban occupants is often received from direct solar radiation and diffuse sky radiation as well. For example, in the sun, the human body receives and absorbs nearly 1000 W/m^2 of direct solar radiation. To obtain an accurate MRT value, this absorption must also be included in the MRT. However, in this chapter, only the balance of thermal radiation from surfaces in a normal temperature range is considered in the MRT. That is, the MRT is calculated only from the temperatures of all the surfaces measured using spherical thermography.

To account for the thermal contribution of the sky, it is treated as a surface above with an equivalent atmospheric temperature and form factor. The apparent temperature of the sky, considered a blackbody, was used as its radiation temperature. Because the apparent temperature of the sky is lower than the air temperature, it effectively functions as a cooling source in summer.

9.2 City Planning and Surface Temperature

9.2.1 Determining Surface Temperature

The temperatures of various surfaces in the city are determined as shown by the example in Fig. 9.3, which illustrates the heat balance according to solar radiation on a certain ground surface.

The radiant energy from the sun changes quantitatively and qualitatively as it passes through the atmosphere until it reaches the ground. As shown in the figure, this energy comprises direct solar radiation, which passes through the atmosphere to reach the ground; diffuse sky radiation, which scatters in the atmosphere and eventually descends to the ground; and atmospheric radiation, which is absorbed by atmospheric water vapor and reradiated according to the temperature of the atmosphere. Additionally, the urban ground surface also receives reflected solar and thermal radiation from surrounding buildings and objects.

Direct solar radiation and diffuse sky radiation are electromagnetic waves in the ultraviolet, visible, near-infrared, and short-wavelength infrared bands, varying in wavelength from 0.4 to several μm. On the other hand, because atmospheric

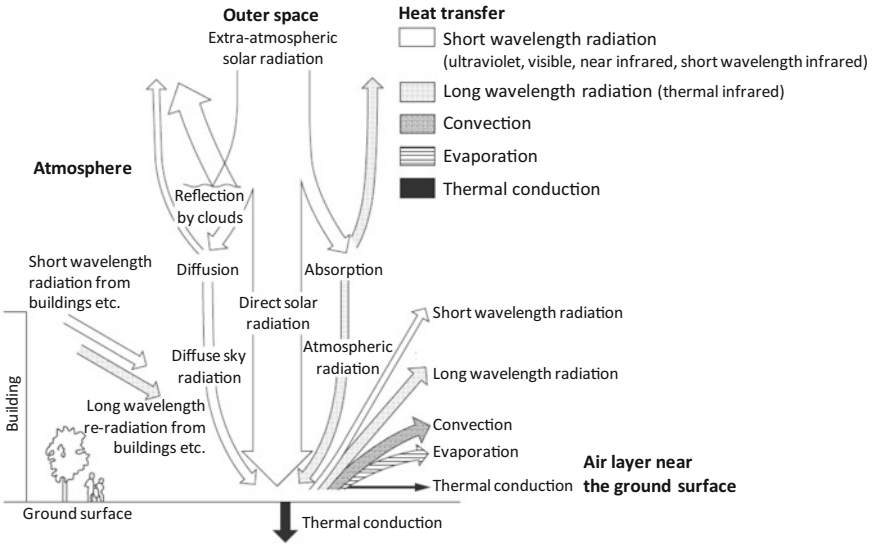

Fig. 9.3 Heat balance mechanism of solar radiant energy on the ground surface

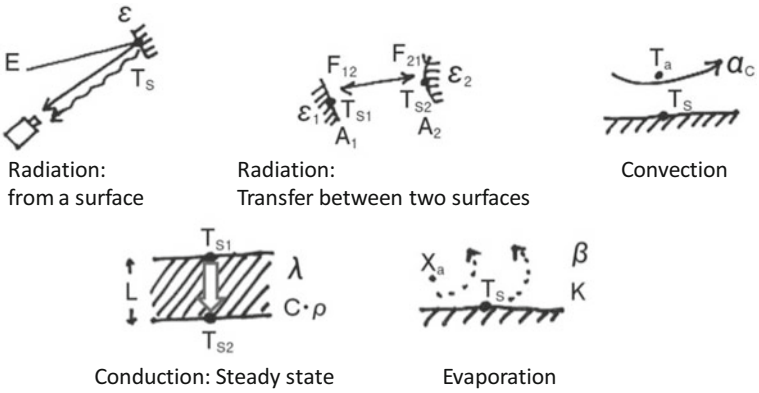

Fig. 9.4 Various heat transfer processes

radiation comprises electromagnetic waves in the thermal infrared band with wavelengths of approximately 10 μm, they are invisible to the eyes and are largely unfamiliar. However, as shown by the heat balance of the ground surface in Fig. 9.3, atmospheric radiation plays an important role along with the thermal radiation from the ground.

As shown by the various heat transfer processes in Fig. 9.4, some of the solar radiation incident on the ground is reflected, while the rest is absorbed, warming the ground surface. Then, owing to air convection in the vicinity of the ground surface, some of this absorbed heat is thermally radiated in quantities commensurate with the

temperature and emissivity of the ground surface, while the remainder is conducted by the ground itself. This absorbed heat also serves as the latent heat of evaporation when water is present on the ground surface. The heat balance on the ground surface can therefore be expressed as:

$$G = (1 - r)\left(S_{\mathrm{b}} + S_{\mathrm{sky}} + S_{\mathrm{r}}\right) + \varepsilon\left(R_{\mathrm{s}} + R_{\mathrm{sky}}\right) - \varepsilon\sigma T^4 + H + L, \tag{9.2}$$

where G is the amount of thermal conduction; r is solar reflectance; S_{b} is the amount of direct solar radiation; S_{sky} represents the amount of diffuse sky radiation; S_{r} is the amount of reflected solar radiation from the surroundings, such as building walls; R_{s} is the amount of long-wavelength radiation from the surroundings, such as building walls; R_{sky} represents the amount of atmospheric radiation; T is the surface temperature; ε is the emissivity; σ is the Stefan–Boltzmann constant; H is the amount of sensible heat transfer by convection, which is calculated by $\langle\alpha_{\mathrm{c}}(T - a)\rangle$, in which α_{c} is the heat transfer coefficient by convection and a is the neighborhood air temperature; and L is the latent heat transfer.

The ground surface temperature is determined as a function of the balance given in Eq. (9.2). The ground surface temperature also changes from moment to moment with the weather conditions; that is, the ground surface temperature is in an unsteady state that can be captured by collecting a time series of thermographs taken using a thermal infrared camera.

9.2.2 Surface Temperature in the Heat Transfer Equation

As can be seen from Eq. (9.2), the surface temperature is included in the expression for each element of the heat transfer phenomenon. That is, the surface temperature is clearly an important parameter when considering the thermal environment according to the state of heat transfer. However, even if the surface temperature is known, it is necessary to keep in mind that the heat conductivity G owing to each heat transfer phenomenon cannot be obtained by itself. Even though the surface temperature is the same, there are many cases in which the amount of heat transfer differs considerably. In other words, "reading the thermal environment according to surface temperature" does not mean that the thermal environment can be understood using only the surface temperature.

9.3 Visualization of the Thermal Environment

9.3.1 What Is a Thermal Infrared Camera?

Thermal infrared cameras have been extremely reduced in size since their invention, and today their appearance is almost the same as that of an ordinary video camera. Accompanying this reduction in size, the principle of measurement employed by these cameras has changed significantly. Starting around 1970, cooled thermal infrared cameras that cool the sensor with liquid nitrogen were used in Japan, but in the 1990s, the uncooled two-dimensional array sensor was introduced. This sensor increased mobility and dramatically accelerated the development of environmental measurement technology, particularly once the price decreased from hundreds of thousands of yen to tens of thousands of yen.

The pixel resolution measured in general thermography is on the order of hundreds by hundreds, the field angle is around 30°, and the instantaneous viewing angle is about 0.2 mrad. Thus, the image quality obtained by a thermal infrared camera is inferior to that obtained by a visible light camera. The wavelength bands frequently used for detection by the sensor are the 3–5 μm and 8–14 μm bands in the infrared region, called "atmospheric windows." Although thermography was first limited to research use and industrial measurement, it is increasingly being applied in everyday life, including as night vision equipment in vehicles.

9.3.2 Measurement Principle of the Thermal Infrared Camera

The section explains the measurement principle employed by thermal infrared cameras to obtain environmental measurements based on the fundamental theory of radiation. The most fundamental theory regarding thermal radiation states that: From objects (gray bodies) above absolute zero temperature, the thermal radiation matches the property (emissivity) and temperature of their surface. In the case of a blackbody, the amount of thermal radiation is proportional to the fourth power of absolute temperature (Stefan–Boltzmann law). The theory of radiation also includes Wien's displacement law, which dictates the relationship between the maximum wavelengths of thermal radiation and surface temperatures. However, to accurately read thermography results, broader knowledge is required.

Specifically, it is necessary to understand that

1. The surface subjected to environmental measurement is not a blackbody, a gray body, or a selected body, and its emissivity value is less than 1.
   For example, the emissivity of a metallic glossy surface is less than 0.1.

2. The emissivity of an object varies depending on the wavelength (spectral characteristics) of the radiation and its angle of incidence on the surface (directivity characteristics).
3. Therefore, the temperature indicated by thermography is not the surface temperature but the radiation temperature in general. An emissivity correction is required to calculate the surface temperature from the radiation temperature.
4. When the distance from the surface to the target sensor is large, atmospheric correction is also required.
5. The wavelengths detected by a thermal infrared camera sensor are generally 3–5 μm and 8–14 μm, called the atmospheric windows. In other words, thermography does not sense electromagnetic waves in all possible wavelength bands.

9.3.3 What Does the Thermal Infrared Camera Measure?

Figure 9.5 shows a schematic diagram describing the types of energy incident on a thermal infrared camera. The energy shown in the diagram consists of (1) the radiation of the target surface itself, (2) the reflection of radiation from the surrounding surface facing the target surface, and (3) the radiation of the atmosphere between the target surface and the camera, as expressed by:

$$E(T) = \tau(\varepsilon E(T_s) + (1-\varepsilon)E(T_r)) + (1-\tau)E(T_a), \tag{9.3}$$

where $E(T)$ is the radiant energy of the black body at a temperature T [K] in W/m^2, T_s is the temperature of the target surface in K, T_r is the radiation temperature of the surrounding surfaces facing the target surface in K, T_a is the air temperature in K, ε is the emissivity of the target surface, and τ is the transmittance of the atmosphere.

It has recently become possible to easily obtain spatial information describing surface temperatures as an image using a thermal infrared camera. Thus,

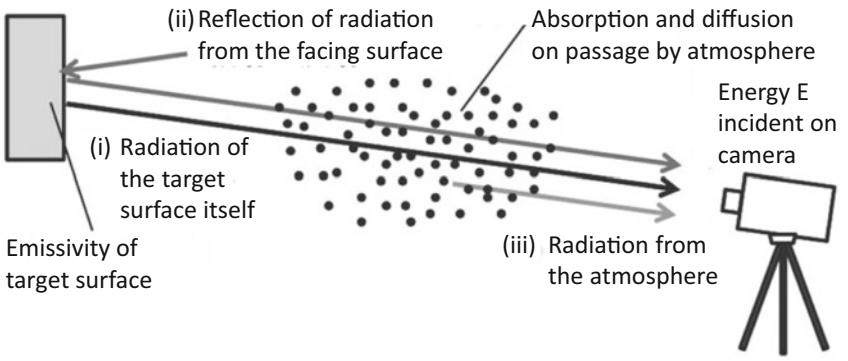

Fig. 9.5 Energy incident on a thermal infrared camera

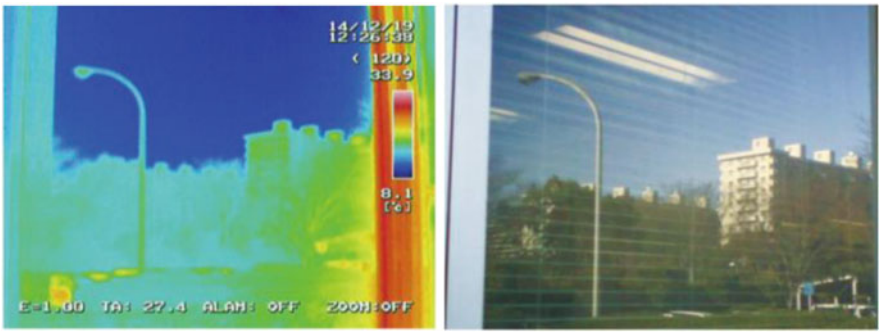

Fig. 9.6 Scenery reflected on a glass surface (left: thermograph) (right: visible image)

thermography has expanded from being a powerful tool for medical and industrial measurement to providing environmental measurements as well. Notably, spatial surface temperature information offers an effective way to understand and identify environmental problems.

For example, in the analysis of the urban heat island phenomenon, understanding the surface temperature would be beneficial in several cases, such as determining how much higher the temperature of a surface is than the air temperature or determining how much sensible heat transfer is emitted from a surface by convection in the atmosphere. Here, it is again important to note that although thermal infrared cameras are very effective because they can visualize the spatial distribution of temperature as thermography, the results obtained are not actually the surface temperatures but the radiation temperatures.

As explained in Sect. 9.3.2, to calculate the surface temperature from the radiation temperature when collecting quantitative environmental measurements, an emissivity correction is needed; in the case of remote measurement, atmospheric correction is often required as well. However, since these corrections are typically complex, the radiation temperatures are often directly equated to the surface temperatures, except when the emissivity of the target surface is small or the distance to the measurement target is long. Therefore, unless otherwise stated, when reading a thermograph obtained by a thermal infrared camera or the like, the readings are considered to be surface temperatures; however, special attention is required when the difference between surface temperature and radiation temperature is very large.

Furthermore, as shown in Fig. 9.6, the reflection of a facing surface is captured by visible image and thermography. The image and thermographs of a transparent floated glass window were captured from a slight oblique so that the scenery of the facing surfaces was reflected on the glass surface. In the figure, both the thermograph and the visible light image show the street lamp and buildings opposite the glass window. However, note the fluorescent lamp shown in the visible light image, which was reflected by the glass surface.

9.3.4 Observing the Thermal Environment of the City by Thermography

9.3.4.1 Surface Temperature Distribution of the City Captured by a Thermal Infrared Camera

The reality of the thermal environment of a city should be considered with an understanding of human thermal sensation. To do this, the surface temperature distributions across the city can be visualized using thermography collected by a thermal infrared camera. If the surface temperature distribution is known, the amount of thermal radiation received by a person from their surrounding surfaces can be obtained. Furthermore, the amount of sensible heat transfer from the surfaces constituting the city to the atmosphere can also be estimated.

The surface temperature distribution of an urban environment is determined by the spatial form and constituent materials of the city. The surface temperatures will vary from moment to moment; these changes can be read from sequential thermographs. The following are among the realities that dictate the thermal environment:

- Temperature differences owing to sun and shade.
- Storage of solar heat absorbed during the day and cold storage from overnight to early morning.
- Wind direction.
- Exhaust heat from building air outlets and heat exchangers.

9.3.4.2 Calculating the MRT of the City by Spherical Thermograph

This section provides examples of spherical thermographs obtained in three different urban spaces.

Figure 9.7 (top) depicts a spherical thermograph captured from the standing position on a sidewalk in a commercial area with large buildings on both sides of the road. Taken on a sunny day in the early summer, the air temperature was 29 °C, and the temperature of the paved surface receiving solar radiation was greater than 45 °C. Thus, a person standing on this sidewalk would receive intense thermal radiation from the pavement surface. If there were fewer surrounding buildings, thermal exchange would only be performed between the human body, the ground, and the open sky; however this exchange is altered by the surrounding buildings. In addition, the air exposed to the heated pavement surface is warmed, increasing the temperature of the road space, contributing to the urban heat island effect.

Figure 9.7 (middle) shows a spherical thermograph captured from the standing position under an artificial canopy extending from east to west, provided to protect pedestrians from rain and solar radiation in a paved station square. Direct solar radiation is screened by this canopy, shading the standing location. However, the pavement surface exposed to the sun is shown in red, indicating a high temperature, and the bottom surface temperature of the canopy is approximately 40 °C due to the

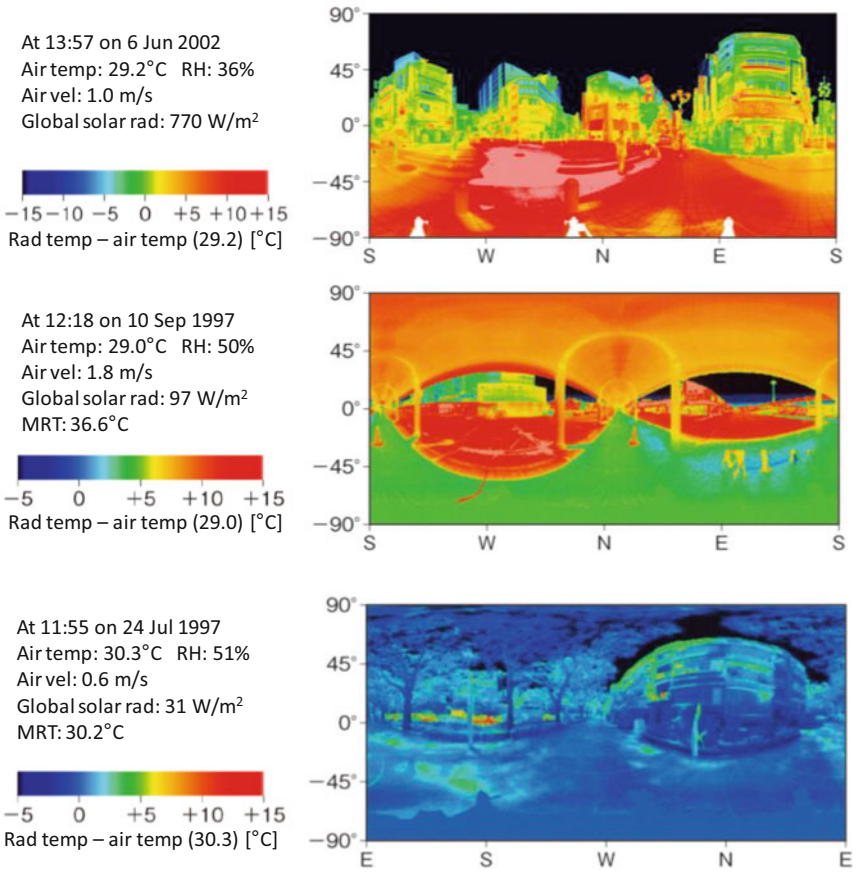

Fig. 9.7 Thermal radiation environment of three different urban spaces observed by spherical thermography. Top: Sidewalk of an intersection in a commercial area (Shinjuku Station East Exit area in Shinjuku ward, Tokyo). Middle: Paved station square under an artificial canopy (front of Minami-Ōsawa in Hachioji city, Tokyo). Bottom: Sidewalk under the trees of Japanese Zelkova with large tree crowns (Omotesandō Avenue in Shibuya ward, Tokyo)

incident solar heat on its top surface. The currently shaded pavement beneath the canopy can also be observed to store solar radiation heat absorbed earlier in the morning, showing a temperature of 35 °C. The MRT for the location in this thermograph was determined to be 36.6 °C, which is higher than the surface temperature of the human face and hand. Thus, though this location is shaded with an air temperature of only 29 °C, it would be very uncomfortable here, owing to the thermal radiation from the surroundings.

Finally, a spherical thermograph captured on a sidewalk under Japanese Zelkova trees, which have large crowns, is shown in Fig. 9.7 (bottom). This thermograph indicates that not only is direct solar radiation screened by the tree crowns but also

there is no heating from above, as was the case with the artificial canopy. Indeed, the temperature of the crown is shown to be nearly equal to the air temperature. Furthermore, because the sidewalks and walls of buildings were shaded in the morning, their surface temperatures remained equivalent to the air temperature at the time of the thermograph. The MRT for the location in this thermograph was determined to be 30.2 °C, which is approximately equal to the air temperature of 30.3 °C, both lower than the surface temperature of the human face. Such an urban environment would therefore feel cool even if there was little wind.

Note that if the sidewalk in the bottom thermograph in Fig. 9.7 was moistened owing to the use of a water-retentive pavement, it would be cooled by evaporative cooling; its surface temperature would not drop to the wet bulb temperature but would still remain several degrees below the air temperature. As a result, the value of the MRT would decrease further below the air temperature, providing a cool area for people walking on the sidewalk.

The three examples in Fig. 9.7 show that the surface temperature varies considerably depending on the spatial form of the city and its constituent materials, defining the thermal radiation environment, and thereby affecting the thermal comfort of residents.

Further Reading

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Chapter 10
Designing the Urban Thermal Environment Using Thermal Simulation

Akira Hoyano and Hiroki Takahashi

Abstract A method is introduced to predict the future thermal environment of a city by inputting a three-dimensional computer-aided design model of the area, conducting a heat balance simulation, and visualizing the results to inform the design of a comfortable urban environment. The design and planning criteria for creating cool living spaces called "cool spots" in the city are discussed, and methods for the planning of a cooler city in the summer are reviewed. Finally, a case study of the city of Tsuchiura in Ibaraki Prefecture, located in the Greater Tokyo Area, is considered to evaluate its past, present, and future thermal environment. This design example is used to show how the simulation result can be used to visualize the created cool spots and discuss a comfortable and attractive city plan with a low environmental burden.

Keywords City · Thermal environment · Cool spot · 3D CAD (computer-aided design) · Heat balance simulation · Surface temperature · Mean radiant temperature (MRT) · City planning

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10.1 City Planning and Thermal Environment Simulation Method

Chapter 9 illustrates how thermography can be applied to investigate the urban thermal environment and how the city is full of heat, especially in summer. What can be done to improve the environment of a city? A method for predicting and evaluating the thermal environment is presented in this chapter to answer this question.

10.1.1 Purpose of Development

The progressive advancement of technologies related to the application of three-dimensional computer-aided design (3D CAD) and computer simulation in architectural design has been remarkable. Notably, these technologies have thus far developed along separate paths. A building and urban design tool based on these technologies is required to realize the reduction of the urban heat island effect, provide environmental assessments of urban redevelopment, and provide support for the design of building and urban thermal environments. This tool can be used by building designers and environmental consultants to integrate general building 3D CAD and thermal environment simulations.

Therefore, the method described in this chapter for the visualization of surface temperature in 3D CAD provides a tool for designers to evaluate the thermal performance of their own designs and can serve as a basis for the communication of environmental predictions and evaluations with urban environmental administrators and the general public.

10.1.2 Principle and Structure

The thermal environment simulation tool can be operated on a general personal computer using typical 3D CAD software and is constructed using the technologies and relationships shown in Figs. 10.1 and 10.2.

The features of the thermal environment simulation tool are summarized as follows:

1. Input and modeling by 3D CAD

   The tool was developed so that the necessary information can be input and output using the building model in the Vectorworks 3D CAD software. This allows architects to predict and evaluate building and urban thermal environments based on drawings at 1/100 to 1/500 scales designed in 3D CAD, as shown in Fig. 10.3.

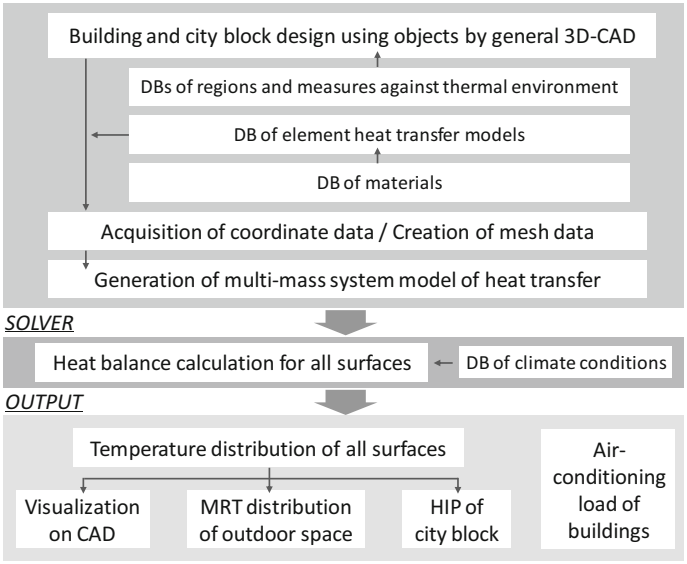

Fig. 10.1 3D CAD-compliant heat balance simulation tool

2. Generation of multi-mass system heat transfer model

   The city model created in 3D CAD is automatically transformed into a multi-mass system model for heat transfer calculation in conjunction with databases describing materials and their thermophysical properties (Figs. 10.4 and 10.5).
3. Thermal environment simulation

   To realize the thermal environment simulation, a simulation system is integrated with the 3D CAD software by applying an outdoor thermal environment simulator to calculate the temperatures of all surfaces in the model and a building thermal load simulator developed by the Hoyano laboratory of the Tokyo Institute of Technology (Figs. 10.6, 10.7 and 10.8).
4. Output and visualization

   Displaying the calculation results for the urban surface temperature distribution using the visualization function of the 3D CAD software allows architects to confirm the effects of their designs on the thermal environment. Furthermore, as environmental evaluation results are often difficult for the general population to understand, visualization makes it possible to realize presentations that can be readily comprehended by not only architects and consultants engaged in design work but also administrative staff and the general public (Fig. 10.2).

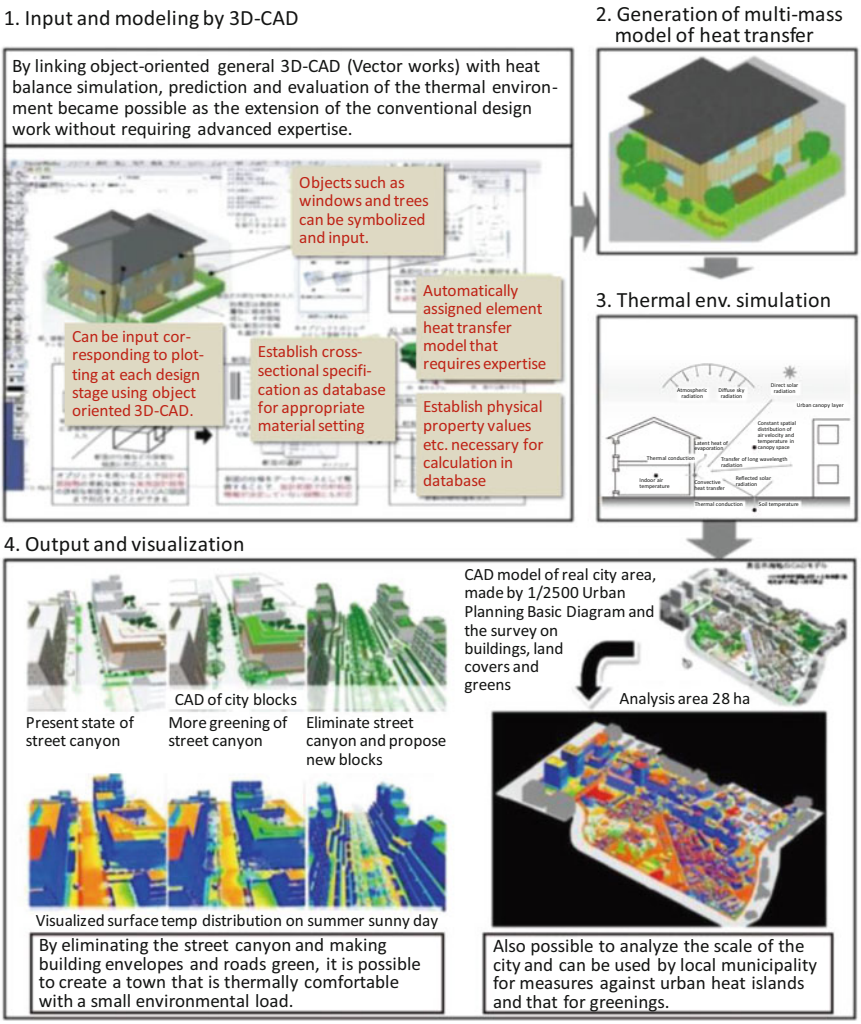

Fig. 10.2 Procedure for using 3D CAD-compliant heat balance simulation tool

10.1.3 Output Quantitative Results That Can Be Evaluated by Designers and Others

Figure 10.4 shows the method used to generate the mesh using 3D CAD data. The finer the mesh, the better the calculation accuracy, but if the mesh is too fine, the large number of elements will require a great deal of calculation time to analyze. For this reason, the mesh resolution is determined so that elements of objects such as walls, roofs, and eaves are represented by pure pixels, each of which consists of a single property.

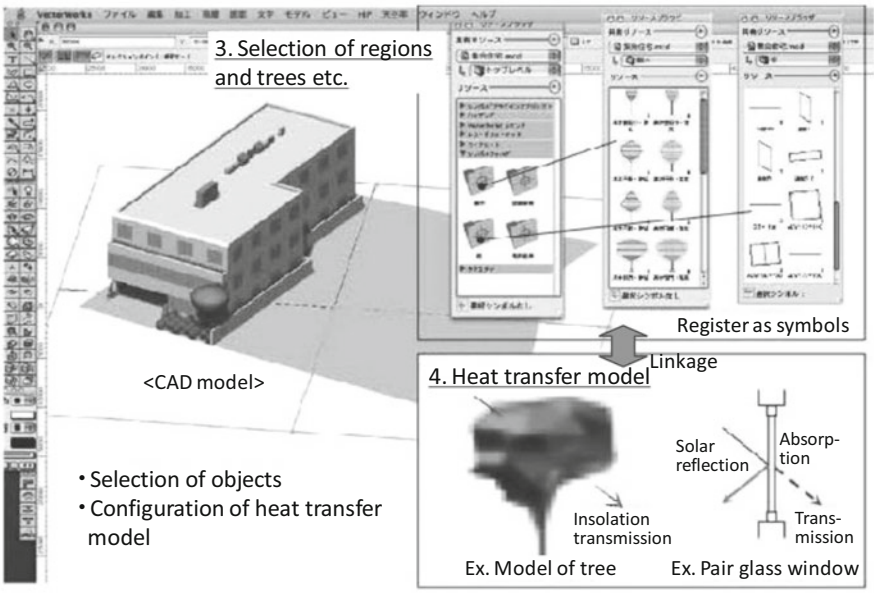

Fig. 10.3 Processes before and after calculation using 3D CAD software

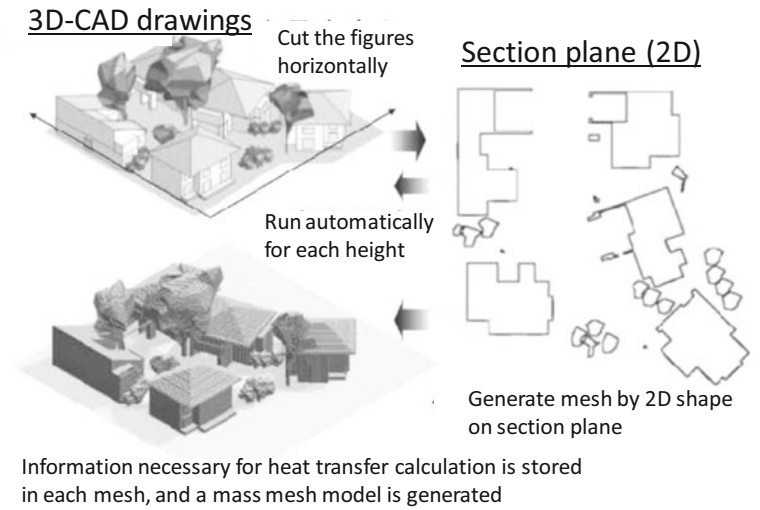

Fig. 10.4 Generation of mesh (mass) system model

As an example, Fig. 10.5 shows a mesh structure with a spatial resolution of 20 cm. The heat balance of each element in the mesh with its surroundings was calculated in the vertical direction, with the results shown in Fig. 10.6. The heat balance equation employed for this unsteady calculation is shown in Fig. 10.7.

