Moonshot R&D MILLENNIA* Program

*Multifaceted investigation challenge for new normal initiatives program

"Research on Dynamic Life Space to be realized by Projecting Infrastructure" Initiative Report

Jul 2021

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I. Concept

1 Proposed MS Goal

1.1 Proposed MS Goal title

"To realize, by 2050, a society that is free from the constraints of infrastructure and has dramatically increased freedom in the way it lives."

1.2 Vision for 2050 society

By 2050, Infrastructure Projection Anywhere (IPA) technology will be developed, allowing infrastructure services to be projected (meaning that it is carried, deployed, and made to work) at any location by making infrastructure portable. As of 2021, our living space would not be possible without infrastructure, and since infrastructure is strongly connected to the region, the main elements of living space like houses are static (Fig. 1: left). However, IPA technology will enable us to live in a society where we are no longer bound to a static living environment, and where more and more people can choose their own way of life as they wish with a variety of options (Fig. 1: right).

The IPA technology will allow various infrastructures essential to human life to be established at almost any location, and provide each household with a self-contained living space like a space station. In addition, broadband network communications technology will make it possible for people to communicate with others as if they were in the same place, no matter where they actually are through rich user experience (UX). Also at that time, fully automated, unmanned fast transport will have been established, so people can get what they need when they need it.

In other words, people will be able to form communities very fluidly while moving their own living space, and engage in activities such as work, education, and entertainment in a completely new way. We call this kind of living space a Dynamic Living Space (DLS). With DLS in place, it will become easier to obtain city-level convenience and comfort in such areas that previously could not enjoy the existence of infrastructure, so the disparities among different land will be eliminated: thus, the concepts of not only offices and schools, but even the city will be transformed from what been tied to a physical world to a virtual one where the functions are isolated. Governments and local governments will become more fluid and unbound to physical locations, and there will be major changes in social structures such as the nature of local governments, addresses, and taxation systems.

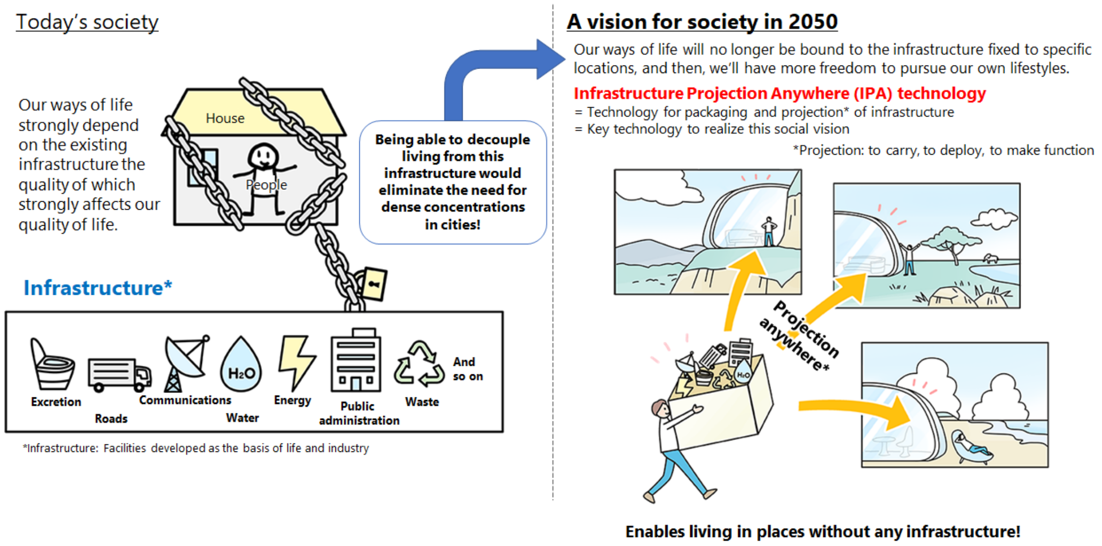

Fig. 1: Envisioned Society in our proposed MS Goal

2 Targets

This goal involves transformation of the ways of living of general households. By making it possible to project infrastructure and detaching it from its constraints with the land, people will be able to start living in the place of their choice (DLS) almost on demand. This is a completely new way of living, for which people can go directly to the places they want to experience and live creatively by maximizing their experiences, giving top priority to experiencing them with their whole body.

Fig. 2 shows a bird's eye view of scenes in the envisioned society, to be achieved by 2050. People live where they desire and form the communities they wish whenever they want. As we will discuss in detail in, two functions that are necessary for people to live human-like lives will realize in this living space:

✓ Functions that make life possible
✓ Functions that enrich life.

The "Functions that make life possible" consist of these three elements:

✓ "Self-sufficiency in energy"
✓ "Circulation of resources"
✓ "Delivery of goods."

We can realize it by separating the infrastructure from the ground and making it possible to project it anywhere.

And, the "functions that enrich life" will be realized by

✓ "Making it possible to experience the surroundings."

In order to realize this lifestyle, this goal aims to establish necessary technologies by 2050 that will serve as the basis for the life in which anyone who wishes to do so can live on demand. Specifically, it is equivalent to the following five technological elements:

- ✓ "Energy self-sufficiency" and "resource recycling" technologies that with a high degree of self-reliance
- ✓ "Fully automated transportation" technology that responds to on-demand needs with a social consciousness that fosters and accepts a dynamic community
- ✓ "Five-sense communication" technology that enables people in remote areas and the environment of remote areas to be recreated without feeling uncomfortable, even if they are not there
- ✓ Technology to realize a colorful "house as an environment-building device" consisting of space building technology and home appliances environment that flexibly respond to people's wishes integrating the above four technologies by turning the hose itself into a space reproduction device.

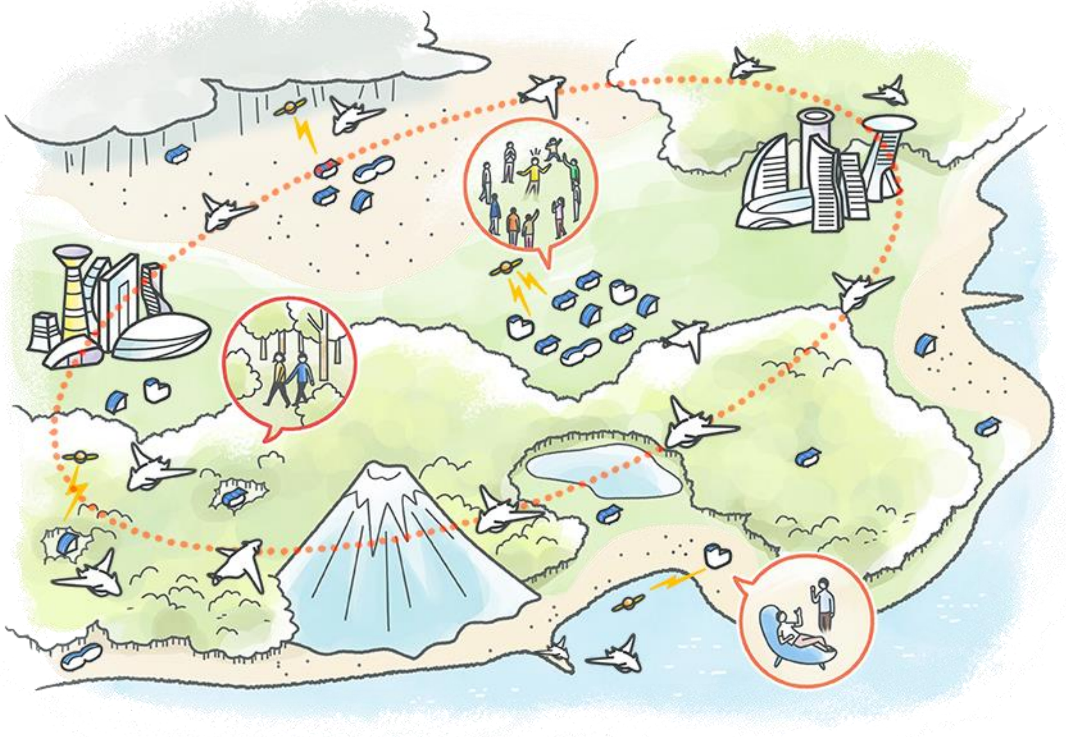

Fig. 2: Image of Envisioned society that has achieved the proposed MS Goal

Fig. 3 shows the scene of life when the above five technologies are completed, which focuses on the image of life. In Fig. 3 (a), natural energy sources supply its energy, water and organic matter are recycled, and fully automated transportation supplies goods that cannot be covered by these sources. In other words, there is no need for infrastructure to be tied to the ground.

To symbolize this, the house equips a tire-like structure with itself. Fig. 3 (b) specifically refers to the water system in (a), where it circulates and recycles water and organic matter. As mentioned that the amount of water used by one person per day exceeds 200 liters [1], it is necessary to improve the efficiency of the storage since water does not shrink. In this figure, the area under the table is used for water storage and interior decoration. Fig. 3 (c) and (d) show that the house has been transformed from a place to live to a device that reproduces a place, making the best use of the outside view during relaxation time as in (c), and transforming the place into something suitable for work during work time as in (d). In any case, it is possible to transmit and recreate the five senses, allowing people to experience and live in the place as if they are there, or as if they can feel the benefits of being there more.

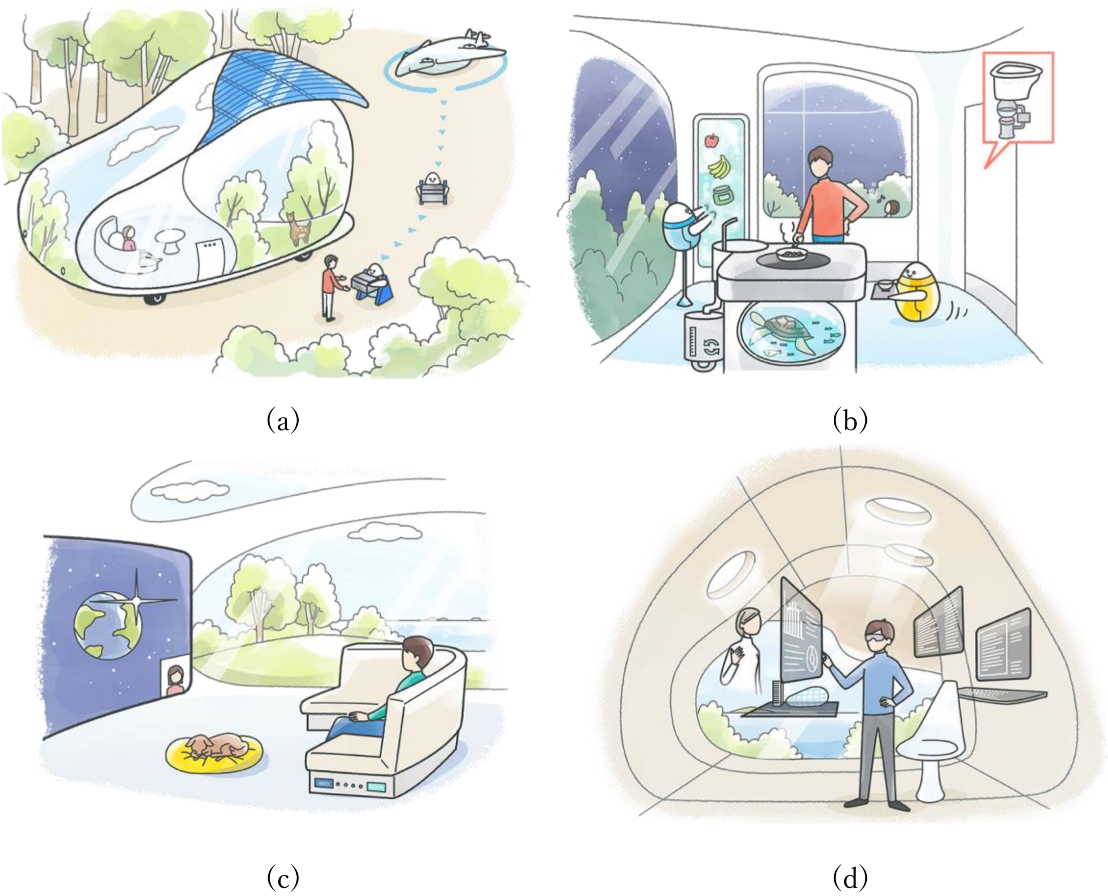

Fig. 3: Symbolic scenes of life with the proposed MS Goal (a) transport, (b) kitchen, (c) relaxation, (d) workspace.

In 2030, an interim period, the basic technologies for building the living infrastructure of the proposed MS Goal should have been established, and the environment will be in place for early adopters to actively try them out, and the groundwork will have been laid for the formation of the social frameworks such as the nature of communities in a society that achieves the proposed MS Goal.

These changes in the concept of society will also greatly change the concept of cities in 2050. The proposed MS Goal is to make the infrastructure projectable and detachable from its constraint with the land, so that people can start living anywhere they want (Dynamic Living Space; DLS) almost on demand. And conceptually, it transforms the city image from the previous stretched one shown on the left side of Fig. 4 to a "set of points" shown on the right. The vision of the present city is to develop infrastructure in a stretching manner, centering densely populated areas. Maintaining the infrastructure for the entire city area requires enormous costs since the number of areas where the population is concentrated in the vast land is small. On the other hand, the hurdle associated with migration will significantly become low if each household maintains their own infrastructure by themselves because there is no longer a need to maintain intermediate sections in order to provide infrastructure for the entire vast city area and the cost of maintaining infrastructure does not change regardless of population density.

As a result, by 2050, it should be possible to live virtually anywhere without the need to build infrastructure, and the development of laws and administrative structures to accommodate the accompanying changes in life should have been completed.

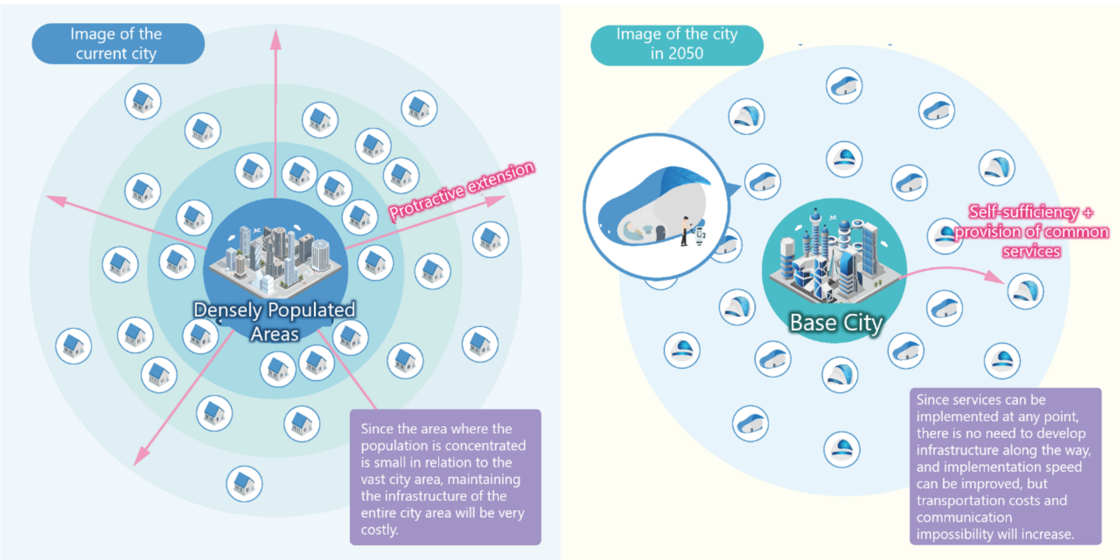

Fig. 4: Comparison between the vision of the city today and the vision of society in 2050

3 Background

3.1 Why now?

This proposed MS Goal is to "realize, by 2050, a society free from infrastructural constraints and with dramatically increased freedom in the way we live," which will respond to two major demands. The first is to eliminate the need for population concentration in cities. The second is to reduce the cost of infrastructure renewal, maintenance, and preservation.

Specifically, as explained below, these will bring about major changes in people's lifestyles, and a wide range of existing social systems will have to be reconstructed accordingly. Therefore, in addition to the research and development of advanced technologies needed to package infrastructures that have never existed before, it will be necessary to change social systems in a broad and multifaceted manner and to collaborate with many related organizations. At the same time, in order for people to shift their lifestyles in a gradual and effortless manner, changes in government and legal systems and a system of adaptation over time are necessary. Therefore, this proposed MS Goal is an issue that the nation must address over the long term.

In addition, the reconstruction of the social system required to achieve the proposed MS Goals will require activities that include a wide range of fields such as "energy self-sufficiency," "resource recycling," "fully automated transportation," "five-sense communication," and "houses as environment-building devices," as described in I.2. In other words, there are many issues that need to be addressed as part of Japan's research and development program.

3.1.1. Elimination of the need for population concentration in cities

City benefits

Human beings, who are social creatures, have been living together by nature, and have activated the economy and culture and built a civilization by enjoying business, scholarship, and entertainment while the city was established and developed through ancient accumulation. Yamazaki [2], an economist, identifies four causes of population concentration in cities: The first is face-to-face communication and reduction of travel costs. People place importance on meeting and interacting in person, and the concentration in urban areas becomes efficient in order to save each other's travel costs. Second, we have a wide variety of goods and services. Due to the large scale of demand, companies will differentiate themselves and naturally diversify goods and services. Third is the diversity of labor. Workers with various abilities gather because the demand is large and a wide variety of goods and services are profitable. Then, various companies gather in urban areas to acquire various workers and further improve productivity. Fourth is sufficient public goods. Especially in places where the population is concentrated, a large amount of budget can be used, so more diverse public services can be received and the area becomes convenient. If more people gather, the cost burden per person will decrease.

On the other hand, people living in urban areas can benefit from urban areas, but they will stay in urban areas knowing the poor living environment and various risks. Overcrowding of cities means pollution of such as air and rivers, urban problems such as traffic congestion and congestion, increased risk of enormous damage in the event of a disaster, inconvenience such as lack of nature and excessive information. It causes many harmful effects such as dilution of rural areas. However, the convenience and charm of the city cannot be enjoyed unless one continues to live in the city.

Disaster crisis

Population agglomeration has become a more urgent threat with the advent of the COVID-19 pandemic. A correlation between population density and the number of infected people has been pointed out [3], and the United Nations' "Policy Brief: COVID-19 in an Urban Worlds" [4] reports that 90% of the number of people infected with COVID-19 occurs in urban areas. In addition, the danger of an earthquake directly under the Tokyo metropolitan area is being pointed out as well as a pandemic in the Tokyo area [5].

Growth limits

Nishizaki [6] claimed "It cannot be said that Tokyo's productivity has been outstanding and has led Japan's growth." and it has confirmed the Williamson-Hansen hypothesis except in low-income countries. The hypothesis is as follows: In the early stages of economic development, there is no nationwide funding to develop infrastructure, so it is advantageous to invest intensively in some large cities and promote the accumulation of entrepreneurs, but as the development stage progressed, it seemed to be the advantages diminish and the disadvantages become relatively large. As a result, in developed countries, high concentration in large cities has a negative effect on the potential growth rate. In other words, there is an idea that Tokyo is no longer able to obtain the benefits of concentration, and Hiroi [7] insists on a shift from unipolar concentration to "multipolar concentration" through simulation results using AI. However, in Japan, the tendency to concentrate on the Tokyo area continues. According to the Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT)'s "Council on the Concentration of Companies in Tokyo" [5], the population of the Tokyo area is steadily increasing, and even from an international perspective, Japan has a high proportion of the population of the Tokyo metropolitan area and is rising. It is thought that the liquidity necessary to secure international competitiveness has been lost due to the fixed concentration.

Exhausted local economy and a sense of stagnation

the population declines, it has been pointed out that the declining birthrate and aging population in Japan will bring about further concentration in the Tokyo area [5], and the exhaustion of the local economy [8] is likely to become even more serious in the future. As urban spongeization [9] progresses, the elimination of rural exhaustion is an urgent issue. However, at the same time, regarding the local circumstances that led to the migration of influxes to the Tokyo area, a MLIT's report [5] lively describes "the inconvenience and feeling of blockage in the local area where he was born and raised" as "Although the percentage of "work" and "going to school" is high, there are a certain number of women who mainly answer "convenience", "entertainment", "feeling of obstruction", etc." Thus, It is impossible to create a flow of people to rural areas without new measures. We understood the behavior of people gathering in the city as a behavior that seeks more freedom, such as escaping from a region where the domination of men over women remains strong, in addition to gaining options for work and going on to higher education.

People living today -- especially the Japanese -- are all living with a sense of stagnation. In fact, the results of our social survey of Japanese people indicate that up to nearly 60% of them have a sense of constraint, fatigue, or boredom in their current lives (Appendix A.1). In addition, the Japanese Cabinet Office "Survey on Young People's Awareness in Japan and Other Countries (FY2018)" [10] shows that the percentage of young Japanese who answered "the future of their own country is bright" is the lowest among the seven surveyed countries, such as Japan, South Korea America, United Kingdom, Germany, France, Sweden.

Considering that the population ratio in the Tokyo metropolitan area has been increasing consistently since 1950, the structure of Japanese society is fixed, and in order to seek an increase in the degree of freedom in Japan, we have no choice but to go to the Tokyo area. We have unknowingly fixed the direction of our lives to those centered on the city, and we have lost the freedom of choice in our lives. Lack of liquidity manifests itself not only as an economic problem, but also as a sense of stagnation in an individual's life.

As mentioned above, despite issues that require urgent and long-term efforts such as pandemics and disaster avoidance, as well as productivity limits and rural exhaustion, the formation of human flow toward rural areas has not yet become a major flow in reality, and the current situation is that there still are structural difficulties in forming that.

3.1.2. Infrastructure renewal/preservation cost reduction

Infrastructure maintenance

In addition to the overconcentration, one of the major issues in Japan are the renewal, maintenance, and preservation of infrastructure. According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)'s FY2018 estimate [11], infrastructure maintenance and renewal costs in the fields under the jurisdiction of the MLIT for the next

30 years are 176.5 to 194.6 trillion yen (37.9 to 38.4 trillion yen for sewerage alone). The aging of the infrastructure that was built during the period of rapid economic growth has become an extremely large and urgent problem. The percentage of facilities that are more than 50 years old will reach 29% in 2023 and 63% in 2033 for bridges with a road width of 2 meters or more, and 27% in 2023 and 42% in 2033 for tunnels [12]. Another cost factor is the development of new infrastructure, such as 5G base stations for cell phones in recent years. A characteristic of such conventional infrastructures is the need to expand them in a stretching manner. For example, even in rural areas with low population density, it is necessary to lay water pipes and power grids. In this phase of population decline, it will be extremely difficult to choose how to maintain the infrastructure and how to renew it as the generations change.

Generational change in infrastructure

On the other hand, leap-frog development has been observed in emerging countries such as the African continent, where cell phone networks have spread without waiting for the spread of fixed-line telephones [1]. Advanced countries with old and well-developed infrastructures must integrate new technologies, which are developing at an increasingly faster rate, into their societies at high speed with backward compatibility.

In light of these factors, drastic measures to reduce the cost of infrastructure renewal, maintenance, and preservation are necessary in order to maintain the rate of growth and maintain an advanced infrastructure.