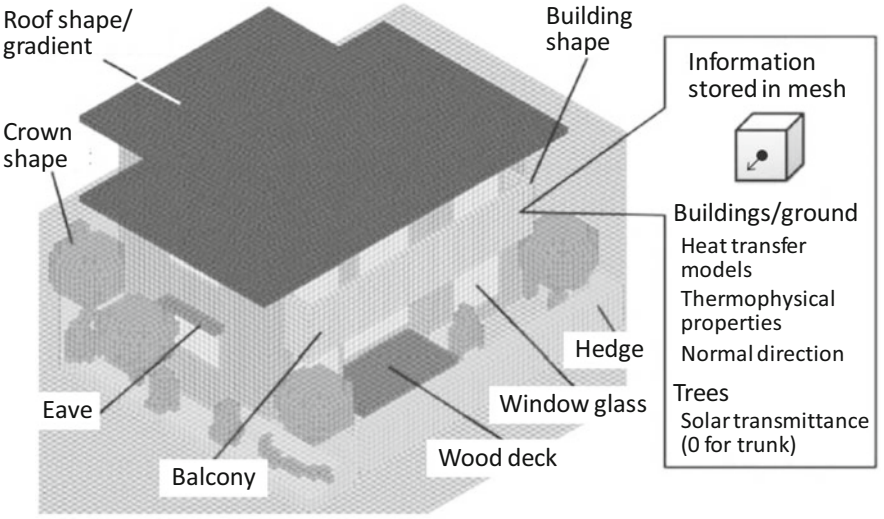

Fig. 10.5 Mesh (mass) model with a resolution of 20 cm

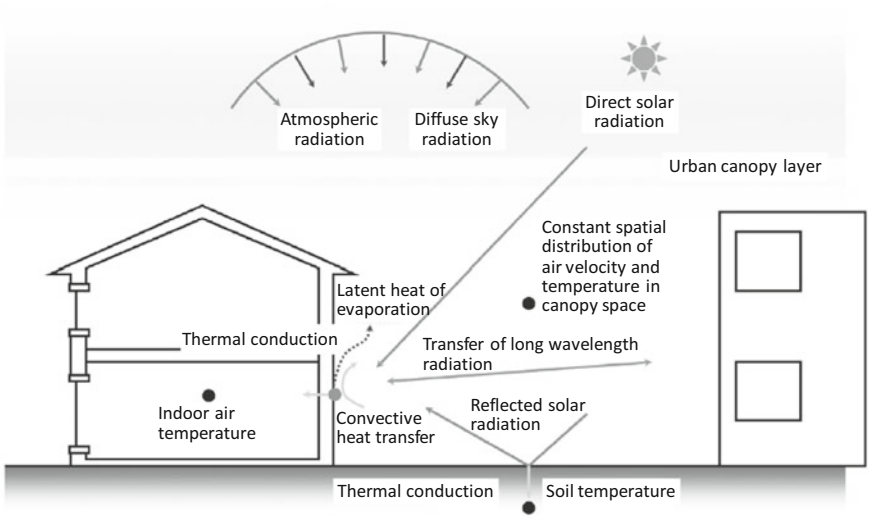

Fig. 10.6 Items for the heat balance calculation for each mesh (mass)

$$-\lambda \frac{\partial T}{\partial x} = a_{su}\left(\cos\theta \cdot I_{DR} + \Phi_{sky} I_{SR} + I_{RR}\right)$$

Thermal conduction

Receiving solar radiation (direct and diffuse sky radiation, reflection from surroundings)

$$+ \varepsilon_s \Phi_{sky} \sigma T_a^4 \left(a + b\sqrt{e}\right) + \varepsilon_s \sum_{i=1}^{n} \varepsilon_i \Phi_i \sigma T_{si}^4 - \varepsilon_s \sigma T_s^4$$

Atmospheric radiation

Transfer of long wavelength radiation to and from surrounding objects

$$+ \alpha_c \left(T_a - T_s\right) + L\beta k(X_s - X_a)$$

Convective heat transfer

Latent heat of evaporation

q: Thermal conductivity [W/m^2]

T: Temperature [K]

a_{su}: Solar absorptance

θ: Incidence angle of direct solar radiation with mass surface [rad].

I_{DR}: Direct solar radiation [W/m^2]

Φ: View factor [*sky*: sky view factor].

I_{SR}: Diffuse sky radiation [W/m^2]

I_{RR}: Reflected solar radiation from surrounding objects [W/m^2]

ε: Long-wavelength emissivity.

Σ: Stefan–Boltzmann constant [W/(m^{2}K^4)]

a, b: Constants in Brunt's equation

e: Atmospheric vapor pressure near the ground surface [hPa]

α_c: Convective heat transfer coefficient [W/(m^2 K)]

S: (subscript) Surface

a: (subscript) Air

n: (subscript) Number of surrounding objects included in the calculation of long-wavelength radiation transfer

i: (subscript) Identifier of surrounding object included in the calculation of long-wavelength radiation transfer

L: Latent heat of evaporation [J/kg]

β: Evaporative efficiency

k: Mass transfer coefficient [kg/(m^2/s(kg/kg))]

X_a: Absolute humidity [kg/kg]

X_s: Saturation humidity at surface temperature T_s [kg/kg]

Fig. 10.7 Basic heat balance equation for each mesh

Finally, Fig. 10.8 shows that the heat island potential (HIP) and the thermal environment can be evaluated using the surface temperature of each element, as obtained by calculating the heat balance. The process for evaluating the HIP and thermal environment is described as follows:

1. First, the spatial distribution of the surface temperature visualized in 3D CAD enables visual interpretation of the relationship between the materials used on the site and the surface temperature, the effect of each method, the difference between shade and sun, etc. Furthermore, the change over time can be animated. It is also

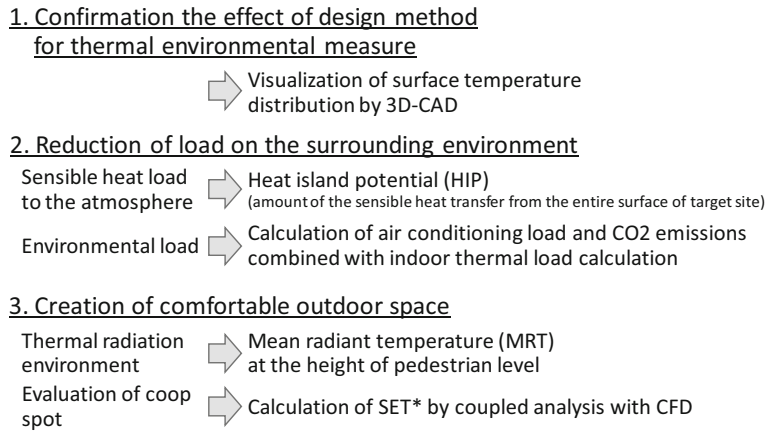

Fig. 10.8 Prediction and evaluation indices of HIP and thermal environment by heat balance simulation

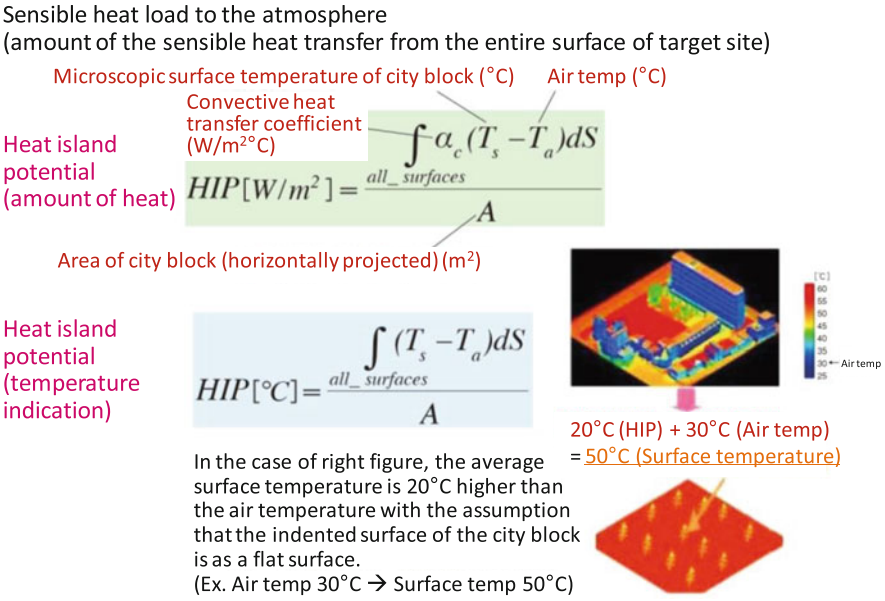

Fig. 10.9 Definition of heat island potential (HIP)

possible to display a walk-through view (the viewing angle is required) within the analysis target area at a certain time.

2. The HIP of the target analysis area can be obtained as the thermal load on the surroundings. The value of the HIP can be calculated as shown in Fig. 10.9 once the surface temperatures of all the faces of the analysis target area are obtained. Assuming that there is no temperature distribution (a constant temperature) or

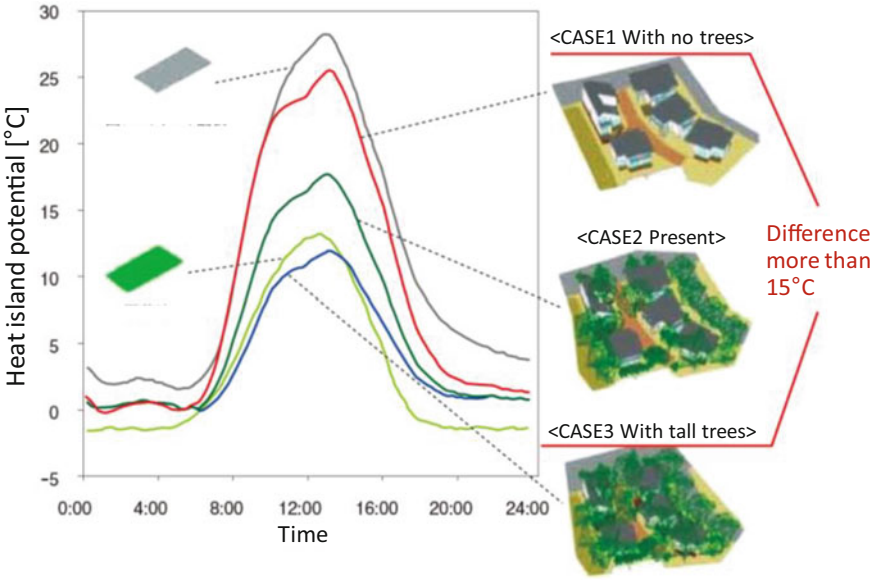

Fig. 10.10 Effect of greening on the daily variation in the HIP of a residential area of six detached houses in Tokyo on a sunny summer day

wind velocity in the building's external space, the HIP value can be represented by a temperature, as shown by the lower equation in Fig. 10.9. This equation divides the sum of all heat from all surfaces in the analysis target area (represented as the difference between the surface temperature and air temperature) by the total area of the target. Thus, assuming the target area is flat, if the HIP is 20 °C and the air temperature is 30 °C, as shown in Fig. 10.9, the surface temperature of the target area is 50 °C.

3. Figure 10.10 shows the daily change in HIP values on a sunny summer day in three residential areas in Tokyo with different green states, illustrated on the right side of the figure. The five wooden houses were the same in all three cases. For reference, the figure also shows the daily change in the HIP for fully asphalt-paved and fully grass-covered areas. Obvious differences can be observed in the HIP values of the three residential areas according to the degree of greening. Indeed, these differences can be as great as those between fully paved and fully grass-covered areas. The HIP of the residential area with tall trees was the lowest among the three, but was not lower than that of the fully grass-covered area from late afternoon to early morning. Indeed, the HIP value of the fully grass-covered area becomes negative in the early morning.
4. The mean radiant temperature (MRT) is obtained as the thermal radiation received from the surroundings at a certain height outdoors. An example of MRT distribution is shown in Fig. 10.11. The left side of the figure shows the distribution of MRT on a road surrounded by buildings whose façades are depicted in gray scale. Despite the fact that there is almost no temperature

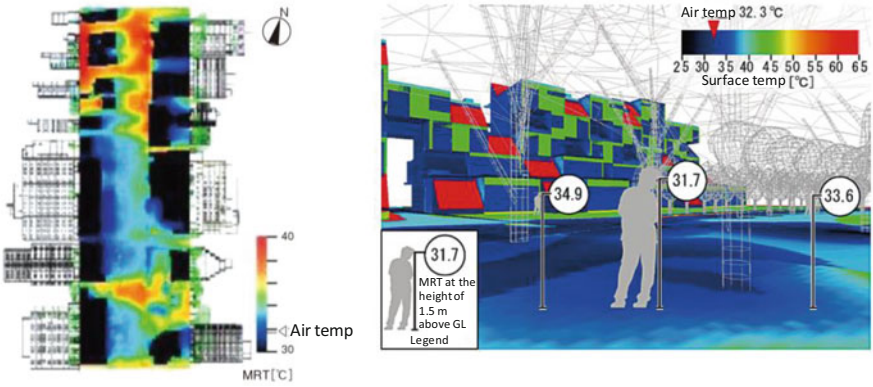

Fig. 10.11 Output MRT at a height of 1.5 m above ground level. Left: MRT distribution 1.5 m above a road as output by 2D planar distribution. Right: The MRT values are indicated in white circles with a human model installed in the 3D surface temperature distribution

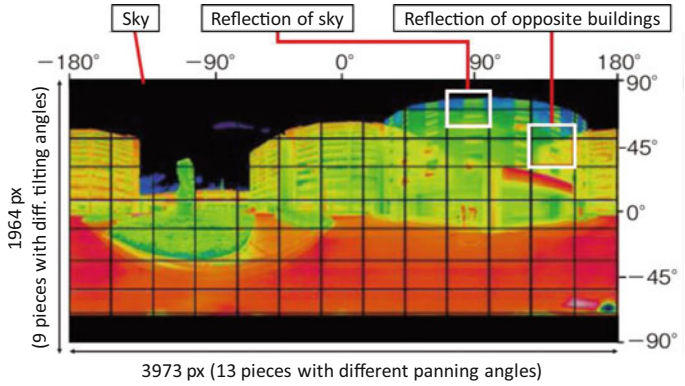

Fig. 10.12 Example of a spherical thermograph

distribution on the road, the MRT varies by nearly 10 °C depending on the location along the road. The right side of the figure shows the surface temperature of the surrounding buildings and the ground, as well as the MRT values obtained for three points 1.5 m above the ground. A difference of 3 °C can be observed between the sunshine and the shade under the trees. Note that the MRT may or may not include solar radiation. The state of thermal radiation received from the surroundings is visually readable, even from a spherical thermograph (shown in Fig. 10.12), which can be obtained using a special thermal infrared camera.

10.2 Creating Cool Spots in a City Full of Heat

10.2.1 What Is a Cool Spot?

In a hot and humid climate like that of a Japanese summer, how can the state of being cool in external space be defined? Torahiko Terada, a Japanese physicist in the early 1900s, memorably described the sensation of coolness in Japan's muggy summer as unsteady and ephemeral: "Coolness is a momentary sensation, and if it lasts, it will turn into cold."

In physiology, a five-point scale consisting of hot, warm, neutral, cool, and cold sensations is often used to evaluate indoor thermal sensation. This evaluation scale is targeted at a nearly steady indoor thermal environment that varies slowly along a single dimension from hot to cold. However, the sense of coolness in the muggy summer of Japan is not a one-dimensional evaluation.

The conditions of the environment that can be used to improve coolness include

- An air temperature lower than the surroundings.
- A moderate feeling of airflow (not constant but fluctuating).
- Cold radiation from the surroundings.
- Low relative humidity (this is most effective when the air temperature is 28 °C or higher).

Design criteria that can improve coolness include

- Thoroughly shielding intense solar radiation from entering the ground and buildings by shading outdoor living space from the sun.
- Aligning urban development with wind direction to promote ventilation through street and building layouts as well as ensuring tree crowns that are sufficiently high to allow the wind to pass beneath.
- Installing greening features such as plants to promote transpiration, enabling evaporation from wet ground surfaces, and providing cold storage shaded and exposed to the passing wind.

In the environmental design of a city, it is not beneficial to simply apply as many of these methods as possible, but rather it is important to devise a way to effectively combine these measures such that synergistic effects are realized. To do so, one can imagine "gently wrapping the ground and buildings in green, and at least in the residential areas, living under the crowns of large trees."

10.2.2 How to Create Cool Spots

To create a cool spot in the city, it is important to provide thorough shading from sunlight and moderate ventilation. Because the properties of cool spots have been

clearly defined, specific cooling methods and their effects can be discussed quantitatively.

Methods for cooling include evaporative cooling, utilization of the earth as cold storage and a cold source, atmospheric radiative cooling, etc., as well as their combined effects. However, the effects obtained by these cooling measures are not as large as the heating effects of solar radiation. In quantitative terms, the thermal radiance associated with methods such as evaporative cooling or atmospheric radiative cooling is only about one-tenth of the solar radiation received by the ground in summer, which is close to 1000 W/m^2. Indeed, a difference of approximately 100 W/m^2 results in dew or frost on the ground in the early morning.

Evaporative cooling and atmospheric radiative cooling are effective when the temperature of the surfaces surrounding a human body can be lowered to below the air temperature. The amount of air that can be cooled by evaporative cooling can be obtained using psychrometric charts. For example, the wet-bulb temperature given an air temperature of 33 °C and a relative humidity of 50% is 24.5 °C, and the temperature of a sufficiently moist surface is almost equal to this value unless that surface receives heat, such as solar radiation, from its surroundings. However, when the relative humidity is 75%, the temperature of this surface can be decreased only to 29 °C.

Indeed, in hot and humid climates such as the Japanese summer, evaporative cooling and atmospheric radiative cooling cannot be expected to have an effect equivalent to that in dry desert areas owing to the large quantity of water vapor in the atmosphere. However, there is no doubt that water discharge in the early morning or after sunset, as practiced in traditional Japanese life, is an effective method of providing coolness through evaporative cooling.

10.3 Towards Pleasant and Refreshing City Planning

Is not the morning dew that shines brightly in early morning sunshine a barometer that indicates a pleasant and refreshing cityscape? However, the city is typically not a pleasant or refreshing environment, as it often comprises faces whose surface temperatures do not fall below the air temperature even in the early morning, such as in building canyons where the sky, which can serve as a huge cold source, can hardly be seen and the paved ground surface has sufficient heat capacity to store solar heat during the day that lasts all night.

The urban environment consists of buildings and ground, as well as the various phenomena related to the microclimate formed among them depending on the pavement, layout and shapes of the buildings, the materials of their roofs and walls, as well as the type of plantings and the shape of their crowns and arrangements. Indeed, paved roads and reinforced concrete buildings receive sunlight during the day and absorb plenty of solar heat, radiating it into the atmosphere through the night and into the early morning, creating sultry conditions even in the darkness.

Modern measures to prevent fire in areas where wooden buildings are densely clustered have unsurprisingly created a safer environment that is nonetheless hot and difficult to live in. Indeed, the urban heat island manifests itself in cities that increasingly consist of reinforced concrete construction, where shadowed spaces created by narrow alleyways have become paved parking lots, open to the sun. In the cities of Southeast Asia and located at relatively low latitudes in China, these conditions must be addressed to realize a comfortable outdoor environment for activities, a comfortable indoor environment, and improved energy conservation.

In an early 1900s novel, Japanese author Kafū Nagai evokes the appearance of dramatic changes in cityscapes, such as those observed in downtowns as Japan advanced into the Meiji and Taisho eras. Trees were cut down, reinforced concrete buildings were erected, and roads were paved. However, there remain remarkable aspects of the Edo period of the mid-1800s or earlier. Considering this, it seems that the common conception of the urban environment as overcrowded with concrete cuboids is less than 100 years old.

What does it mean to plan comfortable and healthy cities that have the small environmental load required in this age of global environmental awareness? From the viewpoint of the thermal environment, city planning can reduce the likelihood of heatstroke by eliminating the urban heat island. Indeed, the main cause of the urban heat island is modern city planning. However, as already pointed out, cities are by nature full of heat. Considering the Japanese summer in the subtropical zone, Japanese author and Buddhist monk Yoshida Kenkō stated in his early thirteenth-century essay "Tsurezuregusa," "A house should be built on a basis considering a summer. And a winter. . . ." This remains true for modern urban planning. Therefore, it is important to consider the criteria for environmentally symbiotic city planning and a specific future for the city that accommodates its climate.

The necessary approach to thermal environment design could include regionality, space, and material aspects. That is, it is critical to design the ground, roofs, and walls that constitute the building's external space according to the regional climate. Indeed, effective methods for improving the thermal environment are strongly related to the characteristics of the local climate. The basis of an environmentally symbiotic thermal environment design is an understanding of climate characteristics and the potential of the land. For example, the climate characteristics are as different between Okinawa, the southernmost prefecture in Japan, and Hokkaido, the northernmost prefecture in Japan, as they are between coastal and mountainous areas. The difficulty of thermal environment design is that it must respond to both the cold of winter and the heat of summer, which may also include considerable humidity, except in parts of Hokkaido and the Tohoku region, in northern Japan. The design criteria for cool spots under such hot and humid climates have already been described. These criteria are based on the heat exchange between a heat-radiating body and a surface whose temperature is lower than the air temperature, which is an important factor in providing thermal comfort. The air in contact with a heat-radiating body is heated, then cooled when it contacts a cool surface, creating a cool spot with air circulation.

10.4 Case Study: Thermal Environment Design and Visualization of Urban Planning in Tsuchiura

In this section, the small-to-medium urban region around Tsuchiura station in Ibaraki prefecture, located in the Greater Tokyo Area, is considered as a case study to describe the process of utilizing the numerical simulation for the visualization of thermal environment design at the city planning stage. To do so, the current thermal environment of the city is first evaluated by discussing the features of city planning while considering the development history. Next, an improvement strategy is proposed to create a more comfortable thermal environment, and its effectiveness is evaluated through simulation. In this manner, the proposed thermal environment is first evaluated from a historical perspective, and the availability and effectiveness of efforts to improve the thermal environment are then confirmed.

10.4.1 Development History and Current State

As in other small and medium cities, the urban area around Tsuchiura station has experienced a decrease in the overall population and an increase in the percentage of elderly residents. As a result, problems in the center of the city include an increase in the number of open parking lots and vacant houses. Meanwhile, high-rise condominiums have been constructed to redevelop the area around the station; thus, low-rise cityscapes and high-rise buildings are adjacent to each other. However, historical buildings remain around the castle ruins park and along the ancient road.

10.4.2 Proposed Utilization of Vacant Lots and Prediction and Evaluation of Thermal Environment

The creation of pocket parks containing tall trees is proposed to utilize the vacant lots in Tsuchiura. This approach capitalizes on the historic character of the city to provide comfortable outdoor spaces for visitors and residents while reducing the prevalence of parking lots typical of modern society. Together with the installation of roadside trees in the street space, this creates a lush cityscape through greening.

To determine how this greening will change the thermal environment, the present and predicted thermal environments are compared in Fig. 10.13 along with the corresponding 3D CAD models.

The left side of the top row in Fig. 10.13 shows the model of the current situation, which consists of a house next to a paved parking lot; the right side shows the proposed plan, which changes the parking lot surface into water-retentive pavement and grasses with the large-crown trees overhead. The middle and lower figures show the corresponding surface temperature distribution and MRT at 1.5 m above the

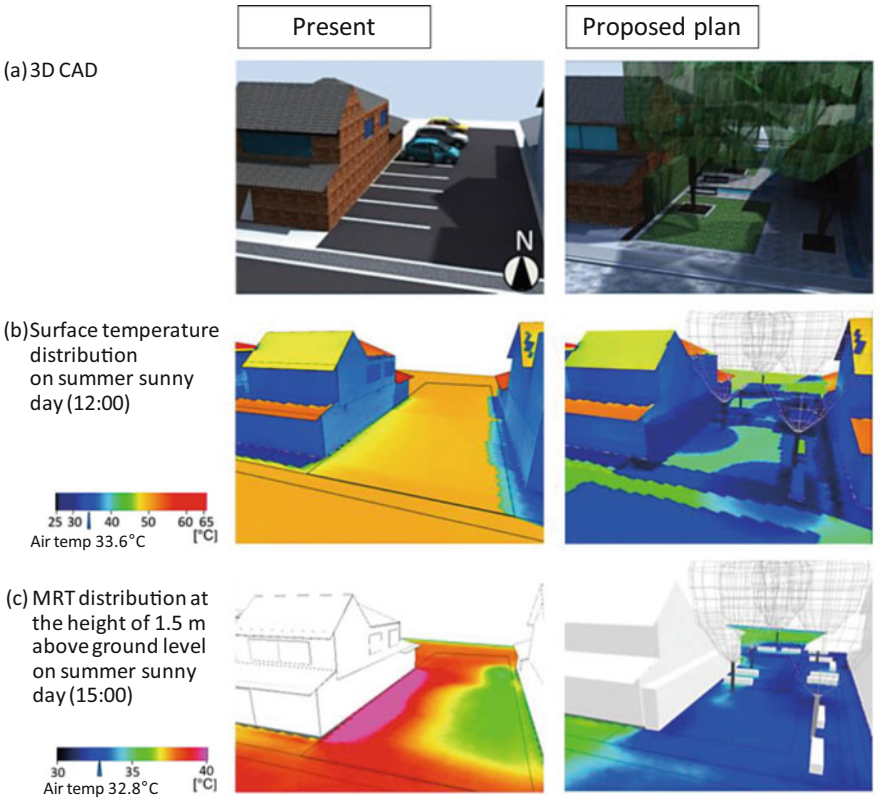

Fig. 10.13 3D CAD and visualization simulation comparing the thermal environment according to vacant lot use on a sunny summer day

ground, respectively, at 12:00 on a sunny summer day. Comparing the MRT values in the current situation with those in the plan, it can be observed that the implementation of greening decreased the MRT closer to the air temperature. In the space under the tall trees, the ground is shaded from solar radiation by large tree crowns. The evaporative cooling effect obtained by sprinkling water on the water-retentive pavement surface further lowers the ground surface temperature to approximately 3 °C below the air temperature. As a result, it can be seen that the MRT is maintained at or below the air temperature and that a large space is provided where the thermal radiation environment is considerably improved. Thus, the thermal environment simulation method allows for the comparison of a proposed plan against the current situation, quantifying the change in MRT according to location and thermal environment improvement method.

Because the visualization method is able to provide images of both the future city as well as its thermal environment, the proposed changes can be easily evaluated, informing discussions on the visible cityscape. It is expected that such visualization

will promote discussions regarding the invisible thermal environment and enable the development of higher-quality environments.

10.5 Conclusion

In Chaps. 9 and 10, the thermal environment of the city was visualized using surface temperatures. This thermal environment is created by the spatial form and materials of the city, and as such can be improved through careful evaluation and selection of materials, space, and design features. The simulation method demonstrated in this chapter provides an approach for the evaluation and discussion of such designs.

Further Reading

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Chapter 11
The Key to Comfortable Space Design

Mikiko Kumamoto, Mototsugu Yanagida, and Yasuhiro Kawahara

Abstract Evaluation of the comfort of space is essential when designing urban areas. Many studies have attempted to objectively evaluate the mind, including psychophysiological methods in which participants were instructed to wear instruments that may have become stressors, potentially interfering with the interpretation of the results. Therefore, in the current study, we attempted to evaluate emotion using thermography, which does not require the use of instruments, is noninvasive, does not impose physical limitations, and can measure nasal skin temperature from a position away from an individual. The results revealed that the nasal skin temperature decreased when stress levels rose; however, the temperature rose when the stress level decreased, that is, during the psychological recovery phase. These findings suggest that by examining these relationships, it is possible to estimate increases and decreases in stress levels by measuring nasal skin temperature using thermography. Furthermore, we introduced experimental results regarding psychological changes in the living environment and discussed the possibility of applying this evaluation method to comfort evaluations in urban design.

Keywords Comfort evaluation · Psychophysiology · Thermography · Nasal skin temperature · Stress evaluation · Emotional estimation

11.1 Introduction

People's minds are formed through their daily lives, and they act according to their minds. Living behaviors are greatly influenced by psychological factors as well as economic, cultural, and social factors. Therefore, when asking for better living

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behavior or preparing a living environment, it is important to know people's minds. This is common when trying to improve the living environment of individuals and when designing urban areas. Currently, urban-environment comforts are evaluated by monitoring the thermal and noise environments. However, these methods of evaluation include questionnaires and interviews, behavioral observation, and measuring physiological conditions in that environment, based on the three reaction systems of people's minds proposed by Lang et al. (1983)—verbal/cognitive, behavioral, and physiological. Verbal/cognitive responses can be examined using survey questionnaires (Venham and Quatrocelli 1977; Yoshida 1988); however, self-report instruments are problematic due to cognitive limitations. Behavioral responses can be examined through behavioral evaluations, but these methods tend to be dependent on the observer's subjectivity and require training and experience for accurate evaluations (Frankl et al. 1962; Nakai 1996; Venham and Quatrocelli 1977). Given the limitations of these two methods, a physiological index of autonomic nervous system induction could provide a more objective evaluation if such an index could be established.

Heart rate, pulse wave, galvanic skin reflex, and hand or face skin surface temperature have been measured as psychophysiological indicators (Venham et al. 1977; Simpson et al. 1974). However, individuals are obliged to wear instruments to collect these measurements, which could become stressors themselves, hindering the accurate interpretation of the results. Therefore, in this study, we attempted emotion evaluation using thermography, which does not require the use of instruments, is noninvasive, does not impose physical limitations, and can measure skin temperature from a position away from the subject. In this paper, we introduce our research on this method of emotional evaluation using thermography and further describe its applicability to the evaluation of comfort in urban design.

11.2 Construction of Emotional Evaluation System Using Thermography in Laboratory Condition

The construction of an emotion evaluation system using thermography was led by Dr. Shimono Tsutomu in the Department of Behavioral Pediatric Dentistry, Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama University. Understanding the state of a dental patient's mind is essential for safe and smooth dental care; thus, developing a method to objectively evaluate patients' psychological states during dental care is necessary.

In a previous study, Taguchi (1994) measured the facial temperature of adults and children receiving dental care and found a correlation between heart rate and the temperature of the nose, left and right forehead, and cheeks. The highest correlation was found for the nose. Interestingly, in adults, the ratio showing a negative correlation was high, whereas, in children, it showed a positive correlation. Nakai (1996) revealed the relationship between the behavioral evaluations of children and

nasal skin temperature. Yoshida (1988) examined the relationship between state anxiety before dental care and nasal skin temperature during dental care, showing a relationship between psychological state and nasal skin temperature.

Although many reports have estimated psychological state by nasal skin temperature measurement using thermography, little research has examined the recovery process from the stress state. Correctly judging a patient's recovery from a stressful experience in an actual dental care context is essential for accurately judging the timing for resuming appropriate care after alleviating the patient's stress. Therefore, a stress evaluation method must be constructed that can be utilized throughout the entire dental care process, including before and after dental care. Moreover, the relationship between psychological states and nasal skin temperature is critical when constructing a stress evaluation method; however, at this time, it is not desirable to create unexpected stimuli other than the stimulus loaded in the experiment.

Therefore, we examined the relationship between psychological state and nose skin temperature, including the stress recovery period in the laboratory where the environment is sufficiently controlled, to establish a method for estimating a patient's psychological state using nasal skin temperature measurements from thermography during the entire dental care.

The participants included 42 adults (7 men, 35 women) who agreed to participate in the experiment with an average age of 26.5 years (SD = 9.0). The temperature and humidity in the laboratory were maintained at 25 °C and 40%, respectively, without noise and wind. Participants received an explanation of the experimental procedure approximately 10 min after entering the room, resting for 10 min to fully acclimate their body temperature to the indoor environment and stabilize their psychological state.

The experimental procedure began with participants continuing to remain in a resting state for 5 min. A researcher then placed 2 × 3 × 4 cm ice blocks in both hands of the subject as a stressor, and ice stimulation was started on the palm. This stimulation continued for 5 min, after which the ice was collected from the participants. After releasing the ice, the participants were allowed to rest for 10 min.

After the experiments, changes in perception levels and psychological state caused by the ice stimulus during the experiment were investigated using a Time Series Visual Analog Scale (T-VAS) for "coldness," "pain," and "stress." As a result, all levels of "coldness," "pain," and "stress" significantly increased at the 0.1% level due to ice stimulation (Fig. 11.1). This elevation began to decrease with the cessation of ice stimulation. Ten minutes after the ice stimulation ended, the "stress" level decreased to a level that was not significantly different from before. "Coldness" and "pain" levels remained significantly higher at levels of 0.1% and 1%, respectively, than the levels before ice stimulation, but when compared with levels during the ice stimulation, both were lower at the 0.1% level.

Furthermore, participants' anxiety levels due to ice stimulation were investigated using the State-Trait Anxiety Inventory (STAI). The survey was administered once in a separate room before the experiment, and it was completed again after the experiment. Participants completed the questionnaire after the experience regarding their anxiety level during the period of ice stimulation. Anxiety levels significantly

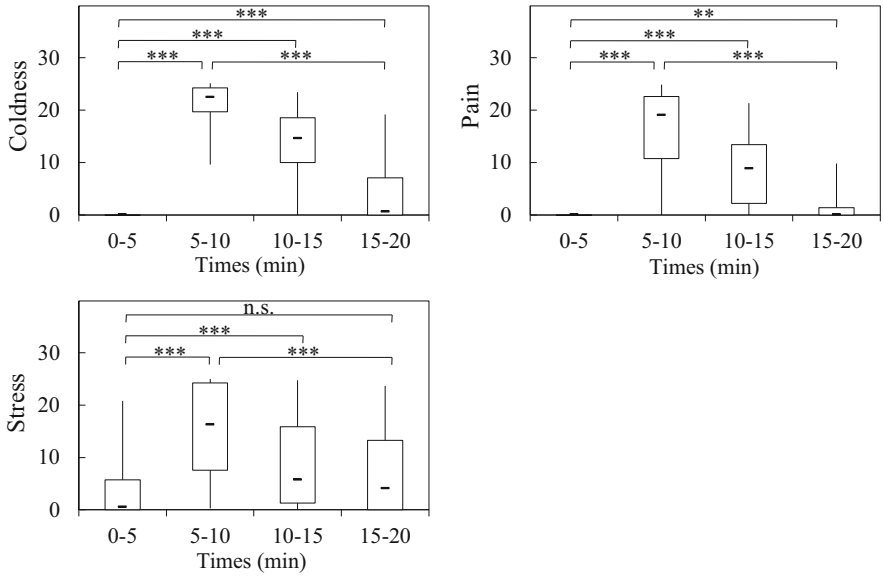

Fig. 11.1 Changes in perception levels and psychological state caused by ice stimulus. $^{**}p < 0.01$, $^{***}p < 0.001$, *n.s.*, not significant

increased at the 0.1% level during the ice stimulation and decreased to a level that was not significantly different from the pre-stimulation levels by the end of the ice stimulation (Fig. 11.2).

Measurements of nasal skin temperature, a physiological index of stress reaction, were performed with thermography. A thermograph (Thermovision 570®, AGEMA) was set so that the participant's face was approximately the same size as the thermogram. The measurement interval was set at 10 s. In the analytic software (Irwin OLE 1.01® manufactured by AGEMA Corporation), the measurement point on the thermogram was the tip of the nose, the measurement area was a 16-dot (4 × 4) square, and the average temperature was obtained. Typical change patterns and thermograms of the participants' nasal skin temperature are shown in Fig. 11.3a, b. The data in which the measurement variable was non-normal or heteroscedastic were analyzed using the nonparametric Friedman's method. Post hoc multiple comparisons were performed using the Wilcoxon signed-rank test with Bonferroni correction. No significant differences in temperature were observed at the beginning of the experiment and after the first rest was maintained for 5 min (Fig. 11.4). Simultaneously with the start of the ice stimulation, participants' temperatures began to decrease, and when the stimulation ended, it was significantly lower at the 0.1% level than at the start of the experiment. After the stimulation was stopped, the temperature started to rise, and 10 min after the ice stimulation, there were no significant differences from the start of the experiment.

These results suggest that when perception levels of coldness and pain, and anxiety levels increased, the nasal skin temperature simultaneously decreased,

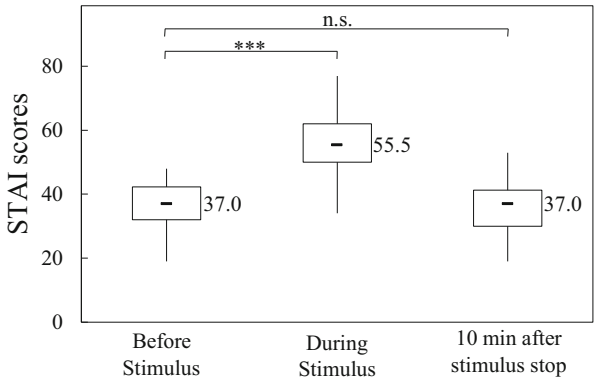

Fig. 11.2 Changes in Anxiety levels caused by ice stimulus. *** $p < 0.001$, *n.s.*, not significant

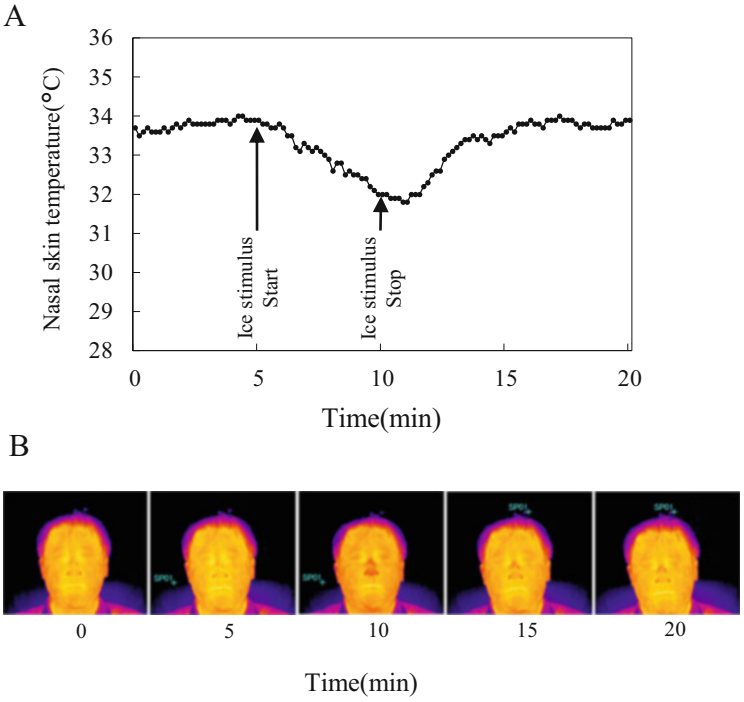

Fig. 11.3 Typical change patterns of the participants' nasal skin temperature caused by ice stimulus (**a**) and the thermograms (**b**)

consistent with previous research reporting decreases in nasal skin temperature during stress decreased over time in the psychological recovery period after the cessation of ice stimulation, the nasal skin temperature began to rise simultaneously and reached the temperature at the start of the experiment. These results suggest that

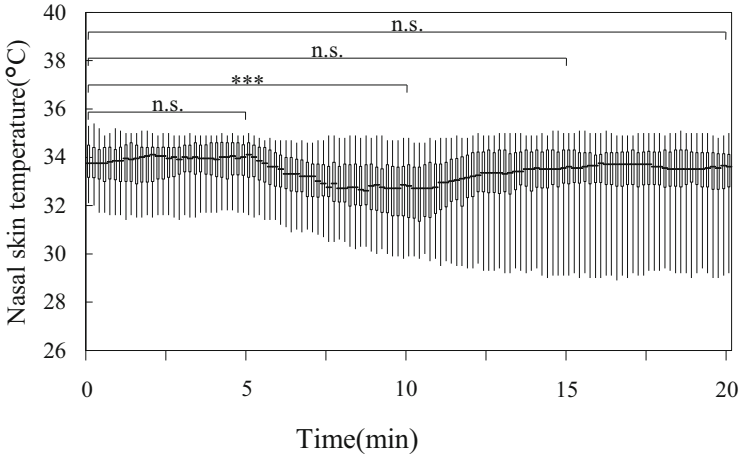

Fig. 11.4 Changes in nasal skin temperature caused by ice stimulus. *** $p < 0.001$, n.s., not significant

by examining these relationships, estimations of the increase and decrease of pain and anxiety are possible using thermography measurement of nasal skin temperature.

The activity of the autonomic nervous system, accompanied by psychological changes, expands and contracts the blood vessels, and skin blood flow mainly affects skin temperature. Specifically, nasal skin temperature primarily reflects changes in blood circulation in the peripheral circulatory system due to autonomic nervous system activity since the nasal vasculature runs through the gap between the skin and nasal bone, whereas in other parts, it runs under the fat layer. Thus, nasal skin temperature effectively reflects changes in blood flow in the peripheral circulatory system. Second, it is concentrated in the nose at the arteriovenous anastomosis (AVA). AVA is a shunt mainly formed between arterioles and venules that regulate surface capillaries' blood flow, the main factor affecting skin temperature change. Since this regulation is dominated by the autonomic nervous system, nose skin temperature markedly reflects vasoconstriction due to autonomic nervous system activity. Thus, information on autonomic nervous system activity due to psychological load can be obtained by measuring nasal skin temperature.

11.3 Nasal Skin Temperature Measurement and its Simplification in an Environment Similar to Practical Use

A barrier to applying this evaluation method in an actual environment is the need for continuous measurement and the length of time required to determine changes in nasal skin temperature. Therefore, this method of stress evaluation must be improved

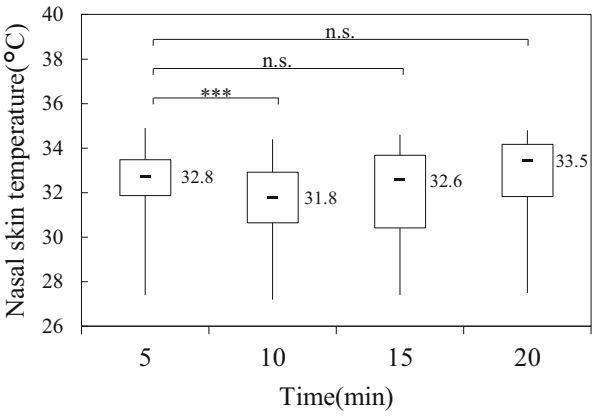

Fig. 11.5 Changes in nose skin temperature at four points to assess the participants's psychological state through ice stimulation. *** $p < 0.001$, *n.s.*, not significant

before it can be put into practical use. Furthermore, in dental clinical care, stressors other than dental care are present, and it is unknown whether the relationship between the psychological state and the nasal skin temperature identified in laboratory experiments can be maintained. We believe that clarifying this point in an environment similar to clinical practice could enhance its applicability. Therefore, changes in the psychological state were estimated by comparing nasal skin temperature between arbitrarily selected time points in an environment similar to the clinic.

The participants included 56 college students (27 men; 29 women) who agreed to participate in the experiment. The temperature and humidity in the laboratory were maintained at 25 °C and 40%, respectively. Unlike in the previous experiment, participants could see other people's movements and hear voices, making the environment more similar to the clinic. This experiment measured nose skin temperature at four points to assess the participants' psychological state through ice stimulation. The points were "the start of ice stimulation," "the end of ice stimulation," "5 min after ending ice stimulation," and "10 min after ending ice stimulation." The explanation of the experiment, the procedure for acclimatization, T-VAS, and STAI were conducted identically to the previous experiment.

The results of the T-VAS and STAI were similar to those of the previous experiment. At the end of the ice stimulation, the nasal skin temperature was significantly lower at the 0.1% level than at the start of the ice stimulation (Fig. 11.5). The temperature 10 min after ending the ice stimulation did not significantly differ from the start of the ice stimulation.

These results showed that nasal skin temperature significantly decreased when participants reported strongly feeling pain and anxiety than before the ice stimulation. When recovering from pain and anxiety, the temperature rises and reaches the temperature before ice stimulation. Therefore, these results suggested that changes in participants' psychological condition at any given point in time could be estimated by comparing the first and last nasal skin temperatures. In addition, this can be evaluated even in situations where there are extraneous human movements and

voices, increasing the possibility for clinical applications. Thus, changes in psychological state can be estimated, for example, by measuring the nasal skin temperature once before a medical examination and performing measurements at time points during the medical treatment when it is desirable to know the patients' psychological state. Alternatively, if one measures the temperature when the patient is extremely stressed, an interval for recovery is necessary before the measurement can be repeated to determine whether the patient has really recovered.

Patients' actual psychological states before dental care are unlikely to be identical to the initial rest state in this experiment and are likely to be periods of psychological stress that include anticipatory anxiety. In particular, the nasal skin temperatures of patients with strong stress tendencies greatly decrease before dental care, and further decreases in temperature due to stress from dental care may not be observed. However, in such cases, it is important to know how relaxed patients are when many patients feel relaxed while waiting and acclimating to the room's atmosphere by communicating with the dentist than how much stress they feel after arriving. At this time, the nasal skin temperature can be used as an index.

The dentist must manage stress throughout dental care. In particular, whether a patient released from a stressful situation can quickly reach a state of relaxation after dental care is an important criterion for deciding the success or failure of the care. Recognizing patients' psychological states has been measured previously through behavioral observation; however, this method relies on the observer's experience. Considering this, objective evaluations of patients' psychological states using nasal skin temperature measurement from thermography could be an important tool for future stress management.

11.4 Application of an Emotional Evaluation System Using Thermography in a Living Situation

We moved our research location to Department of Psychology & Human Life, Sanyo Gakuen University to study the evaluation of both emotions in dental care and typical living situations. We attempted to more objectively evaluate changes in the mind caused in daily life to approach the philosophical question, "What is people's happiness?" At that time, the emotion evaluation system using thermography was considered one of the most effective tools; however, many psychophysiological measures were being used in stress research, but few focused on daily life situations. This may be a reason why there are few application examples of such emotion evaluation systems. Thus, we introduced emotion evaluation using thermography, which we evaluated across several living scenes.

11.5 Verification of the Relaxation Promoting Effect of Eye Masks

Experiments were conducted to clarify whether recovery could be promoted by introducing a relaxation method at the recovery stage of the stress state. In this experiment, a thermal-type steam eye mask was used as the relaxation method. Eighty participants were given work stress before using the eye mask for 10 min to investigate the eye mask's effect during the recovery period following the stress load. As a control group, 75 participants were given the same stress and rest without using an eye mask. The temperature of the left thumb pulp was measured at the "stress load start," "at the end of the stress load (i.e., when starting to use the eye mask)," and "at the end of using the eye mask." In this experiment, the measurement site was not a nose but a finger due to the potential influence of the heat from the thermal-type steam eye mask.

A temperature decrease was observed for both groups after the stress loading, with no significant difference observed between the groups (Fig. 11.6). No temperature recovery was observed in the control group, but in the group that used the eye mask, the temperature recovered to the levels observed at the start of the stress load. After the experiment, participants were asked whether they were able to relax. In the control group, many responses indicated, "I could not relax," but in the group who used the eye mask, many responses, such as "I was relaxed" or "it felt good," were obtained. These results showed that using the eye mask effectively induced relaxation, suggesting that the induction effect could be estimated using thermography to measure nasal skin temperature.

11.6 Can We Also Estimate the Preference of Cheese?

There are individual differences in food preferences, but the evaluation of these preferences is mainly based on a functional evaluation. In this study, we conducted an experiment to clarify whether psychological changes due to food preference and taste can be evaluated using thermography.

There were seven participants (1 man, 6 women), with an average age of 21.6 years (SD = 1.07). Two types of cheese were prepared as the food stimuli that could cause different psychological changes. Cheese A contained a high percentage of fat and was considered to be relatively easy to eat, with a creamy and rich flavor. Conversely, Cheese B has a strong flavor and strong salty taste.

The experimental procedure began with the participants remaining in a resting state for 20 min. Next, they ate Cheese A sandwiched between crackers and rested for 10 min. Then, they ate Cheese B and continued to rest for 10 min. After the experiment concluded, we investigated the participants' experiences with a survey that rated the two kinds of cheese on a 5-point scale with 1 = "bad" and 5 = "delicious."

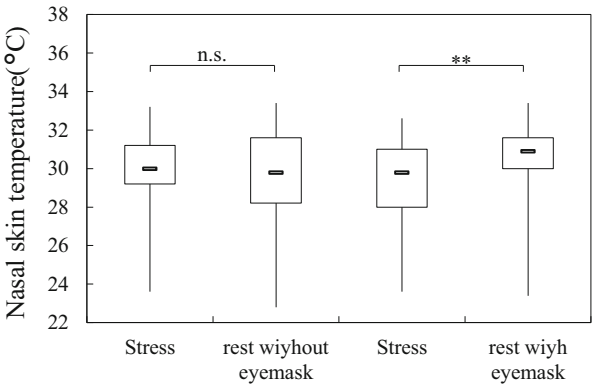

Fig. 11.6 Changes in nose skin temperature in rest with/without eyemask. *** $p < 0.001$, *n.s.*, not significant

Participants 1–6 reported that Cheese A was "delicious" or "somewhat delicious," and Cheese B was "bad" or "somewhat bad," indicating similar preferences for Participants 1–6. Conversely, Participant 7 answered, "somewhat bad" for Cheese A and "bad" for Cheese B, which was a different evaluation from Participants 1 to 6. From a further interview, it became clear that Participant 7 disliked cheese.

Next, the data for Participant 5 are shown as a typical change pattern for the nasal skin temperature of Participants 1–6 (Fig. 11.7). During the rest period after the start of the measurements, the nasal skin temperature was generally stable. Then, when Participant 5 began eating Cheese A, the temperature began to decrease. Even after eating, this decrease continued, but then the temperature began to rise. Next, when eating Cheese B, the temperature began to decrease again. Differences were observed in the amount of temperature decrease when eating Cheese B compared to Cheese A, which means that when eating Cheese B was greater. Together with the results of the questionnaire, the nasal skin temperature decreased when eating Cheese A, which was described as "delicious" or "somewhat delicious," and when eating Cheese B described as "bad" or "somewhat bad," the temperature showed a greater decrease.

Next, the nasal skin temperature of Participant 7 began to decrease when Cheese A was eaten (Fig. 11.8), which continued even after eating. Then, the temperature did not increase, unlike what was observed for Participant 5. In addition, when Participant 7 ate Cheese B, the temperature further decreased. The reason that temperature recovery was not observed after eating Cheese A in Participant 7 may be related to the fact that Participant 7 indicated that Cheese A tasted "somewhat bad." Further research is needed to clarify the psychological conditions caused by food preference and taste with nasal skin temperature measurements using thermography.

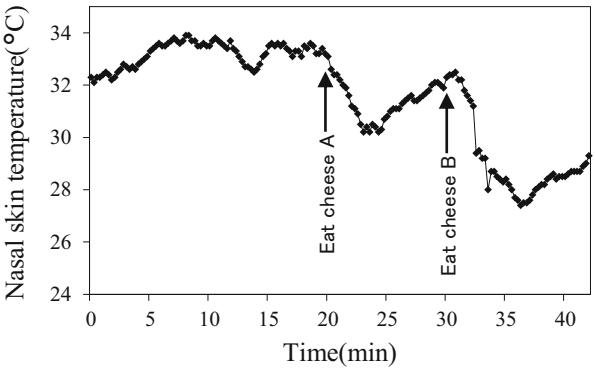

Fig. 11.7 Typical change pattern for the nasal skin temperature of Participants 1 to 6 who like cheese A and dislike cheese B

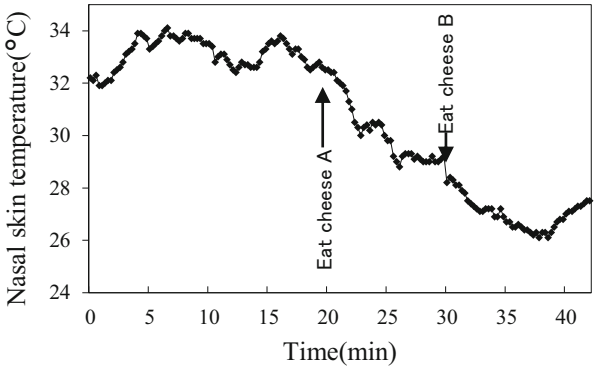

Fig. 11.8 Change of the nasal skin temperature of Participants 7 who dislikes both cheese A and B

11.7 Do You Change Your Mind with the Clothes You Wear?

We know experientially that clothing has a psychological effect. When people put on their work clothes every morning, their motivation for work emerges. When they complete work and take off their work clothes, they become relaxed. Even when work is over, wearing work clothes could make individuals remain nervous and have difficulty relaxing. Therefore, in this study, we performed experiments to determine whether the psychological changes caused by wearing work clothes could be evaluated by measuring the nasal skin temperature with thermography. In this experiment, participants wore suits as work clothes and casual attire as their relaxing clothes.

The experimental environment was maintained at a temperature of 25 °C with a humidity of approximately 50%. Participants included seven college students who agreed to participate in the experiment. We told the participants the schedule for the

entire experiment for approximately 15 min after they entered the room. They acclimatized their body temperature to the environment and rested to stabilize their psychological state. The experiment began with participants resting while wearing casual attire for 10 min. They then changed into a suit and rested for 15 min. Next, they changed back into their casual attire and rested for 15 min. After the experiment, we interviewed the participants.

Three of the seven participants responded that they were nervous after changing from casual attire to a suit. Their nasal skin temperature was stable while wearing their relaxing clothes, and a transient temperature decrease was observed after wearing the suit. Their temperatures recovered quickly but did not reach the temperature while wearing casual attire. When wearing their relaxing clothes again, a temporary temperature decrease was identified, as in the case of wearing a suit, it began to recover immediately. It maintained a stable higher temperature than when wearing a suit. However, the nasal temperature for the four students who reported feeling no change when wearing a suit did not significantly differ between wearing relaxing wear and a suit.

From these results, individual differences in the psychological changes caused by wearing a suit were found, and when the participants experienced stress, their nasal skin temperature decreased. Furthermore, when participants changed to casual attire again and felt relaxed, the decrease in nasal skin temperature recovered.

11.8 Relax in Comfortable Outdoor Spaces

In the workplace environment, wasteful things have been eliminated so that employees can fully concentrate on work, and the color schemes are often monotone (recently, light colors are often used). Desk work is completed silently indoors, and when people become tired, they may go outside for some fresh air. For example, individuals who visit a park surrounded by greenery may take a deep breath upon arrival, helping their weary brain recover. Individuals may be healed by observing trees covered in green in the park or seeing children playing. In this way, it is possible to change the environment and prepare it according to the purpose of daily life behavior. However, if this environment setting is mistaken or the environment itself does not exist, our actions are limited and inefficient. For example, no unusually colored objects are necessary for those who seek relaxation and healing in the park. In addition, for those who want to be energized, blue lights may have a calming effect. Therefore, when creating an environment, it is essential to understand people's psychological states as the subjects of action in the environment. Therefore, we conducted an experiment to study whether emotional evaluation using thermography could be performed under different circumstances.

A participant did desk work for 2 h from 10 a.m. to 12 p.m. without a break. At that time, facial skin temperature was measured using thermography. Then, the participant visited an outdoor garden and remained at rest for 15 min, and facial

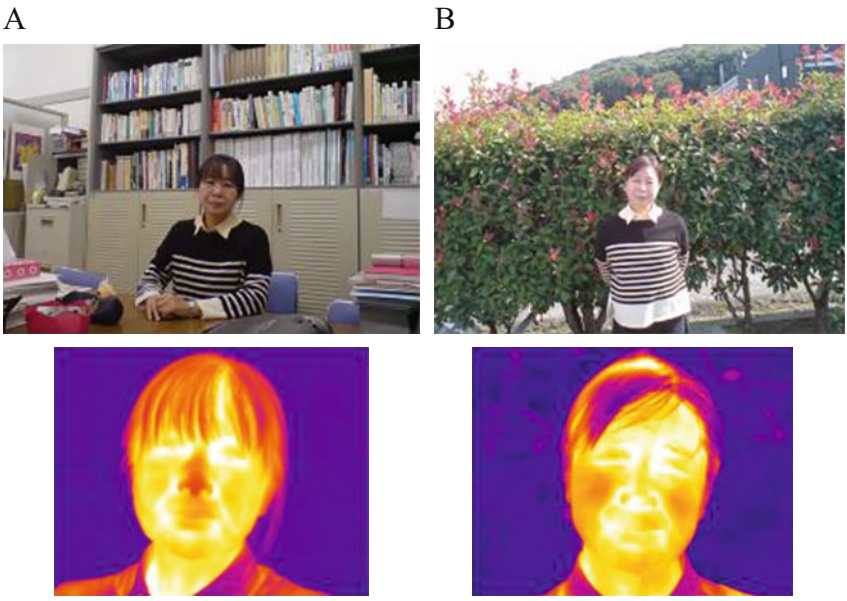

Fig. 11.9 Photographs and thermograms in deskwork (**a**) and in rest (**b**)

skin temperature was again measured using thermography. We also interviewed the participants about their psychological state.

After the desk work was completed for 2 h without a break, there was a temperature difference between the nose and the chin, which was 5.6 °C lower on the nose (Fig. 11.9). However, when the participant visited the garden and rested, this difference disappeared, and the chin temperature had lowered. In the preliminary examination, the chin temperature showed little change at the time of the psychological change. In the interview, the participant reported feeling highly stressed at the end of the desk work and feeling that relaxation was possible by visiting the garden and resting. Given these results, the possibility of evaluating emotional changes across environments by examining the temperature differences between the nose and chin using thermography was suggested.

11.9 Evaluation of Comfort in a Town's Environment

As we have described, monitoring the stress states of people using a thermo-camera could be viewed as a practical technology in a town environment given the low pricing of thermo-cameras and the rapid advancement of image processing technology. The monitoring technology of pulse waves in facial image processing has become a technology available for practical use. Measuring the order of time is necessary to grasp the autonomic nervous system activity, and analysis using

temperature measurements has the advantage of being immediately available. The amygdala, which is deep in the brain, is also known to be involved in processing emotions, including the judgment of pleasant discomfort. Thus, the degree of activity of the deep brain network, including the amygdala, could be determined by analyzing the alpha wave rhythm of the EEG (Omata et al. 2013), and it could be used to monitor daily personal comfort.

Feelings of comfort in a town environment likely differ according to emotion. For instance, an experiment studying the acceptance of a stimulation differed by differences in participants' emotional states, even when experiencing the same environmental stimulation. In that study, participants listened to the same sound stimulus (i.e., chords), and their cognitive reactions were measured by EEG when they were in two different emotional states (i.e., fun and sad). The results showed that the same sound stimulations were recognized to different degrees according to different emotional states (Kawahara et al. 2014). When judging the comfort of a town's environment, judgments must be made according to the users' situation, including their emotions, and the presence of physical information (e.g., the hot–cold and the sound environment), which can be related to differences in the degree of recognition depending on a user's emotion.

The comfort of a space is related to numerous factors based on a user's viewpoint of the space. A space's comfort for a user may change by the social environment (e.g., what kind of person you are with, what purpose you are there for). For example, if you are chatting and drinking with a likable person in a slightly cold space, the situation where the cold temperature causes discomfort becomes difficult to recognize due to the effects of the social environment. In other words, the space in which a user feels comfortable within a town environment is created by synthesizing the space's physical factors and the user's physiological and social factors. The comfort of a space dynamically changes with time and the user's situation. Reports evaluating a space's comfort in both the laboratory and the room have been collected. There have been ongoing discussions about creating a comfortable environment or situation across different fields, and the results are accumulated. When considering the comfort of a town space, the comfort of the space should be evaluated while recognizing the influences of the user's situation.

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Chapter 12
Measuring Brain Activities in the Real World

Yasushi Naruse

Abstract Until now, brain activity measurement has been performed in an experimental environment in the laboratory. However, recent advances in EEG devices have made it possible to measure brain activity in the real world. Humans often act on the basis of unconscious brain activity. By using such an advanced EEG device, it has become possible to visualize unconscious brain activity in the real world. For example, by visualizing and increasing unconscious brain activity related to sound processing, it is possible to distinguish sounds that could not be distinguished. Furthermore, unconscious brain activity related to mental workload can be visualized by using an advanced EEG device.

Keywords EEG · Wearable device · Real world

12.1 Introduction

Electroencephalography (EEG) is a method to noninvasively measure brain activity; it was established approximately 90 years ago. Various studies conducted worldwide have shown that it is possible to extract nonverbal or unconscious information from the brain using EEG data. However, stable measurements using conventional EEG systems may not be possible because EEG data are significantly weak, in the order of μV. Therefore, EEG measurements should be conducted in environments that are not subjected to electromagnetic noise, such as laboratories and hospitals; further, EEG data should only be acquired by technicians or researchers with the relevant skills. In recent years, technological advances have enabled the acquisition of real-world EEG data. In this chapter, we introduce a wearable EEG system that can measure brain activity in a real-world setting, and then we describe the results of studies where the wearable EEG system was employed.

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12.2 Wearable EEG System for Measuring Brain Activity in Real-World Settings

12.2.1 EEG Measurement with Conventional EEG Systems

It is impossible to measure the activity of a single neuron with an EEG electrode placed on the scalp because the signal is significantly weak. We can measure brain activity using an EEG device only when simultaneous changes occur in the activity of tens of thousands of neurons (Hamalainen et al. 1993). However, even in this case, the EEG intensity that can be measured at the scalp is in the order of μV. To improve the signal-to-noise ratio, it is important to reduce the noise during measurements, when the signal is considerably weak. For noise reduction, it is particularly important to reduce the contact impedance between the electrode and the scalp. In conventional EEG measurements, cleaning the scalp entails removing sebum and keratin. Subsequently, a conductive gel is applied between the scalp and the electrode to reduce the contact impedance; the contact impedance should generally be 10 kΩ or less.

Conventional EEG measurements require an electroconductive gel to reduce noise; however, this electroconductive gel is a sticky product that adheres to the hair and the scalp. Thus, participants need to wash their hair after undergoing EEG measurements. Additionally, specialized skills are needed to determine the appropriate amount of electroconductive gel, and therefore it is difficult for a general user to attach the electrodes to the scalp.

12.2.2 Wearable EEG System with Dry Electrode Without Requiring Conductive Gel

12.2.2.1 Active Electrode

An active electrode plays an important role in developing a dry electrode, which does not require the use of a conductive gel. An active electrode contains an amplifier, which is advantageous because it can potentially increase the current in the lead wire by amplifying the signal immediately after measuring the brain wave. Accordingly, the signal-to-noise ratio can be improved. Another advantage of the active electrode is that the input impedance of the amplifier can be set at a considerably higher level than that of a conventional EEG device by receiving signals from the amplifier immediately after measuring the signal. The input impedance of conventional EEG devices is approximately 100 MΩ. However, that of the active electrode is in the order of GΩ or higher. The higher the input impedance, the greater the reduction in the extraneous noise resulting from the higher contact impedance. A typical active electrode has an input impedance of several GΩ. By contrast, we use

an active electrode with a considerably high input impedance of 300 GΩ; therefore, the active electrode has a high tolerance for noise.

12.2.2.2 Flexible Dry Electrode Chip

EEG signals cannot be measured without an electrical contact between the electrode and the scalp. In conventional EEG measurements, the conductive gel electrically connects the electrode and scalp by passing through the hair. If the conductive gel is not used, it is necessary to develop an electrode chip that allows the electrode itself to pass through the hair and contact the scalp. Therefore, we developed a flexible electrode chip that can move in both vertical and horizontal directions using springs (Fig. 12.1). Thus, EEG measurements can be performed without employing conductive gels by attaching this flexible dry electrode chip to the active electrode.