3.2 Social significance

As mentioned in I.1.1, our proposed MS Goal proposes to “realize, by 2050, a society that is free from the constraints of infrastructure and has dramatically increased freedom in the way it lives.” Specifically, by realizing Infrastructure Projection Anywhere (IPA) technology, which allows infrastructure services to be projected (carried, deployed, and made to function) to any location by making infrastructure portable, the various infrastructures essential to human life can be established in almost any location, providing each household with a self-contained living space similar to a space station.

The IPA technology will enable the establishment of various infrastructures essential for human life at almost any location, providing each household with a self-contained living space similar to a space station. This solves the structural difficulties mentioned in I.3.1.

3.2.1. Social significance

In the previous section, I.3.1, I mentioned "eliminating the need to concentrate the population in cities" and "reducing infrastructure renewal, maintenance, and preservation costs" as urgent issues. This will eliminate the need for concentration of population in cities and bring about the fluidity necessary for economic development. In addition, as infrastructure is converted from a stretched system to a point system for each household, the need to maintain infrastructure in the entire city area is eliminated, which reduces the cost of renewal, maintenance, and preservation of the infrastructure system as a whole, and increases the speed of renewal. In other words, it is expected to solve the social issues mentioned above.

The achievement of this proposed MS Goal will mean that people will no longer necessarily have to live in cities in order to enjoy the attractions of urban areas. In other words, urban functions will be combined into a single, portable package, eliminating the negative effects of overconcentration in cities.

3.2.2. Targets' significance

The significance of the social image itself is difficult for consumers to perceive as a direct benefit, but the significance of the scene of achievement is recognized as an experience by consumers. The significance of the social image includes not only the resolution of social issues, but also the elimination of a sense of stagnation. When the potential desire of people for a dynamic life was examined in this research study, it was confirmed that it would be higher if the proposed MS Goals were realized than if they were left as they are, and that the longing for a free life is behind this intention (Appendix A.1.3.6 and A.1.3.8). When asked about their vision of the society they would like to see in 2050, the percentage of respondents who wanted to see "a society where people can move around by themselves and experience various things" was higher than for other societies, which corresponds to the vision of the society to be realized by the proposed MS Goal (Appendix A.1.3.5). This result shows that people desire a dynamic life, if possible. In other words, people's aspirations match the dynamic life image brought about by the above social image, and the proposed MS Goal is highly suitable for society because the scene of achievement is not only socially desirable but also easy for people to accept.

3.3 Action outline

In order to achieve the proposed MS Goal, collaboration by a wide range of sectors and disciplines, as well as international cooperation among developed, emerging, and developing countries, is essential.

The challenge to achieving this proposed MS Goal is that the current infrastructure is fixed to the land. In order to solve this problem and make the infrastructure deployable and functional everywhere, we need to aim for a large-scale transformation from the current social image. To achieve this, it is more important to realize a society with consistent functions for society as a whole through the appropriate arrangement of technology groups than to realize any one outstanding technology. If even one of the important functions to realize the social vision that this proposed MS Goal aims for is missing, the viability of the social vision as a whole will be jeopardized. In addition, the participation of the government, the legislature, and the social sector is extremely important in dealing with the side effects of the transformation of the social vision. Therefore, in order to achieve the proposed MS Goal, it is important for society as a whole to take initiatives by placing the necessary technological elements around the concept of social design as the axis for developing the necessary mechanisms and laws, along with steering by social systems engineering and ensuring the technological consistency of the social vision. It is also important to place the necessary technological elements around the concept of social design.

Since this proposed MS Goal is to realize the urban merit everywhere, the fields and sectors involved in terms of technology are very broad. Therefore, in order to realize the four technological elements described in I.2 ("energy self-sufficiency," "resource recycling and circulation," "fully automated transportation," and "telecommunication with the five senses"), it is essential to collaborate with a wide range of fields, including energy generation and circulation, water circulation and recycling, waste circulation and recycling, transportation, information and communication, houses, home appliances, and construction, as well as cross-sectoral collaboration, including the design of the urban structure. Thus, cross-sectoral collaboration is essential.

Cooperation with other countries is also essential to achieve this proposed MS Goal. As described in detail in III.5, in the course of the research and study to develop the proposed MS Goal., an international workshop was held with foreign nationals from the six major states of the world and Japanese nationals from various parts of Japan. The question of how to make the public function emerged as an issue. In addition to collaborating in research and development with developed countries, it is necessary to work together with emerging countries, especially the East Asian countries that are members of ASEAN, that are currently facing the problem of urban overcrowding, to address the proposed MS Goal. as partners facing the same problem. In addition, if the proposed MS Goal is achieved in Japan, and the relevant technologies are actively exported to developing countries and other countries, it will be possible to support the independent and self-sustaining development of developing countries.

4 Benefits for industry and society

With the achievement of the proposed MS Goal, the dynamical living space (DLS) will be available in society, and cities will be virtualized as services are provided mainly through communication and transportation networks. In other words, the need to live intensively in cities will disappear, and the social structure will change on a large scale. In addition, as urban human relationships that separate work-related ties from geographical ties become universal, local communities that have traditionally relied on geographical ties will be required to build new relationships. This will pose a great challenge to government and welfare. On the other hand, because people will be less restricted to their local area, they will be able to continue to live in the place where they were born and raised, while obtaining new educational and employment opportunities, or on the other hand, they will be able to move to areas where the social infrastructure is becoming difficult to maintain and start new economic activities. In addition, bringing infrastructure functions to individual residences means that the burden on the public will decrease and the burden on individuals will increase. This entails large-scale changes in the social system, such as changes in the burden of public investment (e.g., whether to reduce the tax burden or subsidize households), and changes in the concepts of residence and residence tax associated with migration.

In addition, as infrastructure is converted from stretching to point implementation, the infrastructure investments that have been made in the past will shrink, and the industrial structure will also change on a large scale, as the infrastructure maintenance industry will be replaced by an active infrastructure function maintenance industry for households living distributedly in points. In addition, although the COVID-19 pandemic has made remote work an option, there are many situations in the manufacturing industry where remote work is difficult. While it is not directly stated in this proposed MS Goal, the use of "cybernetic avatars" as stated in Moonshot Goal 1 [14] and "AI robots" as stated in Moonshot Goal 3 [15] will lead to the extreme automation of factories in the manufacturing industry. Thus, we hope that remote work will become a major way of working for all occupations, so that everyone will be able to enjoy the benefits of the Dynamic Living Space proposed in this proposed MS Goal.

II. Analysis

1 Essential scientific/social components

In I.2, we expressed that four functions are required for this MS proposed Goalin 2050, i.e., "Self-sufficiency in energy", "Circulation of resources", and "Delivery of goods" which are for "functions for making up our lives" and "function for enrich life" which reproduce a remote environment with five senses to experience the surroundings. This section describes the derivation of these functions from social issues.

This proposed MS proposed Goal realizes a society in which the degree of freedom for our life is dramatically improved due to deliverance from restrained infrastructure by 2050. In other words, the infrastructure is deployed and functioned everywhere by separating the constraint between the infrastructure and the ground. The functional decomposition of the goals is conducted based on deriving various social functions, with consideration for what kind of flexibility will be required to expand. Specifically, as described in section I, this proposed MS Goal realizes the same functions as a city anywhere you live. Therefore, the expected functions of living in the city are clarified by comparing the city and rural areas. Then, the potential issues that may arise in order to make those functions available everywhere are investigated, the goals are broken down for each function, and the social and technical barriers are clarified for their realization. In this report, when clear definitions and numerical information on cities are needed, we refer to population concentration areas based on the Urban Centre database [16]. (See Appendix A.2 for details.)

First, Details from the derivation of the expected functions of life to the functional decomposition of the goals are described in Appendix A.4. The functional decomposition of this proposed MS Goal as finally derived is the items named “14 items of living” shown in Table 1. In addition to the essential functions of daily life, like energy and living infrastructure, we found that functions such as unexpected discoveries and encounters are also necessary to improve the degree of freedom in daily life. These functions can be reorganized into six functions, which need flexibility: "life," "environment," "information," "community," "work style," and "transportation". These items are then categorized as "functions that exist commonly in both cities and rural areas, although at different levels" (essential functions) and "urban functions that should be enjoyed while maintaining the advantages of rural areas" (differential functions). Essential functions are those that are indispensable to make life possible, and differential functions make life colorful and rich.

Table 1: Functional decomposition based on the envisioned way of living by this proposed MS Goal

Features	Category	Item	Flexibility
Passively enjoyed functions	Essential Functions	1. Energy/Basic Infrastructure	Flexibility of Life
		2. Peace of Mind/Safety Services	
		3. Supporting Services for Everyday Life	
		4. Attractiveness of the Region	Flexibility of Environment
		5. Harmony with the environment	
	Differential Function	6. Unexpected discoveries/unexpected encounters	Flexibility of Information
		7. Opportunities to meet people (interesting and diverse people)	Flexibility of Community
		8. Ability to obtain information for work (getting information through meeting people)	
		9. Ability to receive the education one desires when one wants	
Functions not to disturb activeness		10. Ability to choose a job one desires	Flexibility of Work Style
		11. Easy access to the people, things, and things that are being talked about	Flexibility of Information
		12. No restrictions in obtaining things one wants/needs	Flexibility of Transportation
		13. Easy access to things + sense of security for that	
		14. Ability to travel at any time one wishes	

The envisioned city needs to maintain these functions at the same time and the same quality of life regardless of where one lives, i.e., urban areas or rural areas, for "possible to live anywhere." Possible to live anywhere ultimately means that people can live wherever they want in the unit of household. However, functions such as emergency medical services, firefighting, police, and courts do not have a direct relationship with each household on a daily basis. In order to realize such condition as being "possible to live anywhere," the authors propose a novel form of cities, as shown in the Fig. 4, where such services are shared and maintained by the society as a whole, or such shared service that indirectly guarantees the feasibility of society are located core cities and each household maintain other services independently and in self-contained manner.

Assuming such a vision of a city, it will be possible to make a living by separating the infrastructure from the ground, but what can be enjoyed by living in a city should go beyond just making living possible. Therefore, only the essential functions in Table 1 are satisfied. In order to realize the same quality of life everywhere as in cities, it is necessary to take steps to enrich our lives. In this proposed MS Goal, we propose to realize a remote environment that can reproduce even the five senses, so that people can realize the differential functions (Table 1) that enrich their lives, such as meeting people, going shopping, and experiencing entertainment, no matter where they live. Even as of 2021, environment enabling remote workings are becoming more common, but only to the extent of sending and receiving video using voice and two-dimensional images, which is far different from meeting and talking in person. This proposed MS Goal aims to enable the five senses to be transmitted and received in real time, reproducing even the atmosphere of a place as if you were meeting people and touching things, no matter where you live.

This proposed MS Goal , therefore, aims to make it possible to project (carry, deploy, and make it work) both the "essential functions" and the "differential functions" of daily life anywhere, so that the benefits of the city can be enjoyed everywhere. As a result, the role of a house will change from that of a conventional vessel for living to that of a vessel for realizing these essential and differential functions (Fig. 5).

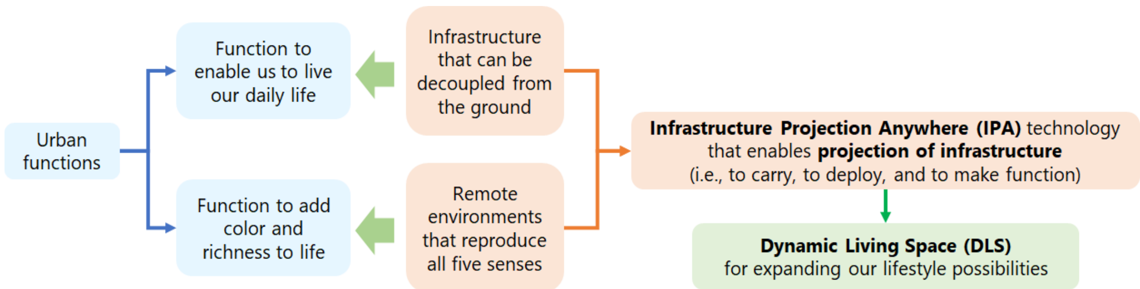

Fig. 5: Concept for realizing urban functions everywhere

Based on the above, Fig. 6 shows a bird's-eye view of the process by which the necessary approaches are derived through the 14 items of living extracted by functional decomposition to achieve the this proposed MS Goal. In the process of deriving necessary approaches for the 14 functions of living , the functions have been selected as necessary on a priority basis based on the concept of Fig. 5, centering on the "envisioned lives in 2050". Although other efforts is required in order to build the society, this report focuses on the five efforts shown in Fig.

6. In addition, as mentioned in I.3, in order to achieve this proposed MS Goal, cooperation by a wide range of fields and sectors and international cooperation with developed countries, emerging countries, and developing countries are indispensable. Details will be described in III.3, III.4, and III.5.

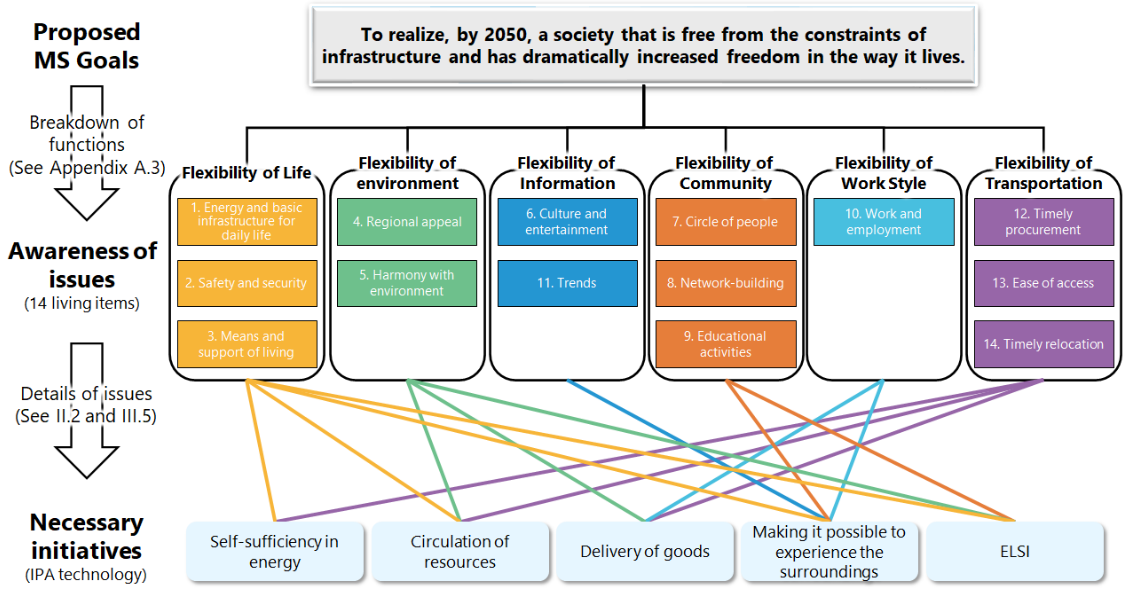

Fig. 6: Bird's-eye view of the path from the proposed MS Goal to the necessary efforts

2 Science and technology map

This section discusses in detail the scientific and technological issues and necessary approaches to achieve the proposed MS Goal for each field, and the research and development required for each technology is presented in a bird's eye view.

First of all, as described in Fig. 5 of the previous section, the functions that make life possible and the functions that make life colorful and rich are both necessary in order for people to live humane lives. Therefore, based on the urban functions decomposed into a total of 14 functional elements shown in Table 1 and the logic model [17], we derived specific issues to be addressed in order to achieve the proposed MS Goal. The logic model skeleton and the details of each functional elements derived from the logic model are shown in Appendix A.4. As a result, we have come to a conclusion, as shown in Fig. 6, that following four functions are essential; “Self-sufficiency in energy,” “Circulation of resources,” “ Delivery of goods,” and "“Making it possible to experience the surroundings".

While those functions should be maintained, when we reconstruct the envisioned society stands as a complete one with consideration of the logical linkage with the starting point to "resolve inconvenience derived from fixed society" as described in I.3.2, a causal relationship as shown in Fig. 7 can be established. Here, we draw the connection of the elements and technologies necessary to satisfy “maintaining functions of infrastructure” as “Functions that make up life” and "maintaining connections with people" as "functions that make life colorful and rich" for “projecting what is needed to realize a living” as a solution to “elimination of inconveniences derived from a fixed society”, The final technology elements obtained include the technology elements described in II.1.

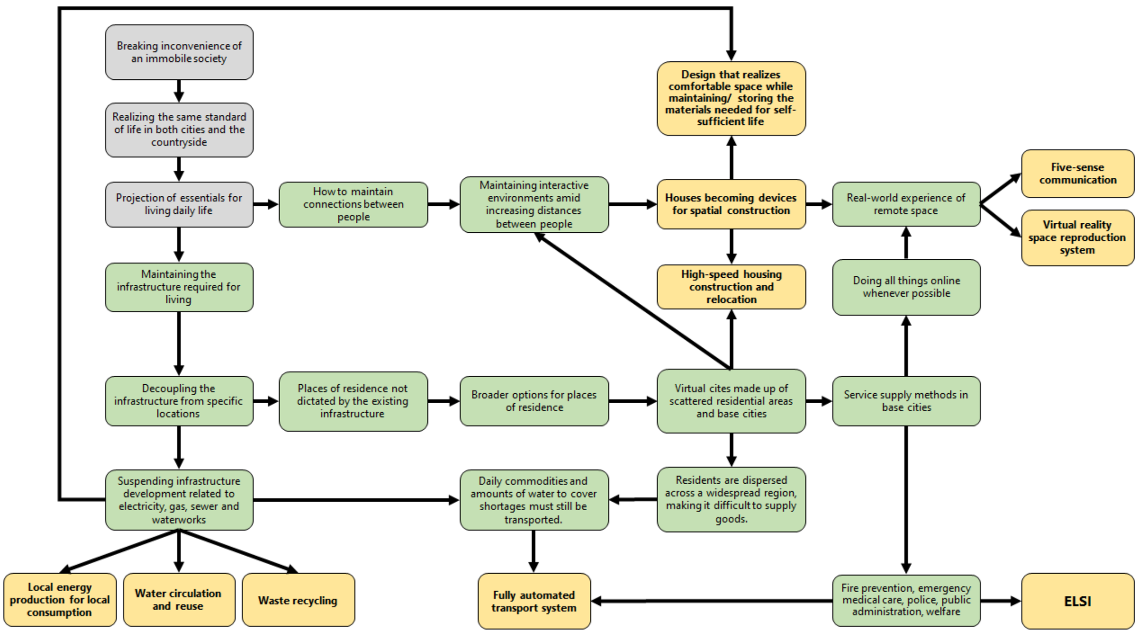

Fig. 7: Logical relationship between motives and means (the gray components represent motives, the yellow represents technical items and ELSIs, and the green represent intermediate steps connecting motives and technical items)

In the following, we will specifically discuss issues related to the realization of the above implementation method. Even if a city is a virtual existence, there are social issues as long as actual people live in it. In addition, it will be necessary to take measures to solve new social issues associated with the promotion of migration of people and the increase in the distance between households. These will be discussed in III.5. Fig. 8 shows the structure of the fields and technology groups related to this goal.

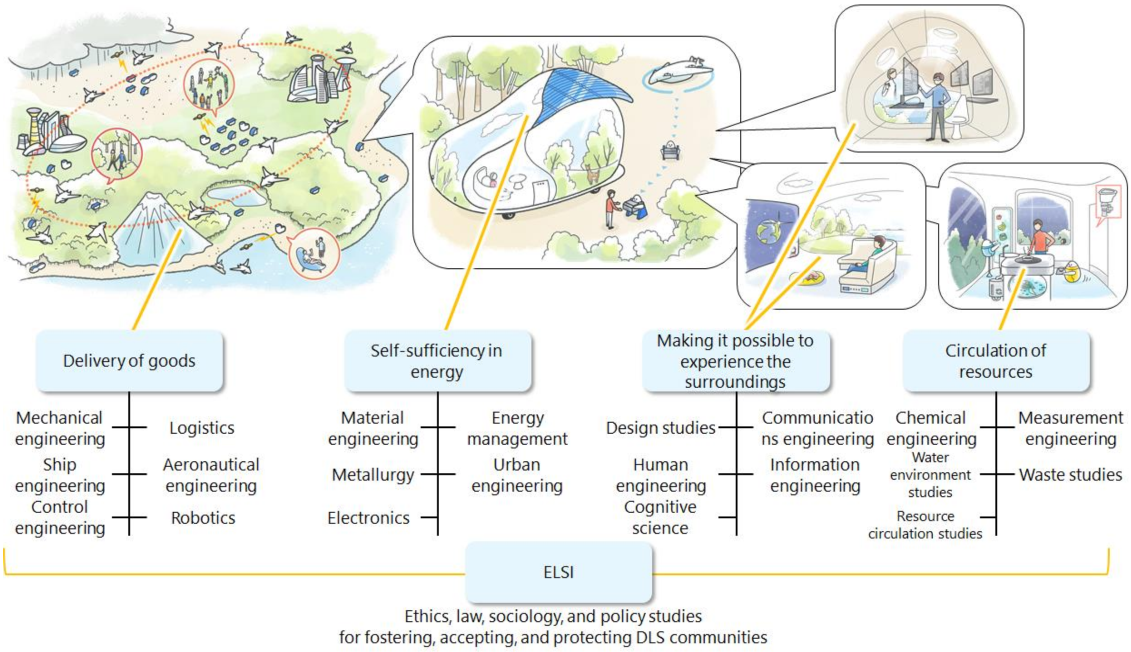

Fig. 8: Structure of the fields and technology groups related to this MS Goal

2.1 Self-sufficiency in energy

2.1.1. Challenges

In order to realize "energy/basic infrastructure" self-sufficiency at the individual household, among the 14 functions for daily lives shown in Table 1 of II.1, it is necessary to be able to have self-sufficient energy in each living space wherever it is located.

The main sources of energy used in the home are electricity, gas, and oil, but functions such as hot water supply, heating, and cooking, which have been carried out by gas and oil, can be replaced by electricity, as shown in the example of the all-electric house [18]. Due to the fact that electricity is difficult to transport, it is sent from the power plant to each consumer through a long power network. Solar power generation systems for home use have also been commercialized, but their power generation fluctuates greatly depending on the time of day, the season, and the weather, and they are assumed to be connected to the grid. Therefore, it is necessary for each household to be able to supply its own electricity so it can use electricity wherever it is, regardless of the existence of the grid.

The electricity consumption of a single-person household with one adult is estimated to be approximately 5.6 kWh/day, which is equivalent to the electricity obtained from six standard household solar panels (5.4 kWh/day: annual average in Kanazawa, Japan, with fewest sunshine hours), assuming it is supplied from renewable sources. This is equivalent to one lithium-ion battery unit (capacity: 5.6 kWh, weight: 68 kg) used in a household energy storage system (see Appendix A.5).

2.1.2. Necessary efforts

The challenge that will be overcome with self-sufficient energy is the land-bound nature of our livelihoods due to energy infrastructure restrictions. Electricity is essential for daily life. However, in a declining population phase, it may become difficult to accept the cost of maintaining power generation and transmission, thus the habitable areas may be constrained by existence of power plants. The solution to this challenge should be the deployment of a land-free energy infrastructure through a combination of energy generation technologies that can be easily established or dismantled at any location and can be done on a household basis, as well as wireless transmission and reception technologies and highly efficient energy savings technologies. This effort is referred to as "energy self-supply" in this report.

The research and development themes for the efforts required to achieve energy self-supply at the household level are likely to differ for each type of energy. In this section, we focus on electricity. A typical power generation technology that can be easily established or dismantled in any location, or for a household unit, is considered to be solar power generation using rooftops and ceilings. Research and development are underway for wireless transmission and reception technology from power generation bases using lasers and microwaves. [19][20] Potentials to store energy in other media instead of electricity are also being explored. One is so called Power to Gas (P2G), which converts energy into hydrogen gas and stores it. Another method is to store it as heat, as has been proposed by one of the Millennia Program, HO-DO-HO-DO, which involves in decentralization and local production/consumption of energy by using small thermal storage devices that take advantage of the climate and other characteristics unique to each region. For a bird's-eye view of research and development in this field, please refer to the report of the relevant team [21].

2.2 Circulation of resources

2.2.1. Water circulation

2.2.1.1. Challenges

In order to realize "energy/basic infrastructure" self-sufficiency at the individual household, among the 14 functions for daily lives shown in Table 1, it is necessary for each living space unit to be recycle and circulate water wherever it is located.

Water supply and sewerage infrastructure has been a major part of the national infrastructure since the days of the Roman Empire, but maintaining the infrastructure becomes increasingly costly, once the system starting from the water source is installed, and accepting such expenditure is expected to become more difficult in population declining phase. Therefore, by establishing a small circulation system for each household to recycle wastewater and manure, we can free ourselves from the constraints of the land on which we live.

If people are to live dynamically, water resources need to be recycled in small amounts. Humans consume approximately 262 kg of water per person per day. Of the total amount, 255 kg is consumed and discharged for bathing, washing, laundry and cooking. 2 kg of water is consumed for drinking and 4.8 kg of water is consumed and discharged in toilets for flushing urine and faces (see Appendix A.5 for details). Even if 100% of the water used for baths and toilets are to be recycled, the drinking water must still be replenished (transported). Although it depends on the state of health, data shows that the water contained in urine and slop is 1.5 kg and 107 g per day, respectively [24]. If we can reclaim these waters, we can reduce the amount of water we have to transport from outside. In order to circulate 100% of water, in addition to improving the regeneration rate of water regeneration technology, the recovery and regeneration of water from organic matter and the atmosphere, which have not been targeted so far, will be an issue. In addition, as the number of regeneration targets increases, the sensing of water quality for proper regeneration becomes an issue.

2.2.1.2. Necessary efforts

In Japan, potable water is provided from water sources such as rivers and dams after purified and disinfected mainly by filtration. On the other hand, sewage such as domestic wastewater is discharged into rivers and oceans after treatment such as removing sediment and decomposing organic matter by microorganisms. In general, the water after sewage treatment in Japan is less clean than potable water, and is purified in the process of circulating in nature after being released into rivers and the sea. In order to decentralize conventional water supply and sewage systems, where pipes are drawn from rivers and the sea for treatment, technology that can reclaim tap water from domestic wastewater is vital.

The pollutants contained in domestic wastewater are roughly classified into the following: 1) trash and sediment (impurities) that are not dissolved in water, 2) aquatic organisms such as microorganisms, 3) organic matter dissolved in water, and 4) ions (inorganic salts) dissolved in water [25]. 1) and 2) can be removed by selecting membrane with suitable size of pores to substance to be removed and filtering. However, 3) and 4) are more difficult to remove than 1) and 2). There are various methods to remove them such as absorption using absorbents, decomposition (combustion) by microorganisms, and oxidation-reduction reaction to make it harmless, as well as filtration using nano-filters and/or reverse osmosis (RO) membranes, depending on the substance [26].

In addition to the types of pollutants contained in wastewater, the amount of pollutants also affects the difficulty and method of treatment. One index is BOD (Biochemical Oxygen Demand). This indicates the water quality depending on the amount of oxygen required by microorganisms for oxidative decomposition, i.e., tap water is 3 mg / L or less, bath and laundry wastewater is 5 mg / L or less, cooking wastewater is about 20 mg / L on average, and urine is about 30 mg / L on average [27].

Considering the water consumption situation mentioned above, if 100% of relatively clean domestic wastewater such as baths and laundry can be regenerated, about 83% of the water used can be regenerated. When 100% of urine and cooking wastewater are regenerated, about 99.8% can be regenerated. Actually, as shown in II.3.2.1, it is difficult to regenerate wastewater to about 100% tap water, so the circulation rate will be lower than this, but the water regeneration rate from wastewater and urine should be improved. Therefore, it is necessary to work on improving the regeneration rate of the regeneration device and saving energy because the circulation rate can be increased. Furthermore, in order to aim for a circulation rate of 100%, it is necessary to consider water recovery methods from a wider range of subjects, such as water recovery from feces and water recovery from organic matter in waste. In the space station, which is completely enclosed, moisture contained in people's perspiration and exhaled air are released in the air and accumulates in the cabin; thus, the air is dehumidified to control the environment, and the collected water is reused as drinking water. Similarly in IPA, it may be possible to reduce the amount of replenishment to zero by obtaining water from the atmosphere by dehumidification and regeneration.

In addition, as mentioned above, it is considered that a mechanism for selecting an appropriate regeneration process is required by sensing water quality. For example, in the space station, some treatment methods are different for urine and dehumidified water because urine and dehumidified water have very different water stains. In the case of space, the water to be recycled is collected separately, so it can be treated without any inconvenience. However, the wastewater of each household may change in pollution, i.e., when cooking, washing, bathing, time, etc. In that case, it may be necessary to optimize the regeneration method by sensing the water quality.

2.2.2. Waste circulation

2.2.2.1. Challenges

In order to realize "harmonizing with the environment", among the 14 functions for daily lives shown in Table 1, it is necessary for each living space unit to be recycle and circulate water wherever it is located. The method of treating waste depends on its constituents (e.g. becomes water and CO_2 when burned, toxic substances are emitted when burned, or does not burn). Therefore, when processing is performed on a household basis, it is considered difficult to handle various processing for each household. On the other hand, if you live in a decentralized manner while maintaining the treatment at a waste treatment plant that is currently constructed along the urban distribution, transportation costs will be higher than at present because it is necessary to collect the garbage to that place. In some cases, waste treatment plants are equipped with power plants that make use of combustion heat, but as the population decreases, the benefits of power generation are expected to diminish as the amount of power generated is low compared to the cost of maintaining the facilities.

Based on the above, in a dynamic life, it is necessary to perform disposal of waste which can handle both garbage that can be converted into useful things such as water and electricity and garbage that generates toxic substances during metal or processing (garbage that is difficult to dispose) on a household basis. Material flow control is an issue for achieving this, i.g., the qualitative analysis and classification method of waste, and avoiding the use of materials that are difficult to dispose.

2.2.2.2. Necessary efforts

As mentioned in the previous section, first of all, it is important to evaluate the constituents and substances of waste qualitatively and quantitatively, and to select and optimize appropriate separation and treatment methods.

A number of researches on material flow of waste have been conducted by local/municipal governments [28] and specialized organizations [29] with regards to qualitative and quantitative analysis of the constituents and substances of waste. It is necessary to develop this kind of research and to link it to research on materials, for instance, to change types of materials that are disposed of in larger amounts to more flammable/recyclable material. We can also consider what kind of garbage can be converted into useful things such as water and electricity.

Regarding the process of converting household waste into useful items such as water and electricity, it is necessary to consider a treatment method that realizes compactness, power saving, and easy operation. In addition, when combining centralized processing and household processing, it is necessary to have a mechanism to qualitatively separate the discarded waste on the spot. Even in modern times, although people carry out some classification of burnable garbage and non-burnable garbage etc., household-disposal of waste may need to be further classified. Therefore, it is also necessary to research sensing technology that identifies garbage that should not be burned by the processing equipment.

2.3 Delivery of goods

2.3.1. Challenges

The first challenge that must be overcome in terms of transportation to achieve this proposed MS Goal is to ensure on-demand performance, followed by the elimination of labor shortages and the reduction of environmental impact. This is because of the following reasons.

In the previous section, by analyzing the difference between the functions of cities and rural areas in terms of dramatically increasing the degree of freedom in people's lives, three items were identified: "not being restricted in what you want," "having easy access to things," and "being able to travel at any time you want." Since these require rapid responses to people's demands, it is important to ensure extremely high on-demand performance. We have already seen the beginning of this trend in recent years: the dramatic spread of online shopping has increased the freedom of shopping, but the impact of this has led to a decrease in the amount of freight per case from 2.43t (1990) to 0.98t (2015), and the number of logistics cases has increased from 13656 (1990) to 22608 (2015) on the contrary [30][31]. Shippers' and consumers' transportation needs for smaller and more frequent shipments are expected to significantly increase if the proposed MS Goal is to be achieved, and this will be a crucial issue to overcome.

The problem of shortage of transporters may arise from the increase in the number of transports to ensure on-demand performance. According to an analysis by the Boston Consulting Group [32], the number of truck drivers, which was about 830,000 in 2017, will decrease to about 720,000 in 2027, while the demand for drivers will increase to 960,000 due to increased transportation demand. This implies shortage of 240,000 truck drivers alone. In this proposed MS Goal, the trend toward smaller and more frequent cargoes is expected to continue, and the number of personnel involved in transportation will need to further increase. Thus, solving the shortage of personnel in transportation will be one of the important issues.

In addition, as the number of transports increases, the number of transport vehicles themselves is also expected to increase. This gives rise to the issues of environmental burden. According to the Ministry of Land, Infrastructure, Transport and Tourism (MILT) [33], Japan's CO2 emissions in FY2019 were 1.108 billion tons, 18.6% of which, or 206 million tons, were emitted from transportation. Automobiles accounted for 86.1% of CO2 emissions in transportation, followed by aviation at 5.1%, coastal shipping at 5%, and railways at 3.8%. An increase in transportation demand suggests that the number of transportation equipment will increase in 2050. If these transportation machines are powered by an internal combustion engine using fossil fuels, which is currently the mainstream, there is a concern that they will emit more CO2. Therefore, the reduction of environmental impact is one of the most important issues for all transportation machinery.

2.3.2. Necessary efforts

Realization of fully automated transportation needs extensive R&D. Although The unmanned transport vehicles are increasingly used in a variety of fields today, the basic performance improvements are essential. Details are given in Appendix A.6; for example, multicopters and other aircraft, which have made remarkable progress in recent years, will also require significant performance improvements in the future. Consideration for the environment is also an important item. When using an internal combustion engine, it is required to shift the fuel to one with a low carbon content such as hydrogen energy. Most unmanned transport machinery is expected to be electric powered. It is needless to say that improvement of battery performance directly improves the performance of electric transportation vehicles. In addition, the reduction of aerodynamic drag (as long as the vehicle moves in the atmosphere) is also important, as it is discussed in the automotive industry [34]. Automated driving technology, which is currently progressing mainly in automobiles, will also require the development of technology equivalent to Level 5 not only in automobiles but also in ships and aircraft [35]. In addition, human resources associated with the operation as well as to the transportation vehicles are also an issue. The current drone operation model and the possibility of reducing human resources are shown in Appendix A.7. R&D related to operation which requires less persons from the aspect of practical management will also become necessary.

As a major breakthrough, in order to achieve this proposed MS Goal, it is important that fully automatic transportation can be applied to air transportation without any problems. Air transportation is costly, but it has many advantages. In air transportation, the transportation route can be selected without being tied to the ground, and the speed is faster than that on the ground. Cars can also move at high speeds on highways. However, in a human-centered society, the speed of transportation machines that move near people will be more limited in the future. In particular, aircraft have pioneered the application of unmanned aircraft to transportation operations. Therefore it is likely that breakthroughs in operational systems for transportation operations using unmanned aircraft will come from the field of unmanned aircraft.

2.4 Making it possible to experience the surroundings (House as a device for five-sense communication and environment-building)

2.4.1. Information and communication

2.4.1.1. Challenges

In order to realize, among the 14 functions for daily lives shown in Table 1, "ability to choose a job one desires" and "ability to receive the education one desires when one wants" and "being able to receive the education you want when you want" wherever one lives, it is necessary to be able to enjoy the same level of sense of reality wherever you are. There are two issues that we aim to overcome in order to achieve this: one is that the senses of touch, taste, and smell out of the five senses cannot be transmitted at a sufficient level, and the other is that there are places where communication is not possible when the residents live in a dispersed manner. By solving these issues, the restrictions imposed by "housing" will be eased, and people will be able to "choose the job they want" and "receive the education they want, when they want it," no matter where they live.

Focusing on work, "the percentage of all workers (employed and self-employed) who are working from home (teleworking) in FY2020 is 22.5%"[36]. Although the percentage of implementation of remote working is increasing due to the COVID-19 pandemic, the essential workers, including doctors, nurses, and caregivers, who need to be in contact with live people, find it difficult to work remotely and are constantly battling the risk of COVID-19 infection, because it is hardly possible for them to remote work. People working in the accommodations and food services industries, where the sense of taste and smell are essential, account for about 6% of the total number of workers, and when the medical and welfare sectors where the sense of taste and smell is needed as a supplementary factor, such as childcare, account for as large as 19% [37]. Therefore, if it becomes possible to operate robots from remote locations and transmit information to and from remote locations in a way that includes the senses of touch, taste, and smell, the number of occupations where remote working is possible will further increase, and people will be able to choose their occupations more freely.

When a large number of people live dispersely, there will be more communication needs in places where the existing communication infrastructure is not well developed or where the communication quality is insufficient. Nevertheless, the current area coverage of communication networks by mobile phones in Japan is far from sufficient if a society where this proposed MS Goal is achieved. The population coverage of mobile phones is already over 90% in Japan, though it varies depending on frequency bands and/or carriers used [38]. On the other hand, however, the no network has reached area coverage of 50%, and the maximum coverage is about 70% [38], indicating that mobile communication services are concentrated in densely populated areas. As discussed in I.3, there are significant costs associated with maintaining infrastructure that has been built in a stretchy manner and building infrastructure in new locations. This is true not only for mobile phone networks, but also for telecommunications infrastructure such as optical fiber lines. As for the line quality of communication required in the communication network, the throughput of about 2 Tbps is necessary for the transmission of the visual information among the five senses (Refer to Appendix A.8 for the derivation). Transmission of auditory and tactile information requires a low latency of from 1 to several ms [39][40]. Also, as for the optical network used when large-capacity communication is required, the transmission speed of 51.2 Tbps per one access network is sufficient because the transmission speed is currently about 100 Mbps per household, but if each person communicates visual information at 2 Tbps in 2050 A transmission rate of 2.56 Ebps per access network will be required in 2050 (see Appendix A.8

for derivation).

2.4.1.2. Necessary efforts

In order to solve the two issues previously mentioned, i.e., that the senses of touch, taste, and smell out of the five senses cannot be transmitted at a sufficient level, and that there are places where communication is not possible when the residents live in a dispersed manner, research and development is needed to realize an "interface with humans" for sensing and reproduction of the five senses and a "point-to-point communication network". Sensing and digitizing the five senses of sight, hearing, touch, taste, and smell, and realizing an interface that can synchronize and play back these sensory information, as well as a communication network that connects the points at ever location, will be a breakthrough that will enable natural and highly realistic communication. The transmission of the five senses of sight, hearing, touch, taste, and smell between two distant points is hereafter referred to as "five-sense communication" in this document [41].

Interface with humans

Communication of sight and hearing have been well researched, developed and implemented in the past. On the other hand, elemental technologies for the senses of touch, taste, and smell have emerged, but their R&D and implementation have lagged behind them. Therefore, in order to realize communication for all five senses, it is necessary to promote information technology for touch, taste and smell. However, it is known that the five senses do not act independently of each other, but interact with each other in what is called "intersensory interaction". Research and development using the mechanism of sensory interaction is also underway [42][43], but since the mechanism of sensory interaction is more complex than when each sense is perceived independently, we should first focus on the technology for sensing and reproducing each sense independently.

As for the sense of touch, research and development is being conducted as haptics technology [44] that realizes a virtual sense of force (force sensation felt by humans when they come into contact with an object). In general, tactile sensation is defined using the reaction from the object and the velocity of the acting device, and robot control uses force control and velocity control (positioning) to control the tactile sensation. If the robot cannot adjust its force at the moment it touches the object like a human, it may damage the object, so robot control with high safety and adaptability is necessary.

For the sense of taste and smell, portable taste and smell sensors and actuators are needed. Taste is quantified by the five basic tastes of sweet, sour, salty, bitter, and umami, and it is known that fullness, which is an element of deliciousness, has a strong correlation with the degree of adsorption with the lipid film on the tongue surface [45]. Therefore, taste sensors will require not only stationary quantification of taste, but also digitization of taste including time response. On the other hand, the sense of smell is much slower than that of taste. This is due to the large number of different types of olfactory receptors (about 400) and the size of the binding between smell molecules and olfactory receptors, as the nose is a more complexly structured sensory organ than the tongue. Therefore, the technology to quantify and quantify olfactory information in a standardized way is needed in the future, and such quantification will play an important role in the design guidelines of olfactory sensors.

From the viewpoint of sensor devices, higher sensitivity and higher dynamic range of chemical sensors are necessary to support the informatization of human sense of taste and smell. As regard to improving sensitivity, chemical sensors using mass-addition effects are now commercially available, but their limiting detection sensitivity is only a few ppb (parts per billion) [46], which is still below the human olfactory threshold of a few ppt (parts per trillion) [47]. In order to achieve this high sensitivity, efforts to improve the sensitivity of the entire system, including not only sensor performance but also chemical selectivity and concentration processes, are necessary. As regard to expanding dynamic range of the chemical sensor, assuming that the Weber-Fechner law (logarithmic relationship between sensory intensity and substance concentration) is applicable to human sensory stimuli and that the six-step odor intensity display method is used to quantify the odor intensity, a dynamic range of about five digits is required for the chemical sensor. In this case, a dynamic range of about 5 digits is required for the chemical sensor. However, since the dynamic range of current chemical sensors is about order of three digits [46], it is necessary to improve the dynamic range by two digits.

The development of actuation devices for advanced reproduction of the senses of taste and smell has lagged further behind the development of sensing devices. This is because there is no standard method to perform sensory stimulation on humans with high reproducibility, and because objectivity and accuracy cannot be ensured in sensory evaluation by humans due to individual differences among subjects, which are obstacles to the development of such devices. Therefore, first of all, establishing standard or specification for gustatory and olfactory response evaluation with high reproducibility, objectivity and accuracy will play an important role in the progress of research and development. In the case of olfactory actuators, which use chemical substances to act directly on the sensory organs, it is clear that the more chemical substances used, the more obstacles there are to their realization in terms of economy and miniaturization. Therefore, it is necessary to identify chemicals that can maximize the extent to which olfaction can be reproduced with fewer chemical species. In addition, the chemicals must be fully verified that they are safe for the human body.

Point-to-point communication network

In order to establish communication at any point in any location, it is desirable to relay and transmit through a non-terrestrial network consisting of relay stations such as satellites, High Altitude Platform Stations (HAPS), and drones that have wide communication coverage. However, since terrestrial optical lines have a higher capacity than non-terrestrial networks, they must be used in combination. As mentioned in "the challenges" section, the amount of information required and the required latency differs among the five senses. Therefore, in order to realize a society in which this proposed MS Goal is achieved everyone can communicate equally even in a society of dispersed residences, transmission over a communication network that is most suitable for each application in terms of communication speed and latency will be crucial.

2.4.2. The house as an environment-building device

2.4.2.1. Challenges

The challenge that we must overcome as a house in achieving this proposed MS Goal is to be able to design and construct the desired place in the living space. Details are shown below.

The house itself is a very large piece of property, and it is difficult to change it from time to time according to people's requirements. In fact, a survey by Japan Federation of Housing Organizations “Judanren” found that 66.7% of people cite the floor plan of a house as a particularly important factor when considering a home purchase [48]. The same survey also showed that the most important aspect of the living environment was convenience for commuting to work or school (59.7%), followed by spaciousness of the site, including the size of the land and amount of sunlight (41.2%). Against this background, one of the important issues is to be able to construct a "place" in which people feel maximally comfortable within the space in which they exist, in order to increase the degree of freedom of living in a house.

2.4.2.2. Necessary efforts

Two approaches can be considered to solve this. One is to be able to easily build a house of the desired shape in the shortest possible time. The other is to design the house so that the human senses are as "good" as possible in a limited space without changing the structure of the house itself. The former is mainly in architecture, and the latter is mainly in design

An off-the-grid house construction using the prefabricated method is an initiative that makes it easier to create a house of the desired shape in a shorter period of time. In this field, the construction period has been significantly shortened by automating the construction with 3D printers and robots. In this proposed MS Goal, building a house is not the only goal. For example, it is important to harmonize the house with the natural environment and to withstand disasters. Moreover, unless the house itself can be easily demolished and reused as well as moved, it is not possible to live anywhere freely. Therefore, a breakthrough is required for the technology to achieve these.

In order to design people to feel "good" instinctively in a limited space, it is necessary to make cross-cutting efforts to measure how people feel, clarify causal relationships, and make them possible to evaluate [49]. In order to measure how people feel and clarify the causal relationship, it is necessary to measure biochemical data in fields such as medical care, and to make efforts in ergonomics and cognitive science. After understanding these scientific aspects, it is necessary to measure what a person feels "good" and change what and how according to the situation, what kind of thing is required for that purpose, and to think about what you create. In recent years, designers' ideas for problem solving have been logically explained and applied to various fields, but it is necessary to make efforts to logically analyze creativity in design. Creativity is extremely difficult to verbalize, so breakthroughs are needed to give a logical explanation to areas that cannot be verbalized.

Appendix A.9 shows a study of refrigerators as an example of collaboration between design and engineering fields. Refrigerators are electrical appliances that are indispensable to modern life, and are large devices that occupy a space of several hundred liters. It is necessary to solve the demands from the design side, such as changing the size as needed and developing a cooling mechanism different from the conventional one, in cooperation with the engineering field.

3 Japan’s position in overseas trends

To start with, we look at trends of various projects related to urban development and urban planning that are underway in Japan and other countries.

In Japan, Toyota is working on "Woven City" concept, which aims to realize the"Connected City" in Higashi-Fuji (Susono City, Shizuoka Prefecture) as a "human-centered" platform where "demonstration experiments" for the future can be conducted [51] through the Woven Planet Group [50]. Panasonic Corporation has been developing Sustainable Smart Towns (SSTs) in Fujisawa City, Kanagawa Prefecture, Yokohama City, Kanagawa Prefecture, and Suita City, Osaka Prefecture, and is promoting joint public-private projects in each area [52][53][54]. In these SSTs, the company is promoting people-centered, "lifestyle-driven" urban development by following the sequence of "smart life proposals -> smart space design ->smart infrastructure construction". Finally, Kazenotani Project (lit. Valley of Winds Project) aims to create "alternatives to an urban-intensive future" [55][56][57]. This project emphasizes the importance of "realizing a rich, human-like life in harmony with nature," and aims to create "Kaze no Tani" as a "place" from a long-term perspective, rather than a short-term urban development project for a specific location.

Now we will look into examples from overseas. Sidewalk Labs, a subsidiary of Alphabet, was working on the Sidewalk Toronto project in Toronto, Canada [58]. Although the project was announced to terminate in May 2020 [59], the publicly available report specifically outlines a development vision for approximately 49,000 square metres of Toronto's waterfront area. Sidewalk Labs had been recruited a variety of partners and planned to use the area as a test field to implement new technologies and new living spaces. In Amsterdam, the Netherlands, an experimental site for a sustainable recycling society called "De Ceuvel" has been developed in a former industrial area in the northern part of the city since 2012 [60][61]. The site was once home to a shipyard, which caused significant soil contamination; however, with the project with a concept to "consider waste as a resource and create a circulation system throughout the site," a town was designed to allow energy and nutrients to circulate within the site.