Figure 12.2 shows the results of simultaneous EEG measurements using an active electrode with a flexible dry electrode chip (hereafter, dry electrode) and an active electrode with a conductive gel (hereafter, wet electrode). The data derived using the wet and dry electrodes were nearly identical. We previously demonstrated that the accuracy of EEG data measured using our dry electrode changes according to the contact impedance of the dry electrode. If the contact impedance of the dry electrode is 100 kΩ or lower, the correlation coefficient of the EEG data obtained with the wet and dry electrodes is 0.9 at the lower limit. If the contact impedance is 300 kΩ or lower, the correlation coefficient becomes 0.7 at the lower bound (Higashi et al. 2017). For precise experimental use, the correlation coefficient should be as close to 1 as possible. However, because a wearable EEG device is used in a real-world setting, where conventional EEG measurements cannot be obtained, the goal should

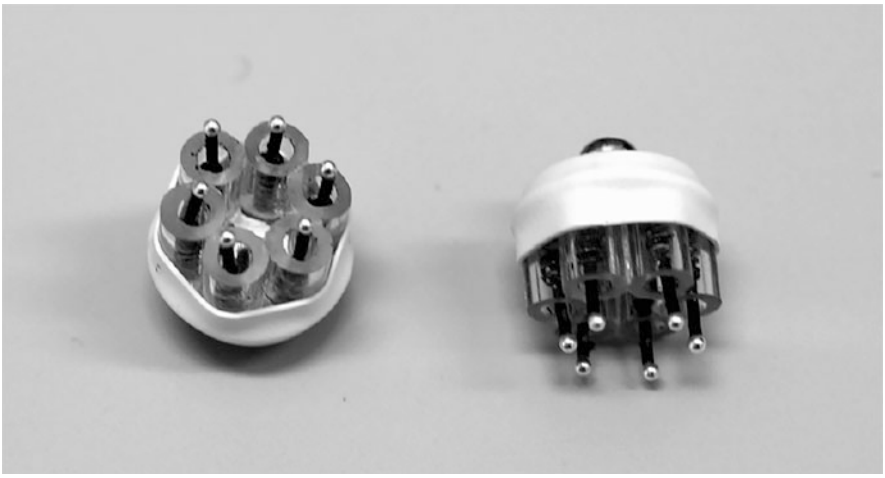

Fig. 12.1 Flexible dry electrode chip

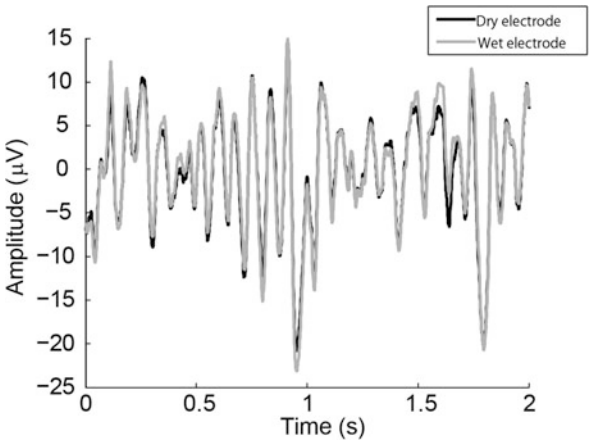

Fig. 12.2 Simultaneous encephalographic recording with dry and wet electrodes

be to achieve contact impedances of 300 kΩ or lower. Three hundred kiloohms is a feasible contact impedance value because the dry electrode is in sufficient contact with the scalp without pretreatment of the scalp. Note that this result depends on the performance of the active electrode to be used, and it is, therefore, necessary to pay attention to the fact that the results differ from those obtained with other active electrodes.

12.2.2.3 Compact EEG Device

We developed a compact EEG device to make it wearable (Fig. 12.3). The compact EEG device has eight EEG electrodes and two external input ports. The built-in battery lasts approximately 4 h and weighs approximately 80 g. We adopted Bluetooth technology for wireless connections. Accordingly, it was possible to acquire EEG measurements with personal computers and smartphones. Figure 12.4 shows the developed wearable EEG system.

12.2.2.4 Headgear

The shape of the head differs considerably among individuals. Therefore, the development of headgear is one of the most difficult tasks when building wearable EEG systems. In particular, the back of the head of many Japanese individuals is flat, making it difficult to fit electrodes at the back of the head. To resolve this issue, we developed a headgear that adopts a hammock structure. The EEG electrodes are mounted on a flexible electrode sheet, and both ends of the flexible electrode sheet are held in place with a rigid outer shell. The wearable EEG shown in Fig. 12.4 has three channels (O1, O2, and Oz) in the occipital area, three channels (C3, C4, and Cz) in the central area, and two channels (FP1 and FP2) on the forehead. However,

Fig. 12.3 Upper: prototype of the electroencephalography (EEG) device. Lower: commercialized EEG device manufactured by MIYUKI GIKEN

even with this headgear, the contact between the electrode and scalp is not sufficient in certain individuals. As poor contact with the electrode is the greatest cause of difficulty during EEG measurements, improvements to the headgear should be pursued in the future.

Fig. 12.4 Wearable electroencephalographic system

12.3 Examples of Brain Activity Measurement in a Real-World Setting

12.3.1 Unconscious Language Learning Using EEG Neurofeedback

Many Japanese individuals have difficulty distinguishing between the r and l sounds in English. For example, when Japanese individuals hear a sequence of words where a "light" sound occasionally intervenes among continuous "right" sounds, i.e., "right, right, light, right, right," all sound the same and cannot be distinguished. However, although the sounds cannot be consciously distinguished, it is known that brain activity differs when hearing the intervening "light" sound, as compared to when hearing the "right" sounds. This difference in the brain activity pattern is known as mismatch negativity (MMN). In other words, the brain unconsciously reacts to the difference in the sounds even if the conscious mind cannot differentiate between the two. It is known that MMN increases with the increasing conscious discriminability of the sound difference.

We have shown that we can recognize the difference between "right" and "light" sounds by enhancing MMN using neurofeedback training (Chang et al. 2017). In this study, we asked the participants to listen to a sequence with the word "light" occasionally intervening in a series of "right" word repetitions, i.e., "right, right, light, right, light, right," and extracted the MMN in real time. The amplitude of the MMN was visualized by changing the size of the green circle as shown in Fig. 12.5; in this figure, when the MMN is large, the green circle is large, and when the MMN is small, the green circle is small. Participants were instructed to concentrate on making the solid green circle presented on the screen as large as possible. The

Fig. 12.5 Neurofeedback system

method of visualizing brain activity and providing feedback to participants in real time is called neurofeedback training. After the neurofeedback training, the participants were able to enlarge the green circle; this means that participants could increase the MMN. As a result, the difference between the words "right" and "light" became recognizable.

12.3.2 Visualization of Brain Workload Through EEG

We have developed techniques to quantitatively visualize the brain workload using magnetoencephalography (MEG), which can measure the electrical activity of the brain with higher accuracy than EEG (Yokota and Naruse 2015). In this study, brain activity in response to sound, called the auditory steady-state response (ASSR), was used as an index of the brain workload. We showed that the ASSR during working memory tasks varied according to task difficulty using MEG. The auditory cortex is activated by sound. By contrast, the frontal lobes are activated during working memory tasks. Activation of the auditory cortex in response to sounds unrelated to the working memory task was modulated by increasing the difficulty of the working memory task, which activated the frontal lobe. Our finding appeared to validate the belief that "we cannot hear surrounding sounds when we heavily concentrate on something."

This study was conducted using MEG, which is a large device and cannot be used in a real-world setting. Therefore, we examined whether it is possible to easily obtain similar results using a wearable EEG system (Yokota et al. 2017). Figure 12.6 shows

Fig. 12.6 Electroencephalographic recording during walking

the experimental setup. In the experiment, the participants walked while wearing a wearable EEG system. The EEG data during walking included related noise. Even in such a setting, we could obtain the result that the ASSR changes according to the difficulty level of the working memory task.

12.4 Conclusion

We showed that it is possible to visualize unconscious information using EEG. Using a wearable EEG system, it is becoming easier to visualize brain activities in the real world than before. The wearable EEG system has the potential to become a human–computer interface capable of monitoring unconscious information.

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Part IV
Utilization of Communication Service and Town Management

Chapter 13
Image and Sound of the City

Eiji Aramaki and Shoko Wakamiya

Abstract It is difficult to describe the impression of a city because a simple combination of the atmosphere of the city's components is not always the overall atmosphere of the city itself. To represent the overall impression of a city, we should consider the ambience of the respective components therein, such as buildings and parks, and their atmosphere, which is a combination of these components. Social sensors, which are the massive number of social media users, enable capturing the atmosphere as a whole. This chapter attempts to represent the urban atmosphere by exploiting social sensors and demonstrates a soundscape map, focusing on sound impressions in cities.

Keywords City image · Urban computing · Soundscape · Social media · Twitter

13.1 Introduction

Urban information is essential in many situations, such as urban planning, safety, disaster prevention, real estate, and sightseeing. Thus, various roles, including those of the government and the general population, require urban information. However, obtaining the information relies on conventional methods such as paper-based questionnaires or environmental investigations involving numerous people.

Another important aspect of urban information is that it consists of various types of information on people, nature, and architecture. In general, urban information can be divided into two types: objective information, such as quantitative data, and subjective information, represented by qualitative data. Both types of information are important.

For example, categorical data such as place types (museums, restaurants, etc.) and numerical data such as the distance from a station or a price would be useful for tourists. In some cases, tourists want to know more subjective information such as

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details about a restaurant with a calm atmosphere or one with a fancy ambience. This type of information is difficult to obtain because it is usually expressed in texts and there is a great variety of expressions. For example, "calm" could be expressed in words such as "quiet," "silent," "peaceful," "gentle," or more complex expression "(it is) Kyoto-like."

More importantly, objective and subjective information may be contradictory. For example, a calm atmosphere and the real volume of real sound may differ. Even if the sound is too loud, a comfortable sound is not recognized as loud. Thus, the image of a city is difficult to compute from individual elements.

In addition to tourism, various situations require the image of a city. When finding an apartment in an unfamiliar city, people want to know about the surrounding atmosphere, for example, whether it is "quiet" and "elegant," and the cost of living and room layout. Thus, they usually make a final decision after viewing. Furthermore, the goal of disaster reconstruction is to reproduce the original image of a city. However, it is difficult to define a city's image.

This chapter introduces approaches to representing a city's image. First, we introduce related work on the representation of urban images, including urban sound, by exploiting information processing techniques (Sect. 13.2). Then, we present the "soundscape project," which aims to produce a sound map to represent the image of a city in terms of urban sound (Sect. 13.3). Finally, we summarize this chapter in Sect. 13.4.

13.2 Related Work

13.2.1 Capturing Image: What/How We See in a City

One pioneering study on urban image representation is "The Image of the City" by Kevin Lynch (Lynch 1960). He conducted interviews in three cities in the United States, finding that people use five fundamental elements to form mental maps: paths, edges, districts, nodes, and landmarks. In other research, a workshop was held with residents wearing a device that measured their galvanic skin response (GSR), which is an indicator of emotional arousal in conjunction with geographical location (Nold 2005). The results were visualized on a map called the emotion map. However, this approach requires significant human power, motivating a semi-automated method.

One solution is to exploit data on social media, such as Twitter,[1] Flickr,[2] and Instagram.[3] Owing to advances in social media, text, images, and videos tagging location information can be shared using mobile devices in real time. In addition to

[1] Twitter: https://twitter.com/

[2] Flickr: https://www.flickr.com/

[3] Instagram: https://www.instagram.com/

the spread of social media, recent information techniques enable us to extract valuable information on people's experiences, behaviors, and emotions from big data over social media. This approach is called the "**social sensor**," because it regards a person as a sensor (Sakaki et al. 2010). We believe that an urban image, especially subjective information, can be represented by collecting, classifying, and aggregating various signals sourced from social sensors without an interview or the use of a special device.

Various attempts have been made to represent an urban image by exploiting geo-tagged texts, which have been accumulated in real time on Twitter and Facebook,[4] check-in logs at a specific location on location-based social networks (LBSNs) such as Swarm[5] by Foursquare,[6] and geo-tagged photos shared on photo sharing services such as Flickr and Instagram.

13.2.1.1 Twitter

Frias-Martinez et al. (2012) examined the possibility of cityscape characterization such as the identification of land use or landmarks. Lee et al. (2013) characterized urban areas by measuring crowd behavior as the number of tweets, number of users, and number of moving users using geo-tagged tweets and extracting the crowd's behavioral patterns for clustering urban areas. Mislove et al. (2010) estimated the moods of people in the United States by analyzing geo-tagged tweets and visualized time changes or regional differences in these moods via a cartogram. Wakamiya et al. (2016) proposed a method to extract three types of landmarks, namely point, line, and area landmarks, by analyzing geo-tagged tweet data, check-in logs at venues from Foursquare, and 3D geographic data.

13.2.1.2 Foursquare

Long et al. (2012) explored local geographic topics through check-ins in the Pittsburgh area on Foursquare using the Latent Dirichlet Allocation (LDA) model. They also compared local geographic topics on weekdays with those on weekends. Their results showed that LDA worked well in finding related places of interest. Noulas et al. modeled human activity and geographical areas based on place categories by applying a spectral clustering algorithm to areas and users of two metropolitan cities—London and New York—with Foursquare data. Their methodology enabled identifying user communities who visit similar categories of places and comparing urban neighborhoods within and across cities. To understand city

[4] Facebook: https://www.facebook.com
[5] Swarm: https://swarmapp.com/
[6] Foursquare: https://foursquare.com

dynamics at a large scale, Silva et al. (2012) presented a visualization technique denominated city image and applied it to Foursquare data in eight cities.

13.2.1.3 Flickr

Kisilevich et al. (2010) analyzed attractive areas based on geo-tagged photos posted on Flickr. Haider and Ali (2018) proposed a method to predict the aesthetic score of a location from Flickr social metadata. Note that the social metadata related to each photo are the number of times the photo is viewed, the number of people who added the photo as a favorite, and the number of comments on the photo.

13.2.2 Capturing Sound: What We Hear in a City

Several studies have attempted to visualize and convert information into other media. The typical conversion is from visual information to sound information, which is referred to as ***auralization***. These studies assume that sound is suitable for representing the entire image of a city. For example, to involve people in identifying, assessing, and planning "everyday quiet areas" in cities, the "open source soundscapes" methodology has been proposed by combining the soundscape approach, the citizen science paradigm, and a novel mobile application called the Hush City app. This methodology was implemented in the framework of the "Beyond the Noise" project by means of a citizen-driven pilot study of a Berlin neighborhood affected by noise pollution and high levels of environmental injustice (Radicchi et al. 2018). However, practically, it would be difficult to obtain environmental sound at a specific location from a large number of people constantly because it would require higher costs. Consequently, only limited data at a specific location and/or time are available.

On the other hand, another approach to generating a sound map without real sound recording has also been attempted. For instance, Wang et al. (2014) constructed a noise map of New York City based on a model to infer the fine-grained noise situation at different times of day for each region of the city using four ubiquitous data sources: 311 complaint data, social media, road network data, and points of interest (POIs). The noise situation of the city, consisting of a noise pollution indicator and a noise composition, was modeled as a tensor of three dimensions: regions, noise categories, and time slots. They tried to recover the noise situation throughout the city by supplementing the missing entries of the tensor through a context-aware tensor decomposition approach.

Furthermore, Aiello et al. (2016) proposed "Chatty Maps," which are detailed sound maps of Barcelona and London at the street segment level. To automatically generate these maps, a sound dictionary was constructed by collecting sound-related terms from different online and offline sources, which were then arranged into a taxonomy. A taxonomy was determined by matching the sound-related terms with

the tags on 1.8 million pictures in Barcelona and London over Flickr and then analyzing how those terms co-occurred across the pictures to obtain a term classification under the assumption that co-occurring terms are expected to be semantically related. However, these studies focused only on measuring noise, causing the limitation of reproducible environmental sound.

13.3 Soundscape

13.3.1 What Is Soundscape?

We have been advancing a project to produce urban images focusing on urban sound that covers not only noise but also all city sounds. The project is called the "soundscape project," which has two advantages:

- Personal information protection: When recording an actual sound, it may record personal information such as a person's name. It is still difficult to recognize and remove human voices. This problem can be solved by synthesizing individual sounds.
- Agreement with subjective impressions: There is a gap between impressions perceived from the actual and recorded sound. For example, a possible phenomenon is when people feel it is noisier in a crowded place than it actually is. This project aims to produce subjective urban sound by synthesizing sound based on actual noise.

Specifically, we deal with three types of elements: nature, artifacts, and humans, the parameters of which can be measured using geographic and SNS data (Sect. 13.3.2). Finally, we produce sound in each city's areas by synthesizing these parameters (Sect. 13.3.3).

13.3.2 Decomposition of Sound

What are the fundamental elements of a city? Lynch's definition (Lynch 1960) is that a city consists of five elements: a path, edge, landmark, node, and district. Our viewpoint stems from data availability. We assume that an urban image can be roughly decomposed into the following three elements:

- **Nature**: river, forest, sea, animal, plant, etc.
- **Artifact**: automobile, railway, factory, store, etc.
- **Human**: crowd (children, adults).

According to the above classification, appropriate methods to acquire the respective information would vary.

As for **Nature**, natural elements can be estimated from map data such as Google Maps[7] and OpenStreetMaps (OSM)[8] because they are static and do not change significantly. For example, the roar of waves and sounds of seabirds could be heard within about 1 km of the coastline. On the other hand, the sound of leaves blowing and of birds near a mountain could be heard and the smell of plants felt. Thus, an atmosphere based on nature can be estimated by exploiting geographic features.

For **Artifact**, artifact elements can be estimated from map data such as Google Maps and OSM or statistical data. For example, it would be noisy near a road with heavy traffic. Although the volume of traffic can be estimated based on the width of a road, it also depends on the weather conditions or season. In addition, it is difficult to estimate how much traffic is generated by different types of vehicles. For example, there is a quiet road, a road mainly used by cars, and a crowded road with many large vehicles such as trucks and tour buses.

Unlike the cases of **Nature** and **Artifact**, it is difficult to estimate **Human** using only map or statistical data because this type of information is a dynamic parameter that changes significantly depending on the date and time. However, it can be extracted from crowd-sourced data, which are created by people in real time, such as tweets over SNS and check-ins at locations.

Thus, it is considered that the information on natural elements can be estimated from static data such as map and statistical data, which can be estimated by analyzing massive crowd-sourced real-time data over social media. In addition, the information on artifact elements can be estimated by exploiting both static and dynamic data. Furthermore, there is a whole image of a city that cannot be decomposed into individual elements. For example, streets lined with trees give an impression of a relaxing atmosphere even if the streets are crowded. In contrast, streets that are not well organized give an impression of a chaotic atmosphere, even if there are few people. Thus, many studies have focused not on single elements or the appearance and functionality of a city, but on the people in the city, because there is a gap between individual elements and the whole image of the city.

13.3.3 Estimation of Sound Impressions

The method to represent city impressions in terms of sound using SNS data consists of the following two steps. Note that we explain the steps by considering a sound element as crowd sound.

Step 1. Collecting subjective sound data:

We set up several areas in a specific city and conducted questionnaires via a crowdsourcing service to ask the city's residents about the volume of the crowd

[7] Google Maps https://www.google.com/maps/

[8] OpenStreetMaps https://www.openstreetmap.org/

sound in the area. Given the area "Gion (in Kyoto)," the questions were as follows: "How much can you hear crowd sound in Gion?" and "How much do you care about crowd sound in Gion?" For the first question, a respondent could choose one of five options: "I can hear it very well," "I can hear it well," "I cannot hear it very well," "I can't hear it at all," and "I don't know." For the second question, the options were: "I really care about it," "I care about it," "I don't care about it," "I don't care about it at all," and "I don't know." The score for the crowd sound in each area was measured based on these responses and regarded as the gold standard.

Step 2. Generating a sound dictionary:

A sound dictionary was generated by extracting words corresponding to crowd sound in the city. First, tweet data in each area were collected, and a morphological analysis was performed. Then, we found words (morphemes) often used in areas with higher crowd sound scores. Specifically, we calculated the correlation coefficient between the frequency of use of a word in an area and the crowd sound score there. In our preliminary experiments, words such as "go home" and "good" were extracted as positively related to crowd sound and stored in the dictionary. On the other hand, words such as "plant" and "north" were extracted as negatively related to the crowd sound. The sound dictionary enables building a prediction model and estimates the score of the crowd sound in areas of other cities.

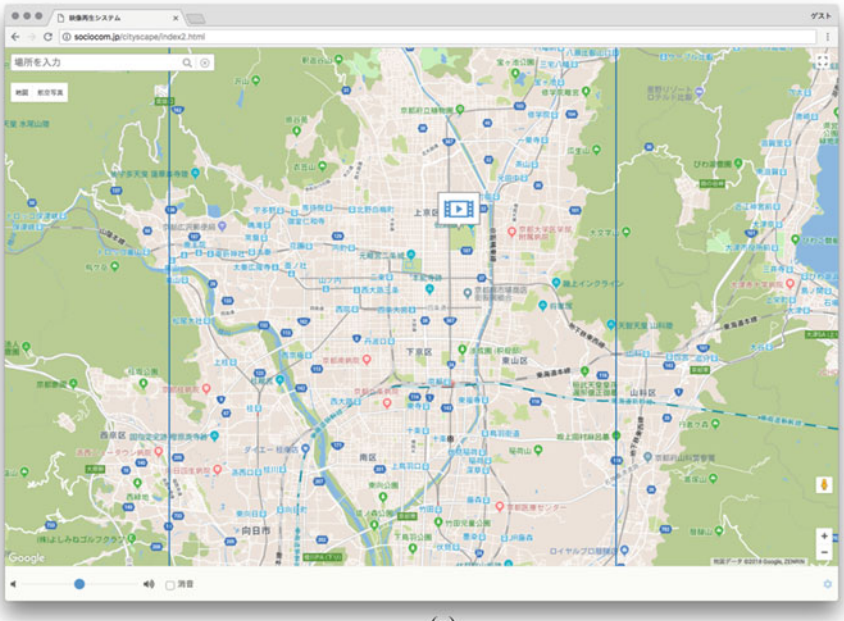
13.3.4 Demonstration of Soundscape

Our demonstration system, "Soundscape Map," was constructed using the above data (see Fig. 13.1). When selecting a location, the system plays a synthesized sound corresponding to the location (Fig. 13.1a). The system also plays a synthesized movie at the selected location (Fig. 13.1b).

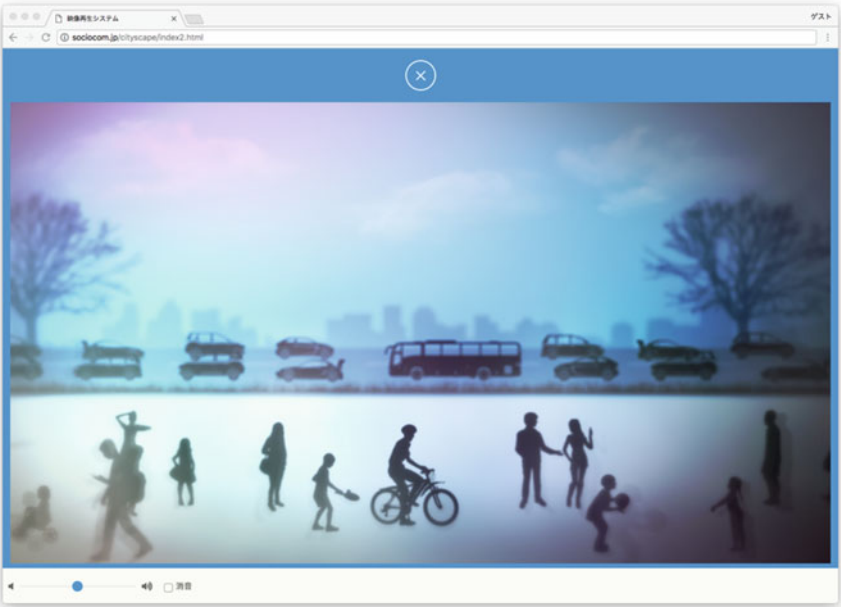
Although the soundscape project is an attempt to represent urban images as sound, it could be considered to exploit other senses such as smells. For example, Quercia et al. (2015); Wang et al. (2014) and Zheng et al. (2014) generated a smelly map to show urban smell on a map. In addition, we will be able to exploit other SNS data as well as Twitter data. Consequently, we now stand at the beginning of such research through the soundscape project.

13.4 Conclusion

This chapter described our approach to capturing the image of a city and explained its application to hearing the image. In capturing a city image, one key issue is how to capture large-scale city images. One solution is to exploit social media. The social media approach enables us to collect huge amounts of data covering the entire city. More importantly, social media is useful for collecting subjective information, because social media texts originate from users' real feelings.



(a)



(b)

Fig 13.1 Soundscape map. (**a**) Urban sound player: It plays a synthesized sound at a specified location and (**b**) Urban image player: It plays a synthesized movie at a specified location

Social media could be a real information source that fills the gap between subjective and objective information. For example, say you try to collect information on "Ginkakuji temple" in Kyoto. Although the actual sounds of "Ginkakuji" might be too noisy because of the numerous tourists, most of the guidebooks to Kyoto introduce this place as a quiet one.

Another point of this chapter is the method of presenting city data. Thus far, the most standard way to show city information is through map-based visualization such as heat and icon maps. This study proposed a new approach to presenting sound-based information. The soundscape project is one example demonstrating the basic feasibility thereof in city image presentation.

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Chapter 14
Mapping the Mood in a City Using Geo-Located Text Data: Case Study of Yaizu Onomatopoeia Map

Yusuke Kita

Abstract The topic of "mood" in a city has been receiving much attention lately. Numerous tourists walk around the city to capture its authentic quality, and amorphous concepts related to city moods such as townscapes and regional characteristics are discussed in city planning and regional management today. To study this topic, we created a mood map of the city based on geo-located text data containing peoples' expressions about the city mood, especially using onomatopoeias. We collected data through a city walk in Yaizu City with 40 participants. Each participant walked around the city, providing data such as onomatopoeia on a smartphone app named "100ninmap." The data along with locations were transmitted to a server and mapped. We classified onomatopoeia based on the five senses and prepared illustrations of participants' expressions to develop the "Yaizu Onomatopoeia Map." Finally, we demonstrated the quantifiability of the data to conclude that these offered information regarding the mood of the city.

Keywords City walk · Cognitive map · Mapmaking · Urban modality · Collective intelligence · Onomatopoeia

14.1 Introduction

14.1.1 Maps and City Mood

When we visit a city for sightseeing, what kinds of maps can we expect to see in a tourist center? In typical tourist maps, spots such as notable places and restaurants are shown, along with some details. Using these, we can embark on our city walk and visit the spots that are dotted in the maps across the city. In this chapter, we raise three issues pertaining to such maps.

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The first issue regarding existing maps concerns places between the indicated spots. Most maps lack information on places that form part of the route between notable spots. Further, people's sightseeing styles have changed in recent times. More people now prefer walking leisurely in cities rather than using tourist buses to just visit notable places. Walking within the city is also a part of the daily lives of the inhabitants of the city. In fact, "walkability" indices, which measure how friendly a city is to walkers, have become prevalent in city planning nowadays (Ewing and Handy 2009). This implies that the entire area between notable spots could potentially hold interest for walkers.

The second issue concerns information bias. Maps are intended to be useful for everyone, and map editors do their best to choose *general* information. Consequently, all tourist maps available in tourist centers and guidebooks tend to be similar. However, there is still a variety of information about a city that is distributed among its inhabitants. For instance, local people may have personal knowledge and sentiments about the city or its areas, and a walking traveler is often exposed to multiple perspectives.

The third issue concerns mood. Tourist maps show us *what exists in the city*, but do not convey *what the mood of each place is like*. We experience a variety of feelings when walking around a city, such as "the slopes are exciting around here" or "the sunset is beautiful." Although we experience it every day, a city's mood or quality is often difficult to capture, visualize, and share with others. Objective data such as population, temperature, and crime rate do not explain mood, because the latter is a subjective and personal experience. Mapping moods is therefore all the more interesting because of such challenges.

This chapter attempts to design a map that is different from the existing ones. Our map visualizes the mood of the city as experienced by numerous people, including in places located between notable spots. Through this, we propose a method for mapping the quality of the moods of the city that is based on collective intelligence and that may have a significant positive impact on the city walkers. For instance, such map would make it possible for tourists to choose to walk only on quaint streets or enjoy local spots and unexpected scenes not found on ordinary tourist maps.

Furthermore, mood maps for the entire city have other significant implications. In the context of vague and qualitative concepts such as townscape and regional characteristics used in today's city planning and regional management, an actual mood map created without using conventional statistical data can offer a new perspective. Additionally, for newcomers choosing a district to live in, the ability to foresee the moods of various urban districts is particularly beneficial. A mood map can help find places with compatible moods, such as quiet parks or safe streets.

14.1.2 Related Work

Prior studies have considered the mapping of urban quality. Lynch (1960) attempted to create maps of people's mental images of the city. He invented many research

methods for measuring and mapping urban quality, and his work is highly regarded in the field. Gould and White (1993) created mental maps of Britain, which showed the areas that people desired to live in different cities. Schafer (1977) strived to measure and visualize the sounds around us, like noise and the singing of birds, to design the "soundscape" of a city. In the preceding chapter, Aramaki and Wakamiya, with whom the author works on the "100ninmap project," listed recent works on the creation of mood maps that use information technology.

In the studies cited above, maps of our environment were created using a panoramic viewpoint. This chapter is an attempt to create a map of city mood from the viewpoint that is found inside the city. This is based on geo-located text data sourced from a smartphone app.

In implementing studies related to city mood, the author has typically used the concept "urban modality" to indicate the overall mode of a city (Kita and Monnai 2010, 2011a, b, 2014). However, in this chapter, we use the word "city mood" to focus on creating maps rather than discussing the theoretical background of urban modality.

14.2 Approach

14.2.1 Geo-Located Text Data

In this chapter, we attempt to create a map of the *collective* mood connected to people's sensations. Because mood is a subjective phenomenon that cannot be sensed directly, the sensation needs to be translated into readable data that can be used to create a mood map of the city. We use text data delivered by city walkers to accomplish this.

Photographs and videos are believed to be the most ideal media for communicating mood, as humans gather considerable information from sight. However, photographs and videos reveal what a person sees, but not their sensations. On the other hand, words can represent all kinds of phenomena, ranging from physical aspects of the world to our feelings and thoughts. Therefore, even vague phenomena like city moods can be successfully represented by words.

Collecting text data about city moods as written or spoken of by numerous people can help determine a collective mood. Furthermore, we can determine a general trend within the text data by categorizing, numbering, and analyzing words. It means that text data not only represent qualitative phenomena but also can be treated quantitatively, even though the mood is challenging to quantify.

Furthermore, with the help of positional information, text data can be plotted on a map. Owing to the popularity of GPS devices such as GPS loggers and smartphones, obtaining positional data has become very easy. In fact, some parts of the information posted on social media sites such as Twitter and Instagram contain positional data.

We developed a smartphone app, "100ninmap," to collect geo-located text data posted by users while walking in the city. As "100 nin" means "100 people" in Japanese, the name "100ninmap" reflects our objective to design a novel map based on collective intelligence. The user, while walking, enters text data in the form of their feelings on the app. The text data is transmitted to a data server along with the geo-location automatically obtained by the smartphone, which then plots the text on a map. We refer to the text data posted via the app as a "tweet," much like a post on the social networking service Twitter.

14.2.2 Free Descriptions and Onomatopoeias

Since 2012, we have been attempting to visualize the mood of a city using free descriptions. We assumed that we could create mood maps like a "liveliness map," "beauty map," and "coolness map," by collecting large amounts of free descriptions provided by people while walking in the city and processing these via natural language processing (NLP) technology. However, these free descriptions turned out to be too complex, chaotic, and sparse, making it difficult to abstract tendencies from them (Kita et al. 2014). For example, numerous tweets in this data are not specific to any place: "I'm hungry" and "I met with my friend," and relate to information that cannot be understood from written words. It became difficult to process such complex descriptions containing considerable noise using NLP.