One of the efforts necessary to make these newly created cities and towns function in a holistic and unified manner is the establishment of urban operating systems or reference architecture. In the Strategic Innovation Program (SIP) of the Cabinet Office, the Smart City Reference Architecture has been published in the "Project for Architecture Construction and Demonstration Research of Cyber Space Infrastructure Technology Using Big Data and AI" [62]. These urban operating systems and reference architectures uniformly define "minimum required data, authentication, and other exchange rules" just like computer OS do. This will allow "services and data to be interconnected and distributed efficiently" between and within cities.

In the following, we discuss the trend of research and development for each item described in II.2.

3.1 Self-sufficiency in energy

Among the energy sources, we focused on electric power, which is energy that can be used for many purposes. Regarding self-sufficiency of electricity, using renewable energy can make annual income more than expenditure. However, since there is no system that sufficiently absorbs time fluctuations and seasonal fluctuations, it is necessary to connect to a conventional power network. The research and development trends of renewable energy, power storage systems, and wireless power supply are shown below.

The current electric power infrastructure consists of a long power network connecting power plants and consumers, and it has been, and will continue to be enhanced to cope with large-scale disasters and the massive introduction of renewable energy. In addition, primary energy used for power generation in Japan is heavily dependent on fossil fuels, with a dependence of 85.8% (FY2018) and a primary energy self-sufficiency rate of 11.8% (FY2018), which is low compared to OECD countries [63].

Although the detailed electricity balance is unknown, a case study of a household with a residential PV generation and storage system [64] reported that the income from electricity sales exceeded the electricity price.
However, the power output from the PV cells and the power input and output by the lithium-ion storage battery are DC current, while the power distribution from the power network is 100V/200V AC. Therefore the power distribution to the home requires conversion from DC current to AC current, which requires complex system configuration along with the control of the power generation and storage system [65].
The most common type of solar cell, accounting for 90% of the market, is the crystalline silicon solar cell. Several types of solar cells are known which differs in silicon crystal systems and solar cell structures, but heterojunction solar cells are known to be highly efficient crystalline silicon solar cells. One of the technologies that is expected to be developed in the future is Perovskite solar cells, which was originally invented by Professor Tsutomu Miyasaka and his team at Toin University of Yokohama, thus, this technology is originated in Japan. Tandem solar cells, which consist of stacked crystalline silicon solar cells and perovskite solar cells, is expected to achieve high efficiency by effectively using light of different wavelengths [66]. In general, solar cells are black and opaque because they absorb visible light, but colorless and transparent photovoltaic devices that absorb infrared and ultraviolet light to generate electricity have been developed, and are expected to be used as solar cells that take into account the design and lighting of buildings [67].

Lithium-ion batteries are widely used as secondary batteries due to their high energy density, but there are some safety issues. In order to solve safety issues in secondary batteries, all-solid-state batteries, in which the electrolyte of the lithium-ion battery is replaced by a solid material, have been attracting attention, and research groups at the Tokyo Institute of Technology and the National Institute for Materials Science have made significant contributions to their development. In addition, research and development of various batteries including the next-generation lithium-ion battery, which is an advanced form of the conventional lithium-ion battery, sodium-sulfur battery, and redox flow battery, is being promoted [68].

As for solar and wind, among the renewable energies, fluctuation in power generation due to weather conditions, time of day, and other factors are causing issues. As shown in Appendix A.5, the annual power generation amount can generally cover the energy consumption of ordinary households even with solar power generation. However, the influence of seasonal fluctuations is large, and the amount of power generation in winter is much lower than the amount of power generation in summer. When the amount of generation exceeds the demand, surplus electricity must be stored. The method of converting surplus electricity into gaseous fuel to store and use is called Power to Gas (P2G), and demonstrations are in progress in

Germany and the United States. Research and development of an autonomous hydrogen energy supply system using P2G is also underway, in which hydrogen generation by electrolysis, storage, and fuel cell power generation (output: 3.5 kW) are contained in a single container. By storing surplus electricity as hydrogen gas, though depending on the capacity of the hydrogen tanks, it will be possible to flexibly distribute electricity between days of the week and between seasons [69].

Shimizu Corporation and the National Institute of Advanced Industrial Science and Technology (AIST) have developed "Hydro Q-BiC", which not only can store a large amount of hydrogen in a small space (about 1/1000th of volume) using hydrogen storage alloys, but also has succeeded in reducing the risk of ignition by preventing the alloy from becoming too fine, which had been a problem in the past [70]. The company is currently conducting a demonstrational operation at a market in Koriyama City, Fukushima Prefecture.

The Qi standard, an electromagnetic induction method, is widely used for wireless power supply to electronic devices for daily use, and commonly used for smartphones and other devices. The Society of Automotive Engineers (SAE) International in the U.S. has developed several standards for wireless power supply to electric vehicles using the magnetic field resonance method, including WPT1. Wireless power-over-air technologies using microwave are being researched and developed by Japanese companies including Toshiba and Panasonic; it enables wireless power supply to IoT devices for healthcare and industrial applications at a distance of 10 m or greater [71].

3.2 Circulation of resources

The water cycle and waste cycle are described in relation to the resource recycling cycle. The conventional water cycle is a combination of artificial treatment by water and sewage facilities and natural water cycle, but here we describe the artificial water cycle. II.3.2.1 shows practical examples and research trends regarding the improvement of efficiency of recycling technology, expansion of water to be recycled, and related issues. II.3.2.2 shows practical examples and research trends of waste circulation when it is converted into energy, which is a candidate for household treatment, and when it is reused as a substance.

3.2.1. Water circulation

A good example of a household-based water recycling technology is the water reclamation system on the international space station (ISS). The main "water sources" at the ISS are water contained in sweat and exhaled breath, urine, and their washing water. Because showers and washing are not carried out on the ISS, organic matter and inorganic salts are contained in higher concentrations than ordinary wastewater on the earth, thus, water reclamation in a compact and power-saving manner is more difficult than on the ground. In NASA's water reclamation system currently operating on the ISS, salts in urine are removed by distillation, and then combined with water contained in perspiration and exhaled air to reclaim drinking water by ion exchange resin, membrane filtration, and catalytic oxidation [72]. As a more compact and power-saving system, Japan is also developing its own water reclamation system. This system uses the decomposition of organic matter by electrolysis and the removal of ions by ion exchange resin and electrodialysis, and does not require consumables for operation, which achieves a regeneration rate of 85% for urine [73]. Possible future improvements in these water reclamation technologies include improvements in the performance of catalysts and ion exchange resins. In addition, biological treatment, which is commonly used on earth, has not been adopted in the ISS because its stability is an issue compared to the chemical treatment described above. However, if that is solved, it could be a more efficient system, and research is being conducted [74].

Air can also be used as a "water source" on the ground. Aeris developed by Aquatech Co., Ltd. condenses air to produce drinking water. Aeris produces drinking water wherever there is a power source [75]. In addition, small water circulation systems have already been realized for shower and hand washing water. The WOTA BOX, an autonomous decentralized water circulation system developed by WOTA Corporation, uses four types of filters, including a reverse osmosis (RO) membrane, to remove pollutants, and by adding chlorine and irradiating with ultraviolet rays, more than 98% of shower wastewater can be reused [76].

For RO membranes and NF membranes, which have even finer pores, Japanese companies account for about 50% of the global market share, and for other membranes as well, Japan possesses some of the world's leading technology and know-how. One of the challenges is to improve the maintenance and durability of the membrane, and the materials and the devising of the module structure has been a main topic of the research and development [77].

Along with the above mentioned treatment technologies, it is also important to establish effective combinations for appropriate treatment methods depending on the composition of the domestic wastewater. In this case, the water cycle can be achieved efficiently by using sensing technology to select the optimal treatment method, and such optimization technology will also be a subject of future research.

Disinfection technology to keep the recycled water clean for a long period of time is also important. In terms of IPA technology, water may need to be stored for an extended period of time, UV disinfection and filtering just before use alone cannot maintain sufficient water quality if biofilm is generated in the storage tank. In the ISS, iodine and silver are used as disinfectants, but iodine needs to be removed before drinking, and silver has been reported of issues of precipitation in the tank. Another disinfecting technology currently investigated involves the use of nanobubbles. In the aforementioned WOTA, chlorine is used as a disinfectant in addition to UV disinfection. Since chlorine is consumable, better disinfection technology that improves maintainability is a research issue.

3.2.2. Waste circulation

As for the "reclamation of useful waste," some waste treatment facilities are still generating electricity from combustion heat, and large-scale facilities are also realizing biogas conversion [78], such as poultry litter methane fermentation power generation [79]. There are some examples of the development of reduced-sized devices [80], however smaller devices with lower maintenance costs is yet to be developed. It is also possible to obtain water from organic wasters by wet oxidation method using a catalyst and so on. [81]. As for food waste, methods to convert it into water by decomposition treatment using microorganisms [82] and to convert it into fertilizer [83] have been put into practical use. These methods are expected to become applicable for waste other than food waste.

Other wastes that are difficult to process are currently disposed of in landfills, but there may be effective ways of usage, for example, to compress to convert them to use as structural elements or shredding them to make materials for 3D printers. In case of wastes generated in space, they are currently packed in used supply ships and other vehicles and burned as these vehicles reenter the atmosphere, but researches are underway to use thermo-compressed wastes as building materials [84]. At first glance, recycling to collect PET bottles and obtain materials for PET bottles, as in the current waste disposal, seems to be useless even if it is realized on a household basis. However, the technology for 3D printing from plastic waste has also been realized [85], and the development of such reuse technology may support the achievement of the proposed MS Goal.

3.3 Delivery of goods

In this proposed MS Goal, four items are mentioned as efforts to make the on-demand property of goods transportation extremely high, i.e., improvement of environmental compatibility of unmanned aerial vehicles, improvement of performance, improvement of autopilot technology, and saving manpower in the operation system.

As for the environmental compatibility of transportation machinery, the main focus will be on electrification, but electric vehicles are already on the road, and research is being conducted on various other machines. Unmanned vehicles, in particular, are considered to have a strong tendency toward electrification due to the fact that they were first developed as small vehicles. Aircrafts are conventionally powered by fossil fuel, but there have been a number of efforts for electrification globally [86]. As for ships, a roadmap for emission-free international shipping is being considered in Japan, with the aim of achieving zero greenhouse gas emissions by 2050[86].

In order to improve the performance of electric powered machines, it is vital to improve the battery performance and reduce the aerodynamic drag. Currently, electric-powered drones are used in a variety of transportation equipment, but in order to improve the performance of batteries, research and development need to be conducted not only on lithium-ion batteries, which are currently the mainstream, but also on batteries with even greater capacity. For lithium-ion batteries, performance targets for 2030 have been set globally, and theoretically, the performance will be extended to about four times higher than the current average performance[87]. In addition, one of the post-Li ion batteries, Ca ion battery is expected to be a field Japan can drive the development, with Tohoku University has developed a new electrolyte for the Ca ion battery, for instance[88].

As for autopilot technology, Level 4 implementation and legislation for automobile autopilot technology are in progress led by the United States, where safety standards have been issued[89]. As for ships, research and development of automation and unmanned systems is progressing worldwide, and Rolls-Royce has published a technology roadmap for automatic and unmanned navigation by 2035[90]. The Ship & Marine division of the company is leading a project called Advanced Autonomous Waterborne Applications (AAWA), which has received €6.6 million in support from the Finnish government [92]. Research of development of those smart shipping technologies are conducted globally, specially in Northern European countries. A summary of the trends in each country is detailed in the reference [93]. Unmanned vessels are expected to increase in number in the deep sea domain, and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is conducting research and development of various elemental technologies required for next-generation cruise probes [94], which is expected to contribute to Japan's strength.

In automatic delivery, efforts are being made to save labor in the operation system. In the United States, Starship Technologies has realized an unmanned delivery service using self-driving robots [95]. In Japan, the New Energy and Industrial Technology Development Organization is carrying out a technology development project in the robot / AI field to realize a new automatic delivery service using autonomous driving robots [96]. While it is expected that unmanned delivery by drone will be implemented in the future, it is considered that there are high hurdles for automation of delivery during flight. Therefore, it is necessary to guarantee the safe realization of the service by referring to the knowledge of these land transportation services.

3.4 Making it possible to experience the surroundings (House as a device for five-sense communication and environment-building)

3.4.1. Information and communication

We have already mentioned the R&D items for the five-sense communication, "interface with humans" and "communication network connecting point to point", and this section discusses based on these points.

3.4.1.1. Interface with humans

For the "interface with humans", various research and development and practical applications have been carried out for each of the five senses. Regarding the sense of eyesight, research and development of free viewpoint images, which can reproduce images from any viewpoint using images taken from multiple directions, and volumetric images which store human motion as three-dimensional digital data and make it possible to play them back [97], have been conducted and some of them have already been put to practical use [98]. In the field of hearing, research and development has been conducted on stereophonic sound, which can reproduce and perceive the direction, distance, and spread of sound in three dimensions. Currently, standardization is underway both domestically and internationally for the widespread use of 22.2 multi-channel acoustics at home [99]. Google' Project Starline combines 3D image acquisition, real-time compression, and 3D displays to create realistic online communication, as if the other person is actually there in front of you [100].

As for the sense of touch, the technologies involved in vibration has reached the level of commercialization, but the sense from the skin that we feel on a daily basis is mostly in the research and development stage. The research scale of haptics technology is expanding, partly driven by the increasing demand for non-contact technologies due to the spread of COVID-19 pandemic, resulting the global haptics market expected to grow from 12.9 billion dollars (approximately 1,366.3 billion yen) in 2020 to 40.9 billion dollars (approximately 4,332.2 billion yen) by 2027 [101]. A technological roadmap in a white paper published in 2020 [102] predicts that robots will be able to perform human tasks that require dexterity around 2035. In Japan, efforts are being made at the Haptics Research Center at Keio University for the practical application and deployment of real haptics technology [44]. Motion Lib Inc., a spin-off from the Center, has developed a general-purpose force-feedback IC chip called AbcCore that simplifies the implementation of real haptics, and is conducting demonstration experiments to enable work that requires craftsmanship, such as wiping off adhesives from roll surfaces in the thin steel plate manufacturing process [103] and plastering [104]. As for remote operation by robots, it has also been partially implemented in the research and development on MS Goal 1, which aims to realization of cybernetic avatars [14].

As for the sense of taste and smell, projects have been carried out to elucidate the reception and transmission of chemosensory signals such as "smell", "taste" and "pheromone" in humans and the information processing mechanisms in the brain [105].

Regarding the sense of smell, it is known that humans have about 400 different olfactory receptor genes, and a group at Osaka University has succeeded in producing an olfactory receptor sensor using all human olfactory receptors to quantify all the odors that humans feel [106][107]. In addition, the JST's Research Results Optimization Support Program (A-STEP) "Creation of AI perfumers using human olfactory receptor sensors" [106] is currently undergoing with the aim of "building a database that accumulates measurement results of olfactory receptor responses to a large number of odorants (so called odor DB) , and based on this database, reproducing a target odor with a simple combination of fragrances. As for the sense of taste, quantitative evaluation of the five basic tastes is now possible with tabletop equipment, and marketing based on the results is being developed.

Taste and smell sensors are mostly biosensors based on piezoelectric effect or piezoresistive. Since these biosensors are low-power, small, and inexpensive, it is expected to realize devices that enable non-specialists to sense taste and smell information. The principle of measuring chemical concentration can be divided into two main categories. The first method is to measure the vibration frequency change of the mass addition effect caused by the adsorption of chemical substances on the receptor coated on the surface of the piezoelectric device, and the second is to measure the surface stress change caused by the adhesion of chemical substances as the resistance value change. As for the former piezoelectric vibration sensor, a sensor using a piezoelectric thin-film acoustic resonator (FBAR: Film bulk acoustic resonator), which is highly compatible with semiconductor processes, has been developed instead of a quartz crystal microbalance (QCM). The trend toward smaller footprints and mass production is progressing. As for the latter, membrane-type surface stress sensor (MSS) is used: the MSS Forum has been formed to promote the social implementation of MSS-based olfactory sensors and the social contribution based on them, and the development of olfactory sensor elements is underway [108]. The development of core materials for piezoelectric devices is also advancing. Research and development of highly performance piezoelectric materials made by adding scandium (Sc) to aluminum nitride (AlN), which is a typical conventional piezoelectric material, and composite nitride piezoelectric materials without Sc, which is a rare earth, have been vigorously pursued in recent years.

There are two major methods of taste and smell actuation underway: one is to use chemical substances directly on the sensory organs, and the other is to stimulate the sensory organs with electricity or light to simulate them. In case of the former approach (actuator is used to reproduce taste), a combination of five basic taste chemicals is used to act directly on the sensory organs. For example, a taste display is in process of development, in which a gel electrolyte with five basic flavors is placed in direct contact with the tongue and the amount of ions introduced is controlled by applying an electric current to change the taste [109]. It is known that the sense of taste needs to reproduce 5 basic tastes, while the sense of smell needs to combine about 100 chemicals to reproduce it with high accuracy [110]. Since it is difficult to prepare all of these many chemical species and combine them in real time, current commercially available scent generation devices play scents by combining several pre-prepared scent cartridges [111]. On the other hand, the development of micro-machining technology by wafer process has made it possible to precisely control microfluidics, and it is now possible to mix multiple liquid chemicals on a chip [112]. Research and development of atomizers using surface acoustic waves (SAW) caused by piezoelectric vibration is also underway. By combining these microfabrication technologies into a single chip, it may be able to create a highly reproducible olfactory actuator [113]. In the field of microfabrication technology and surface acoustic wave control technology, central to these devices, Japan has been leading the world in integrated research and development from material technology to production technology since the dawn of the industry-government-academia collaboration system. The latter, actuator using electric stimuli, is advantageous in that it does not consume chemical substance like the former does. However, it is necessary to elucidate the mechanism that relates electrical and light stimulation to taste and smell, and to research and develop a safety evaluation index for the human body.

3.4.1.2. Point-to-point communication network

In Japan, while the 5th generation mobile communication system (5G) have become available since 2020, studies have already begun on the concept of the next generation of communication systems called Beyond 5G and 6G. "Roundtable Meeting on Beyond 5G Promotion Strategy" for the Ministry of Internal Affairs and Communications(MIC) [114] describes that 5G's features of "high speed and large capacity, low latency, and multiple simultaneous connections" will be further enhanced in Beyond 5G, which will require not only "ultra-high speed and large capacity, ultra-low latency, and multiple simultaneous connections" but also "autonomy, scalability, ultra-safety and reliability, and ultra-low power consumption." These features are also common in white papers and other reports published by various organizations, including domestic and foreign [115][116][117][118][119][120]. Among these characteristics, "autonomy" and "scalability" are especially relevant to achievement of this proposed MS Goal. "Autonomy " is the ability to immediately build an optimal network according to the needs of the user without being aware of whether it is wired or wireless. As described in II.2.7, in order to realize five-sense communication, the route, quality and quantity on the communication network must be optimized according to the application. "Scalability " is the ability to use communications in any location, including sea, air, and space, by using satellites and HAPS with wide coverage as communication paths. As for satellite, satellite constellations consisting of a large number of satellites are being developed around the world. SpaceX's Starlink plans to launch a total of more than 12,000 satellites, and more than 1,500 have already been launched [121][122]. HAPS Mobile is developing an unmanned aircraft for HAPS, and successfully completed a stratospheric flight (flight altitude of 62,500 feet: about 19 kilometers) in September 2020[123]. Rakuten Mobile is working with U.S.-based AST on its Space Mobile plan, which aims to build a communications environment that can provide stable service even in the event of a disaster [124]. This project aims to realize a broadband communication infrastructure capable of covering 100% of Japan through direct communication between existing smartphones and satellites.

3.4.2. The house as an environment-building device

Two types of trends regarding houses as environment-building devices will be described. One is about the house that can be built in an extremely short time from the viewpoint of construction, and the second is about the design that builds the desired environment from the viewpoint of design.

One solution is to be able to build the house you want in a very short time, so that everyone who wants can change their living space according to the demands of the moment. The off-grid houses using prefabricated construction methods follows this direction. Recent development regarding off-grid houses is that it has become possible to build a prefabricated house in about eight hours by using a 3D printer, and there are companies that actually provide properties that have been built in that way [125][126]. Similarly to the trend in the use of 3D printers, research and development is also underway to make construction unmanned. At DFAB House, robots assemble the wooden framework, and the ceiling slab is manufactured using a 3D printer [127]. In this way, the introduction of 3D printers has shortened the construction period of houses.

Adding new devices to the interior of a house, rather than building a new house itself, is one way to make the house a desirable environment. This is mainly a design effort. In recent years, insight analysis has been conducted in collaboration with ergonomic research to observe users and extract issues when designing things. For example, chairs and keyboards that are adapted to human movement and body structure from an ergonomic point of view have been coming out into the world. In addition, research has been conducted not only on the area that people can consciously recognize, but also on the areas that people feel comfortable by instinct or habit, without recognizing it [128]. It has become clear from the field of neuroscience that humans unknowingly undergo a biochemical reaction (homeostasis) in response to changes in the environment [129]. It is also the original purpose of design to aim for a design that works well on them after understanding the reactions that unconsciously go in the direction of "good" and "happy" such as homeostasis. It can be said that this is one of the recent trends that has been attracting attention as a design for well-being. Due to the nature of the field, trends related to well-being are often practiced in the medical field. It is categorized in detail as to what should be measured in order to live better, and the constituent factors of well-being are being elucidated, i.e., there are three categories: physical characteristics / biological reactions, behavior / behavior, and subjective reports [130]. In the field of consumer insight analysis, a method of insight analysis using big data called diginography [131] also exists as a domestic trend. As mentioned above, Japan is expected to have strengths in this field.

Another major trend in recent years is that the interpretation of the designer's way of thinking has advanced and is beginning to be widely accepted by society. The designer's thinking in design is often divided into two stages, visualized by a double diamond: problem finding and problem solving [132]. Design Thinking [133] visualizes mainly the problem-solving part of designers' thinking, and in recent years it has penetrated not only the design of things but also various domains such as management [134]. On the other hand, the research and development of problem finding is also very important because problem solving depends on the quality of the question itself [135]. One of the researches is called speculative design [136]. This design speculatively explores various future possibilities and makes the world a better place. In the awareness of various problems these days, it is thought that this design is useful for living in harmony rather than thinking after being given a problem. Therefore, further development in this field is expected. Speculative design has been increasingly applied to different fields from art, as in the case of design thinking. For example, the UK has hosted workshops using speculative design methods to plan for an ageing society, and this has become a project involving the government [137][138]. In addition, although the term human-centered design itself has existed for about 30 years [139], it has been emphasized in social design in recent years, i.e., one of the major keywords of Woven City [50] is “human-centered.” Finally, we will describe the domestic trends regarding creativity. Creativity is the ability that designers need to come up with / conceive new things. It is recognized that in order to be creative, it is important to be exposed to primary information through a variety of senses, represented by experiences such as those available in travel [140]. Here, primary information is information that is not restricted by human interpretation. For example, rather than seeing something through a video, it is equivalent to experiencing that "something" in a situation where all senses are not restricted. What the designers are aware of is also an area that has not yet been verbalized. In general, approaches are being attempted from the fields of neuroscience and psychology [141]. Until now, the structure of creativity itself has rarely been verbalized, but as a recent trend, an interpretation of creativity has been given from an analogy with evolution [142].

III. Plan for Realization

1 Area and field of challenging R&D, research subject for realization of the Goals

In II.1, the technical issues deduced from the "functions that make life possible" identified in II.2 are described: now the technical means to implement to supply these functions anywhere without resorting to the installation of extended infrastructure everywhere consist of:

- "energy self-sufficiency," which make it possible to obtain energy on the spot,
- "resource circulation," which minimize the need of tap water supply and recover organic matter from used water,
- "fully automated transportation," that transport waste material as well as any goods that cannot be self-supplied
- "five-sense communication," which help realize a colorful and fulfilling life assuming basic life is possible anywhere, and
- "house as an environment-building device," that can reproduce a colorful environment anywhere given implementing devices that make the above possible.

Social systems engineering, which integrates these technologies to synthesize what kind of urban structure should be realized, and ELSI (Ethical, Legal, Social Issues), which takes into account changes in the social structure, will together be the means of implementation that constitute the envisioned society. It is shown in Fig. 9. The main fields and areas of research and development necessary to realize a society with a dramatically increased degree of freedom are shown in Fig. 10.

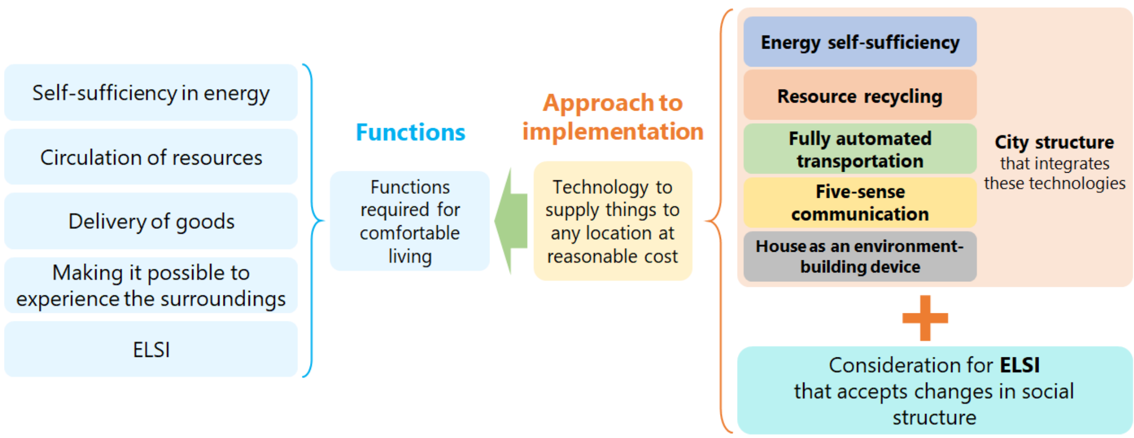

Fig. 9: Necessary functions for human-like living and their means of implementation

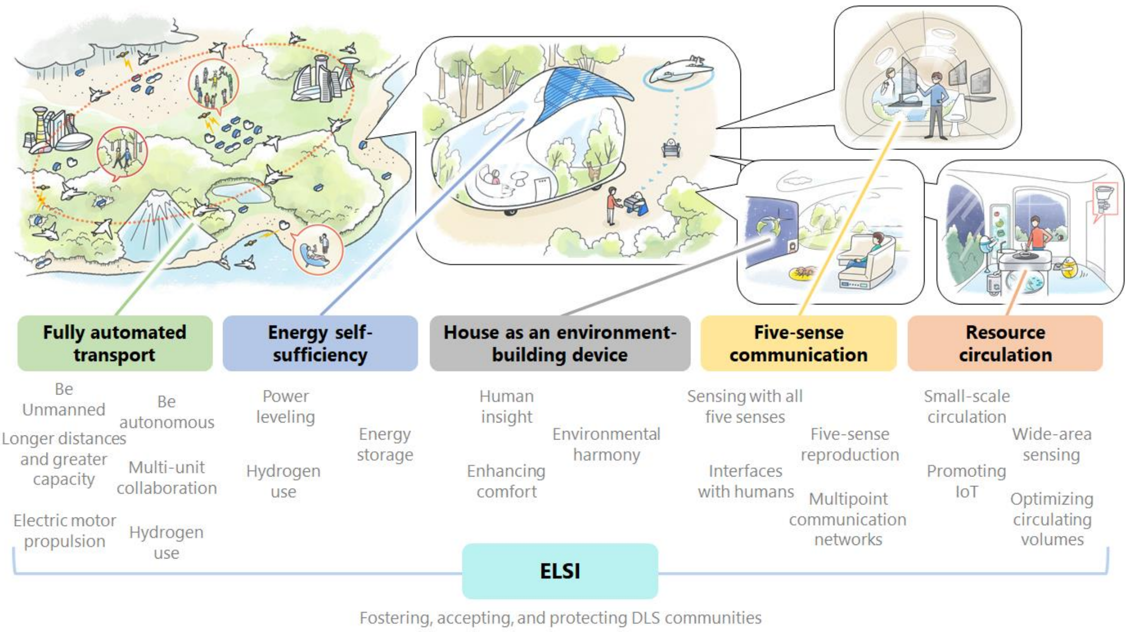

Fig. 10: Major fields and areas of research and development necessary to realize a society with a dramatically increased degree of freedom

This proposed MS Goal sets a social image. Society cannot be established with only disparate technical elements, nor can it be established with logical flaws. Rather, it is established as a society by striking the balance of the various technologies. Therefore, individual technological elements are naturally required to realize the social vision, and the key to the realization of the social vision is to clarify in detail the reason why each technological element is required and why the technology is needed there. In addition, as mentioned in II.1, when social changes are brought about by the social implementation of technology, social issues are sure to arise with psychological effects, and these must be addressed by ELSI, i.e., public responses such as regulations, administrative responses, and welfare, and the involvement of the social sector such as NGOs. In other words, collective impact [143] (i.e., collective social change) needs to occur. Also, a new governance model must be created at the same time [144].

Therefore, the most important research areas are the above-mentioned technological elements and the architectural design of the society that continues to be maintained as a consistent social image, including the ELSI, after bundling these technological elements [145]. In other words, society is a system of systems that consists of many subsystems. It is the core research subject of this MS Goal to find the design cycle of the social system, by organizing the causal relationships among the constituent technological elements and establishing subsystems that can supply the necessary amount, as well as by designing a social system as a whole determining what kind of balance can be established to demonstrate by social experiments, measure the shortcomings, and improve the design.

1.1 Energy self-sufficiency

・Energy saving technology

Much of the energy that supports the functioning of cities is expected to shift to renewable energy sources, and as mentioned earlier, research and demonstrations on P2G are underway. On the other hand, as the introduction of renewable energies expands, their output fluctuations and surplus energy are becoming a problem, and a mechanism to stabilize energy is needed. There has been a lot of attention paid to technologies for storing energy, including storage batteries such as lithium-ion batteries, and hydrogen is one of the technologies for which technological development is accelerating. Since hydrogen is basically stored in tanks, it does not discharge naturally and is suitable for long-term storage. In addition, the use of hydrogen storage alloys can compress the volume to about 1/1000th of its original size, making mass storage possible.

In other words, it is considered to be suitable for larger scale or longer span operations than usual. We are considering the possibility of cross-seasonal energy management: for example, surplus electricity generated in spring and autumn, when solar power generation is high and energy demand at facilities is low, can be stored in hydrogen and used in summer and winter, when energy demand tends to peak.

The "Hydro Q-BiC" described in II.3.1 can store a large amount of hydrogen in a compact manner, but it is not practical to carry it around because it requires a large-scale device. Therefore, the evolution of this technology, such as making it more compact and improving the energy management of the home, is expected to improve the freedom of the DLS consumers. By converting electric power into hydrogen using solar power generation or wind power generation, etc., and safely storing the hydrogen using hydrogen storage alloys, it may be possible to stably secure and use the energy necessary for living space and transportation even when there is insufficient sunlight or wind. In addition, since this system will spread to base cities as well, it is necessary to upgrade the energy management of the entire city.

1.2 Resource circulation

Since researches on individual technologies for the recycling of resources such as water and waste are already underway in various fields, we will only emphasize the importance of these technologies again in this proposed MS Goal. However, we believe that systematizing these individual technologies and optimizing them from the perspective of cost and other factors is an important research area for realizing this proposed MS Goal. The technology for local production and local consumption of material circulation and energy described in the previous chapter is actually considered to have its optimum point in combination with the transportation of water, waste, batteries, fuel, etc., which also diverts some of the existing infrastructure. It will be important to conduct research to parameterize each technology and transport and to combine them into a method for optimizing the infrastructure. In other words, this kind of "circulation system engineering" is the most important research area to be addressed.

In addition, for its social implementation, it is necessary to study the construction of social systems such as monitoring of each parameter and logistics adjustment system by IT technology. If households are to own their own infrastructure packages, it is expected that their maintenance will be a challenge. Sanitation is essential for water circulation and waste treatment, and its safety management is essential for electricity. It is expected that there will be dangerous situations if left to individuals, and at the same time, taking away individuals' time to maintain infrastructure packages reduces the benefits of distributed infrastructure. In addition to establishing automatic autonomous control of infrastructure packages, it is necessary to establish technology for remotely sensing the status of infrastructure packages and a management system that automatically takes the necessary actions based on the sensed content, so that people can enjoy the same infrastructure as they do today without worrying about anything.

Taking the water circulation as an example, as mentioned earlier, the appropriate treatment method differs depending on the type and amount of pollutants contained in the wastewater. Monitoring of water quality and equipment is the key to efficient treatment. Although there are many ways to monitor water quality, rigorous identification and quantification of constituents is quite time-consuming and requires simple indicators and sensing technology. The water reclamation system on the ISS constantly monitors the integrity of the water and equipment, mainly by electrical conductivity, and occasionally samples the reclaimed water to monitor the total organic carbon (TOC) content, pH, etc. in orbit, and periodically performs detailed component analysis on the ground. The integrity of the equipment is also constantly monitored by monitoring the pressure and temperature.

On the ground, as shown in [146], there is a study to solve the problem of maintaining sewerage facilities under a declining population by using ICT, and a study group has been held on the use of sensing and collected information (big data) [147]. It is thought that similar technology will be necessary for the water circulation of the proposed MS Goal. The same kind of "remote management or automatic autonomy of distributed infrastructure" will become necessary for power (energy) circulation, waste disposal, etc.

In addition, especially for water, "expansion of water circulation targets" is necessary to achieve complete circulation in the future. As mentioned earlier, it is not possible to reduce the amount of water transported to zero only with existing objects that can be recycled, such as wastewater and urine. As mentioned in the section on water circulation in II.3.2.1, it is necessary to promote research and development of technologies to efficiently obtain sufficient purified water, as exemplified by the technology to generate water from air. For example, since water is produced by the combustion of organic matter in waste, it is expected that it will be possible to develop a system that obtains water simultaneously with the combustion process.

An example of a cost reduction scenario for replacing the water infrastructure with a circulation system for each household is shown in Appendix A.10. The water circulation is expected to reduce the cost of maintaining the water supply infrastructure. Based on the reduced cost and the number of households, the target price per unit of the water circulation device can be estimated. The same kind of estimation can be applied to other devices, and it will be necessary to develop technology to reduce the cost to that target amount.

1.3 Fully automated transportation

Research and development of unmanned vehicles and robots to assist in the transportation process is necessary to realize fully automated transportation. As for the process of realization, both assume that the system will first be spread by remote control and then become autonomous as the technology progresses. Therefore, as a first step, remote communication technology that can be connected from anywhere is necessary. As a result, remotely operated robots or transporters will be able to perform transportation tasks that currently rely on human power, and people will be able to work from any location. Next, research and development are required to ensure that transport aircraft and robots can perform their tasks autonomously, including control technology to avoid collisions and fly regardless of weather conditions. For unmanned transport aircraft, it is also essential to establish a flight management system for smooth operation in anticipation of increasing demand. In addition, to ensure on-demand performance, it is necessary to develop an aircraft with a high payload capacity in vertical take-off and landing flight and capable of high-speed transport over long distances. From the viewpoint of reducing the environmental load, it is desirable that the drive source of the aircraft be electric. Among the above, the most significant research issue to achieve the goal is the development of an aircraft that can transport a high payload over a long distance with vertical takeoff and landing capability. Based on global intercity range data using Urban Centre database [16] (see Appendix A.2), it was estimated that a range of 252.8 km would be required to carry intercity transportation between base cities. However, according to the study of battery performance and achieved range (see Appendix A.6), this target is not achievable at this time. Also, since 1000 km and 2000 km will not be achievable even in 2050, the development of next-generation batteries will be essential. In terms of the shape of the airframe, there are research issues to be solved in order to devise a superior airframe that combines a fixed-wing airplane, which is superior in terms of payload, fuel efficiency, and speed, and a multicopter, which has vertical takeoff and landing functions.

1.4 Five-sense communication

As described in II.2.4.1, in order to realize five-sense communication at any location (point), and to enable two people who are far apart from each other to have the same perception as in a physical space in a virtual space without any sense of discomfort, it is necessary to conduct research and development to realize an "interface with humans" for sensing and reproducing the five senses and a "point-to-point communication network" for transmitting the five senses. By establishing a communication technology that is suitable for each of the five senses, it is possible to provide sensations equivalent to being there even at a distance. Furthermore, even in the case of a point dwelling, if an interface with people is implemented in the dwelling space, the room can be transformed into a work room or a communication room rather than a mere space, and a space that provides various functions and values, i.e., a "house as an environment-building device " as described in III.1.5 can be realized.

・Five-sense sensing technology and Five-sense reproduction technology

In order to establish five-sense communication at each point, devices that enable sensing, pro-sensing, and actuation of the five senses at every location must be realized and implemented in the living space. Furthermore, in order to enable five-sense communication even when people are out of their living space, wearable devices that people can carry with them and devices that move with people while floating, such as drones, are also necessary, and in such cases, technology that directly reproduces three-dimensional spatial and temporal information in physical space is necessary.

For tactile sensation, research and development is needed to realize tactile devices with high response speed and multi-point controllability to enable robot control with high safety and adaptability wherever they are. From the point of view of taste and smell sensor devices, technologies related to high sensitivity and high dynamic range of chemical sensors are necessary to realistically support the informatization of human taste and smell. From the point of view of actuator devices, by means of direct application of chemicals to sensory organs, assuming that the number of devices is proportional to the type of chemical substance, it is clear that economic efficiency and miniaturization are obstacles to the realization of olfactory actuators. Therefore, if we want to promote the use of olfactory actuators, we need to identify chemicals that can maximize the range of olfactory reproduction with fewer chemical species. The chemicals must also be safe for the human body. The method of stimulating the sensory organs with electricity or light to simulate taste and smell is advantageous in that it does not consume chemical substances as the former does, but it is necessary to elucidate the mechanism that relates electrical and light stimulation to taste and smell, and to research and develop a safety evaluation index for the human body.

In addition, in the transmission process of these five senses information, not all information from the sender side is transmitted to the receiver side, but filter processing considering the personality of the receiver side is also necessary. For example, filter processing, such as reducing bitterness for infants receiving taste, or increasing sensitivity for users with taste loss, is important for the user's safety and comfort.

・Point-to-point communication network

Depending on the required communication application, visual information, which has a large amount of information and requires a throughput of about 2 Tbps, is compressed and transmitted using not only wireless lines but also high-capacity optical lines, and auditory and tactile information that requires a low latency of several milliseconds should be prioritized and transmitted by a relay station such as a drone close to the ground. It is necessary to conduct research and development on communication platforms and network slicing technologies that can optimize the path, quality, and quantity on communication networks to meet the needs of the amount of information and time perception required by the five senses.

1.5 House as an environment-building device

In order to realize a house as an environment-building device, it is necessary to promote research and development in the following two research fields and areas related to design, because the design for people to go anywhere by themselves and experience it with their whole body is important in the proposed MS Goal. One is the research field related to the way people feel in areas that they cannot recognize, and the other is the research field related to the way designers feel and their creativity in relation to primary information that is the source of ideas.

The field of research on how people feel in areas that they cannot cognize is an integrated field consisting mainly of ergonomics and cognitive science. In this paper, we refer to this as human science. There are two stages in the research and development of human science. First, in order to design something for people to live better (=well-being), it is necessary to research a theoretical framework that people perceive as "good" regardless of whether they are cognitive or not. This is also related to the research being promoted in the field of five-sense communication, but since the five senses are not the only sensors by which people perceive something, it is desirable to conduct research on other items as well. Next, once these senses are clarified, research and development in the direction of measuring them, controlling them, and optimizing them will be necessary in this field.

Research fields related to the way designers feel about primary information, which is the source of ideas, and creativity will mainly be in the fields of cognitive science and psychology. A situation in which people freely experience and are flooded with primary information is the goal of this MS, and at the same time, how to utilize this primary information is an important element. Unlike consumer insight analysis, the direction of this research is to clarify how the designers themselves, who receive and conceive of the information, feel about the primary information and how they exercise their creativity. The clarification of new ways of perceiving information and decision-making processes for designers in the fields of cognitive science and psychology will make it possible to logically explain the creativity that is being demonstrated in various fields, just as design methods are spreading into various fields. Therefore, there are a wide range of fields where this research can be applied, and it is expected that research on methods for better creativity will be promoted in each field.

2 Direction of R&D for realization of Goals

Based on the contents of III.1, the milestones to be achieved in 2030, 2040, and 2050, respectively, and the specific R&D themes to be addressed to achieve the milestones are shown in Fig. 11, in order to realize the achievement scene of science and technology. The effects that achieving the milestones will have on society are described in Appendix A.10.

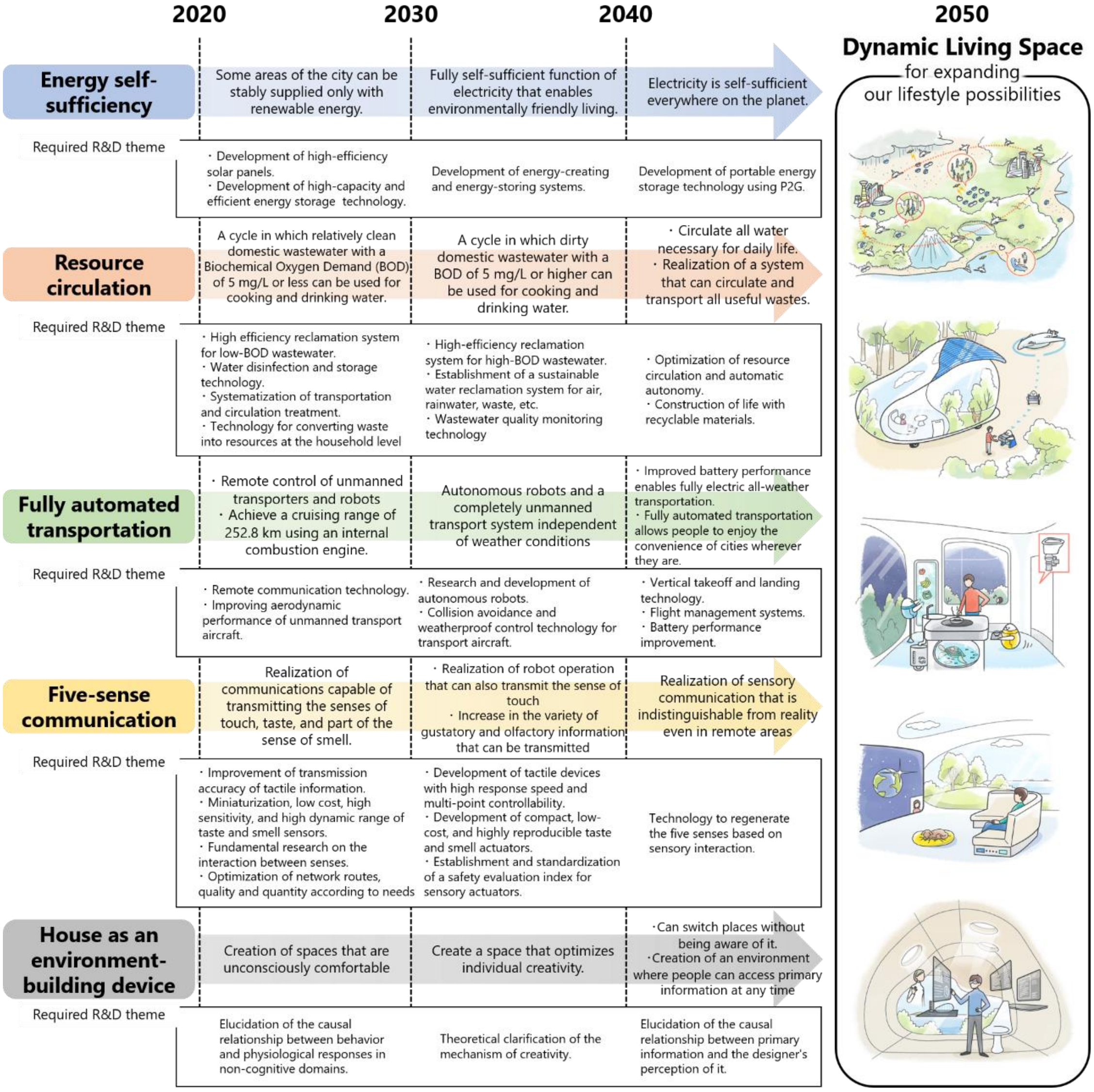

Fig. 11: Milestones and R&D themes to 2050

3 International cooperation

Cooperation with other countries is also essential for the achievement of this proposed MS Goal. In addition to collaboration in research and development with developed countries, it is also necessary to work together with emerging countries, especially the East Asian countries that are members of ASEAN, which are currently facing the problem of urban overcrowding, to address the proposed MS Goals as partners who share the same problems.

Cooperation with developing countries can contribute to the rapid development of infrastructure in those countries. If this proposed MS Goal is achieved in Japan and IPA technologies are actively exported to developing countries and other countries, it will be possible to support the independent and self-sustaining development of developing countries.

For example, it has the potential to provide a stable supply of water and energy to developing countries that still do not have a well-developed infrastructure. This is similar to the phenomenon of mobile phones spreading ahead of fixed-line phones in developing countries, and is expected to lead to lower infrastructure development costs. In fact, "the population penetration rate of mobile phones is now 80.8% even in Africa, the lowest level, and there is no longer much difference between developed and developing countries" [148]. Considering that if the social image becomes specialized to our country, the market for deploying the accompanying technology as a product becomes smaller and more expensive, collaboration with other countries is also a necessary element for the development of IPA technology.

As described in detail in III.5, we held an international workshop with foreign nationals from the world's six major continents and Japanese nationals from various parts of Japan to investigate the social acceptability of the proposed social vision in various countries around the world. It is necessary to continue such international activities to continuously investigate the social acceptability.