Therefore, we changed the content of tweets from free descriptions to onomatopoeias. This prevents data from becoming too complex, as the vocabulary of onomatopoeias is limited compared to that of free descriptions, and in turn makes categorization and analysis easier. Moreover, onomatopoeias are a good choice for representing city moods, especially in Japanese.

As our study is based in Japan, we collected data on onomatopoeias in Japanese. Japanese onomatopoeias represent a wide range of phenomena, including sight, sound, smell, and emotion, as opposed to English onomatopoeias, which usually only represent sound (Millington 1993). For instance, "kirakira" refers to something shining brightly like a star or a jewel, and "wakuwaku" represents the emotion of a person who is excited about what happens next. In addition to physical elements such as buildings and trees, movement, sound, and feelings are also represented by Japanese onomatopoeias. Onomatopoeias thus serve as an ideal tool for creating maps of qualitative phenomena, such as mood.

However, onomatopoeia is just one of the tools that represent the mood of a city. Mood maps can also be created by limiting tweets to adjectives, haikus, and short poems. We can create various maps corresponding to situations like the goals of mapmaking, characteristics of the city, languages used, and so on, by choosing a suitable representation method.

14.3 Yaizu Onomatopoeia Map

14.3.1 Collecting Data

We updated our app, 100ninmap, with new functions to collect onomatopoeia data. The app consists of a tweet screen and a map screen (Fig. 14.1). Users can enter an onomatopoeia on the tweet screen when they see, hear, or feel something. To complete the tweet, users are also required to provide explanatory text written in free descriptions, followed by an impression evaluation that captures the impression conveyed at that location to the user on a five-point scale ranging from −2 (minimum) to +2 (maximum). Data thus collected are transmitted to the server along with the geo-location, and the letters of the onomatopoeia tweeted by the users are immediately automatically plotted on the map screen. As more people walk around the city using this app, with the passage of time, users can instantly view more onomatopoeias being plotted on the map. The username and explanatory text accompanying each tweet are also revealed when tapped.

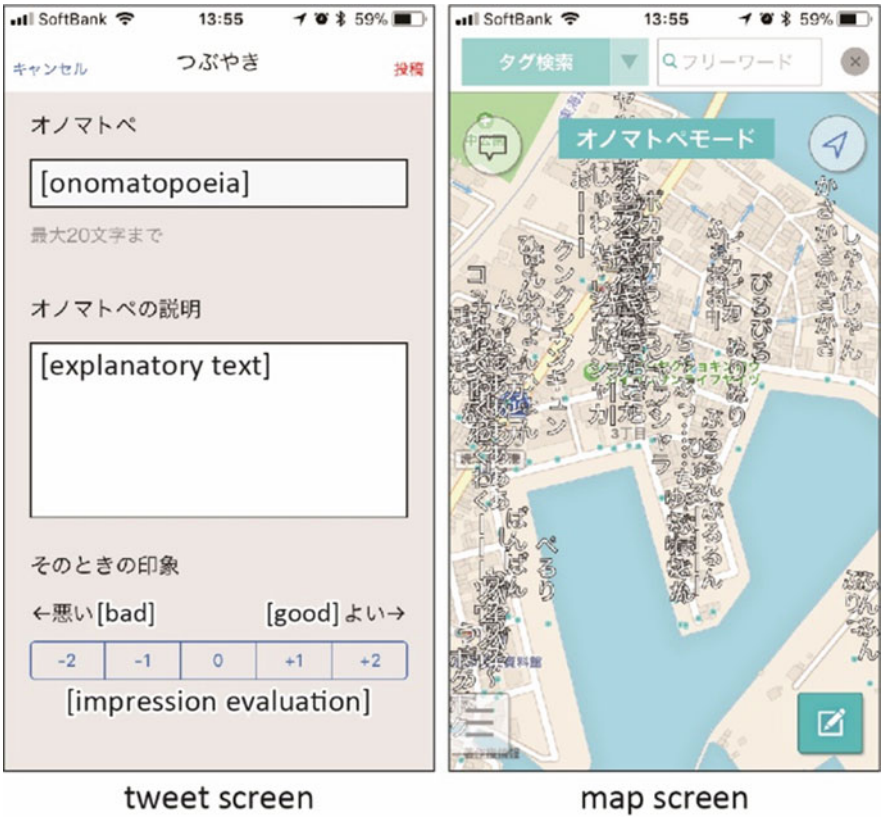

Fig. 14.1 Screenshot from the app 100ninmap

We conducted a city walk for data collection in Yaizu, Shizuoka Prefecture, Japan, on February 2, 2017. Yaizu is a port town known for deep-sea fisheries but does not have famous sightseeing spots. We expected to capture the lively scenes along the ocean and the unknown charm of Yaizu by collecting onomatopoeia. Forty people participated in the city walk, including 36 university students (11 males and 25 females), three high school students (all female), and one corporate worker (male). After being provided instructions on the goal and method of the city walk, participants walked around the city and tweeted on the app for 4 h. The participants could walk anywhere, alone or with their friends. They could also rest and have lunch without any limitations. We obtained 533 data points. Participants seemed to enjoy walking in Yaizu on a sunny winter day and tweeting onomatopoeias.

14.3.2 Mapping Onomatopoeias on Paper Map

The automatically generated map screen of the 100ninmap app (Fig. 14.1) is a visualization of the city mood. However, details on the map screen are revealed only by tapping the onomatopoeic words. The map also cannot be viewed without a smartphone or app. Therefore, to communicate the mood of Yaizu to a large number of people, we decided to create a printable physical map.

We began by categorizing onomatopoeias based on the five senses and coloring each category differently. Next, we selected onomatopoeias that better represented the mood of the city, and prepared an illustration based on the explanatory text for each. Finally, we placed the categorized onomatopoeias and corresponding illustrations on a map of Yaizu, viewed from the sky above the ocean. Figure 14.2 shows the completed "Yaizu Onomatopoeia Map" (we use the French word "onomatopée" in the map because Japanese usually use "onomatopée" instead of "onomatopoeia"). Figure 14.2 is printed in black and white, but a clearer version of the map is available online (https://www.100ninmap.com/images/maps/yaizu_onomatopee_map.pdf).

14.4 Analysis

14.4.1 Analysis of Tweet Data Based on Categorization

We begin our analysis by examining the impact of map-making activities using onomatopoeias. First, what are the data collected from the city walk using onomatopoeia like? Does the collected data adequately represent the mood of Yaizu City? If we can identify trends across the data that reflect the mood of the city, our methodology can be proven suitable for mapping the mood of the city.

Based on the sense perceptions used by the participants, that is, the five senses, we organized the data into five categories. Here we also encountered onomatopoeias not related to the city mood but rather to the physical states of the users, such as

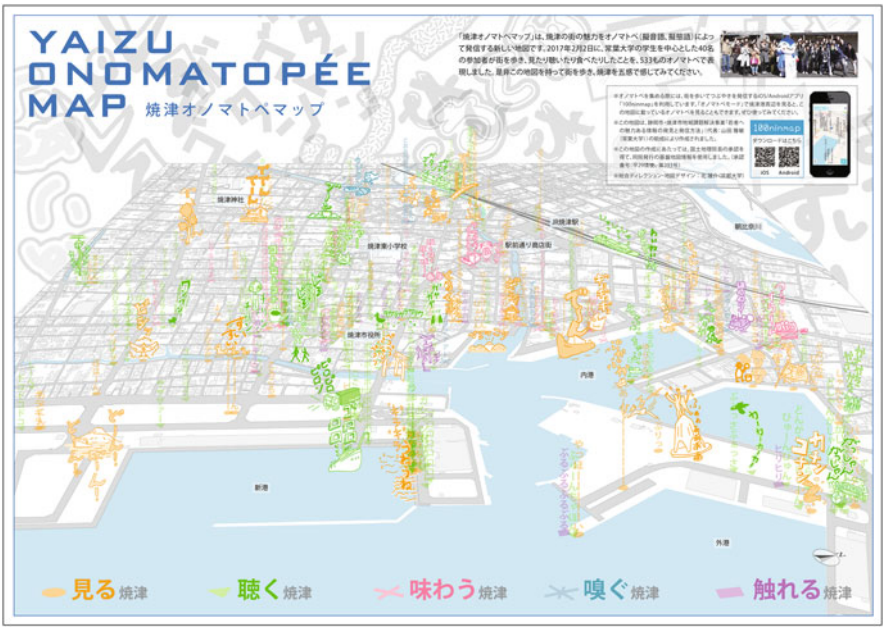

Fig. 14.2 Yaizu onomatopoeia map

"Guuguu," representing hunger, or "Tekuteku," which means the user is walking. We classified such tweets under a category labeled "body." After categorizing the onomatopoeias, the number of uses and the correlation coefficient between use and evaluation were calculated for each category. This is illustrated in Fig. 14.3. In the figure, for each category, the bar on the left shows the total number of uses of each category, and the bar on the right shows the correlation coefficient between use and impression evaluation (on a five-point scale of −2 [minimum] to +2 [maximum]). A high correlation coefficient score for a category implies a better mood when participants use words in the category.

We then categorized objects represented by onomatopoeias using the explanatory texts as a reference and prepared Fig. 14.4 in the same manner as Fig. 14.3. Figure 14.4 presents 13 major classifications like buildings and roadside items, and these major classes are further classified into a total of 58 minor classes, such as restaurants and grocery stores.

Figure 14.3 illustrates that people make more use of their ears than their eyes when grasping city moods through onomatopoeias. Because we generally obtain more information about our surroundings via our eyes, this indicates that the use of the five senses changes depending on whether onomatopoeias are being used as a representative tool or not. Thus, moods captured by people can vary with the mode of representation.

The objects of the expressions in Fig. 14.4 encompass a wide range of phenomena, ranging from static objects like buildings, vehicles, and plants to more dynamic

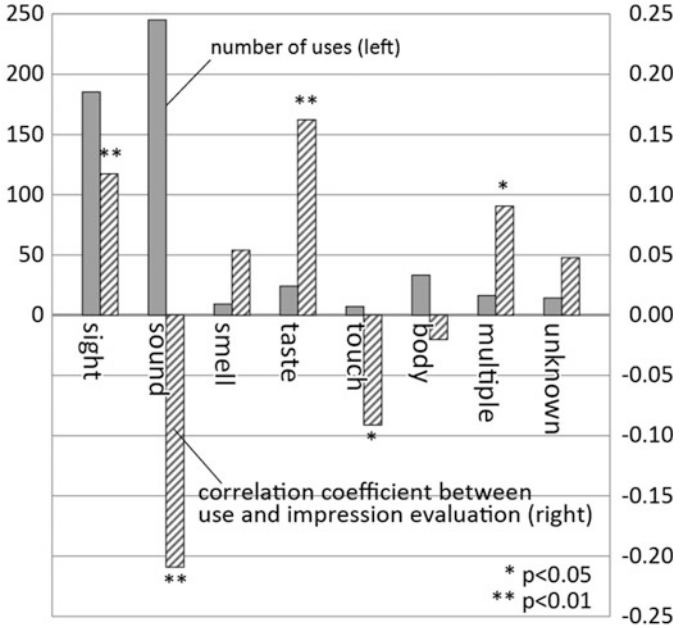

Fig. 14.3 Number of uses based on sensory classification and correlation coefficient between use and evaluation

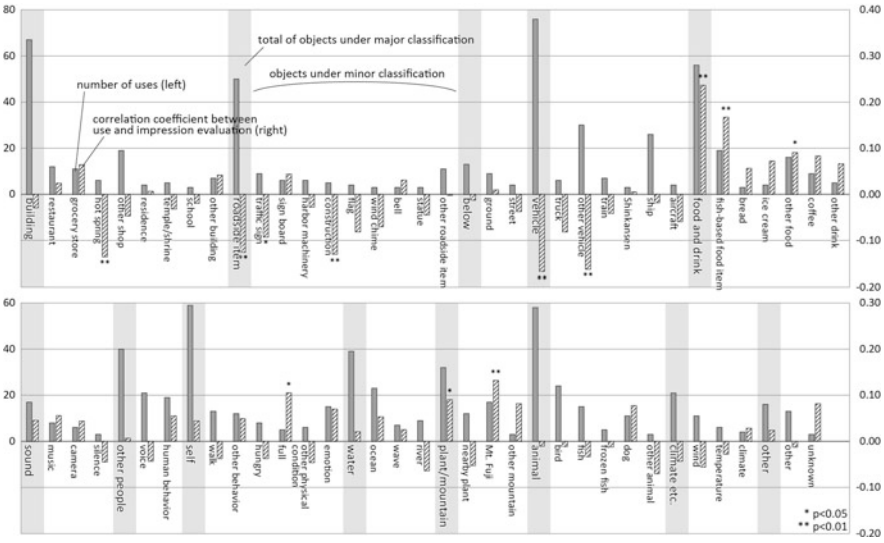

Fig. 14.4 Number of uses based on object classification and correlation coefficient between use and evaluation

objects like people's behaviors and the climate. Furthermore, objects related to the ocean, ships, and fish represent features of Yaizu City, especially well. In terms of the actual onomatopoeias of such objects, ships are represented by "Pukapuka" (denoting a floating object), "Burorororororo" (resembling the sound of the engine of a small boat), "Doon" (meaning big and imposing), and the ocean is represented by "Kirakira" (denoting a shiny object), "Chapuchapu" (resembling the sound of small waves), and so on. These onomatopoeias indicate not merely ships and the ocean, but their conditions and movements as well. Therefore, onomatopoeias can convey moods and scenes of the city richly better than phrases like "there is a big ship," or "I can see the shining ocean."

In examining the correlation coefficient between use and evaluation, the average score of evaluation across all tweets was found to be 0.925. The high score implies that participants largely captured good rather than bad moods in Yaizu using onomatopoeias. The correlation coefficient also shows relative differences among the categories. For instance, the sense of sound in Fig. 14.3 and categories such as construction and cars in Fig. 14.4, perceived mainly through sound, are negatively correlated with impressions, while the sense of taste in Fig. 14.3 and foods in Fig. 14.4 are highly positively correlated with impressions. The evaluation score suggests that participants heard both good sounds and noise. In contrast, participants enjoyed the fish dishes served at the Yaizu port during lunch. Foods turned out to play an important role in understanding city moods, in the city walk conducted between 11 a.m. and 3 p.m.

Overall, we gathered a sense of the actual Yaizu City from the data obtained through the city walk. Besides such distinctive elements as the ocean and ships, a variety of encounters and experiences like small shops, car noises, birds, dogs, and even the distant Mt. Fuji, are reflected in the data. These observations demonstrate that the onomatopoeia map offers a reliable visualization of the mood of Yaizu City.

14.4.2 Comparative Study of Maps

We next considered if the map on the app, generated automatically from the collected data (Fig. 14.1), and the physical map with colored and illustrated onomatopoeias (Fig. 14.2) realistically communicated city mood to their users. Is there a difference between such maps and the existing sightseeing ones?

For this, we conducted a comparative survey with 38 university students, asking them to compare three maps (Fig. 14.5) using Scheffe's method for paired comparisons (Nakaya modified method) (Nakaya 1970). Map A is a conventional map that is currently distributed by Yaizu City, Map B contains unprocessed onomatopoeias, similar to the map on the 100ninmap app, and Map C is the Yaizu Onomatopoeia Map. The comparison was conducted in seven parts across three indexes: "I: easy to understand information of the city," "II: easy to understand city mood," and "III: makes me want to walk in the city." In addition to the comparison, we asked the students to provide their impressions of the three maps by free description.

Fig. 14.5 The three types of maps shown in the comparative survey (part)

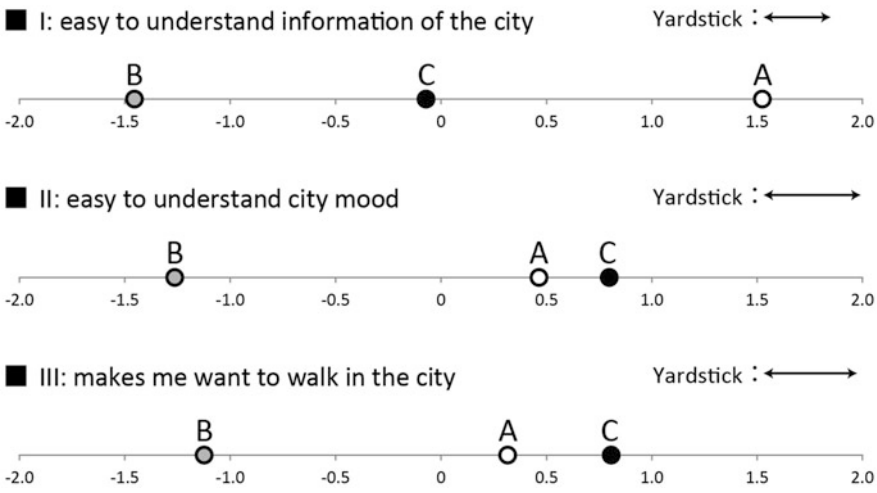

Fig. 14.6 Scale diagram of the results of the comparative survey

Figure 14.6 illustrates the results of the survey, indicating that the existing map helps determine what exists in the city better than the onomatopoeia map. However, the latter communicates the mood of the city, inviting users to walk in the city, implying that our goal has been broadly achieved. The onomatopoeia map represents *how* the city is rather than *what* is actually there in the city.

The participants of the survey provided the lowest scores in all indexes to Map B. This map became too complex with the letters overlapping. It was thus difficult to communicate the city mood using a map on which onomatopoeias are directly plotted. We could solve this problem to some extent by categorizing onomatopoeias based on the five senses and including illustrations for characteristic onomatopoeias. The categorization and illustrations were accomplished using the explanatory texts that the participants provided with the onomatopoeias. While free descriptions are valuable for representing city moods, imposing restrictions on their content makes them useful.

There remains much scope for the improvement of the map, as evidenced by the small difference between maps A and C in Fig. 14.6, even for indexes II and III. The map on the app could be more graphical, considering the large number of people using smartphones nowadays.

14.5 Potential for Future Work

This chapter discusses a method of visualizing city mood based on geo-located text data by using the example of the Yaizu onomatopoeia map. Although city mood is an amorphous concept, we succeeded in creating a map for communicating city moods by designing a method for data collection and visualization that is better than conventional maps.

Future research can extend and adopt such mapmaking to create maps of multiple cities. While we created the onomatopoeia map to primarily visualize the city mood of Yaizu for visitors, the approach could be customized depending on the goal, venue, and objective of the map. For example, Sect. 2.2 points out that different mood maps can be made by limiting tweets to adjectives, haikus, and so on. In fact, we make more theme-specific maps ("*Strange* map," "*Cute* map," "*Sky* map," and so on) (Ito et al. 2020; Ito and Kita 2021; Kita 2021; Kuwabara et al. 2020) in a local area called Yoita, Nagaoka City, Niigata Prefecture, where we started our mapmaking project in 2019. The mood of the area can be better represented by designing multiple maps rather than just one.

Another potential direction for this research is to collect and use the vast amounts of unorganized data available online. For example, Nakamura et al. (2013) created approximate maps of the five senses and sentiments (positive/negative) by collecting and analyzing text data from Twitter, which included onomatopoeia and geo-location.

As stated in Sect. 14.1, maps capturing city mood can have a significant positive impact on sightseeing, house finding, and city planning in today's scenario. These maps enrich our viewpoints on the city by representing how the city actually is. When urban designers, architects, inhabitants, and visitors begin to perceive the city from the viewpoint of city mood, the city can be a more beautiful, comfortable, and pleasant one.

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Chapter 15
Town Management Organization in Japan

Junichi Suzuki

Abstract To create a vibrant city, "hardware," including roads and buildings, must be maintained, and an appropriate environment should be created for "software," like the communication of people therein. However, Japanese towns and commercial areas have lost their vitality, and it is unclear what to do with them and how to leverage and activate them. To resolve this, towns and commercial areas must be revitalized using the "town management method," which involves comprehensively managing the entire town. The targets of town management include the development of major infrastructure, information transmission, and event planning. These approaches are practiced but are often performed individually by different organizations and people, and the effects are not easily spread throughout the town. Therefore, these efforts should be conducted in a unified manner. Here, a "town management organization" (TMO) is needed to execute these efforts. With the trust of the people involved in town development, such as cities, various organizations (commercial and industrial associations, merchant associations, etc.), merchants, and citizens, TMO is a semi-public sector organization that could promote town development. In this chapter, "Roppongi Hills" is an example of a TMO that encourages the formation of fans and raises consumers' sense of belonging by promoting visitors' community activity.

Keywords Town management organization (TMO) · Vertical garden city · Community Activation Committee

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15.1 Roppongi Hills' Concept of a "Vertical Garden City"

Roppongi Hills is a complex facility that opened in Minato-ku, Tokyo in 2003. It is run by Mori Building Co., Ltd. (hereinafter Mori Building), a major real estate company. Mori Building is based on the concept of a "vertical garden city" (Minoru 2012) in town development. A vertical garden city is a super-high-rise compact city in which urban functions such as work, housing, play, business, study, recreation, and culture are stacked vertically. A super high- rise is realized by combining the subdivided land to increase the floor area ratio and simultaneously minimize the building-to-land ratio. As a result, it is possible to increase the amount of land that can be greened on the ground and create a rich living space and time. The aim is to create a compact city by mixing various complex facilities into the facility simultaneously to attract a variety of people and promote the birth of a new culture. Reiko Ieda of the Town Management Division at Mori Building states the following (Fig. 15.1):

After half a century of trial and error, the ideal city model we arrived at is a green skyscraper city. It is a Vertical Garden City. This urban model reproduces the center of a sprawling megacity with superblocks (a type of city block that is much larger than a traditional city block). This model is intended to realize a compact city that can be enjoyed on foot by effectively utilizing the sky and basement of the city center and incorporating various urban functions such as work, housing, play,

Fig. 15.1 A vertical garden city

business, study, rest, culture, and exchange in a three-dimensional and multilayered manner.

You cannot increase the land, but you can increase the space if you make the building super high-rise and use the underground. If city functions are integrated vertically, travel time will be reduced and free time doubled. You will have more choices in life and more time to relax. A town where you can live on foot should be easy for children and the elderly to live and work in. This is more suitable for a knowledge-based information society and an aging society with fewer children. By utilizing the sky and underground, the ground can be opened to green and people. Parks, plazas, forests, rivers and ponds, short golf courses, futsal courts, and even urban ranches may be possible. Along with urban development, rebuilding railways, roads, and other infrastructure to make it earthquake-resistant and widening the space between buildings will create a disaster-resistant urban structure. By utilizing the center of the city in this way, it is possible to preserve the surrounding and suburban nature.

By setting up artificial ground on the third floor above the ground and connecting buildings, people, bicycles, wheelchairs, and strollers can be moved safely and comfortably.

"Hope in the sky. Green on the ground. Joy in the basement."

By taking advantage of the characteristics of the sky, above ground, and below ground, a completely new eco-friendly city can be created. Certainly, a single person or company cannot change a city. A grand design is needed, and consensus must be reached. Furthermore, some things cannot be done with the current legal system. However, it is not impossible if many people think, "Let's do it for the better." Japan has the technology, wisdom, and experience. Social changes such as globalization, the knowledge information society, and aging and a declining birthrate are also calling for a change in urban structures. By creating as many examples as possible, we hope to gain the consensus of the people, achieve a breakthrough in urban revitalization, and spread this philosophy domestically and internationally.

15.2 Roppongi After Development

Before development, at the center of the Roppongi area was a large-sized facility of the TV Asahi Broadcasting Corporation. In the southern part of the district, small and medium-sized stores, offices, and wooden houses were mixed and densely packed on fragmented residential land. In addition, public facilities were underdeveloped, and there were problems with urban disaster prevention. After development, complex facilities were built based on the concept of a "cultural city center." As of 2018, the area became a town visited by 40 million people every year. For this chapter, we interviewed Reiko Ieda of the Town Management Division at Mori Building on the details of Roppongi Hills (Fig. 15.2).

Fig. 15.2 Roppongi Hills

One characteristic of Roppongi Hills is the Mori Arts Center, which is a collective term for multiple cultural facilities built on higher floors. The Mori Arts Center was set on the upper floors, which are generally considered a conspicuous part of a skyscraper. The aim was to make this place a centripetal force to attract various people. The cultural facilities have an art museum and a membership club. The Mori Art Museum, located on the top floor, exhibits contemporary art from around the world. There is a viewing platform just below the museum, where you can enjoy cafés and exhibitions overlooking Tokyo. Furthermore, a sky deck was set up on the rooftop to create a space where people could go outside and relax. The membership club, also part of the Mori Arts Center, is a floor for executives with limited membership. It is open as a community space for residents in urban areas. It has a restaurant, a seminar venue for companies, and a nomad space. Community spaces like these were born with the idea that the communication of people, not the building itself, attracts new people.

Town planning centered on the culture of Roppongi Hills is spreading to the surrounding areas. The National Art Center, which was built after Roppongi Hills, the Suntory Museum in Tokyo Midtown, and the 21_21 DESIGN SIGHT Museum, together with the Roppongi Hills Mori Art Museum, form what is called the Art Triangle. As this example shows, Roppongi is becoming an art city.

15.3 Roppongi Hills TMO Initiatives

Mori Building established the Town Management Preparation Office at the planning stage of Roppongi Hills, and since 2003, when the project was completed, it has expanded its organization as a town management business office and has been working on the management of Roppongi Hills. The Town Management Office will conduct branding and promotion activities to strategically create an image of the city of Roppongi Hills, hold entertainment and other events that will be developed throughout the city, propose plans for improving services, and create local communities. The company produces the entire city from a wide perspective, from business activities to the mass media to one flower planted in the garden. Examples of TMO initiatives follow (Roppongi Hills 2020).

Roppongi Hills has a large event venue called Roppongi Hills Arena. Roppongi Hills Arena is a window to the town and an event venue where you can experience the whole town as a cultural center. A well-known event is "Roppongi Art Night," which is a one-night-only art feast set in the city of Roppongi. Roppongi Hills, Tokyo Midtown, The National Art Center, and Roppongi Shopping Street cooperate to promote the entire city. This suggests a new lifestyle of enjoying art in your life by scattering artworks, as well as works such as design, music, video, drama, and dance, throughout the city of Roppongi, where various commercial and cultural facilities are concentrated.

It also aims to improve the cultural image of Roppongi by integrating art and the city and to become a pioneering model for urban development in the Tokyo metropolis. This project was sponsored by the Tokyo Metropolitan Government and the Tokyo Metropolitan Foundation for History and Culture as the "Tokyo Culture Creation Project." Such a facility-crossing event requires that companies be bundled. Mori Building's TMO coordinates this. Various facilities are being united to promote further synergistic effects. In addition, the TMO works on a daily basis to consider ways to improve services and to support branding.

An important aspect of a TMO is the education of staff working in facilities. To share the Mori Building's concept of values while various people visit and work, it is necessary for the staff to understand the purpose and philosophy of the building. Therefore, Mori Building has a staff college program, where training is conducted for staff working in hotels and stores. During the training, the staff are trained on the purpose and philosophy of the town, and new exchanges and awareness can be created because staff members belonging to different sites perform group work. By combining not only the hardware of facilities but also the activities of software to nurture people, the program leads to even better facilities.

On the roof of the movie theater in Roppongi Hills, the garden where rice and persimmons grow is spreading. The Roppongi Neighborhood Association manages the garden. The Roppongi Neighborhood Association was established to foster a community among people living and working in Roppongi and in cooperation with neighboring town councils to promote the creation of a culturally international city. To make Roppongi Hills a more comfortable city, it actively conducts voluntary

monthly cleaning in the "Roppongi Cleanup," spring festivals, Bon dances, and earthquake disaster drills. The activities of the Residents' Association are conducted on three pillars, manifesting as safety and security activities, community activities, and local contribution activities. A dense community, including local people, has been created since its establishment in 2004, contributing to the revitalization of the Azabu and Roppongi areas, including the Hills. Members are locals from various positions related to Roppongi, such as companies with stores and television companies. Mr. Tanizawa, the chairman of the association, said that sharing the goals of the community for many years is the key to success.

Roppongi Hills also held various other events to activate communication. One example is a seminar event called "Hills Breakfast." In this event, one guest is invited every morning at 8:00 to give a speech. About 200 people visit each time, eat breakfast, drink coffee, relax, and share values. In addition, a club activity called "Hills-bu (Hill Club)!" is also run in the community. This is a club activity for adults where people living and working in Roppongi bring their skills. There is a wide range of departments, including salsa clubs, English clubs, beer clubs, wine clubs, kimono clubs, and basketball clubs, and the variety is increasing each year. It is managed by the Hills Community Activation Committee. Various people work while utilizing their skills, leading to further activation of Roppongi.

15.4 Creating a City that Does Not Fade

Roppongi Hills' TMO focuses on software rather than hardware. Going forward, the TMO plans to further promote towns through regional collaboration in events such as Roppongi Art Night. To that end, while large-scale facilities in the region such as Roppongi Hills and Tokyo Midtown will be the driving force, cooperating with local shopping streets is necessary to devise plans that unite the region. Administrative cooperation is indispensable in these efforts. To effectively develop area management, it is effective to utilize facilities such as open vacancies created through redevelopment projects.

A town becomes less fresh over time, but communication between people grows over time. Therefore, activating people's communication leads to maintaining the value of the town. "I want to continue to create a city that will not fade over time," says Ieda.

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Part V
Social City Development Using Social and Physical Information in Cities

Chapter 16
The Future of Real-World Marketing

Junichi Suzuki and Yasuhiro Kawahara

Abstract Information and communication technology (ICT) has been increasingly proliferating into towns. Communication between visitors regarding current information about the town is expected to increase in the future with the further development of communication tools such as SNSs. In future towns, it would be possible to monitor various constituent elements of the city, such as people, buildings, and the environment, in real time. In such a scenario, the revitalization of the town and the value of the space can be promoted by creating a place where visitors can communicate closely with each other, thereby forming a community in real space.

In this chapter, we first review the efforts to visualize customer traffic aimed at the revitalization of the town and customer relationship management (CRM) measures using advanced ICT that are spreading to local areas. We introduce examples of the use of advanced sensing technology to visualize and enhance each visitor's comfort level. We then describe a case study on the confluence of SNS and wearable devices aimed at revitalizing the local community by targeting modern consumers with a strong interest in sports.

Keywords Customer relationship management (CRM) · Customer loyalty management · Biometric marketing · Town user interface (UI)

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16.1 Visualization of Customer Flow and Real-Space Marketing

16.1.1 Capturing Behavior

In recent times, there has been a growth in services that measure customer traffic at stores and commercial malls, thereby facilitating interventions for their improvement. Although there has been a significant demand for customer flow analysis for supporting the improvement of store and sales floor layouts, it is nonetheless challenging to obtain devices that accurately measure location information in indoor spaces. Consequently, to satisfy such requirements, stores have resorted to manual analyses of customer flow. However, as mentioned in Chap. 8 on recent technological trends, various devices, such as laser sensors, voice, Wi-Fi, and camera-based methods, can be used to serve as position measurement devices.

As the variety of tools available for analyses has widened, it is now possible to identify store bottlenecks based on the data gathered from such devices, subsequently modify the layout of stores, aisles, and sales floors, change display contents, and improve operational efficiency. Previously, this type of information was available only from point of sale (POS) data. However, by analyzing data on potential customers approaching product shelves by incorporating these recent tools, such as by measuring the number of customers entering the store, the amount of customer traffic in each aisle, the amount of customer traffic on each sales floor, and the purchase rate of stop-by visitors matched with POS data, it has become possible to implement more effective sales measures. It is likely that the detection of the non-purchasing of products can lead to the discovery of problems on the sales floor. In addition, some stores now offer one-to-one promotions in real time on smartphones and in-store digital signage terminals based on customer traffic.