4 Interdisciplinary cooperation

This team spans a wide range of institutions specializing in transportation, information and communication, housing, architecture, administration, and psychological aspects, making this activity itself a cross-sectoral collaboration. Therefore, the linkage among the themes that emerged from this study, such as urban structure, energy self-sufficiency, resource circulation, fully automated transportation, five-sense communication, house as an environmental-building device, and ELSI, is particularly important for achieving the moonshot goal. There is also a need for collaboration across other fields and sectors that could not be initiated within these themes, as well as across fields and sectors outside of these themes under consideration. In particular, the energy field is one of the essential fields for establishing human life, and the solutions of the proposed MS Goal study team "Moon Village - HO-DO-HO-DO[21]" and "Electrolytic Personal Grid Team[22]", which have tried a similar decentralized society, are expected to be consistent with the realization of the social image set forth in this proposed MS Goal. In addition, the "FlexInfrastructure Consideration Group[23]" proposes solutions for "autonomously evolving information infrastructures" and "flexibly changing building spaces" with the aim of realizing a "lifestyle that anyone can enjoy anywhere, anytime", which is expected to be consistent with the realization of the social vision set forth in this proposed MS Goal.

5 ELSI (Ethical, Legal, Social Issues)

So far, we have referred to the efforts to achieve the proposed MS Goal from the perspective of science and technology. In this section, we will discuss the ethical, legal, and social issues that are assumed to be involved in realizing a society in which the proposed MS Goal is achieved, and the efforts to resolve them. To lead a dynamic life, the needs for governmental and private services that are closely related to our daily lives will become more diverse and sophisticated, and the social implementation of IPA technology will require a major shift in government and social systems.

In considering what kind of life they would like to realize, eight items have been selected from the 14 items of life shown in Table 1 of II.1 (8 items: "2. Services for safety/security," "3. Services to support life," "4. Attractiveness of the community," "5. Harmony with the environment," "7. Opportunities to meet people (opportunities to meet interesting and diverse people)," "8. Information for work (obtaining information through meeting people)," "11. Easy access to people, things, and things that are being talked about", "12. Unrestricted access to what I want and can get"). In order to realize these ideals, it is necessary to give consideration to ELSI with social acceptability in mind.

In addition, in order to examine the international social acceptability of dynamic living, an international workshop was held with general foreign nationals from the six major continents of the world (the Americas, Europe, Africa, Asia, and Oceania) and general Japanese nationals recruited from various parts of Japan. (See Appendix A.12 for details). As a result, as shown in Table 2, although there was an overall positive response to the social vision set out in the proposed MS Goal, the issues that emerged were how to maintain the community and how to make the public functions work.

Table 2: Advantages and disadvantages of the vision of society set out in the proposed MS Goal as pointed out in the international workshop

Advantages	Disadvantages
• It will support vulnerable people whose access to employment opportunities and urban resources is limited by their area of residence. • If applied to countries and regions with underdeveloped infrastructures, it is possible to lower the barriers to the installation of new infrastructures. • It is possible to live close to places related to your hobbies or research subjects • Forming small groups with the same values can strengthen connections. • It reduces land occupation and leads to a more equal society. • In island countries, the disparity between islands with cities and the rest is large and can be corrected. • Enabling decentralized agriculture and various forms of land use (freeing us from intensive agriculture) • Barren areas such as deserts can be utilized.	• Connections to the community disappear, contributing to the risk of solitary death. • There will be a disparity between those who have access to IPA and those who do not. • In case of disaster/emergency, it is unclear who is in charge of rescue and support. • They may lose their communities and their identities. • What will be the jurisdiction of the social safety net and how will it function? • It allows anyone to step into nature, which can lead to environmental destruction. • Who controls the individual movement/residence?

The results of the online survey we conducted also revealed that people have concerns about dynamic living in multiple dimensions (Appendix A.1.3.8). For example, "I worry if there is no hospital nearby when I get sick during or at the destination" and "It is troublesome to go through the paperwork associated with moving" stood out as particular concerns in dynamic living. There were also concerns about the estrangement of human relationships, such as "I don't want to be separated from my family" and "I think I will be separated from my friends," as well as concerns about administrative services, such as "I think I will not be able to enjoy social security.

From the above, based on the 14 items of livelihood shown in Table 1 of II.1 and the results of the international workshop and online survey, we have derived ethical, legal, and social issues that may arise under dynamic living, and solutions to each of them (see Appendix A.13 for the process of derivation). Under dynamic living, while the borderlessness and individualization of the region increases the degree of freedom of personal choice, the constantly changing situation in the "neighborhood" causes various anxiety factors. For example, in a society with weak person-to-person connections, the sense of isolation of individuals deepens as a counterpart of unrestraint, and a sense of dissatisfaction and helplessness about problems that cannot be handled by the individual accumulates [149]. It also raises concerns about increased crime due to the lack of neighborhood visibility. Therefore, in order to achieve the proposed MS Goal, it is necessary for the government to create a society where everyone can live comfortably by developing a crime-deterrent environment and system, and an emergent community that keeps people communicating with each other, while protecting the privacy of individuals. It is important to note, however, that not all people will live a dynamic life with IPA. Therefore, a gradual transformation of the social system is required so as to enable coexistence between those who engage in dynamic living and those who do not.

In order to achieve the proposed MS Goal and to realize a society where everyone can live comfortably, the following section proposes 11 ELSI issues and their solutions. As shown in Fig. 12, these 11 ELSI tasks can be grouped into three categories. "Protecting people" refers to issues related to human life and human rights, and "Protecting places" refers to issues related to the protection of the natural environment where people live. "Protecting society" is a challenge to improve the quality of society, which can only be established when people and places are protected.

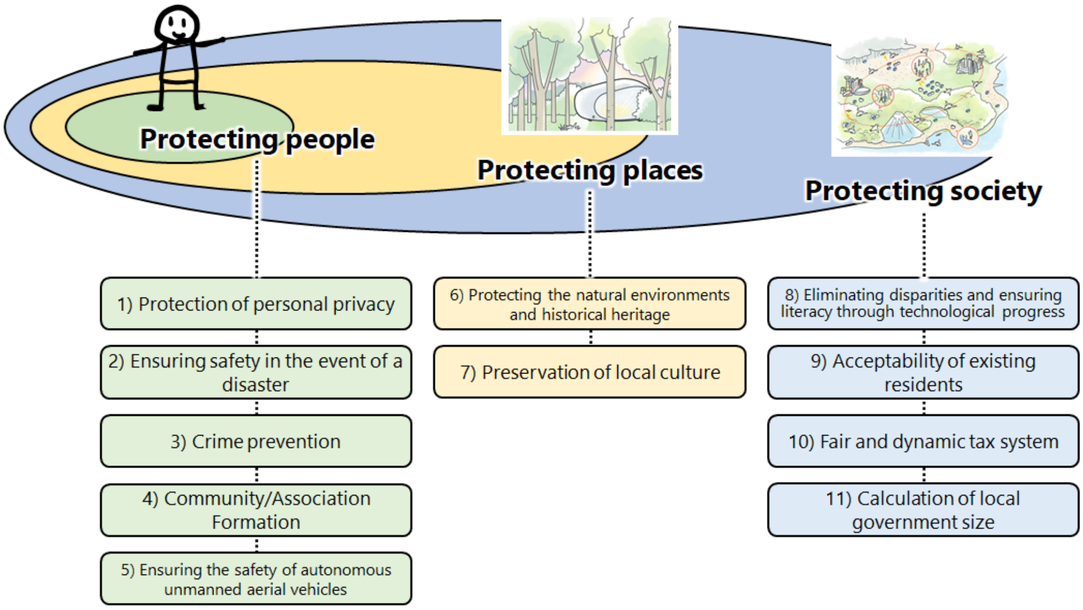

Fig. 12: Initiatives for ELSI needed to increase social acceptability

[Protecting People]

1) Protection of personal privacy

In order to provide detailed administrative services to residents in a society where this proposed MS Goal has been achieved, it is necessary to know where each person is by address management, personal identification, and personal tracking. This makes it easy to deliver mail and supplies. On the other hand, there are concerns about a surveillance society, and the issue of personal privacy is also expected to arise. The "Personal Information Protection Law" and other privacy protection measures will be important. Since the current Personal Information Protection Law requires various appropriate measures such as specifying the purpose of use, consent of the individual when providing data to a third party, restrictions on the acquisition and provision of unnecessary data, deletion of unnecessary data without delay, data security management system, and complaint handling system, it is necessary to establish new special measures for implementation and operation.

Therefore, a system is required that enables people who need to receive services to exchange information without having their personal information identified. Since it is necessary to manage the information of the residents who move incessantly by dynamic life, it is necessary to have a method to collect and manage the movement information of the residents who come and go incessantly. In addition, it is necessary to digitally create a framework that enables strict management at the intermediate levels so that the collected information does not lead to the identification of individuals, because the information necessary for the provision of services must be appropriately extracted, processed, and passed on to the necessary parties. For example, by applying a technique called "secret computation", which allows computation while keeping the contents of the data secret, it is possible to handle information while protecting the confidentiality of data related to personal information [150]. It is believed that the government will continue to play a role in ensuring that only those targets who need to know the information are provided with the necessary and sufficient amount of information.

2) Ensuring safety in the event of a disaster

In a society where this MS target has been achieved, people can live in any place, so they cannot grasp the safety of the area they are going to live, such as the risk of landslides and floods in the place they have moved to. Furthermore, in the event of a disaster, they may not know where they should evacuate to. In addition, in the event of a disaster, there is a possibility that administrative responses such as police, fire, ambulance, and rescue will be delayed because people's whereabouts are unknown.

In order to solve the above problems, it is necessary to identify risks in advance and develop hazard maps by using huge amount of data automatically collected from past disaster information [151]. Whenever a person intends to live in a disaster-prone area, it is necessary to have a system that automatically communicates the disaster risk and history of the area through risk-sensing sensors. In addition, in the event of a disaster, systems to minimize damage are essential, such as drones providing appropriate guidance to evacuees based on information on the location of people known in advance by the government, or detecting people who are unable to move due to injuries and automatically requesting rescue.

3) Crime prevention

In a society in which this proposed MS Goal is achieved, it is assumed that the freedom of residence will increase, and as a result, people will live in more dispersed areas than at present. Therefore, it is assumed that the scope of crime prevention, which has been the responsibility of the government, will become even larger, making it more difficult to prevent the occurrence of crime, detect the occurrence of crime, and take subsequent action.

Therefore, the implementation of drone patrols is expected to improve the deterrence of crime and early detection of crime. However, when referring to and identifying personal information in order to arrest criminals at a later stage, it is considered that privacy issues for individuals in the general public other than criminals will also arise, and it will be necessary to consider these trade-offs. In addition, in order to curb domestic crime, which is difficult to detect, it is necessary to have a system that allows people who feel threatened or victims to widely send out SOS signs and a system that allows those people to escape immediately, and these systems need to be properly developed by the government.

4) Community/Association Formation

In a society where this proposed MS Goal is achieved, it is hoped that people will be able to live anywhere and have many opportunities to meet diverse people, as described in II.1. In today's society, however, the only way for physically separated people to form relationships is through social networking services on the Internet. The international workshop (see Table 2 in III.3) pointed out that under dynamic living, "connections with the community disappear, contributing to the risk of solitary death" and "the possibility of losing community and identity". Therefore, in a society where this proposed MS Goal is achieved, it is thought that a place for communication that builds dynamic relationships through new encounters will be necessary. In addition, the functions that traditional communities have played, such as crime deterrence, disaster prevention, and prevention of isolation, will also be essential.

Therefore, the function of a community/association in a society that achieves this proposed MS Goal requires the functions that have been carried out by neighborhood associations and community centers are realized not only in physical space but also in virtual space. Here, the place is called an "association" rather than a "community". Community is traditionally defined as the place where one was born and grew up, or a place where one is connected by blood ties through shared regional bond, ancestral worship and beliefs, or a strong connection that serves as a foundation for child rearing and care. An association is like a school or a company, where people who share the same goals and interests are connected by their own will, and belong to it as long as they benefit from it, and leave it when they no longer benefit from it [152][153]. In this association, it is desirable to realize virtually the same sensation as the real space with five-sense communication so that "emergent" [154] communication with others can be generated and promoted.

However, associations do not replace communities, and there are still values that can only be provided by traditional communities. Therefore, it is necessary to strengthen relationships that lead to early detection of lifestyle issues and to enhance detailed welfare services by creating an environment where people can see each other.

In addition, it is necessary to pay attention to the maintenance of communities/associations when employment, education, and the maintenance and building of relationships are all carried out remotely using technologies such as five-sense communication. It is expected that there will be an increase in the number of cases where people meet new people and build relationships only online without ever meeting in the real world. Therefore, it is necessary to clarify how the relationships formed in such environments differ from those in traditional human relationships and communities/associations.

5) Ensuring the safety of autonomous unmanned aerial vehicles

In a society where this proposed MS Goal is achieved, people will be able to live anywhere, and package delivery using unmanned aircraft will become mainstream. Rather than a single aircraft or two flying simultaneously along a limited number of specific flight routes, as is the case in the current unmanned aircraft logistics demonstration experiments, it is assumed that the complex air traffic environment will be created in which a large number of aircraft are flying simultaneously to each delivery point, each as close to on-demand as possible. Among these issues are preventing the aircraft from colliding with anything, fostering social acceptance among residents and others of the noise caused by the aircraft, and developing a system to enable flight.

In addition to the aircraft certification and pilot licensing systems currently in place, it is necessary to revise the Civil Aeronautics Act and other laws. The technical requirements include the development of technology for the aircraft and peripheral equipment to ensure safety, such as the avoidance of collisions between aircraft and the prevention of collisions with manned aircraft and objects, and the development of technology and flight route design to keep the noise level at a level acceptable to local residents. It is also necessary for the national government to take the lead in developing a system to ensure safety so that autonomous, unsupervised flights are permitted even in high-risk manned areas.

[Protecting Places]

6) Protection of the natural environment and historical heritage

In a society where this proposed MS Goal is achieved, people will be able to live anywhere, with or without existing infrastructure, which may lead to the deterioration of the natural environment of their habitat and the destruction of historical heritage and landscapes. In particular, restrictions must be placed on travel to areas where the natural environment is protected, such as national parks and World Natural Heritage areas. Therefore, it is necessary to identify in advance the areas that cannot be inhabited, such as the areas to which the registered property itself including World Heritage sites belong and the buffer zone [155] defined around it, and to have a system to convey this information to people who are thinking of living in that land. In addition, in order to allow trustworthy people with a low risk of destroying the environment to live in a particular area, mechanisms such as understanding the residential history of each individual and incorporating systems into residential spaces that are recyclable and do not produce waste in the first place would be effective.

7) Preservation of local culture

In a society where this proposed MS Goal is achieved, it is expected that there will be a free influx of people with different values in many lands. This leaves relatively few people to pass on the culture of the area. Furthermore, it is possible that newcomers do not want to know about the local culture, do not respect it even if they recognize it, or do not propagate it even if they know it. The cause of this is thought to be the lack of efforts to facilitate the natural transmission of local culture, which is an issue.

Therefore, in order to protect local culture in a society where this proposed MS Goal has been achieved, it is necessary to introduce a system that not only actively transmits local culture, but also passively transmits local culture. For this purpose, it is considered effective to have a mechanism that people can naturally see when they go to a place, or a mechanism that allows people to know about the local culture before they go there. Tools that can convey reality, such as information projection systems (XR, including Virtual Reality (VR) and Augmented Reality (AR)) that link land and local culture through information projection technology (3D spatial information + temporal information) in physical space, are needed.

[Protecting Society]

8) Eliminating disparities and ensuring literacy through technological progress

Due to recent technological innovations, the functions of personally owned devices have become more sophisticated, and the services offered have become broader. However, in a society where smartphones and other information terminals are widespread, the information gap between those who own them and those who do not, for reasons such as "economic reasons," "not knowing how to use them," and "lack of interest," has become a social issue [156]. This is thought to have led to a narrowing of the range of services that individuals should be able to enjoy. In addition, there are many cases of crimes occurring and adverse effects on others, such as discrimination, due to the lack of information literacy among SNS (Social Network Service) users. Therefore, even in a society in which this proposed MS Goal is achieved, there is a risk of a similar disparity between those who can enjoy services based on IPA technology and those who cannot. This was also noted in the international workshop (see Table 2 in III.3).

The technology related to this proposed MS Goal needs to be usable by everyone so as not to create people who cannot use it. For example, terminals and systems used by individuals need to be designed to be highly available and universal [156]. It must also ensure that literacy about the technology is automatically fostered and that its quality is maintained. In addition, for the middle class that chooses to maintain the status quo instead of choosing a dynamic lifestyle, it would be effective to put in place subsidy policies that encourage a dynamic lifestyle. The determinants of an active transition to a dynamic life are primarily a desire for novelty and a high level of dissatisfaction with the status quo (Appendix A.1.3.7). Even if a person with this characteristic leads the way in transitioning to a dynamic lifestyle, the rest of the population may not dare to change their current lifestyle and may not be able to take the plunge into the adoption of IPA technology. Therefore, in order to increase the user population of IPA technology and to ensure social transformation, one of the measures could be to provide subsidies to local governments to encourage them to migrate to the society where the proposed MS Goal archived.

9) Acceptability of existing residents

In a society where this proposed MS Goal has been achieved, there may be conflicts between new residents of the area (new residents) and those who originally lived there (called existing residents). The main reasons for this are problems between residents due to differences in rules between the land that new residents have lived on and the land that existing residents live on, and anxiety among existing residents about the influx of new residents. This is an issue that has arisen in modern times due to moving and migration, but it is expected to become more pronounced in societies where this proposed MS Goal is achieved, as the degree of freedom of residence will increase.

Therefore, in a society in which this proposed MS Goal is achieved, a system in which the rules to be conveyed are automatically transmitted as digital information at the time of entry is considered to be effective in order to enable residents to understand the local unwritten rules of the area in advance. In addition, in order to reduce the number of people who cause problems in the first place, it is necessary to take measures such as making it possible to generate electricity using the waste generated, so that as little waste as possible is produced, and attaching membrane sheets to the exterior walls of living spaces so that noise from the outside world is blocked.

10) Fair and dynamic tax system

In a society in which this proposed MS Goal is achieved, when people are able to freely choose their place of residence, it is expected that many local governments will not be able to provide the financial resources to provide appropriate services under the existing system of residence registrations and residence taxes, because people may move their residences in a short period of time. Currently, the resident tax for a given fiscal year is paid to the municipality in which the resident is registered as of January 1, based on the resident's income for the previous year. According to Article 22 of the Basic Resident Registration Act [157], "a person who has moved in (omitted) shall notify the mayor of the municipality" of his or her name and address, the date of moving in and the previous address "within 14 days from the date of moving in". In addition, Article 22 of the Civil Code [158] stipulates that "the home of each person's life shall be his or her address. As for the address, "it used to be a prevailing theory that a person could have only one address" [159], but nowadays, "there can be more than one center of life, and the view that the place most closely related to the legal relationship in question should be taken as the address" [159] is also obtained.

Therefore, in a society where this proposed MS Goal is achieved, the concept of residence registrations and residency tax needs to be changed. As mentioned in the previous section, if a system that can easily and securely identify the location of individuals is established, it may be possible to collect taxes more flexibly than at present. It is desirable to be able to change the place where one's resident tax is paid more flexibly, such as paying tax to the municipality where one is located at the moment, through a mechanism or system that allows one to transfer one's resident registration more flexibly.

11) Calculation of local government size

One of the representative items in the calculation criteria for local allocation tax currently being formulated by the national government includes the national population census (the population of Japan obtained from the national census) [159]. In a society where this MS target is achieved, it may not be a good idea to simply calculate using the population alone. It is anticipated that this will result in many local authorities being unable to provide the financial resources to provide appropriate services.

Therefore, in a society where this proposed MS Goal is achieved, it is necessary to determine the size of local governments and the allocation of local taxes according to dynamic population and area, rather than simple national population.

IV. Conclusion

This study describes the sense of stagnation and reduced freedom brought about by a fixed structure such as the current relationship between cities and rural areas, and investigates and researches ways to make it possible to enjoy the benefits available in cities everywhere in order to increase the freedom of living. As a means of doing this, we proposed to detach the infrastructure from the ground so that it could be projected (carried, deployed, and made to function) anywhere. The technology for this is referred to as Infrastructure Projection Anywhere (IPA) technology in this research study. Since this IPA technology is expected to make it possible to live anywhere and to easily move one's place of residence, the dynamic living space realized by IPA technology is called Dynamic Living Space (DLS). As a result, from a social perspective, the concentration of urban areas is no longer necessary, and we can expect to reduce the disadvantages of urbanization and the renewal, maintenance, and preservation costs of infrastructure systems as a whole. Also, from a consumer perspective, it will eliminate the sense of stagnation of an unconsciously fixed, urbanized society, and allow people to choose to live as they want to live, enjoying the benefits of urbanization wherever they want to live, regardless of where they live. This study proposes the realization of DLS using IPA technology as a proposed MS Goal.

In order to make this proposal a reality, the following research was conducted.

First, by projecting infrastructure, we conceived a new urban model that provides urban functions to scattered residential points centered on a base city, instead of the current urban structure that requires extensional expansion. Based on the current distribution of cities, this urban model is required to cover a vast area of 252.8 km in diameter for one base city (See Appendix A.6.2). In this way, a virtual urban space with a service area covering almost all of Japan can be realized.

Next, By analyzing the functions expected in daily life, we have identified 14 functions (14 items of daily life) that realize the six flexible functions that should be provided in this virtual city service area, and have shown that in order to be able to enjoy these functions anywhere, four major types of functions are necessary: "Self-sufficiency in energy," "Circulation of resources," "Delivery of goods," and "Making it possible to experience the surroundings". In order for people to be able to enjoy these things anywhere, four main functions are necessary: energy self-sufficiency, resource circulation, the delivery of goods, and the ability to experience "place. He also pointed out that it is necessary for social sectors such as government, legislature, and NGOs to be prepared to deal with the new problems that will arise as a result of the transformation of social structures. He also pointed out that the social sector, including government, legislature, and NGOs, needs to be prepared to deal with the new issues that arise with the transformation of social structure.

In order to implement these functions, it is necessary to consider the five technological elements of energy self-sufficiency, resource recycling, fully automated transportation, communication with the five senses, and the house as an environment-building device, as well as the urban structure that integrates these elements, and the ELSI that accepts changes in the social structure. A scenario for the realization of the social vision was created.

Based on the above, the proposed MS Goal of this research is to enable the decentralization of the urban structure by realizing the Infrastructure Projection Anywhere (IPA) technology, and to realize a dynamic living space (DLS). This will allow people to have more freedom in their lives, eliminate blockages, and maintain a high level of living in a sustainable manner.

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Appendix

A.1 Online survey

A.1.1 Purpose of this study

The purpose of this study was the following three: To understand people's potential demand for the proposed MS Goal, to identify the characteristics of people who desire a dynamic life with infrastructure projectable technology, and to identify people's attitudes to the proposed MS Goal.

A.1.2 Method

A.1.2.1 Procedure

A web-based survey was conducted on April 23, 2021. A total of 17,777 registered survey company monitors aged 18-49 residing throughout Japan were asked to participate in the survey. Responses were obtained from 2,056 respondents (11.6% response rate). The questionnaires were assigned without gender or age bias. Of these, 77 responses were excluded as invalid because the same option was selected consecutively in the first and second halves of the questionnaire, leaving 1,979 respondents for analysis.

A.1.2.2 Surveyed items

Dynamic Life Intentions The Dynamic Life Intentions scale consists of five items: "I would like to move freely between various places," "I would like to live in an environment different to my current one," "I would like to continue living in my current place" (inverse item), "I would like to live in various places if I did not have to worry about rent," and "I would like to move far away from my current place." All of these items were created independently by the investigator. Participants were asked, "Does the idea of leaving your current place of residence and moving to various different places appeal to you as a lifestyle?" and asked to answer on a scale of 1 to 5, from "1: Not at all" to "5: Very much".