16.1.2 A Device that Inspires Visitors to Come Again

We now introduce a case in which a high repeat visit rate was achieved by a customer loyalty management measure called “co-creation.” This was accomplished at the “Jinseki Kogen Tiergarten,” which develops experience tourism that includes ranches, farms, and restaurants, under the theme of “caring for life” in Jinseki Kogen Town, a marginal village in Hiroshima Prefecture (Jinseki Kogen Tiergarten 2020).

Jinseki Kogen Tiergarten is a nature-experience theme park that opened in Jinseki Kogen-cho, Hiroshima Prefecture, in 2015. Experts across various fields and local residents collaborate on the ranch, dog run, farm, and rare plant gardens included in the facility. The point of appeal for visitors to the theme park is that it enables them to have meaningful experiences and learn through interactions with local people. Jinseki Kogen-cho is located in the Chugoku mountains at an altitude of about 500 m in the eastern part of Hiroshima prefecture, which has a population of about 10,000.

Fig. 16.1 Jinseki Kogen Tiergarten website (after logging in to My Page)

This highland town is surrounded by 381 square kilometers of forest. In recent years, the disparity between urban and rural areas has widened, and marginalized communities pose a social challenge. Jinseki Kogen-cho is no exception, and the theme park faces certain difficulties because of its location.

Since the opening of the theme park, its caretakers have emphasized connecting with customers who have visited once so that they will visit again. For example, Tiergarten offers only two types of admission tickets—a 3-month passport and an annual passport. There is no one-day pass available for visitors. This emphasis on visits over a period of time, Tiergarten explains, is meant to build a continuous relationship with visitors. For the same reason, their website has a "My Page" (Fig. 16.1) feature that allows customers to log in by entering the ID and PIN code on the back of their admission ticket. Additional features on the website include the number of visits, status confirmation, gift guidance, and reservations for experience events. This system has been devised so that people who have visited once can feel at home in the facility.

In addition, the Tiergarten admission ticket carries an integrated circuit (IC) tag, which is rare in a local theme park (Fig. 16.2). Consequently, when an admission ticket is passed over a contactless near-field communication (NFC) reader at each facility or shop in Tiergarten, the customer's event and purchase history from that day are recorded. If customers return within the validity period of the admission ticket, they can eat items, such as puddings or soft ice cream, that they purchased at the park on their previous visit. The facility calls this service "Buy One, Get One Free," and it serves as an incentive for customers to repeat visits.

Tiergarten also allows people to buy admission tickets as gifts for their friends, and when people who have been presented with gift passports visit the park, they can

Fig. 16.2 An IC admission ticket, the "annual passport," issued by Jinseki Kogen Tiergarten

obtain the same benefits as the original visitor that gave them the ticket. Therefore, if a visitor responds to the "Buy One Get One Free" incentive described above and revisits during the validity period of the passport, the original visitor, who is the existing customer, can be considered an "evangelist" and brings new customers to share free desserts. This serves as a model example for real-space marketing.

In this manner, businesses that adopt a customer-participation approach, thus involving users in the marketing process, can transcend the limits of their own internal resources and create value through collective intelligence and the behavior of the consumer. This method is effective. The development of hardware and software technologies that embed this approach, which is preceded by web marketing, into real space is the key to implementing a system that can be activated in a wide variety of towns. Thus, Jinseki Kogen-cho in Hiroshima Prefecture, which was once called a marginal village, is now improving through the efforts of the Tiergarten. Although the mechanism for creating repeat visits is not visible on the surface, it functions behind the scenes.

In real-space marketing in the age of social media, it is important to form user experiences and obtain evaluations (user reviews). Customer feedback generated by actual experiences with products and services creates a ripple effect of information that, in conjunction with the ground reality, leads to the creation of a brand. A co-creation approach that focuses on attracting new customers with the help of

existing customers can build a fan base that is enhanced by brand satisfaction and customer loyalty, rather than being built solely on products and services. In addition, the risk of failure of a new product may be reduced through real customer feedback.

16.2 Biometric Marketing

16.2.1 Efforts at Visualizing Comfort and Promoting Outdoor Use by Visitors

In a social city, where users engage in interactive communication using SNSs on a daily basis, attempts have begun to individually calculate the "comfort level index" for each visitor by comprehensively analyzing not only environmental information (such as solar radiation and heat) but also biological information (such as one's pulse rate) and social data (such as the number and relationships of accompanying persons).

There is currently a movement in Japan toward the effective use of facilities' outdoor spaces. Efforts are made to guide indoor users to outdoor spaces that are adjacent to the indoor environment. In recent years, an index named "Sotowork Index" (Takenaka Corporation 2013) has presented comfort standards for outdoor spaces that quantify comfort on six levels, according to weather, temperature, wind speed, and solar radiation. Furthermore, a smartphone app named "Kokochi Up Navi" ("Comfort Up Navi" in English) was developed by Obayashi Corporation, ISID Ltd., and The Open University of Japan in 2016, utilizing not only environmental information but also biological information (pulse rate) from the visitors to estimate their comfort level (ISID Press Release 2016). This app also provides an index in which the logic of the analysis is updated based on feedback from users in each space where it is used. In the demonstration experiment, the degree of comfort of the current location is estimated through signage applications (Fig. 16.3) based on biometric information from visitors and information on their relationships with their companions. In addition, the app features an agent on the screen to advise visitors on where to go from their current location if they wish to improve their comfort level.

The comfort level was calculated using a CCD camera mounted on a digital signage terminal installed in the city. When the face of the visitor is photographed, the fluctuation of the heart rate is captured, and the degree of tension is estimated, and the subject's degree of comfort is then estimated, taking into account evidence from the relationship with the accompanying person and outdoor real-time environmental information. This system is implemented as a service in towns to individually recommend outdoor spaces based on what the system calculates to be more comfortable for the customer.

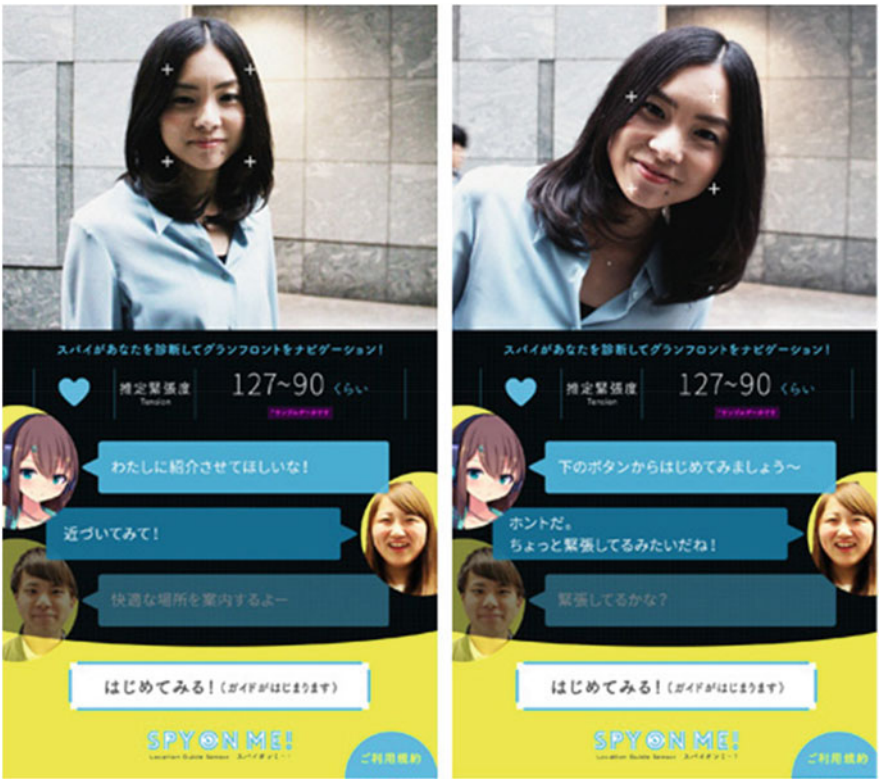

Fig. 16.3 Screen image of the verification signage app "Spy on Me"

16.2.2 Cooperation Using Wearable Devices

The interest in using sporting events as a means of regional promotion is increasing globally. However, in the case of, for example, a local marathon competition, it is not possible to attract people merely by conducting the competition. As part of the effort to develop sports-themed cities and revitalize local communities, new methods have been developed around a sports motif, such as measuring each participant's daily casual exercise and converting it into points. These were combined with attempts to also train and enhance the mind in an application. Participants can divide themselves into teams, compete for points, and complete a given mission as they continue to exercise while having fun. Screenshots of the application are shown in Fig. 16.4.

However, even among those that care about their health, it is not easy to create a habit of exercising or of participating in a sport. Therefore, in this trial, daily physical activities, such as walking, running, and climbing stairs, are converted into team-based games using wearable devices and SNS. The games are devised to motivate participants to exercise. In such an attempt, if a system is introduced in which office workers and neighbors that do not have much daily contact form a team or visit a touch point provided in the area (Fig. 16.5), this may lead to the formation of a local

Fig. 16.4 Confirmation screen for daily exercise amount converted to points

community and the promotion of sports. This may become a space where not only the highly motivated but also ordinary people, including both youngsters and seniors, who desire to be healthy can enjoy sports together.

Considering the following three features, we can argue that this trial, as described above, was made possible by using wearable devices combined with readily available social media.

The first is the team competition format. Participants were teamed either randomly or with friends. SNS is used for communication between team members, in addition to serving as a virtual space where participants can post exercise reports and encourage each other. This results in the formation of a virtual community that can motivate participants because they are working together, whereas it would be difficult to continue using a wearable device alone.

16.3 Town User Interface (UI)

16.3.1 User Interface for Town Service

As described above, new forms of real-space marketing can be actualized through information communication terminals that serve as contact points for visitors and

Fig. 16.5 "Every sport!" The experimental event was held around Osaki Station in March 2015.

residents in the town space. The user interface for implementing the town service described in the previous section includes digital signage in a town with touch panels and cameras, input functions from users, IC card terminals that read/write IC card information and provide services for individual users, and wearable information communication terminals linked to a service system that can interpret visitors' behavior.

A user interface can be thought of as a component or method for transmitting information between a computer system and a human. The following flow captures the evolution of user interfaces as they become more compatible with humans: command line interface (CLI) → graphical user interface (GUI) → natural user interface (NUI) → organic user interface (OUI) (Fig. 16.6). The CLI is an interface for operating a system using character-based commands via a keyboard, and the GUI is an interface for operating a system based on computer graphics and a pointing device, such as a mouse or touch pad. The interface of the personal computer that many people use today can be considered a GUI. The time to introduce NUIs more widely has now arrived. With an NUI, a machine is operated by the human senses, and therefore the operations are accomplished with natural actions performed by humans. Examples of these are touch panels, gesture inputs, and voice interaction systems. Smartphones and street digital signage interfaces function effectively in a town space. An OUI is envisioned as an interface that matches the input content with the output result solely based on the user's action, and not the shape of the plane,

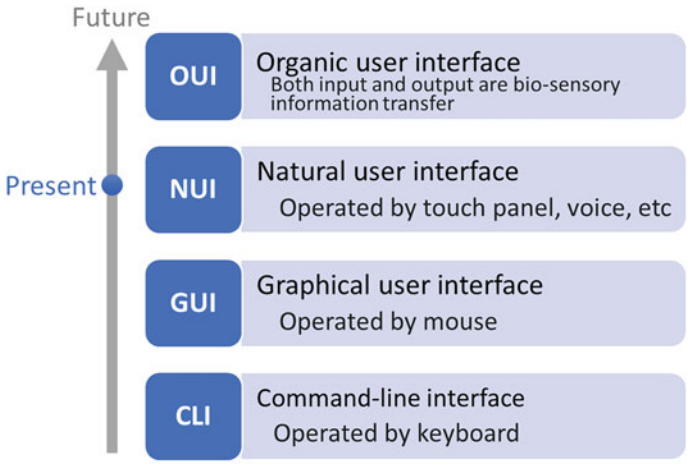

Fig. 16.6 Transition of user interface

thus allowing more intuitive operation and information reception. It would be essential for the user interface of a town space to allow residents and visitors to interact naturally without interrupting daily activities outdoors (Fig. 16.6).

Kinect (Microsoft) is a gesture-based input device that has been proposed for practical use in living spaces as an NUI. It is used for rehabilitation treatment as well as gamification and has been installed in a department store show window in the United States. As a practical example, it can serve as a virtual fitting room in which clothing can be changed on a display without being actually worn. This example illustrates that NUI has begun to penetrate real space. In a town space, interfaces combined with virtual reality (VR) or augmented reality (AR) have also been considered. Another example is a guidance system that superimposes an electronic map of a destination over an image captured by a smartphone camera. It is conceivable that as technology evolves, various types of interfaces will eventually be implemented according to people's behavior in the town space. If people's interactions with the city diversify, the manufacturing of various interface options may become a key issue in the technological development of town spaces.

Finally, we interviewed Yoichi Ochiai, a media artist and associate professor in Japan, about his future user interface. Japan has tended to prioritize functionality and convenience for the masses and has mass-produced industrial products that many people can use, thereby creating a market for the products. However, the time has arrived for more personalized products and services that cater to personal tastes.

With the evolution of interfaces and technology, virtual objects increasingly overlap with real objects, and this will become evident in the town. Virtual objects can be easily rewritten, so they can be moved more flexibly, for example, by switching time or based on the person that uses them. The result is a future in which our experience of the town is more personalized.

In the future, people will consider more carefully what they would like to do, and the ways in which they interact with the city will be diverse based on their hobbies and preferences. If the manner in which people interact with the city diversifies, computers can be designed to some extent to support these interactions, but the issue of how to create various options to match this diversity will be key.

It is thought that there exist elements of both the "virtual" and the "material" in the virtual reality world. A person has a choice between "virtual" and "material," or man and machine. Some people want to sing, while others want the machine to sing. Sometimes, we want to add little information to the material. How do we personalize these options? What kind of narrative should we think about for the relationship between humans and machines? We are conducting research on these questions at the "Digital Nature Laboratory" at the University of Tsukuba.

Our laboratory has imagined various options brought about by computer applications between virtuality and materiality. By implementing these in computer science, we aim to solve various problems from industry, scientific study, and art and to create new cultural values in people, computers, and nature.

To date, humans have considered natural and artificial objects separately. Among these objects, computers are very close to artifacts, and we treat computers as things. The "digital nature" that we are studying is like a computer melting into natural space. There may be a future in which the distinction between humans and computers will soon be lost, and the distinction between nature and computers will soon disappear. Humans will transition to a new view of nature, and empty spaces will become new media. When considering the future environment of a town, empty space turning into media will perhaps imply a considerable change in the ways of expression and the user interface. A key upcoming research theme will therefore be about how space can be transformed into media and how people will be affected by such media.

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Chapter 17
Blockchain for Decision-Making

Junichi Suzuki

Abstract In Chap. 4, an approach to attracting and engaging new consumers using leading-edge technology was introduced from a user experience (UX) perspective. This chapter delves into the underlying technology, blockchain, that enables such applications. Blockchain is a technology that has the potential to revolutionize society. It builds a distributed ledger on a network and is expected to be used not only in the financial domain but also in a wide range of fields as a new trust protocol to ensure the legitimacy of information that travels across the Internet. In this chapter, the features of blockchain and the context of the background in 2016 that led to the adoption of the Blockchain 2.0 scheme as a decentralized platform during the heyday of Web 2.0 are explained.

Keywords SDGs · Ethical consumption · Summer school program · Web 2.0 · Blockchain · Token economy protocol

17.1 Necessity for Implementation of Blockchains: Realization of a Flat and Open Internet with Web 2.0

With the rapid development of hardware and software, such as smartphones and blogs, in recent years, anyone can create and transmit information on the web today. Consequently, we are at the prime of the so-called "Web 2.0" era, which was initially predicted about 10 years ago. The history of the Internet has been described as witnessing "a big wave once every 10 years," and Web 2.0 is considered one such wave. It is a service driven by user participation, in which each Internet user participates on a level playing field. It is characterized as being an inclusive service in which ordinary users actively share information and evaluate the content shared by other users. Typical examples are Wikipedia, an online encyclopedia, and social

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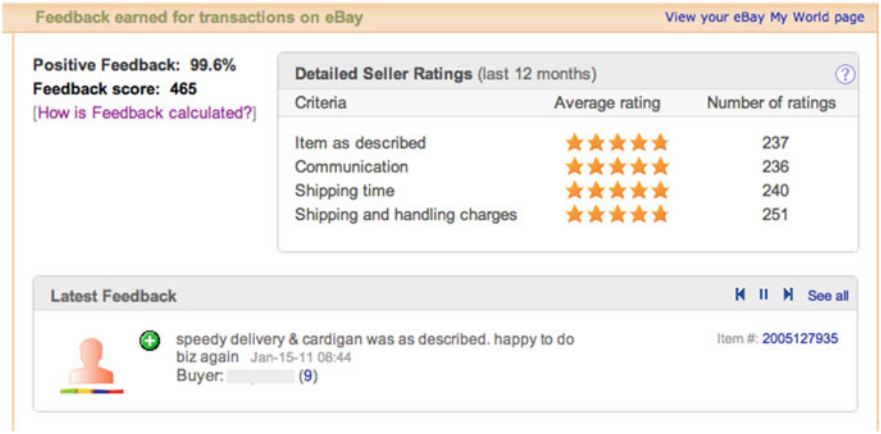

Fig. 17.1 Auction site eBay's seller evaluation (feedback) confirmation screen

bookmarks, which are online bookmarks published by users on the Internet and shared with a specific or general audience.

Umeda Mochio, the author of a book titled *The Theory of Web Evolution* (Mochio 2006), remarked, "Everyone who wants to participate in an act of expression such as writing, photography, narration, music, painting, and video can participate. To select the best among them, we can build a system akin to the preliminary high school baseball games conducted for selection to *Koshien* (the National High School Baseball Championship in Japan), and the information chosen in this way is superior to the information prepared by authorities and experts. The quality of the information obtained in this manner will be of higher quality than the information delivered by authorities such as professors, newspaper reporters, and critics." However, as stated by Umeda, the realization of this objective requires a "preliminary to *Koshien*" system to select the best from the available information of varying quality.

In Web 2.0, schemes whereby parties can evaluate each other after each transaction, which were first implemented in the Internet auction service and then subsequently generalized, enable third parties to recognize the credibility of each party. This process of democratic consensus building, leading to the development of "collective intelligence," has been adopted by many web services since the 2010s and has proliferated into our lives through repeated trial and error. Today, consumers have access to social network services (SNSs) that are naturally rooted in mutual trust, in which they receive and send interactive information. The most important feature of the late stage of Web 2.0, from 2010 onward, is that people acquired the ability to foster trust in others and the information shared by them based on their social graphs, regardless of their authority on a topic conferred by their position in society. This is one of the social impacts of Web 2.0.

Recently, services that use the collective knowledge of people, such as matching services aimed at matching partners, evaluation-sharing services that specialize in restaurant reviews, reviews on auction sites (Fig. 17.1), social lending, and cloud

funding for business and public use, have extended to the private domains of consumers, and the scope of these services is continuing to expand each year. In addition, the fact that anyone can easily disseminate and relay information has led to the formation of an "influencer layer" of users, which influences public opinion beyond the boundaries of SNS. Thus, the mode of information communication has drastically changed over the years: earlier, information was unilaterally communicated by the "authoritative sources," comprising university professors, newspaper reporters, critics, and so on; today, due to the prevalence of the Internet, a vast amount of information is created and communicated through the generation of collective intelligence in an interactive and nonhierarchical environment. Consequently, the influx of SNS into the authoritative layer, whereby authoritative sources also refer to SNS as a source to obtain information, has occurred in recent years. On the other hand, a reversal of this phenomenon can also be observed. For example, a part of the influencer layer that has garnered the trust of a follower base on SNS has partially shifted the axis of information transmission to mass media.

This type of flow can be considered the first step in the "preliminary to Koshien" transition. However, this can also lead to adverse phenomena such as the emergence of information summarization websites that lack credibility and the rapid spread of "fake news" items through SNS. These in turn engender negative outcomes, such as the manipulation of public opinion by fake news. With respect to food safety, problems such as the obfuscation of production conditions and "fake food" are becoming serious social issues, particularly in Asia and Oceania. To address such issues of trust, blockchain can be used to demonstrate to consumers the legitimacy of products and services, as its underlying mechanism ensures that the information recorded cannot be technically altered (the possibility of tampering is extremely low).

17.2 Blockchain Technology and the Internet-Based Real World

17.2.1 Areas that Actively Utilize Blockchains and Their Characteristics

Blockchain is the core technology underlying Bitcoin. It is a data-recording mechanism characterized by anti-tampering properties and a decentralized consensus network that was proposed in 2008 by Bitcoin's inventor, Nakamoto (2008). A simpler definition is that a blockchain is "a mechanism that ensures the reliability of transactions by the intervening eyes of a third party." For modern consumers that are attempting to determine value based on the collective wisdom of people, rather than the unilateral credit recognition by established authorities, blockchains offer a daily decision-making and democratic consensus-building process supported by the technology. Blockchain technology provides an extension to the daily lives of the Web

2.0 generation, which values open, nonhierarchical relationships and interactive trust-building processes.

Regional differences exist in the coverage of blockchain services. However, there are already regions and cultural areas that readily accept services supported by blockchain technology. An overview of relevant global initiatives yields numerous examples, including efforts that are underway to incorporate blockchain technology into Dubai's smart city concepts, the implementation of a tax return system to reduce tax collection costs in Eastern Europe, and the mushrooming of numerous blockchain-based startups and the Bitcoin Embassy (a currency research institution) in Israel. In such countries or regions, there are experts in computer science, mathematics, and cryptography. In addition, they also have flexible and rational national characteristics. Furthermore, a positive attitude toward implementing blockchain services may be related to the regional political situation, history of the country, and stability of the country's financial market.

As an antithesis to the conventional "centralized" technology, which provides users with a single, large service using cloud computing, certain new web services have appeared. They leverage a distributed network technology that is not dependent on a specific service operator. The rapid growth of the new German SNS called "Mastodon" is a good example. There are technical and socio-cultural similarities between the reasons for the popularity of the new web services and the increasing popularity of blockchain. Similar to how Web 2.0 values usurped the then-ideal methods of communication in cyberspace, social change caused by the Internet, which is still considered an amateurish revolution that has not yet been embraced by authorities, is gradually changing consumers' consciousness and beginning to influence their daily behavior.

17.2.2 Technical Characteristics of Blockchain Technology

So far, we have described an outline of the social background that led to the emergence of the blockchain, the differences in approaches and attitudes that were adopted throughout the period corresponding to the modern history of the Internet, and other closely related factors. We now explain the technical characteristics of blockchain by focusing on its differences from the conventional system. First, the two types of blockchains, which may be easily misunderstood, are discussed. Blockchains are broadly divided into public and private types. Public blockchains usually have a completely nonhierarchical relationship, in which it is not possible to grant authority for modifications to some participants and not others. Hence, the process of democratic consensus building in public blockchains is believed to have high affinity, and studies on their utilization are being conducted in line with these characteristics. By contrast, a private blockchain has an administrator. Although it is possible for the administrator in a private blockchain to limit the number of participants and dynamically upgrade the specifications of the computer and network

environment, it is inferior to the public type because of its drawbacks in terms of anonymity and publicity.

Next, a clear understanding of the relevant distributed database system and consensus-building process used in blockchains is essential. Consensus building, also called "mining," is a technical process that identifies information that is to be written to the database. In a centrally managed database, data can be updated consistently unless an administrator commits an error. Furthermore, only one database needs to be updated, which enables high-volume transactions to be processed at high speeds. On the other hand, in a blockchain, transaction information exists in a distributed database; hence, if the transaction information is not appropriately synchronized and updated, only a part of the database will be updated, and the other parts will remain in their earlier states. Therefore, a consensus-building process should be established to consistently update the database.

In particular, since anyone can participate in the maintenance of a distributed database of a public blockchain such as Bitcoin, it typically requires more than 10 min to form a consensus to correctly perform data recording. This avoids a malicious user's attempt to enter falsified data and therefore records only correct and genuine data. By contrast, a private blockchain can reduce the time consumed by the consensus-building process by limiting the number of participants involved in the maintenance of the distributed database, thereby significantly increasing the transaction speed. In addition, because private blockchains can narrow the scope of data reference to the operator, they are better suited for many use cases, such as in consortia led by financial institutions.

One advantage of the private blockchain compared to the conventional centrally managed database is that the former involves less risk of arbitrary change by the operator because data are recorded in the form of a chain that is difficult to change. Another advantage is that services are not disrupted as long as at least one of the distributed computers in a private blockchain is running. Therefore, a private blockchain is suitable in domains where the accuracy of data is required, system downtime is not allowed, and low-cost maintenance operation is required. Examples are medical trial data that require evidence of data integrity and scientific research data that require long-term storage of ongoing records. Another example is that of a private blockchain introduced in agricultural production and distribution in the Aya-cho (a town in Miyazaki prefecture, Japan) demonstration experiment. In this case, soil management history and inspection results for the past 3 years prior to the start of cropping would be continuously recorded as production management information (transaction data) based on the aforementioned characteristics. The local government office was adopted as the manager for this purpose.

17.3 Demonstration Experiments that Leverage the Characteristics of Blockchain

The previous chapter introduced the case of Information Services International Dentsu (ISID) Co., Ltd., which has been engaged in a demonstration experiment to increase added value and boost ethical consumption by visualizing the philosophy of producers using blockchain technology. In this chapter, we introduce the next stage of the *Aya-city* study on ethical consumption.

17.3.1 Demonstration Test for Ethical Consumption in France

In May 2019, ISID's Open Innovation Lab conducted an "ethical consumption" demonstration test in France with the cooperation of Sivira Co., Ltd. and Katsuki Wines (a family-run winery in *Aya-city*) (ISID 2019a). The purpose of the test was to verify how domestic wines with guaranteed production history are evaluated by French consumers and whether visualization of the winery's contributions to sustainable development goals (SDGs) will motivate ethical consumption.

The restaurant "ZEBRA" in Paris collaborated with the team on the experiment. The owner, Mr. Curreck, said, "ZEBRA is actively using organic ingredients, and there are many customers who are willing to try new things. I felt that it would be interesting to be the first store in Paris to handle ethical Japanese wine." Figure 17.2 shows a picture of participants of the experiment at ZEBRA.

In addition to the evaluation of a product from Katsuki Wines, the experiment is also intended to introduce the "Token Economy Protocol" (TEP)[1] jointly developed by ISID and Sivira for the first time to the general public. Mr. Fujii of Sivira explained, "If a token is given to customers for a desired action or contribution to a certain community, and the token has value, a new value system or economic zone can be constructed."

When a visitor consumes Katsuki Wines' bio wine, the SDG token will be given for "ethical behavior." Tokens enable customers to join a consumer community with similar values. Within the consumer community, we envision a future where people who contribute to ethical consumption or adopt desirable actions will be correctly evaluated and therefore conferred with higher trust.

[1] TEP is a general-purpose middleware protocol designed to realize the "token economy," in which all assets and data defined on the blockchain, that is, tokens, are used as a means of exercising rights based on individual values. By providing a general-purpose protocol, various applications will be able to cooperate with each other in the same blockchain environment.

Fig. 17.2 Zebra customers who are comfortable with experimenting with new things

In this case, a hard wallet[2] was used to receive the tokens. The hard wallet incorporates anime elements to reduce psychological barriers for users. The 17 SDGs were anthropomorphized into anime characters (Fig. 17.3).

The SDG token is transferred when the hard wallet is held over the smartphone. This wallet enables visitors to intuitively understand the kind of activity they are participating in, even if they do not fully understand the technical mechanism. Many customers visited, and most of the 50 bottles of wine were consumed by the completion of the demonstration test. Among the participants, the seniors showed a strong interest in wine itself, whereas the younger BOBOs,[3] who prefer "Lifestyles of Health and Sustainability" (LOHAS), were more proactive towards learning about the mechanism of the SDG token and TEP.

Lowering the threshold for introducing blockchain can have a desirable effect on people. First, they would be able to participate in the SNS community using the SDG token, which would motivate them to practice ethical consumption. Second, in an economic area connected by a common set of values, the evaluation can be performed using a unique standard that does not exist in conventional mass

[2] A hard wallet (named so for being hardware based) is one that implements a mechanism to store a user's private key in a contactless IC terminal and read it from an NFC-compatible mobile device to ensure quick transaction signatures. In this demonstration experiment, it is used as a wallet to manage tokens associated with 17 SDGs.

[3] BOBO is an expression used to describe a French bourgeois-bohemian socioeconomic group, meaning "a well-educated person with one foot in the bohemian world of creativity and the other in the bourgeois realm of ambition and worldly success."

Fig. 17.3 Holding the hard wallet personifying the goals of the SDGs over a smartphone

marketing. It is important for people to gain an understanding of these possibilities through their own experience. This experiment was a step towards this.

17.3.2 Application of Token Economy Protocol to the Education Field

In Japan, reforms on entrance examinations have been ongoing in recent years, leading to, for example, the abolition of the National Center Test for University Admissions, in the midst of active discussions on how education should be reconsidered. This may perhaps be an era when the recommendation letter, which can perhaps provide a more accurate reflection of one's ability and interests, is emphasized over the paper test, which is akin to a one-shot game. On the other hand, it is difficult to consistently capture the purpose and the kind of learning that has been acquired by a student, including through extracurricular learning and volunteer activities, in a recommendation. To address this issue, the Open Innovation Lab applied the token economy protocol from the French experiment to the field of education (ISID 2019b). Using blockchain, we verified a mechanism whereby the learning history, the relationship between the instructor and students, and the relationship between students could be proved.

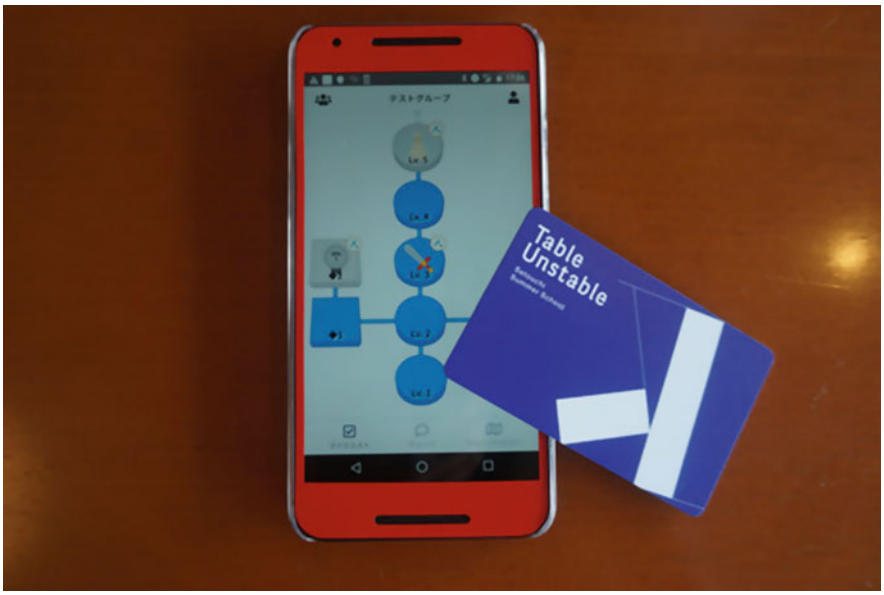

Fig. 17.4 Hard wallet (card) and application screen

This experiment was conducted at a summer school where students learned about SDGs from Yoichi Ochiai, who works as a media artist. The summer school was held for elementary and junior high school students in Hiroshima and Okayama prefectures. The children who participated logged in to the app by holding their hard wallet (NFC card) over their smartphones and recorded their learning. This card also serves as an owner identification card on the blockchain. We set up many squares, similar to a stamp rally, in the app and prepared a "quest" to progress to the next square from each square. By introducing such a game, we aimed to encourage children to learn voluntarily (Fig. 17.4).