In addition, all participants were asked to respond to the Dynamic Life Intentions Scale under the following two conditions. Under the first condition, participants were asked to read a scenario of a condition achieved by IPA technology, and then asked to imagine living in that condition and to respond on a scale ("with IPA" condition). The scenario was: "Imagine that in the future the following condition has been achieved. Suppose you can move around as much as you want, whenever and wherever you want, and live wherever you go. For example, on an isolated island, on top of a high mountain, on the sea, or in outer space. There, your standard of living can be maintained at the same level as in a city, and the same quality of communication is possible remotely as in person." Under the other condition, participants were asked to respond to the scale without mentioning IPA technology (without IPA condition).

Advantages and concerns of living a dynamic life with IPA Technology A total of 18 possible advantages and concerns of living a dynamic life using IPA technology were independently developed and rated for each item on a scale of 1 to 5, from "1: Very much disagree" to "5: Very much agree." The details of each item are described later and shown in Table A. 5.

Life satisfaction To the life satisfaction scale of[161], the item "I feel that my current life is restricted" was added for a total of eight items. The details of each item are described later and shown in Table A. 2. Participants were asked, "We would like to ask you how you feel about your current life," and requested to rate each item on a scale of 1 to 5, from "1: Very much disagree" to "5: Very much agree."

What is important to you in your daily life The investigator created a list of 17 things that are considered important to people's comfort in their daily lives and asked people to rate the degree of importance of each on a five-point scale from "1: Not at all important" to "5: Very important." The item contents are described later and shown in Table A. 3.

Desire for novelty Some items were selected from the Japanese translation of [162], "Measuring Novelty Seeking in Tourism," and modified to meet the purpose of this study. The total of 9 items surveyed were: "My ideal life would be to see things I have never seen before," "I would like to live a life free of boredom," "I want adventure in my life," "I would like to change my environment to experience something new," "I would like to experience different customs and culture," "I want to have a feeling of discovering new things in some parts of my life," "I want to experience new and different things in my life," "I would like to experience unexpected things in my life," and "I do not plan my life in detail, to allow unexpected things to happen." Participants were asked to rate each item on a scale of 1 to 5, from "1: Very much disagree" to "5: Very much agree."

Images of society that we would like to see realized in 2050 Participants were presented with 10 different visions of society and asked to rate how much they would like to see each of them realized in 2050, on a scale of 1 to 5, from "1: Very much want it to happen" to "5: Very much don't want it to happen." Details of the items are described later and shown in Fig. A. 3.

Frequency of use of online services Survey subjects were asked to rate their frequency of use of "Sending and receiving e-mail," "Use of social networks (e.g., LINE, Facebook, Twitter, Instagram)," "Online meeting tools (e.g., Zoom, Teams, Skype)," and "Online shopping" on a scale of 1 to 5, from "1: Never" to "5: Very often."

Telework experience Respondents were asked whether they had teleworked from home in the past year and for how long. Participants were asked to select one of the following options: 1: I have never teleworked, 2: Yes (duration: 0-3 months), 3: Yes (duration: 3-6 months), 4: Yes (duration: 6 months-1 year), or 5: Yes (more than 1 year).

Basic attributes Respondents were asked their gender, age, marital status, whether they had children, whether they lived with their parents, household income, size of the city they lived in, and the number of times they had relocated since age 18.

A.1.3 Results and discussion

A.1.3.1 Attributes of respondents

The mean age of respondents was 35.14 years (SD = 8.55). Other attributes are listed in Table A. 1.

Table A. 1: Attributes of respondents

Gender	
male	966
female	1,013
Age	
18 - 29	33.1%
30 - 39	33.4%
40 - 49	33.5%
Family composition	
have kids	36.8%
live with parent	30.8%
Family income (yen/year)	
less than 3 million JPY	21.1%
3〜6 million JPY	42.9%
6〜9 million JPY	22.5%
more than 9 million JPY	13.5%
City size (population)	
less than 100 thousand	22.4%
100 thousand - 1 million	48.8%
more than 1 million	28.9%

A.1.3.2 Scale structure

For the reverse scoring items that make up each scale, the values of each respondent were inverted by "6– (score)." Then the following factor analysis was conducted. Each of the extracted factors was used as a scale, and scale scores were calculated by dividing the total score of all items comprising the scale by the number of items.

Firstly, factor analysis was conducted on the eight items that make up life satisfaction. Unless otherwise explained below, factor analysis was conducted using the maximum likelihood method, with varimax rotation applied to measures where multiple factors were extracted. The results showed that the eigenvalues were 3.25, 1.23, 1.01, 0.72, ..., so a three-factor structure was adopted. The results are shown in Table A.2. Based on the characteristics of the items that make up each factor, the first factor was labeled "life dissatisfaction," the second factor was "life satisfaction," and the third was "life stimulation." The estimated reliability coefficients of the factors were Cronbach's α = 0.75 for "Life dissatisfaction" and 0.79 for "Life satisfaction," and the scale was judged to have a certain degree of reliability.

Table A. 2: Factor structure of life satisfaction

Factor	Items	Mean	Factor 1 (α=.753)	Factor 2 (α=.793)	Factor 3	Communality
Dissatisfaction of life	I feel bored with my present life.	3.02	0.67	0.26	0.04	0.52
	I feel inadequate in my present life.	2.86	0.65	0.33	-0.02	0.53
	I sometimes feel tired of my present life.	2.55	0.56	0.26	-0.03	0.39
	I do feel that my present life has become a pattern.	3.10	0.56	-0.06	0.28	0.40
	I feel constrained in my present life.	2.31	0.47	0.29	-0.19	0.35
Satisfaction of life	My present life is fulfilling every day.	3.20	0.22	0.77	0.19	0.68
	I am satisfied with my present life.	3.16	0.29	0.73	0.14	0.64
Stimulation of life	I find my present life to be highly stimulating.	2.58	0.00	0.20	0.71	0.54
		Eigenvalue	1.85	1.51	0.67	
		Cumulative contribution ratio (%)	23.18	42.07	50.50	

Factor analysis: Maximum likelihood method, Varimax rotation

Next, a factor analysis was conducted on the 17 items comprising the importance of living. Since the eigenvalues were 4.73, 2.16, 1.80, 0.88, ..., a three-factor structure was adopted (Table A. 3). From the characteristics of the items that make up each factor, the first factor is composed of two items that exclude the item "emphasis on a spacious relaxed life," the second factor is "emphasis on improved living facilities," and the third factor, which has a low factor loading and a different meaning to the other two items, is composed of two items, excluding the item "there is a nearby school or nursery for my child," and is labeled "emphasis on network expansion." The estimated reliability coefficients of the factors were Cronbach's α = 0.79, 0.78, and 0.69 for "emphasis on spacious relaxed living," "emphasis on improved living facilities," and "emphasis on network expansion," respectively.

Table A. 3: Factor structure of what is important in life

Factor	Items	Mean	Factor 1 (α=0.789)	Factor 2 (α=0.785)	Factor 3 (α=0.642)	Communality
Emphasis on living with more space	No need to worry about noise.	4.06	0.70	0.15	-0.03	0.52
	No need to worry about being seen.	3.84	0.70	0.06	0.00	0.49
	Not crowded.	3.93	0.67	0.07	0.07	0.45
	Low cost of living	4.04	0.58	0.22	0.04	0.39
	large house.	3.79	0.46	0.20	0.19	0.29
	Rich natural environment.	3.59	0.46	0.06	0.35	0.34
	Good internet connection.	4.16	0.41	0.41	-0.06	0.34
	Easy to get around by car	3.50	0.40	-0.01	0.34	0.28
Emphasis on the development of living facilities	Many stores around, like clothes store etc.	3.37	0.04	0.66	0.13	0.46
	Several restaurants around, easy to eat out.	3.49	0.04	0.65	0.13	0.44
	Easy to get information	3.51	0.10	0.64	0.23	0.48
	Cultural and entertainment facilities such as libraries, theaters, and movie theaters are nearby.	3.38	0.14	0.57	0.21	0.39
	convenient to transportation	4.08	0.19	0.52	-0.18	0.34
	Good access of medical facilities	3.90	0.32	0.52	0.15	0.39
Emphasis on network expansion	Active neighbors	2.46	0.01	0.01	0.76	0.58
	Have an opportunity to meet many people.	2.92	-0.01	0.32	0.65	0.53
	Schools and nurseries nearby for children to attend.	3.40	0.18	0.20	0.45	0.27
		Eigenvalue	2.73	2.57	1.68	
		Cumulative contribution ratio (%)	16.07	31.18	41.04	

Factor analysis: Maximum likelihood method, Varimax rotation

Dynamic life intentions were factor analyzed for each condition. Resulting eigenvalues were 3.27, 0.85, 0.35, ... "with IPA," and 2.81, 0.76, 0.61... "without IPA," and a one-factor structure was adopted under both conditions. The estimated reliability coefficients of the factors were Cronbach's $\alpha = 0.86$ for the "with IPA" condition and 0.80 for "without IPA," which were judged to be sufficiently reliable.

Factor analysis was conducted on the nine items comprising novelty desire, and since the eigenvalues were 5.16, 0.93, 0.64, ..., a one-factor structure was adopted. The estimated reliability coefficient of the factor was Cronbach's $\alpha = 0.91$, which was considered to be sufficiently reliable.

Factor analysis was conducted on the four items comprising the frequency of use of online services. Since the eigenvalues were 1.86, 0.87, 0.67, ..., a one-factor structure was adopted. The estimated reliability coefficient for the factor was Cronbach's $\alpha = 0.61$.

A.1.3.3 A feeling of entrapment in your current life

To examine the sense of entrapment people feel in their current lives, we checked the distribution of responses to the five inverse items that make up life satisfaction (Fig. A. 1). As a result, the proportion of respondents who answered "Somewhat" or "Very much" to "My current life is restricted" and "I feel bored with my current life" was about 30%; about 40% answered "I feel dissatisfied with my current life," over 50% answered "I sometimes feel tired in my current life," and over 60% answered "I feel that I am stuck in a rut in my current life."

From these results, it is clear that a large number of modern Japanese people feel bored and tired with their current lives. Although less than 40% of respondents do not feel restricted in their current lives, about 30% do feel restricted, indicating that a significant proportion of people feel entrapped in their current lives.

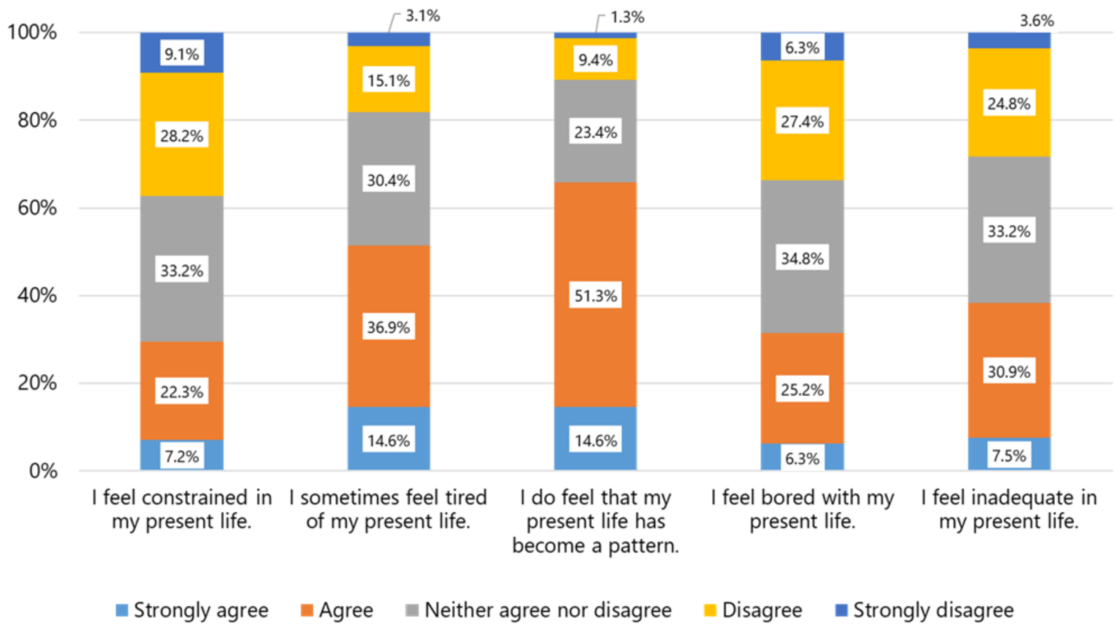


Fig. A. 1: Responses to the question about feeling of entrapment

A.1.3.4 What is considered important for a comfortable life

The mean values for each of the three factors of what is important to people in their daily lives are shown in Fig. A. 2 for each city size (error bars indicate standard deviations). To compare the degree of importance of each item according to city size, a one-factor analysis of variance was conducted with "emphasis on a spacious relaxed lifestyle," "emphasis on improved living facilities," and "emphasis on network expansion" as dependent variables, and city size (three levels: large, medium, and small) as an independent variable. The results showed that the main effect of city size was significant for "emphasis on spacious relaxed living" ($F(2, 1976) = 23.71$, $\eta p2 = 0.072$, $p < 0.001$), and multiple comparisons confirmed significant differences between city sizes ($ps < 0.01$). Emphasis on a spacious lifestyle tends to be higher for smaller city size. The main effect of city size on "emphasis on improved living facilities" remained significant ($F(2, 1976) = 0.08$, $\eta p2 = 0.038$, $p < 0.10$). Overall, the mean was higher, but there were no statistically significant differences between city sizes. In contrast, the overall average value for "emphasis on network expansion" was low. The main effect of city size was significant ($F(2, 1976) = 5.03$, $\eta p2 = 0.031$, $p < 0.01$), and multiple comparisons revealed a significant difference between large and small cities ($p < 0.01$). People living in smaller cities rated the importance of maintaining and building human networks as more important in their lives than people living in large cities.

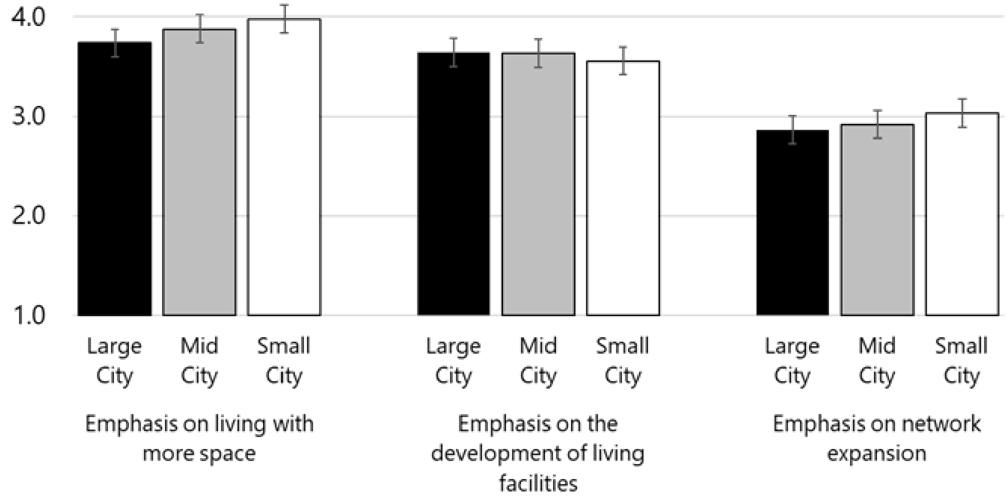


Fig. A. 2: Three factors of importance in life

A.1.3.5 Ideal vision of society

Fig. A. 3 shows the distribution of responses for each vision of society, for understanding the vision of society that people want to see realized in 2050. First of all, 55.5% and 47.9% of all respondents, respectively, wanted to see "a society in which people can physically experience various things by moving around themselves," and "a society in which people can experience work, leisure, and other activities in a virtual space," which corresponds to the vision of society to be realized as the proposed MS Goal. The proportion of respondents who wished for the reality of "a society in which work, leisure, and everything else can be conducted in virtual space," which means living exclusively in virtual space, was 30.6%. This result suggests that a relatively large number of people want the society which achieves the proposed MS Goal.

In addition, the proportions of respondents who hoped for the realization of "a society in which people can live in previously uninhabitable places, such as outer space, deserts, and high mountain tops," "a society with expanded urban areas in which people can enjoy urban lifestyles over a wide area," and "a society in which more people move to the countryside and enjoy a slow life" were 41.6%, 46.4%, and 56.5%, respectively. These are visions of society that reflect other aspects of the proposed MS Goal. Overall, we confirmed a high demand, but the idea of a society in which many people can move to the countryside and lead a relaxed lifestyle is considered particularly desirable.

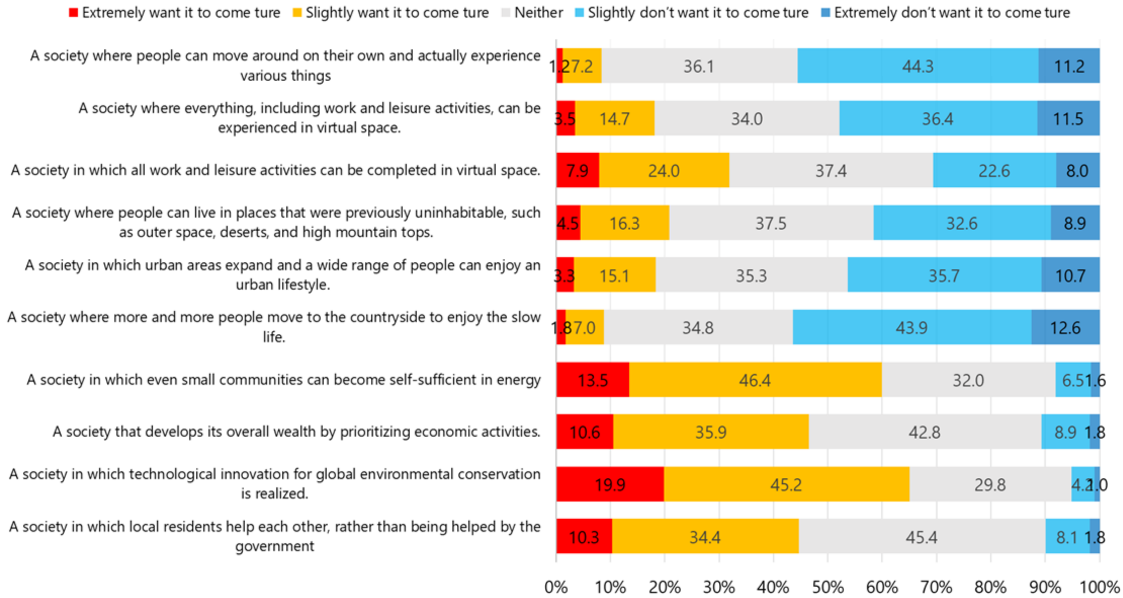


Fig. A. 3: Desired society in 2050

A.1.3.6 Inter-condition comparison of dynamic life intentions

The extent to which people are willing to live a dynamic life (intention) was examined for each condition, with and without IPA (Fig. A. 4; error bars indicate standard deviations). In the "with IPA" condition, all items were above the median of 3, but the mean of the inverse item was lowest, at 3.01. In the "without IPA" condition, the mean values of the three items, "I would like to move freely to a variety of places," "I would like to live in a different environment," and "I would like to move to a place far away from where I live now," indicating a positive attitude toward dynamic living, were below the median value of 3. On the other hand, the mean value of the inverse item was 3.18, which was the second highest among the five items.

In addition, a two-factor analysis of variance with and without IPA (2 levels: within participants) × intention variable (5 levels: within participants) was conducted to check whether the differences between variables for each condition were statistically significant. The results showed that the main effect of the presence/absence of IPA ($F(1, 1978) = 400.53$, $\eta p2 = 0.17$, $p < 0.001$), the main effect of the intention variable ($F(4, 7912) = 133.78$, $\eta p2 = 0.06$, $p < 0.001$), and the interaction effect ($F(4, 7912) = 185.95$, $\eta p2 = 0.09$, $p < 0.001$) were all significant. The results of the simple main effects test showed that the four items reflecting positive attitudes toward dynamic living had significantly higher means under the "with IPA" condition than under the "without IPA" condition ($ps < 0.001$). On the other hand, the mean of the inverse item, indicating sedentary living intention, was significantly higher "without IPA" than "with IPA" ($p < 0.001$). Do these results indicate that people's latent desire for a dynamic life is not so high?

Here, we focus on the result of dynamic life intentions conditional on affordability, as in "I would like to live in various places if I did not have to worry about rent." In common with all conditions, their mean values were the highest among the items. This result is definitely evidence that people have a latent desire for a conditioned, dynamic life. This is consistent with the results of the other three items reflecting positive attitudes to dynamic living, where the mean value "with IPA" technology was higher than that “without IPA." Therefore, the fact that the three items indicating dynamic life intentions in the "without IPA" condition were rated lower than the inverse items indicating sedentary life intentions cannot be considered to be an indication that people have little desire for dynamic life, but rather suggests that the desire for dynamic life is latent under various constraints.

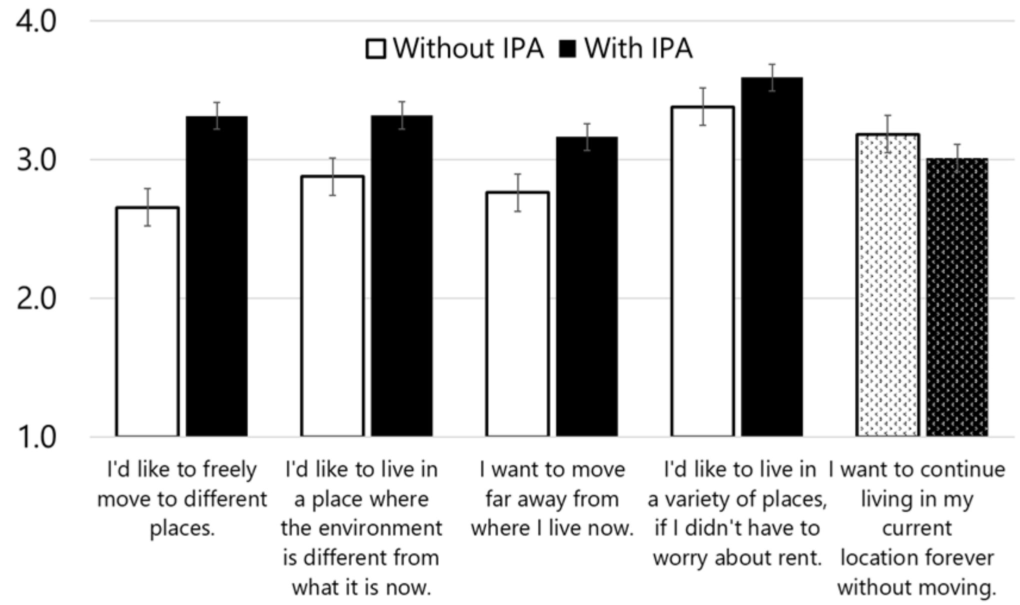


Fig. A. 4: Mean values for each dynamic life intention item

A.1.3.7 Determinants of dynamic life intention with IPA technology

Hierarchical multiple regression analysis (forced imputation method) was conducted to examine the factors that define the dynamic life intention of the "with IPA" condition. The dynamic life intention scale in the "with IPA" condition was used as the dependent variable, and in Step 1, attributes (age, marital status, presence of children, living with parents or not, number of home moves, household income, city size), frequency of online service use, and telework experience were entered. In the second step, we introduced life dissatisfaction, desire for novelty, emphasis on a spacious relaxed life, emphasis on improved living facilities, and emphasis on network expansion. The results are shown in Table A. 4.