Quests are linked to learning and interacting with others, such as "presenting what you have learned in a presentation" and "making friends." When students complete a specific quest, they are given a token to prove it. By obtaining tokens, students gain the right to join the community. Teachers do not force anything in this community, and companies do not provide instructions. It is an autonomous decentralized organization (DAO), which is an organization in which students voluntarily participate without a central administrator. One of the objectives of this experiment was to verify whether a DAO would truly emerge with the proactive participation of the students.

Sivira continued to monitor the summer school to check whether the students are willing to touch the app and operate it intuitively. All students cleared the first quest on the first day. Some students completed all the quests on the first day. Sivira continued to monitor the summer school to check whether the students are willing to touch the app and operate it intuitively. All students cleared the first quest on the first

day. Some students completed all the quests on the first day, so an additional quest was added for them. With the app having a game element, no additional explanation was required, and the students voluntarily progressed through the quests. By completing each quest and obtaining tokens, even if one loses their paper certificate, they can always prove that they learned SDGs from Mr. Ochiai if they have a history on the blockchain.

Mr. Fujii of Sivira remarked, "The DAO protocol, a common rule for creating apps, allows multiple companies, universities, and organizations to create apps that issue tokens based on a common philosophy. The value of the tokens increases as the number of participants increases. It may be possible to imagine a world in which students with many tokens will be exempt from the entrance examination. If you complete a quest, you will be able to reach a certain point. With this point, for example, we developed the application on the assumption that, although it is a dream, direct admission to the University of Geneva would be possible, and we will continue to develop technology toward that goal."

Summer school participants can continue to communicate on the app after the completion of summer school. Instructors can also join the community and build long-term relationships, which may provide an opportunity for them to write recommendations or invite the participants to the lab. Therefore, in the blockchain-based approach, events such as summer schools may become the starting point for SDG activities and career development. This would lead to a long-term engagement involving continuous learning and certification, in contrast to the traditional approach of examinations in which the evaluation is based on a single event.

17.4 Summary

In this chapter, we confirmed the effectiveness of Blockchain 2.0-based systems, through several empirical experiments. The experiments indicate the potential for methods dealing with big data to develop further in the field of artificial intelligence (AI) technology, which is effective with a large amount of learning data, in conjunction with IoT devices that store data without human intervention, as information and communication infrastructure technologies such as 5G communication and quasi-zenith satellite systems become more sophisticated in the future.

Today, changes in the nature of information communication originating in cyberspace have impacted the awareness of consumers and are beginning to affect their daily activities in real space. With respect to food safety and consideration for the ecosystem, using Web 2.0 combined with blockchain technology (as in the example of the decentralized platform technology based on the Blockchain 2.0 scheme from the experiment above) enables an environment in which consumers can evaluate each other's value by sharing materials that are not only endorsed by authorities but also evaluated by consumers themselves. This is akin to the "preliminary to Koshien" mechanism predicted by Umeda.

Through this pilot project, we witnessed the emergence of new markets by connecting rural and urban areas, producers, and consumers. One example is a customer who came to a store with a mother whose child was suffering from allergy symptoms. She understood better than anyone the value of vegetables grown with plant-based compost and saw the irreplaceable value in the vegetables grown in Aya Town and the town's commitment to publicizing its production history. We were reminded that the goal of the Internet of Value by Blockchain (IoVB), a research project that supports regional revitalization through the use of blockchain technology, is to appropriately match the values and needs of individuals. An example of such individuals may be those who are not satisfied with the organic certificate of the Japanese Agricultural Standards (JAS). We intend to continue our research with the aim of creating a society in which producers, consumers, and all stakeholders involved in organic farming are rewarded.

To achieve complete food traceability, the entire food supply chain from production to consumption must be made visible. Food distribution does not always take the form of simple direct sales, such as direct delivery from the producer to the consumer, as was the case with the demonstration experiment. Therefore, it is necessary to involve transportation companies, medium-sized wholesalers and retailers, as well as food service providers when cooking and processing are required. Furthermore, it is important to record the work carried out by each operator at each stage of the food chain and communicate it to the next consumer by recording it on the blockchain, as may be appropriate. Nevertheless, this is a challenging objective to achieve in practice. In addition to the efficient system using the Blockchain 2.0 scheme, which exhibited positive results in this demonstration, we will also continue to explore the approach based on the Blockchain 3.0 scheme in the age of Web 3.0, in which administrators do not exist. In other words, we would like to explore an approach based on a full P2P public blockchain credit approval model in which users and individual consumers can exercise discretion over their data in response to the de-platforming trend.

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Chapter 18
Web 3.0 and Blockchain in Real City

Junichi Suzuki

Abstract The Internet of Things (IoT), sensing technologies, and artificial intelligence (AI) are fundamental for social cities. The emergence of new technologies from these fields has broadened the concept of cyber-physical systems (CPSs) and advanced the progress towards seamless communication services without boundaries between physical and digital spaces. However, this also implies that the challenging issues pertaining to anonymity and trustworthiness of information that have occurred on the Web may reappear in the physical space of the city. It is therefore necessary to solve the difficult problem of linking identities in real and digital spaces in a manner that guarantees reliability and the trustworthiness of information. A new CPS technology called "blockchain" attempts to address this issue. Blockchain not only solves the problems posed by anonymity and unreliability but also reliably connects information about people, products, and digital content online and offline. Further, by capturing individual values, such as the entities or individuals trusted by a user, blockchain can facilitate new business schemes in which the final price of a product is individually adjusted according to the trustworthiness and community influence of individuals involved in the supply chain. This chapter is a summary of its history and potential.

Keywords Web 3.0 · Ethereum · Blockchain · Cyber-physical system (CPS)

18.1 Introduction

A cyber-physical system (CPS) was originally conceived as one in which virtual space and physical space are closely connected. In such a system, a computer transfers information from real space (physical space) into virtual space (cyberspace), analyzes it with its computing power, and feeds it back to enhance the real

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world for users. However, with the emergence of a new CPS technology called "blockchain," the supply chains of certain services, which were previously limited to cyberspace, can now extend into real space, thereby merging real space and cyberspace. For the application of CPS to urban development based on the concept of "social city," the issues of untrustworthy information caused by anonymity in web space and difficulty in granting credit on an individual basis, owing to deficient means of confirming historical or real-world community information, can be resolved by blockchain technology. This chapter introduces this technology.

In an open network such as the Internet, a blockchain, which is a "distributed ledger technology" that enables highly reliable financial transactions and the exchange of critical data, has undergone a revolutionary technological evolution over the past 10 years since its introduction in 2008. It is a technology that can make our everyday lives easier, support the granting of individual credit, and better accommodate individuality and diversity. However, with the rapid technological evolution of the blockchain, the evaluation and definition of the blockchain have drifted over time, resulting in confusion regarding the understanding of the technology today. Specifically, a correct understanding of the essence of the technology is lost among many people owing to the nature of the discourse on the technology over the years, and this prevents us from understanding the present state of the technology.

Blockchain has been touted as "the next revolution since the Internet," although its technological evolution and the speed of its implementation in society, including in the nonfinancial domain, far surpasses that of the Web, a service on the Internet. For the benefit of readers interested in working on blockchain, this chapter introduces the era of "Blockchain 1.0," a technology for cryptocurrencies such as Bitcoin, through "Blockchain 2.0," which enables the use of blockchain in the fintech field, and then to "Blockchain 3.0," where the use of blockchain extends into other fields with the technological evolution of the web and the demands of society. This chapter provides the reader with a bird's-eye view of the history of technological evolution in just over a decade to the present-day state of blockchain.

18.2 Evolution of the Web

18.2.1 Dawn of the Internet—Web 1.0 and Portal Sites

The advent of the web was a revolution. The World Wide Web (the Web), invented in 1989 by Tim Berners-Lee of the European Organization for Nuclear Research (CERN), dates back about 20 years prior to the advent of blockchain. The Web spread rapidly throughout the 1990s as a new option for the media environment then, in which "paper" and "radio waves" were the norm, and began to be used in a variety of applications and fields. At that time, it triggered a social phenomenon called the information revolution, and people were excited about the dawn of the Internet age. In the early days of the Web, it was common to use telephone lines for dial-up

connections, and it is still fresh in our minds that there was an ear-splitting sound emitted from the modem, and the communication cut off of telephone and fax lines due to the occupation of the communication lines.

The changes in the media environment from the 1990s to the early 2000s brought about by the advent of the Web are referred to as "Web 1.0." Web 1.0 was termed a revolution, but the content was not much more than a collection of static sites, and the mode of participation was rather primitive, mainly through browsing. Because the connection fee for the Internet was on a pay-as-you-go basis in those days, it is characteristic of the Web 1.0 era that we had to go "offline" when we were not connected to the Internet and "online" when we were connected to the Internet. The communication infrastructure was still in the process of technological evolution, and we had to wait for a considerable amount of time to download music that only took a few minutes to listen to. Consequently, we had not been able to conceive the idea of seeking interactivity and real-time performance on the Web at that time.

In the history of the Web, which was dominated by Europe and the United States, the dawn of the Internet in Japan began with the appearance of Yahoo Japan, a giant in the IT industry, which built a generation of portal sites. In December 1995, Masayoshi Son, the founder of Yahoo Japan, visited 27-year-old Jerry Yang and David Filo, the founders of an obscure venture firm and still graduate students at Stanford at the time, at their Silicon Valley office. Masayoshi Son proposed to invest 10 billion yen in a collection of website links called "Jerry and David's Guide to the World Wide Web," a prototype of the service that would later lead to Yahoo Japan, as well as their entry into Japan. Masayoshi Son's brother Taizo Son and Makoto Arima, who later became the head of Google Japan, were responsible for the development of the Japanese language version and completed the mission in a very short period of time. This Japanese version marked the beginning of the Web 1.0 era in Japan.

18.2.2 The Age of the Platform Heyday—Web 2.0 and SNS

While people were captivated by the information world of Web 1.0, a disruptor appeared in Silicon Valley. "BackRub" (later Google), developed by two Stanford students, Larry Page and Sergey Brin, was a groundbreaking search engine with a complex algorithm, unlike Yahoo, which relied on human input. With the spread of high-speed communication infrastructure such as ADSL and fiber optic lines, the start of cloud services by Amazon, the spread of smartphones such as the launch of Apple's iPhone, and the start of Facebook and Twitter services, the Web became a place where people not only browsed but also participated.

The era of the heyday of platform providers led by Google, Apple, Facebook, and Amazon (GAFA) in the late 2000s is called Web 2.0. In this age of "always on" connection to the Internet, it became possible for like-minded people to form a community on social network services (SNS) without being bound by physical boundaries. It can be said that Web 2.0 is the "age of social media," in which people

have acquired the means to transmit and spread information. In 2008, when Yang resigned as the CEO of Yahoo! in the United States due to the stagnation of the company's business, a number of interactive platform operators appeared in Japan, supporting people's desires to transmit information (and thus their desire for recognition) through smartphone applications and allowing anyone to freely post and evaluate information.

In the 2010s, GAFA and other platform providers established a business model in which they provided certain goods and services free of charge in exchange for the acquisition and use of personal and other information. They increased market accessibility for contractors and contributed to improving consumer benefits, while promoting data oligopoly through network effects, implying that the value of a product or service is dependent on the number of users and economies of scale and the cost per unit is reduced by increasing production volume and scale. Consequently, Europeans became concerned about the impact of these companies on the fairness and competitiveness of the business environment and the oligopoly of personal privacy information. Specifically, their concern was that the monopolistic scheme for the collection of personal and other information by GAFA and other platform operators was an abuse of their dominant position and could be an invasion of privacy and an obstacle to a fair business environment.

Recent years have particularly seen a trend towards the strengthening of laws and regulations related to privacy and identity, such as the General Data Protection Regulation (GDPR) in the EU, the personal information protection legislation in Japan, and the California Consumer Privacy Act (CCPA) in California, USA. Consequently, businesses in Europe are now required to treat information such as browsing history and cookies as personal information. Businesses that want to use the users' personal information for business purposes are now obliged to obtain the users' consent in advance. In Japan, although it has been argued that it would be difficult to impose strong regulations on platform operators such as those in the EU, amendments are being made, and Web 2.0 platform operators are beginning to be regulated in a similar manner.

18.2.3 Beyond the Web 2.0 World—Two Web 3.0 Worlds

So far, Japan has been hit by the Web 3.0 wave twice. Starting in the early 2010s, the first wave of Web 3.0 appeared in the computing world, which came with the evolution of information technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR), Internet of Things (IoT), and cloud artificial intelligence (AI). This first wave focused on the possibilities of next-generation devices such as head-mounted displays (HMDs) and AR/MR glasses, touted as the next generation of devices to take on the role of the smartphone, the main device of Web 2.0, emphasizing the analysis of real space data with cloud AI. The second wave of Web 3.0 started in the late 2010s. As practically everyone had a smartphone as a means of information transmission in the Web 2.0 era, the "personalization of the Web"

rapidly advanced and the problems of privacy and identity caused by it became apparent, as mentioned previously. Consequently, the second wave of Web 3.0 focused on the use of blockchain technology as a fair, democratic, and transparent consensus-building tool that also helps accommodate a range of individual needs and values.

18.2.3.1 First Wave of Web 3.0: A Computational World Led by IoT and Cloud AI

Hironao Kunimitsu, an entrepreneur who built his business along with the growth of the Internet in Japan, describes the change from Web 1.0 to 2.0 as an event related to the transition from hypertext to social graphs, and the change from Web 2.0 to 3.0 as the explosive increase in big data associated with the spread of IoT (Kunimitsu 2017). The figure below summarizes this as the arrival of cloud AI, which processes data into meaningful data, along with the trends in devices (Fig. 18.1).

Kunimitsu said, "For example, we actually get together at a conference. That's 100% real scenery, right? However, if the background of the meeting room where everyone is gathered looks bleak, you can virtually change the background to Hawaii's scenery. Further, let us conduct 50% of the meetings in real space and 50% virtually. Let us get together online with HMDs to have a meeting with a remote team. This is 100% virtual. The concept of MR, which we are told we will eventually reach, is a worldview where this percentage can be changed at will, where the real and virtual come and go seamlessly."

In "The Second Times," which released a special issue on "Leading the Way to Diversity," I attempted to categorize the research and development trends in various countries related to virtualization technologies such as AR and MR, which were still in the experimental stage in 2008, and proposed the concept of crossed reality (XR) as a vision for the future (Suzuki 2008). More than a decade later, HMDs such as the Oculus Rift and Microsoft HoloLens, other IoT devices that have

Web Trend / Element	Web1.0	Web2.0	Web3.0
Device	PC (Win/Mac)	Smartphones (iPhone/Android)	VR/AR/MR (?)
Data	Hypertext (Google)	Social Graph (Facebook)	Internet of Things (?)
Processing and Analysis	Managed Server (RackSpace等)	Cloud Server (Amazon)	Cloud + AI (?)

Fig. 18.1 Trend changes up to Web 3.0 (Kunimitsu 2017)

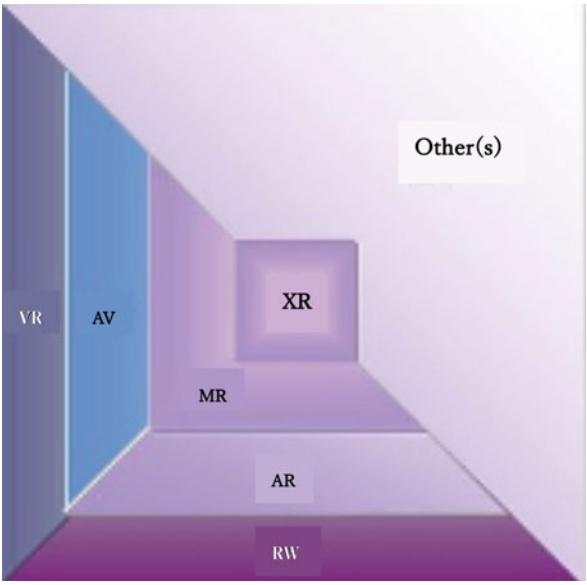

Fig. 18.2 Typology of virtualization technologies (created by the author) (Suzuki 2008). *VR* virtual reality, *RW* real world, *AV* augmented virtuality, *AR* augmented reality, *MR* mixed reality, *XR* crossed reality

developed sufficiently for practical use, and the development of social communication infrastructure technologies such as the quasi-zenith satellite system and 5G, have made it possible for the real and virtual to become connected seamlessly, which is the world Kunimitsu foresaw. The arrival of the XR world was not far away.

In the Web 3.0 world, an important factor is the domain in which "participants share information about each other's attributes" (defined as XR in the above figure). It represents a "society that endorses diversity" in which we recognize each other's values by considering the political beliefs and behavioral philosophies of others and by superimposing our own identities, such as our way of life and way of thinking, on them. We also live in a society where people can choose the best course of action for all parties based on the results of real-time sensing and cloud + AI calculations.

The worldview of Web 3.0, as the first wave, provides an important point of view on identity management in the digital space, and it has evolved into discussions led by organizations such as the Decentralized Identity Foundation (DIF) and the World Wide Web Consortium (W3C), involved in technologies for international identity, such as self-sovereign identity (SSI), decentralized identifier (DID) standards, and Fast Identity Online (FIDO) standards as alternative authentication technologies to password authentication. Future research on these issues is also underway in the academic field. In a discussion on the virtualization process for placing a digital human as a legitimate alter ego on the web, which is one's own alter ego in a fully digitally transformed blockchain 3.0 society, it is noteworthy that "mutual ID authentication," which captures the world of XR as shown in Fig. 18.2, is required in this virtualization process.

18.2.3.2 Second Wave of Web 3.0: A Blockchain-Based Mutual Credit World

With practically everyone possessing a smartphone and therefore a means for information dissemination, "web personalization" has advanced to the stage where credit is formed for nameless individuals as well. However, Web 2.0, which is a flat and open Internet world where all those that wish to participate in social networks can do so on an equal footing, has brought to light problems such as identity and credential forgery, impersonation, and fake news. For example, in a case where a recipe using honey as a "menu for infants" was posted on a website of user-contributed recipes run by a major platform operator, which caused a serious accident, the user who wrote the recipe was highly rated in the community.

In addition, in the case of misrepresentation of the actual place of origin of agricultural products that was discovered on a portal site for supporting regional development, the vendor was certified as an expert in the field of agriculture. Recently, the number of doctors registered with a major dating service exceeded the number of doctors in the country, and there were numerous cases of unidentified sources and false information spread on the platform. This difficulty in ensuring the reliability of information was considered to be detrimental to Web 2.0.

Haruo Takasaki, KDDI Research Institute, explains in his book "Prospects and Challenges for the Web 3.0 Era" that it is necessary to discuss the following themes that may emerge in the Web 3.0 era, which are uncertain elements of Web 3.0 (Takasaki 2010). This was an accurate foresight of various issues that would later become reality.

1. Is it possible to properly engage stakeholders in the intelligent web environment of Web 3.0 (i.e., address issues such as the new digital divide, universal access, and net neutrality)?
2. How can a policy respond to the collection and integration of information? Concepts of information ownership (copyright), control, and responsibility are strongly challenged in this environment (these include intellectual property systems, privacy protection, and information accuracy assurance).
3. It is difficult to determine what the social response will be. It is difficult to predict what situations will result from endless computer processing and storage capacity in the cloud and people's disregard for the rules (issues of securing identity, user and social acceptability, dealing with new crimes).
4. As a result of the increasing networking capabilities of a wide range of people and organizations, the traditional processes of value sharing and efficient access to resources may be disrupted. This could undermine trust and expose vulnerability to new damage (network system reliability issues, addressing vulnerabilities).
5. The ability of individuals and organizations to configure new layers of international relations through the intelligent web of Web 3.0 threatens to undermine the importance of nation-states (security issues, international relations, and international competitiveness).

6. While it can be expected to provoke innovation, it can also lead to information overload and require autonomous or collaborative filtering and rating of information intermediaries (the problem of dealing with information explosion and the problem of information controllability).

According to Mr. Takasaki, the Web 3.0 era is an era for discovering solutions to these problems. For this, we needed to wait for the appearance of the blockchain "Ethereum" proposed by Vitalik Buterin in 2013, and the concept and technology of smart contracts defined in Ethereum (Buterin 2013). "Ethereum" and smart contracts are discussed below.

18.2.3.3 Web 3.0 from a Business Entity's Perspective—Transition to the Era of Individuals Exercising Data Discretion

Business operators need to maintain pace with trends in data protection laws and regulations that regulate the lock-in of users and monopolistic use of information by companies, the strengthening of regulations in each country, and the development of services to strengthen individual data discretion in each country. In light of the discussions on international standards, it is necessary to consider whether a company should continue to operate in accordance with the new standard or whether it should relinquish some of its users' personal information considering the expected increase in management costs and security risks.

Choosing the latter policy implies that the control of the data is transferred from the application operator to the individuals who use the application. As certain restrictions are imposed worldwide on the personal information that previously was handled by businesses at their own discretion, Web 3.0, from a business entity's point of view, challenges the conventional idea of managing user information as the company's own asset. Rather, it poses the question of how to use individuals' personal information in a manner that respects them and confers on them the power of ownership of their information. Therefore, it requires deliberation on how application operators can obtain the data required to work across applications, and also rethinking the world from the perspective of users by allowing applications to use personal information while simultaneously respecting individual discretion.

18.2.3.4 Web 3.0 as an Urgent Need of Society Today—Recent Unjust Events and Social Issues

Arguably, events that have greatly upset the fairness and humanitarian justice of the social system in recent years are another reason for the growing interest in blockchain as a facilitator for a fair social system that does not depend on centralization and a democratic consensus-building system. The following are three examples of unjust events that have been reported in recent years, which can be regarded as adverse effects of centralization, and the movement towards addressing such

social issues with a decentralized system that ensures transparency from the perspective of Web 3.0.

1. Fraudulent entrance examination at a school of medicine (2018)
   In August 2018, during the investigation on fraudulent entrance exams at Tokyo Medical University, it was found that the son of the former director of the Ministry of Education, Culture, Sports, Science, and Technology passed by illegal means. Further, it was revealed that scores were deducted for female examinees and numerous examinees challenged the examination results multiple times. In March 2020, the Tokyo District Court ordered the university to return examination fees to disadvantaged examinees. With this ruling, the unfairness of the selection process during entrance examinations began to be changed.
2. Mandatory installation of Covid-19 tracking apps (2020)
   The Indian government adopted a strict approach by practically requiring its citizens to install an app to track the contacts of Covid-19-infected people. However, the app was not transparent, and there were arguments both from within and outside the country that it forced people to install an app that could potentially be used for surveillance after the pandemic is over.
3. Slave labor in Uyghur (2020)
   In September 2020, a clothing giant, H & M, issued a statement that it would stop procuring cotton from China's Xinjiang Uyghur Autonomous Region due to confirmed cases of forced labor. They said that there are more than 1700 production bases connected to H & M worldwide and that it would respond immediately to any company found to be involved in forced labor in the future; however, the regional authorities' audit organization stated that it would not carry out an investigation.

Problems such as these can be fundamentally addressed by implementing blockchain technology. In the first example, universities can prove that their entrance exams are carried out fairly by the transparency and non-tampering characteristics of the blockchain. If blockchain technology was introduced in the second case, the type of information collected by the government would be guaranteed by the transparency of the blockchain. In the third case, blockchain technology would enable the workers themselves to prove that there was no forced labor in the production process, and simultaneously, the consumer could verify whether the goods were produced under fair labor management and therefore decide whether to purchase such products. In other words, by matching the rights of workers involved in the production process with with those of conscientious consumers, goods produced by forced labor can be prevented from entering the commercial stream. This is therefore an approach to ensuring appropriate management.

18.2.3.5 The Essence of Web 3.0 Is the Empowerment of Individuals

As mentioned previously, Japan has encountered the concept of Web 3.0 twice in the past. Specifically, the computer world enabled by the first Web 3.0 is a method of

instantaneously determining "how to maintain one's identity as the source of one's thoughts and actions" in relation to others by means of cloud + AI technology. Alternatively, it is a method by which smart contracts are used to personalize incentives for each party involved according to their diverse values based on behavioral evaluations of each participant. This latter viewpoint represents the second Web 3.0 for a fair and transparent society. Although the technologies and approaches used were different, the conceptual goal of consensus-building discussions is similar. Blockchain has attracted attention as an elemental technology for the realization of the Web 3.0 concept; therefore, it is an essential social infrastructure technology for the realization of a society that recognizes diversity.

18.3 Speed of Blockchain Evolution Surpasses that of the Web

In the history of the evolution of the Web as outlined in the previous section, where does the technological evolution of the blockchain fit in? Blockchain evolved from "Blockchain 1.0," as the technology for cryptocurrencies as represented by bitcoin, to "Blockchain 2.0," which enabled us to use blockchains in fintech, and to "Blockchain 3.0," which enables us to use blockchains in areas other than fintech, in just over 10 years. In this section, we review the history of the technological evolution that has occurred.

18.3.1 Blockchain 1.0—The Elemental Technology for the Bitcoin Cryptocurrency

Blockchain, as a mechanism in which all nodes (the devices that comprise a computer network) manage each other's latest data copies in a decentralized manner, first went live in 2009 as the technology behind Bitcoin. This innovative technology could prove the existence or nonexistence of data and whether they had been tampered with by assuring the authenticity of the data from all network participants. Therefore, blockchain makes it possible for network participants to verify "who sent what to whom" based on information held by each other, without relying on a centralized method, thereby enabling value transfer on a decentralized network. However, the understanding that most Japanese have of blockchain has not yet advanced from that of Blockchain 1.0. This is only an early-stage model application of blockchain, which was used exclusively for the exchange of Bitcoin, as an electronic transaction system for the purpose of exchanging money.

18.3.2 Blockchain 2.0—The Emergence of Ethereum and Smart Contracts

With the advent of Ethereum in 2013, financial platform companies in the banking, securities, and insurance industries (fintech companies) expanded the scope of blockchain applications beyond currency transactions. The era in which blockchain began to be used as a decentralized platform, with its scope of application extended to financial fields such as fund settlement, securities settlement, and cross-border settlement, is called "Blockchain 2.0."

One typical example of the use of blockchain in the Blockchain 2.0 era is traceability initiatives in Aya Town, Miyazaki Prefecture, introduced in Chap. 4. Another example is the Trade Lens platform, which was co-founded by IBM with the shipping company Maersk in the trade finance sector. The platform focuses on one of the advantages of blockchain, the shareability of information, and has created a mechanism that allows information about trade finance to be shared among the parties involved, with appropriate access control. The paperwork involved in international trade has been digitalized and information on shipping, such as the status of ships and goods, can be readily shared among the parties involved, demonstrating the effectiveness of blockchain, even when the counterparty cannot be trusted. On the other hand, this example shows that the necessity of adopting blockchain may be questionable when the trust relationship between network participants is established in advance.

Around this time, the phrase "Why Blockchain?" began to appear in the Japanese IT industry. This was a movement that disagreed with such a trend in the Blockchain 2.0 era, when rebuilding existing systems with blockchain became a trend. The idea behind the movement was that the requirements for the adoption of blockchain should be either that network participants do not trust each other or that the reliability of the information exchanged is not guaranteed. According to this criterion, the use of blockchain is not necessary when a certain level of credit is shared in advance among members, such as in the case of the application of blockchain to a syndicated loan (a financing method in which major financial institutions form syndicated groups and cooperate to provide loans), which became a widely discussed topic at that time.

The Ethereum network allows users to program their own transactions and design their own contracts. This made it possible to place a value on anything, not just money. In Web 2.0, a variety of information is exchanged through platform providers such as social networking sites and news sites, but this information exists in the realm of electronic data and does not have a physical presence. However, by using Ethereum, data on the network can exist as original, uncopiable data, and therefore electronic data can be treated as valuable in the real world. Because of this feature, it can be considered that Blockchain 2.0 was implemented in such a manner that it coexisted with the platform providers leading the Web 2.0 world.

18.3.3 Blockchain 3.0—From Centralization to Self-Sovereignty

In June 2020, the Japanese Cabinet Office held the fourth Digital Market Competition Conference and published a draft interim report on the competitive assessment of the digital advertising market. In the draft interim report, it was mentioned that, as a trend in the last few years, the movement to realize a decentralized web without a mega platform is growing stronger, as individuals and corporations increasingly manage their own data by utilizing technologies such as blockchain, rather than centralized mega platforms. As a direction to be pursued, the report proposed that "trust" in the data society should be reconstructed by shifting from a centralized data governance structure to a system in which "individuals and corporations control access to data, which should belong to them, and can manage the value arising from the use of data" (construction of a layer of data governance). This is illustrated in Fig. 18.3.

In response to increasing demands for transparency and rights management in society, there have been calls for a review of centralized management through mega platforms, to which personal information has been attributed in the Web 2.0 world, and for a shift towards self-sovereign, self-directed management. In addition, the use of blockchain is also beginning to change from the implementation model based on coexistence with mega platforms to a new implementation model where individuals

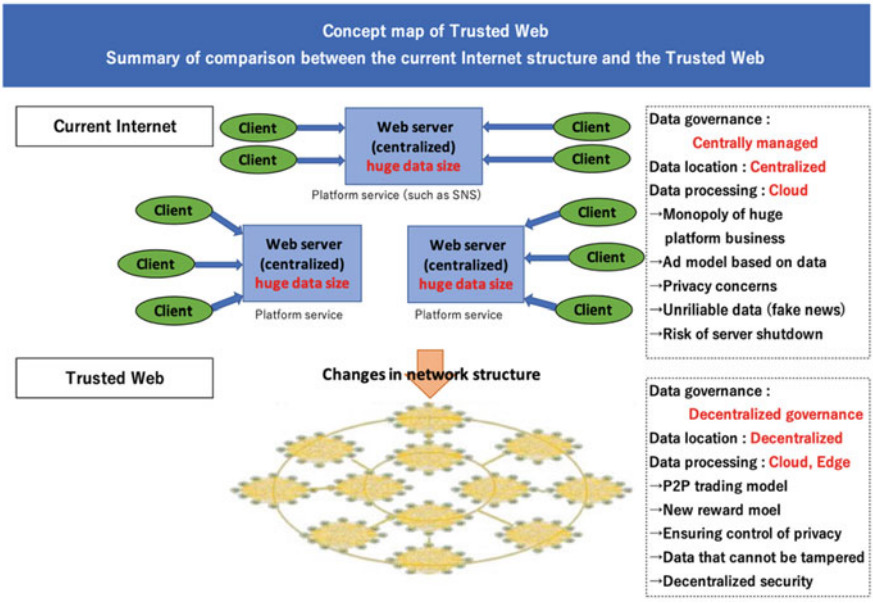

Fig. 18.3 Comparison with current Internet structure. (Created by the Digital Market Competition Headquarters, Cabinet Secretariat (Cabinet Office, Government of Japan 2020))

can exercise discretion over their data. The term Blockchain 3.0 refers to the use of blockchain in the Web 3.0 world outside of the fintech domain by using blockchain-specific functions such as peer-to-peer (P2P), smart contracts, and proof of existence.

18.3.4 Web 3.0/Web 2.0 and Blockchain 3.0

We now illustrate the difference between Blockchain 2.0 and Blockchain 3.0 using the example of an attempt to send copyright payments directly to an artist, without an intermediary, by activating a smart contract when the music is played. In Web 2.0, the business model would be based on the Blockchain 2.0 scheme, in which the platform provider acts as a principal, collects royalties from users, and pays the artists. However, by using the Blockchain 3.0 scheme, Web 3.0 allows us to provide the user with an additional value that exceeds the value of the song itself. For example, when the song is played at a particular place and time that the user trusts, the context of the song has added value to the user that is beyond the value of the song itself. Influencers and companies that contribute to the organization of time and space could be rewarded in the same way as the songwriter, based on their level of influence. Such use cases based on Blockchain 3.0 schemes that incorporate external economies (or external diseconomies), which represent effects and influences that spill over outside the service market and are difficult to assess using traditional economic indicators, are now being considered.

In addition, in the case of decentralized automobile transportation systems, the possibility of exchanging data (in this case, messages of gratitude, etc.) and making small payments when a user yields the driving lane to another vehicle at a highway interchange point, without the platform provider acting as an intermediary, is being researched. Furthermore, research has been conducted on the application of blockchain to the management and control of air transportation systems, such as delivery services by drones and flying taxis, and the premise for using blockchain in these cases is especially being examined. This is because there exist concerns that the conventional centralized data distribution model cannot cope with the bottlenecks of centralized servers owing to the increase in the number of IoT terminals supporting the sensor economy and other activities. Therefore, because of the enhanced availability resulting from information distribution, the number of implementations of the Blockchain 3.0 model is expected to increase in the future.

18.3.5 Future of Blockchain 3.0

The areas of interest in Blockchain 3.0 include traceability, tokenization, and self-sovereign identity, examples of which are included in this book. Blockchain 3.0 is not limited to cryptocurrency (Blockchain 1.0) and the financial sector (Blockchain 2.0), but captures a wide range of blockchain applications, including in nonfinancial

sectors. In advanced blockchain application areas in the two forms of Web 3.0 mentioned in the previous section, the relationships among people, goods, and electronic data (digital content) are traced in real time by automated contract enforcement mechanisms using smart contracts, and the results are individually adapted to each of the parties involved. A cross-application service model with self-sovereign IDs, which gently leads to optimal behavior by issuing utility tokens as incentives, has also begun to be considered.

In addition, the P2P credit approval model ushered in by Blockchain 3.0 is particularly threatening to business domains with centralized revenue structures. For example, in the case of traceability services for organic agricultural products (discussed in Chap. 4), consumers can verify the process of the production of crops, which would be difficult to trace through general centralized distribution, and can learn about the method adopted by the farmer to produce the product and the process of distribution by which it was delivered to them. Consumers that find value in the economics terms "external economies" and "external diseconomies" to refer to effects and influences like the latter, which spill over outside the service market, such as the sincerity and passion of producers, and consumers who are conscious about the environment and natural ecosystems and prioritize consideration for the environment over taste will find value in products that are difficult to discern by conventional evaluation criteria used by the central distribution system (distinctions based on variety, size, weight, etc.).

Furthermore, it is possible to record a person's behavioral history on the blockchain and turn the history into an asset. For example, in the case of the traceability service for organic agricultural products described above, producers who continue their production activities with conviction and consumers who support their production philosophy through selective purchasing behavior called "ethical consumption" gain a certain level of credit in the community that shares their values. Farmers, as environmentally conscious producers, and consumers, as ethical consumers, form individual brands. In addition, we are working towards the democratization of the examination process for colleges and universities, in which students can prove not only their academic ability through the entrance examination but also the history of extracurricular studies and volunteer activities that they have participated in, evidenced by tokens. By enabling cross-certifying with other students and nonteaching instructors that have participated in the same activities, we aim to enable students to substantiate their career aptitude and commitment to social issues, which are difficult to prove through traditional entrance examinations alone. These can then be presented to the schools that they apply to and the employers they wish to work for as self-credit obtained on their own initiative, without the need for a centralized certification agency.

18.4 Summary

In this chapter, we attempted to obtain a correct understanding of the current state of blockchain by overviewing Internet history, beginning with Web 1.0, and the manner in which the social implementation of blockchain was accomplished in just over a decade. This began with the Blockchain 1.0 era, in which it emerged as a technology for cryptocurrencies such as Bitcoin, through Blockchain 2.0, which was primarily used in the fintech domain, to Blockchain 3.0, which now extends into areas other than fintech, owing to the technological evolution of the web and the demands of society.

The effects and impacts on businesses and services include not only the benefits that can be obtained directly by the people who receive the services but also the effects and impacts on other people, the surrounding local environment, and the global environment. In this chapter, we use the economics terms "external economies" and "external diseconomies" to refer to effects and influences like the latter, which spill over outside the service market. We see a society led by Blockchain 3.0 as one in which those with the same values can evaluate the external economy through P2P without using an intermediary such as money.

It is important to note that the transition from Web 2.0 to Web 3.0 is not necessarily a linear and irreversible paradigm shift, as was the transition from Web 1.0 to Web 2.0. With the increase in corporate information management costs due to global institutional strengthening and greater individual self-discipline, the Web 2.0 world will continue to remain a scaled-down business scheme for GAFA and other platforms (perhaps as part of the Web 3.0 federation). In other words, although the social implementation model of Blockchain 3.0 mentioned in this book is primarily developed in the Web 3.0 world, part of the Web 3.0 world exists in a model of coexistence with the Web 2.0 platform, and therefore, a Blockchain 2.0 scheme. The further development of information and communication infrastructure technology and the explosive spread of IoT terminals will usher in a full-fledged sensor economy. As a result, it will take many years before people cease to feel the need for the Web 2.0 world.

In addition, in the cross-application world led by Blockchain 3.0, the discourse on international standards for authenticating the identities of network participants, such as DID and FIDO, which were mentioned earlier in this chapter, and the discourse on social capital as a network with shared rules and values that facilitate cooperation within and between groups, will be crucial. Akin to the manner in which protocol technology has contributed greatly to the evolution of the Web, the future evolution of blockchain is expected to see the emergence of new protocol technologies such as programmable IDs (PIDs), which are commonly used for humans, objects, and electronic data (digital content). I hope that this book will inspire readers to further discuss the future of the Web and the token economy, which will be led by blockchain.

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Chapter 19
Toward the Social City

Saburo Saito and Yasuhiro Kawahara

This chapter is based on Saito and Kawahara (Kawahara and Saito 2017), "Social City and Urban Development (SosharuShityi To MachiDukuri)," Chapter 15 in Kawahara and Saito eds. Social City (Sosharu Shithi), pp. 242–254, 2017, The Open University of Japan Press (in Japanese), which is slightly modified for this chapter.

Abstract We have been looking at various research examples and technological schemes as challenges for a new urban development using sensing and information and communication technology (ICT) in "the social city." This chapter further discusses how we grasp the activities of the people in the city. Furthermore, we describe how to enhance the value of the city by effectively supporting individuals' decision-making when they decide on their activities in the real space of the city by innovating customized intelligent communication between people and between people and the city. We also discuss the importance of the social relationships and city formation system with various actors involved in the city. Finally, we envisage the possibility of a new form of city formation system in the social city.

Keywords Town · Urban development · Consumer behavior · ICT · Social city · City formation system · Town management · Decision support system · Consistent estimation · Big data · Town equity

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19.1 Social City and Big Data

19.1.1 Understanding the Real-Time City

As challenges to a new urban development using ICT in the social city, we have been looking at various mechanisms and technologies for collecting information on the behaviors of consumers when they visit the city and the environment of the city they visit. Here we discuss the idea of measuring and estimating the *Kaiyu* behaviors of consumers in the city in real time[1, 2] Consumer shop-around behaviors are referred to as *Kaiyu* in Japanese, a term widely used in several fields such as city planning, marketing, real estate, tourism, and urban development policies.

In Chap. 2, we have estimated the number of visitors who move along the walking path of history in *Dazaifu* City. (Cf. Saito et al. (2022a)) More specifically, we obtained this estimate by applying a simplified consistent estimation method to the on-site *Kaiyu* micro-behavior history data from the *Kaiyu* behavior survey.[3] This procedure proceeds as follows. First, the consistent estimation method enables us to estimate the density of visitors' *Kaiyu* movements or flows among central tourism districts in *Dazaifu* City. Then, we expanded this density by the observed number of visitors to the *Dazaifu Tenmangu* Shrine. In other words, we estimated the number of visitors to *Dazaifu* City as a whole and the number of visitors undertaking *Kaiyu* from one place to another consistently, using the consistent estimation method based only on the *Kaiyu* micro-behavior history data and the actual observed number of visitors at one place.

Figure 19.1 illustrates the algorithm employed in the consistent estimation method.[4]

Let us briefly explain the equation in Fig. 19.1. The equation in Fig. 19.1 looks complicated at first glance but makes sense when looking at it in detail.

Consider the on-site random sampling survey conducted at a city center. Recall that the random sampling survey is carried out by randomly selecting samples from visitors to the city center. The choice-based sampling bias for the on-site random sampling survey occurs because people who visit the city center ten times a month are ten times more likely to be selected as a sample than those who visit once a month. To remove this choice-based sampling bias, we give the inverse of each sample's visit frequency to the city center to each sample as a weight to equalize the probability of being selected as a sample.

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[1] See Saito (2010, 2013) that discussed the idea in more detail. Also refer to Saito et al. (2022c), Chapter 5 in this volume.

[2] Refer to MIT SENSEable Lab and Real Time Rome for the efforts to visualize the activities in the city. Cf. Calabrese and Ratti (2006).

[3] The first Survey of Sightseeing *Kaiyu* Behavior in *Dazaifu* City (May 29, 30, 2010).

[4] As for the consistent estimation for the on-site *Kaiyu* micro-behavior history data, refer to the original papers, Saito et al. (2001) and Saito and Nakashima (2003). Also refer to the Japanese patent granted to this method (Saito 2006).

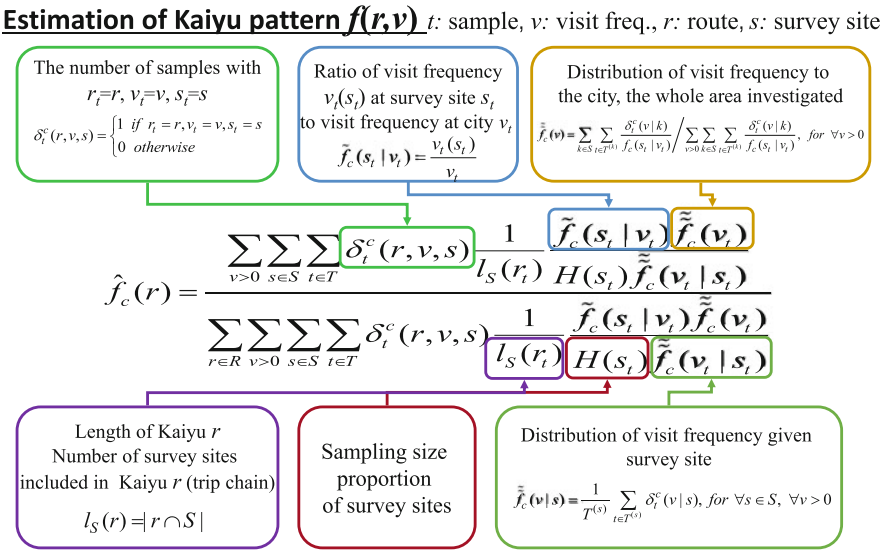

Fig. 19.1 Consistent estimation of the *Kaiyu* pattern from on-site samples. [Cf. Saito (2006) JP3793447]

In this way, we can create a weighting system that works as if we selected the samples randomly from their place of residence, even if we are sampling them randomly at the on-site they visited, by giving them the weights to equalize their likelihood of being selected as a sample, consequently removing the choice-based sampling bias.

We apply this idea to the *Kaiyu* micro-behavior history data collected by the on-site random sampling survey. In the on-site random sampling *Kaiyu* survey, we set up multiple sampling sites or survey points in the city center and randomly select samples from the visitors to those survey points. Note that the visit frequency to the survey points differs sample by sample. Thus, where the samples are selected matters.

Hence, in addition to the visit frequency to the city center by the sample t, i.e., v_t, we must also consider the visit frequency to the survey points where they are sampled, $v_t(s_t)$. Furthermore, the probability of being selected as a sample differs for each sample depending on the number of survey points each sample visited during *Kaiyu*, the length of *Kaiyu*, $l_S(r_t)$, and the size of samples selected at each survey point or the sampling ratio, $H(s_t)$.

The equation in Fig. 19.1 considers all these factors, assigns a weight for each sample t, and performs aggregation.

Next, the graph in Fig. 19.2 shows the fluctuation in the number of visitors per day at several large commercial complexes in the *Tenjin* district, the city center commercial area of Fukuoka City, Japan. The regular peak is the peak in the number of visitors on Saturdays and Sundays. These facilities have people-counting systems that measure the number of visitors in real time. Therefore, while this graph shows

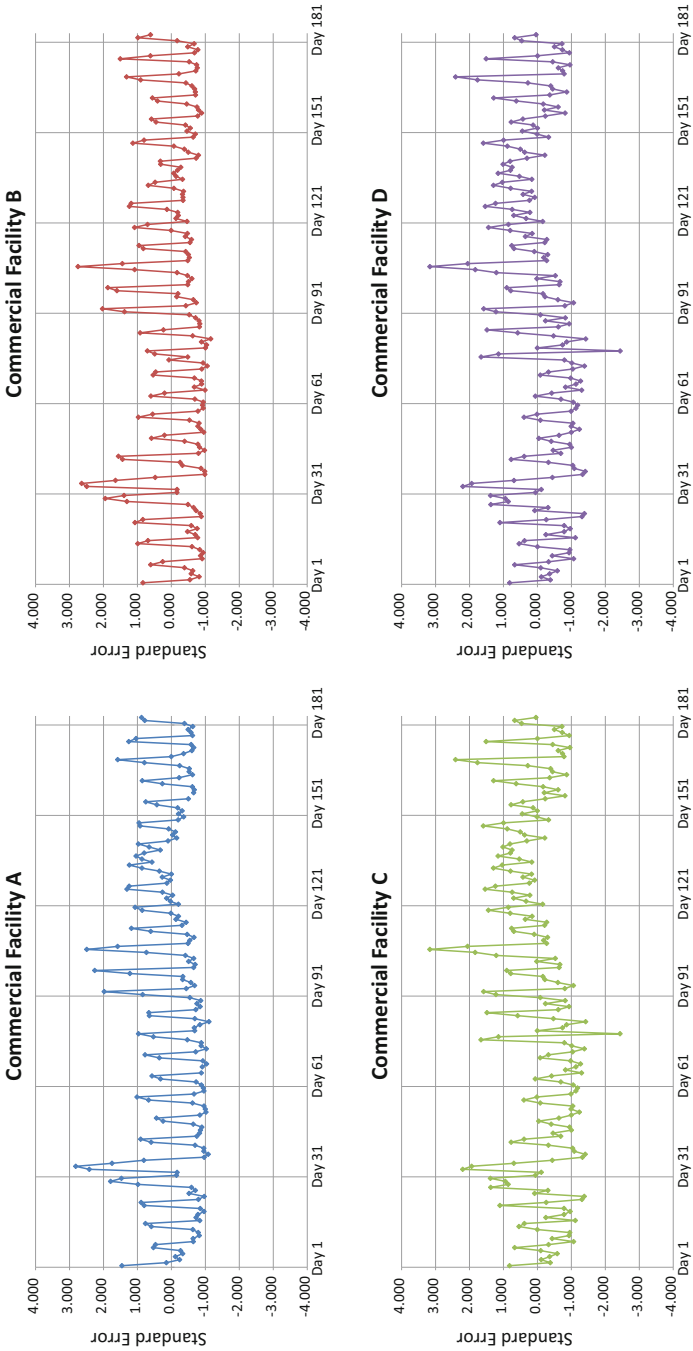

Fig. 19.2 Daily fluctuation in the number of visitors to large commercial complexes in *Tenjin* District, Fukuoka City, Japan (from January to June 2012) (The numbers are normalized by the annual average per day and the annual standard deviation)

the total number of visitors aggregated daily, we can see the fluctuation of the number of visitors in real time, such as over 5 or 10 min if using real-time data,

On the other hand, with the emergence of various methods of measuring location information using smartphones, such as GPS for outdoor use, and Wi-Fi, iBeacon, and Indoor Messaging System (IMES) for indoor use, we now have an environment in which we can obtain microdata on the history of people's indoor and outdoor movements in real time.

By combining these methods, we can understand where people gather in the city and how they move in real time.[5]

Furthermore, if the behavior of individual consumers is modeled using *Kaiyu* micro-behavior history data, we can estimate the current state in real time and predict the *Kaiyu* movements of people 30 min or an hour from now.

19.1.2 Decision Support System to Enhance the Value of the Town: Urban Development Management

A town accepts a variety of visitors and consumers. Therefore, we defined the concept of "town equity" as the value of the intangible asset of the attractiveness of a town fostered in the minds of individual visitors.[6] Thus, it should be noted that the concept of town equity is inherently a disaggregated concept defined at the individual level. Hence, when we refer to the value of a town, we refer to the sum of each individual's valuation of town equity. Therefore, when we consider enhancing the value of a town, we must consider to what extent the town equity is increased for what people and what kind of town equity. When understood in this way, town equity at the individual level can be regarded as the value of a town reflected in the minds of its people and constituting the value of a town.

Furthermore, to enhance the value of a town, we must increase the value of the town as perceived and evaluated by each of the individual visitors. To do this, we must simultaneously respond to the diverse needs of visitors and consumers who visit the town. Hence, it becomes indispensable to have a system or a mechanism that supports the real-time decision-making a variety of visitors make on the spot by providing information customized to each visitor.[7]

[5] Saito (2013) proposes to compose and distribute a town equity index for each city based on the number of incoming and outgoing visitors, which fluctuates in real time.

[6] Saito (2018), Chapter 18 in Saito and Yamashiro (2018), discusses more deeply the concept of town equity and the goals of urban development.

[7] As for the online decision support system on the spot in real space that increases the value of the town, see Saito (2005, 2012a, b, 2014) and Saito et al. (2022c), Chapter 5 in this volume.

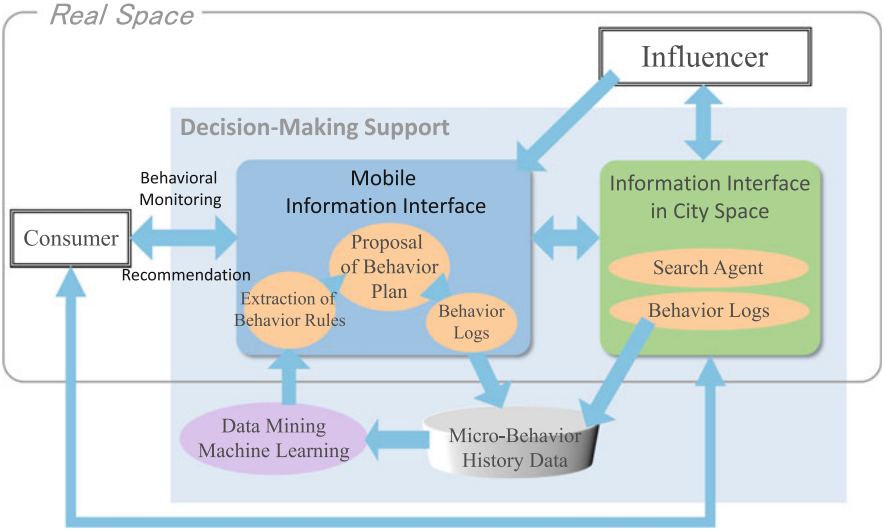

Fig. 19.3 Online decision support system in real space

We conceptualize the mechanism to enhance the value of the town in Fig. 19.3. One method to enhance the town's value is to record the semantic interactions visitors carry out with town information when they make their decisions in the town,[8] as seen in the case of *Tenmonkan*, *Kagoshima* City, Japan, in Chap. 3, and connect them to the on-site decision support through mining and deep learning[9] based on these recorded information processing micro-behavior history data of visitors (Cf. Saito et al. (2022b)).

The other method is to let visitors communicate with others through SNS and influencers to share the town information according to their concerns.

Both methods are strategies to increase the visit values individual consumers perceive and experience when they visit the town by accurately understanding their needs and providing the appropriate on-site decision-support by information and recommendations, consequently raising their town equity.

The challenges of the new urban development utilizing mobile ICT by the social city can also be understood as devices enhancing the value of the town to revitalize the town.

[8] As stated in Chap. 3, the information processing micro-behavior history data easily becomes very big. (See Saito 2012a, b). Also see Imanishi et al. (2018).

[9] As big data becomes usual, concerns with mining big data have shifted to machine learning and AI (artificial intelligence). As for recent remarkable progresses in deep learning, refer to LeCun et al. (2015).

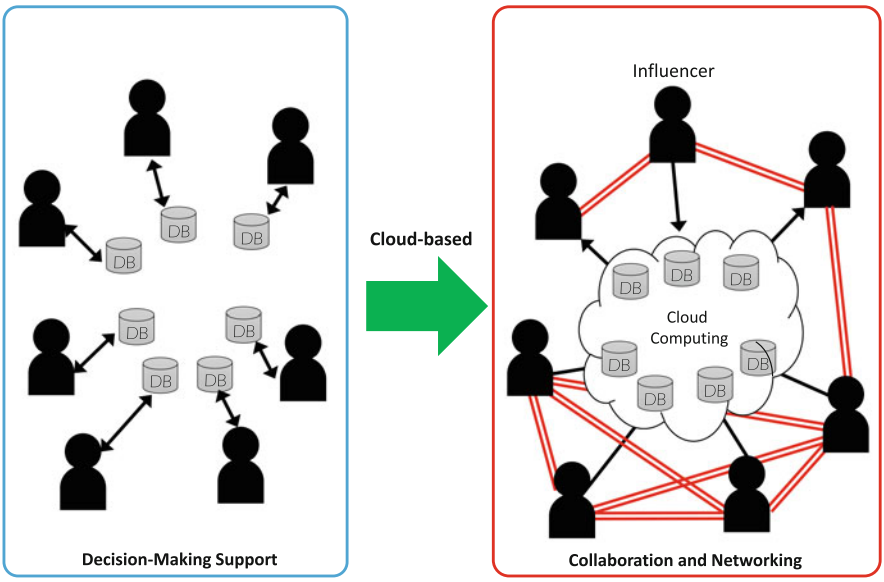

Fig. 19.4 Cloud computing, collaboration, and networking

19.1.3 The Social City and a New City Formation System

We have argued that the challenges of the new urban development using ICT in the social city may bring innovation in evaluating urban development policies. The main point of discussion is the possibility of obtaining micro-behavior history data of consumers visiting the city in real time, which has not been possible before. In particular, the possibility of obtaining data on the micro-decision-making process of how consumers communicate, interact with town information, and make decisions on-site in the real space of the city. If we made this possible, the effects of soft urban development policies such as information provision, marketing, and promotion could be fed back and grasped at the individual level in real time.

Furthermore, as emphasized in this book, the advancement of mobile ICT and informatization and cloud computing of information infrastructure such as social networking services have increased the possibility of more effective communication and collaboration.

While Fig. 19.3 focuses on the on-site decision support customized for individual consumers, Fig. 19.4 illustrates how this decision support, if cloud-based and interconnected, would encourage collaboration among people who share interests and trigger new behaviors by linking people with messages from influencers.

If this is the case, the subsequent development should attempt to organize a new city formation system. The new city formation system should form, maintain, manage, and develop the city by incorporating the individual consumers' real-time

evaluation of urban development policies using their real-time micro-decision-making data into a social decision-making system for urban development.

Various regions and districts have organized TMOs (Town Management Organizations).[10] TMOs aim to carry out strategic town management to determine what strategies towns should take to increase their values by considering themselves as one business entity while bundling various business entities involved in urban development. Thus, their role is a collaborative system for strategic town management. However, almost no TMOs have gone so far in strategic town management. Its partial cause is that currently, no information system exists that is effectively utilized by TMOs to measure and evaluate the effects of their own policies.

Unlike TMOs, the novelty and potential of the social city approach lie in its lightness. In the social city, it is possible to create a collaborative mechanism to increase the value of the town for themselves by creating a small network on the Internet through communication and interaction among the initiators, administrators, visitors, consumers, residents, and influencers of the town who share the same interests, motivations, and preferences. This kind of micro and autonomous city formation system that coexists in a multidimensional and multilayered manner can be said to be a feature of urban development by the social city.

We provided a viewpoint of a city as a city formation system that we regard as a complex autonomous system composed of three systems; the physical, the activity, and the social decision-making system. However, with the advancement of technologies such as ICT, smartphones, and SNS, it is possible to construct a micro-city formation system that can manage a complex system of hardware, activities, and social decision-making in a shorter time, in a smaller area, and by a smaller group, like a microgrid, at a lower cost and according to specific interests.

Thus, the social city should form a mechanism for its urban development where various micro-city formation systems, micro and autonomous collaborative systems for urban development, can coexist in a multidimensional and multilayered manner on the Internet platform and information.

19.2 Information Sharing and Community Formation

We have mentioned that the status of the town and the people in the town can be grasped and managed in real time by the information communication equipment embedded in the town and can be effectively used. For example, it is common that information transmitted through SNS is shared among acquaintances as information

[10]There are TMOs collaborating in a wide area of *Kyushu* Island such as We Love *Tenjin* for Fukuoka City, *SukiTai Kumamoto* for *Kumamoto* City, and We Love *Tenmonkan* for *Kagoshima* City. On the other hand, in Tokyo, *DaiMaruYu* Area Management Council in which three distrcts, *Otemachi, Marunouchi, and Yurakucho* neighboring Tokyo Station collaborate with each other for the area management [Cf. (Urban Renewal Promotion Division, City Bureau, MLIT (Ministry of Land Infrastructure, Transport, and Tourism) 2012)].

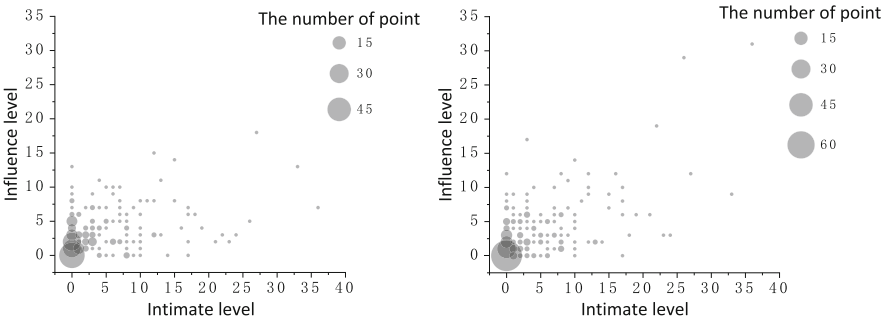

Fig. 19.5 Relation between the ratio of clicking the "Like" button and the closeness of interpersonal relationships (left: relationship between the receiver and the creator of original information, right: relationship between the receiver and direct information transmitter)

about the town, and then the town is utilized based on this information. Moreover, suppose the status of people using the town (e.g., alone or in a hurry) can be grasped based on such information. In that case, the town information system may present information on appropriate facilities to use and generate communication between people at that location.

Here, we introduce the experiment we have carried out using the monitoring method for social behavior. In the experiment, we asked all people in a group of 16 travelers to use a simple SNS app on a smartphone to send and receive information when they were free to do sightseeing.[11] The app recorded three properties for each piece of information received by each traveler: whether the person who received the information clicked the "Like" button, who sent the information, and who created the information,

As a result, we found that there was a relation between the rate of "Like" that the receiver gave to the sender of the received information ("influence level" shown as the vertical axis in Fig. 19.5) and the length of time that the sender met with the receiver ("intimate level" shown as the horizontal axis in Fig. 19.5).

Furthermore, we found that the above relation is more vital for those who sent information directly to the receiver (direct information transmitter) (right chart of Fig. 19.5) than those who created the received information (left chart of Fig. 19.5) (Suzuki et al. 2016).

[11] More specifically, the experiment proceeds as follows: First, a creator, one person in every 16 travelers, created the information and uploaded it to the app. Then, the app transmits this information with the creator's name to a randomly selected one person from the other 15 travelers, excluding the creator. Next, the information receiver, the person who received the information, decides whether to click the "Like" button or not. If the "Like" button is clicked, the app automatically transmits the information with the creator's name and the last transmitter's name to a randomly selected one person from the other remaining 14 travelers, excluding the creator and this information receiver, in this case, the information transmitter. The information transmitting process continues until it ends when some information receiver decides not to click the "Like" button.

From this experiment, if we assume that a person who spends a long time together, which a mobile communication terminal can monitor, is regarded as a "close friend," the above result can be thought of as the information received from a close friend has more social influence and causes more the recipient's behavior of pressing the "Like" button. This experiment also shows that the influence is even more vital when the information is transmitted directly.

Utilizing the social evidence above effectively in the ICT mechanism in the town makes it possible to revitalize the town and promote community formation. For example, getting more people interested in the town will be possible by transmitting information through their close friends. Also, providing information about the city's facilities to people, taking into account their specific interests in visiting the city, will induce them to interact with the facilities. The interaction generated among people through these facilities may grow into an influential information transmission channel among them. Thus, the above mechanism to form people's interactions in a limited space may lead to the town's revitalization and the generation of the community.

19.3 Environmental Information and Behavioral Change in City Space

The town's situation at any given time also affects the decision-making of the visitor to the town. When it is hot, people may want to have a cold drink in a cool place, and when they are tired of the crowd, they may want to rest in a quiet place. Although it is hard to imagine having a long chat with close friends under solid sunshine, we may see people discussing over a cup of hot tea in a chilly space.

We have discussed the use of outdoor space from the angle of the effective use of facilities and the interaction space for people. There have been attempts to promote the use of outdoor spaces by monitoring the visitors and the space (Akagawa et al. 2015).

Compared to indoor spaces, outdoor spaces are affected more significantly by the changes in the environment. Thus, in order for people to use them as comfortable spaces, it is necessary to grasp the environmental information of the space (temperature, solar radiation, wind speed, and loudness) and the state of the people using the space at that time (metabolism and people with whom they are with). Therefore, one effective means is the one that guides people to outdoor spaces according to their needs predicted in real time by monitoring the environmental information of the spaces and the state of the people.

The context of the visitor's behavior and changes in the social situation can be considered criteria for selecting a place to guide. Today, with the development of city infrastructure using ICT, it has become possible for the town to implement algorithms that can anonymously predict such information.

The utilization image of the social environment and the physical environment described here is shown in Fig. 19.6.

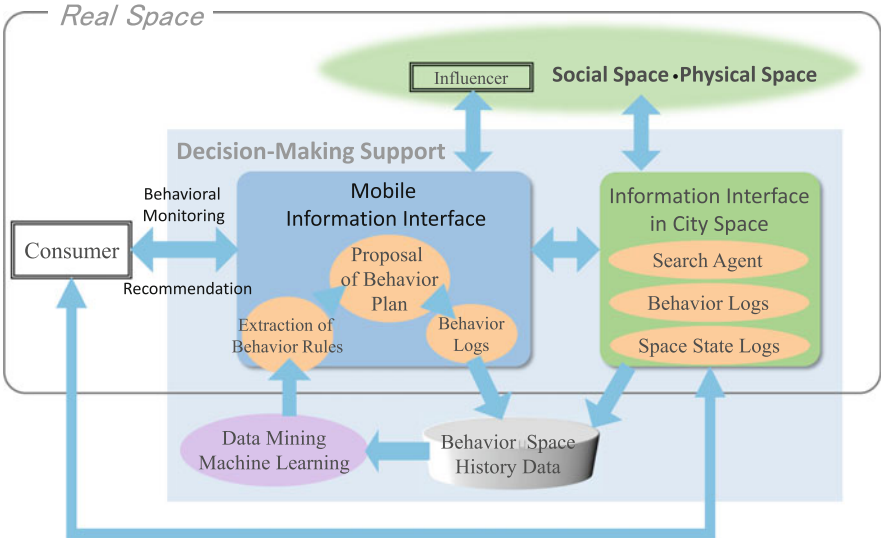

Fig. 19.6 Utilization of social and physical information in the social city

The provision of individually helpful information to visitors of the town and the feedback via SNS through the filter of their use of the actual city space create the interaction between the visitors and between the visitors and the favorite city space in the specific situation and become a social lubricant or intermediary for urban development.

We have discussed the mechanisms, cases, and technologies to realize the social city from various viewpoints. The key to urban development is to share and utilize the information between real and virtual spaces seamlessly while predicting the timing of social decision-making. Soon, more and more cities will be equipped with this kind of system. In the future, it is expected that the number of towns in which such mechanisms are set up will increase, and when one visits a town, one may notice the social mechanisms contained in the town.

We hope that the accumulation of experiences from social events and feedback in the cities will lead to a social city where people vividly communicate with each other and decide by themselves how they enhance the value of their city through a new city formation system.

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