The results showed a significant increase in the variance explanatory rate from Step 1 (R2adj = 0.04, $F(9,1969) = 9.57$, $p < 0.001$) to Step 2 (R2adj = 0.23, $F(14,1964) = 42.67$, p

< 0.001) ($\Delta R2 = 0.19$, $\Delta F (5,1964) = 97.99$, $p < 0.001$). In Step 1, the effects of having children ($\beta = -0.08$, $p < 0.05$), number of home moves ($\beta = 0.13$, $p < 0.001$), household income ($\beta = -0.06$, $p < 0.05$), city size ($\beta = -0.06$, $p < 0.01$), and frequency of using online services ($\beta = 0.14$, $p < 0.001$) were significant. Overall, the magnitude of the standard partial regression coefficients was small, but the number of home moves and the frequency of using online services showed relatively high positive effects, while the rest showed negative effects with standard partial regression coefficients lower than 0.1. All the variables newly input in Step 2 showed significant effects except for the emphasis on improved living facilities, whereas the influence of all the variables entered in Step 1 became smaller. Desire for novelty ($\beta = 0.30$, $p < 0.001$), life dissatisfaction ($\beta = 0.22$, $p < 0.001$), and emphasis on a spacious relaxed life ($\beta = 0.13$, $p < 0.001$) had positive effects, while emphasis on network expansion ($\beta = -0.14$, $p < 0.001$) had a negative effect. Among the variables newly introduced in Step 2, the standard partial regression coefficients of all variables that were found to have significant effects exceeded 0.1, and the effects of novelty desire and life dissatisfaction were particularly large.

These results indicate that dynamic life intention when IPA is achieved are greatly influenced by the desire for novelty, dissatisfaction with current lifestyle, emphasis on a spacious lifestyle, and emphasis on network expansion. In particular, a high desire for novelty and adventure and a sense of restriction and boredom with one's current life increase the dynamic life intention, while people who seek to maintain social contacts and meet new people tend not to desire a dynamic life. In addition, personal characteristics such as a high frequency of relocating and frequency of using online services, i.e., people who are accustomed to moving home and using the Internet, may make the transition to a dynamic life easier.

	Step1		Step2	
Age	-0.04		-0.02	
Marriage	-0.01		-0.04	
Presence of kids	-0.08	*	-0.05	
live with parents	0.01		-0.01	
Number of moves	0.13	***	0.09	***
family income	-0.06	*	-0.05	*
City size	-0.06	**	-0.04	*
Frequency of use of online services	0.14	***	0.10	***
Telework experience	-0.01		-0.01	
Dissatisfaction of life			0.22	***
Novelty Sexual Desire			0.30	***
Emphasis on living with more space			0.11	***
Emphasis on the development of living facilities			-0.01	
Emphasis on network expansion			-0.11	***
R^2	0.04		0.23	
Adjusted R^2	0.04		0.22	
F value	9.57	***	41.88	***
$\triangle R^2$			0.19	
$\triangle F$ value			95.88	***

(Note 1)*** p<0.001, ** p<0.01, * p<0.05

(Note 2) The assignment of categorical variables is as follows.
・Marriage -1: Unmarried, 1: Married
・Live with parents -1: No, 1: Yes
・Family income 1: Less than 1 million yen, 2: Less than 2 million yen, 3: Less than 3 million yen, 4: Less than 4 million yen, 5: Less than 5 million yen, 6: Less than 6 million yen, 7: Less than 7 million yen, 8: Less than 8 million yen, 9: Less than 9 million yen, 10: Less than 10 million yen, 11: Less than 12 million yen, 12: Less than 15 million yen, 13: Less than 20 million yen, 14: More than 20 million yen.
・City size 1: Population less than 100,000, 2: Population 10,000~1,000,000, 3: Population more than 1,000,000.
・Telework experience -1: No experience, 1: Experienced

Table A. 4: Determinants of dynamic life intentions

A.1.3.8 Advantages and disadvantages of using IPA technology to live in multiple locations

To examine the kind of expectations or concerns about dynamic life behind the high level of dynamic life intention with IPA technology, we calculated the mean and standard deviation of the perceived advantages and disadvantages of dynamic life with IPA technology, as well as the correlation coefficient between these and dynamic life intention "with IPA" condition (Table A. 5).

First, a look at the average ratings of advantages and disadvantages for each shows that advantages had a higher average overall score, close to 3.5. On the other hand, the mean values of the disadvantages varied. The highest mean values were for "I am worried that there will be no hospital nearby if get sick while moving or at the destination" and "the paperwork involved in moving is a hassle," while mean values were particularly low for "I am afraid that I will cause trouble for others at the destination" and "I am worried that it may lead to environmental destruction." Also, "I think it is unlikely that I will be able to provide my children with a desirable education," "I think living a mobile life will increase my chances of encountering crime," and "I think living a mobile life will increase my risk of encountering a disaster" had a median score close to 3. These results show that people were equally aware of the various advantages that IPA technology can bring. On the negative side, they were particularly concerned about coping with illness and the effort involved in mobile living, but less concerned about the inconvenience mobile living might cause to others, environmental damage, educational opportunities, criminal harm, and disaster risk.

The results of the correlation analysis also showed that all of the advantage items that showed significant moderate correlations with dynamic life intention were brought about by IPA technology. Of these, the strongest correlations were with "I can enjoy the different environments of each place" ($r = 0.51$, $p < 0.01$), "I can live where I want without restrictions" ($r = 0.47$, $p < 0.01$), and "I can break out of the rut of life ($r = 0.43$, $p < 0.01$). Thus, overall, there was a significant positive correlation with advantages, but only a fairly low correlation and some non-significant correlations with disadvantages. These results suggest that behind the high level of dynamic life intention is the expectation that this will allow them to enjoy advantages in many aspects of their lives.

Table A. 5: Implicit expectations or concerns in dynamic life intention

Benefits and Concerns for Dynamic Living with IPA Technology	*M*	*SD*	Correlation coefficient with dynamic life intention
Enjoy the different environments of each place.	3.54	0.91	0.509**
Can live wherever I want without restrictions.	3.58	0.92	0.474**
Meet people from different backgrounds where I go.	3.43	0.91	0.341**
Can break out of the rut of my life.	3.61	0.86	0.425**
Can get out of annoying relationships.	3.47	0.94	0.294**
Can decide where I want to live, based solely on my own preferences and convenience.	3.52	0.93	0.389**
Living a dynamic life allows me to experience nature.	3.59	0.85	0.349**
Can experience the culture and nature of different places.	3.69	0.83	0.355**
Worried about there's no hospital nearby if I get sick on the road or at a destination.	3.92	0.92	0.072**
Might unable to provide a desirable education to my children.	3.13	1.00	0.01
Living a dynamic life might increases the likelihood of become a crime victim.	3.04	0.92	-0.02
The paperwork associated with the move is a hassle.	3.96	0.89	0.116**
Might going to be a nuisance to others where I move.	2.87	0.93	-0.074**
I don't want to be separated from my family.	3.52	1.08	-0.117**
Might going to lose touch with my friends.	3.31	0.99	-0.04
Might unable to enjoy social security.	3.25	0.93	0.01
Worried it will lead to environmental destruction.	2.82	0.96	-0.04
Living a dynamic life might increases the risk of disaster.	3.05	0.91	-0.045*

(Note)** p<0.01, * p<0.05

A.2 Ratio of Urban Centre to total city area

According to the UN's World Population Prospects (2018), 55% of the world's population lives in urban areas, and that number is projected to reach 68% by 2050. Sustainable development in the context of global urbanization trends depends on how well we can respond to urban expansion in low- and lower-middle-income countries, which are projected to experience the fastest urbanization by 2050[163]. In fact, the proportion of the population living in cities is 50% in Asia, 82% in North America, 74% in Europe, and lowest of all in Africa, at 43%, which means that urbanization is most advanced in mature societies.

We will try to analyze cities in Japan, to understand the reality of cities in a mature nation. The reason we chose Japan is partly because of the ease of collecting data and ascertaining actual conditions. First, as a premise, we are using the open data provided by the Global Human Settlement Layer (GHSL) [16], and we are describing cities using the concept of "Urban Centre" in the GHSL (Fig. A. 5). Calculations show that the distance between adjacent (closest) Urban Centres in Japan has a median value is 29.5 km (and mean of 40.0 km). Given that cities with values close to this median are extracted by considering them two cities with typical Japanese city spacing, the Otaru-Sapporo distance, which includes Sapporo, a large city, is excluded (Table A. 6). It was found that, with a few exceptions, the area defined as a (GHSL) "Urban Centre" was only a very small fraction of the total city area (Fig. A. 6). In Iwakuni, for example, only 6% of the city's area is densely populated. Currently, the provision of government services and infrastructure to the entire city area is a major burden on local finances, so from an efficiency perspective, it is possible to concentrate people in the Urban Centre to save on infrastructure investment. However, the COVID-19 pandemic that began in 2020 has significantly increased the risk of urbanization, there are also negative aspects to urbanization, such as the fact that very highly concentrated urbanization of Tokyo, the world's largest city, has led to the hollowing out of rural Japan. Japan's population is expected to continue declining, which is likely to ease the excessive density of Tokyo, but some observers predict that this easing will only serve to reinforce the unipolar concentration of population in Tokyo[5].

As advancing urbanization is left unchecked, Japan continues to take initiatives to try and eliminate the extreme concentration in Tokyo, but such efforts do not seem to have produced any significant results as yet. Unless we improve on the fact that current urban services are based on concentration in the first place, it will be difficult to avoid concentration in cities, even if pandemic risks, urbanization risks, and city maintenance costs are acknowledged. Therefore, this study discusses what can be done to separate new infrastructure from existing infrastructure and distribute it to all households, assuming a model of distributed living. To achieve this, we will first estimate the volume of current urban services, and then estimate what demands will be placed on energy consumption, water consumption, information transmission, and logistics when these services are distributed to individual households. We will also conduct surveys and research with the aim of proposing technologies to provide a more comfortable lifestyle than that in current urban areas. Diversification of infrastructure provides outcomes such as risk diversification, reduced maintenance burden, and reduced fossil fuel consumption. In addition, changing the nature of conventional infrastructure, which must be developed incrementally, so that it can be developed on a point-by-point basis for each household, opens up the potential to dramatically develop infrastructure in developing countries, just as mobile phones have spread in Africa without depending on the prior establishment of fixed-line telephones.

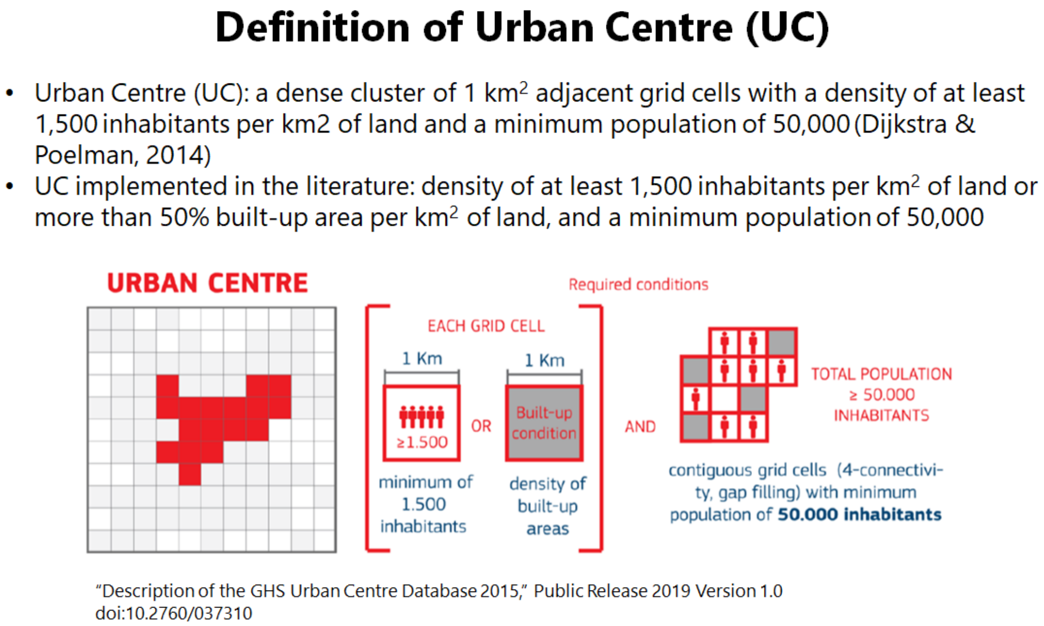


Fig. A. 5: **Definition of "Urban Centre"**[16].

Table A. 6: **Extraction of 27 km to 33 km (±10%) of Urban Centre location data.**

UC distance (km)	City 1	City 2
32.2	Otaru	Sapporo
32.8	Izumo	Matsue
29.5	Saga	Omuta
30.8	Iwakuni	Kure
28.1	Kagoshima	Kirishima
30.7	Kirishima	Miyakonojo

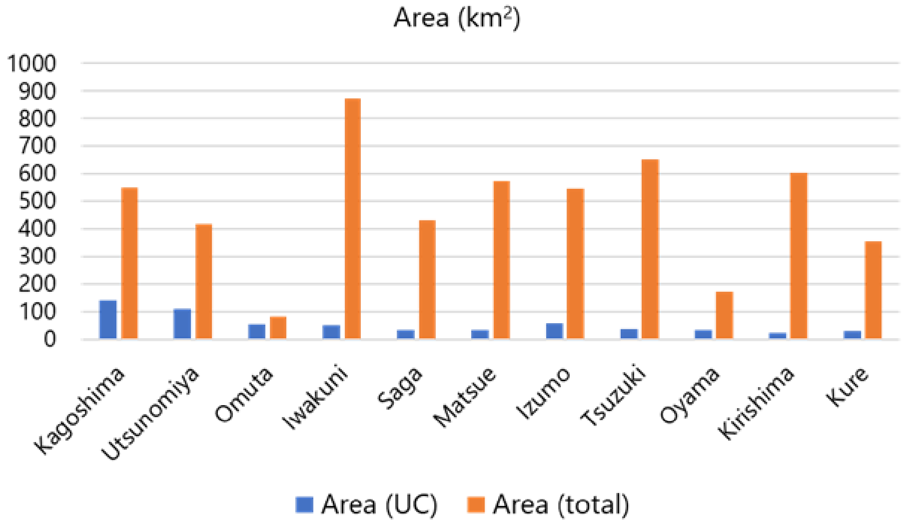


Fig. A. 6: Urban Centre area compared to total city area.

A.3 Functional breakdown of the proposed MS Goal based on functions expected in daily life

In order to clarify the functions expected of daily life, we first extracted the "functions that make up daily life" that are expected in both "cities" and "rural areas," and then clarified the "functions that are common to cities and rural areas, although at different levels" (essential functions) and the "functions of cities we want to enjoy while maintaining the advantages of rural areas" (difference functions). Specifically, we conducted a group discussion using the KJ method[164]and extracted (1) "what cities offer us" and (2) "what we expect from rural areas" by grouping the elements that emerged, and then further associated them with (3) "functions that make up our lives," (4) "types of functions of essential infrastructure," and (5) "functions of cities we want to enjoy while maintaining the advantages of rural areas" (enriching functions). Table A. 7 shows the results of the analysis.

Table A. 7: Expected items and elements of daily life

Items	Elements
(1) What cities offer us	● On-demand nature ● Employment ● Education ● Interaction with people ● Transportation ● Information ● Entertainment
(2) What we expect from rural areas	● Meals

	● Outdoor activities ● Eco-friendly living ● Culture ● Human relations ● Reset function ● Less stimulation (peace of mind) ● Spaciousness
(3) Functions that make up life	● Transport infrastructure ● Safety and security ● Medical care, public services, disaster prevention, safety net ● Shopping ● Assured hygiene ● Education ● Housing ● Social network ● Natural environment ● Workplace ● Infrastructure (water, sewerage, electricity, gas) ● Public broadcasting ● Impression of land (image) ● Internet access
(4) Types of functions of essential infrastructure	● Energy/living infrastructure ● Safety and security services ● Living support services ● Harmony with the environment
(5) "Functions of cities" we want to enjoy while maintaining the advantages of rural areas = functions that enrich our lives	● Unexpected discoveries, unexpected encounters ● Opportunities to meet people (interesting and diverse people) ● The ability to travel at any time you want. ● Information (easy access to the people, products, and ideas that are being talked about) ● Information (job information, meeting people) ● The ability to choose the job you want to do ● The ability access education whenever you want ● Easy access to things + resulting peace of mind ● No restrictions on what you desire or can access

We then analyzed which part of (3) plays a role in (4) and (5) based on the analysis results obtained in Table A. 7. Whereas (4) are functions (essential functions) that both cities and rural areas have in common at a necessary and sufficient level, despite some differences in degree, (5) is a function that only cities currently enjoy, or that can be enjoyed to a much higher degree in cities, but that would be desirable to enjoy to a similar degree in rural areas (difference function). These are the elements that enable a rich life.

In a society where this proposed MS Goal is achieved, both essential and different functions will be available everywhere. In addition, we labeled these functions in terms of their flexibility. To increase the degree of freedom in daily life, it is essential to have the "flexibility" to realize the desired lifestyle anywhere. "Living" and "environment" were defined as the minimum necessary elements, and the other flexible elements were defined as value-added elements.

A total of 14 functions, consisting of five essential functions and nine difference functions that were identified, are shown in Table A. 8. In this table, the functions are listed in order from the ideal environment (passively enjoyed functions) to the unobstructed behavior (functions for keeping activeness unobstructed). These are the social functions that should be fulfilled when living freely, and the ability to realize these social functions is a concrete task for achieving the proposed MS Goal.

The contents of Table A. 8 are described in detail below. Firstly, the five essential functions in (4).

1. Energy/living infrastructure

In addition to what is generally called infrastructure, such as water, sewerage, city gas, and electricity, this includes the house itself and functions such as toilets and bathrooms in the house.

2. Safety and security services

This includes safety nets for daily life, such as medical facilities, evacuation shelters, and government.

3. Living support services

This refers to the waste management system, including waste disposal facilities, road cleaning services, and activities of neighborhood associations. We decided to include services such as supermarkets, pharmacies, bookstores, and childcare facilities too. However, since there is a large difference in degree, depending on the region, this is also dealt with in the difference function described below.

4. Appeal of the local community

This includes things that depend to a degree on human sensibility, such as air quality, the natural environment, and brand awareness of the locality.

5. Harmony with the environment.

Taking care of the environment means eliminating or reducing the negative impacts of new things introduced to the locality with other people and other life, and to guarantee the freedom of each region to have its own environment.

The nine different functions belonging to (5) are described below. This is abstract, but it can be summarized as elements that people expect from cities and the flexibility that is lacking in rural areas.

6. Unexpected discoveries and encounters

This indicates a desire for unusual surprises, new or accidental stimuli, whether man-made or natural. It also means seeking opportunities to connect with people unexpectedly through the use of each locality's facilities and cultural activities. In other words, these people want to incorporate freshness into their daily lives, and they desire this flexibility from the environment they find themselves in.

7. Opportunities to meet people (interesting and diverse people)

Related to the freshness mentioned above, this expresses the desire for diversity to further expand exchanges and meet people with unfamiliar ideas, and to have the flexibility to access such a diverse community regardless of where one lives.

8. Access to job information (meeting people)

This has almost the same meaning as "6," but it expresses a more specific desire beyond the flexibility of "6," e.g., access to guidance about working conditions and ways of working. It is a function that connects "6." and "10." It is not just a place to meet people, but it requires flexibility so that opportunities to learn of job openings and business partners do not vary from place to place.

9. The ability access education whenever you want

These opinions emerged from perceptions (for example) that major preparatory schools are only located in cities, that there are no schools in rural areas, and that there is a difference in the level of classroom learning between cities and rural areas. People desire the flexibility to receive the education they want anywhere, regardless of region.

10. The ability to choose the job you want to do

This is similar to the point about education above. It derives from the current perception that job availability varies greatly depending on region and locality. This is one of the reasons for the phenomenon of people relocating to other regions because there is no industry they want to work in. [5][165] Regardless of the locality they live in, they desire more options for work they can get involved in and the flexibility to work in an industry that they are interested in and suitable for.

11. Information (easy access to the people, products, and ideas that are being talked about)

Here, "people, products, and ideas" refers to information, not tangible things. It derives from the desire for easy access to labeled information, like advertising in cities. We can find information by searching on the Internet, but we desire the flexibility to access such labeled information passively, not through active effort. There is also a desire for the flexibility to adjust the amount of information, e.g., to not receive information when you do not want it.

12. No restrictions on what you desire or can access

This is the opposite of the previous item. It is the desire to obtain tangible goods and services. Under current conditions, it is possible to obtain most of the items handled by e-commerce vendors such as Amazon in all areas with well-developed infrastructure. On the other hand, fresh fish, restaurant meals and other food, and other items not sold online can only be obtained at local markets. In some areas, there are no medical facilities nearby. There is a desire to eliminate these differences and ultimately have the same flexibility wherever we are.

13. Easy access to things + resulting peace of mind

The above items are obtainable in a short time and with this comes a sense of security. For example, if a car breaks down, the severity of the consequences and how to prepare for such an eventuality will be different depending on whether the breakdown occurs near a city, where many shops and services are accessible, or if it occurs where these are not accessible. This is why we ultimately desire the flexibility to have things available at any time.

14. The ability to travel at any time you want.

The frequency of public transportation services and the routes they operate limit the time and range of travel and the amount of luggage that can be carried, but we desire the flexibility to move when and where we want. Private cars achieve some of this flexibility, but their flexibility is limited by low speeds (relative to rail), congestion, and road maintenance.

Table A. 8: Functional decomposition based on the living of this MS target proposal

Category	Item	Flexibility
Essential function	Energy/living infrastructure	Flexibility of Life
	Safety/security service	
	Living support services	
	Appeal of the locality	Flexibility of Environment
	Harmony with the environment	
Difference function	Unexpected discoveries encounters	Flexibility of Information
	Opportunities to meet people (interesting and diverse people)	Flexibility of Community
	Access to job information (obtaining information by meeting people)	
	Ability to receive the education one desires when one wants	
	Ability to choose a job one desires	Flexibility of Work Style
	Easy access to the people, products, and ideas that are being talked about	Flexibility of Information

	No restrictions on what you desire or can access	Transportation
	Easy access to things + resulting peace of mind	
	Ability to travel at any time you want.	

A.4 Problem identification using logic models

As described in II.1, it was found that there are 14 functions expected for daily lives (hereinafter "14 items for daily lives") with which the six flexibilities of "life," "environment," "information," "community," "work style," and "transportation" are achieved. This section describes the results of a study of the technologies required to realize these 14 functions using a logic model (Fig. A. 7) based on the city envisioned Fig. 4.

A logic model is "a systematic illustration of the cause-and-effect relationships among the resources to be invested, the activities, the resulting products and services, the outcomes, and the impact of those outcomes for a given project." [16] The logic model template used in this study is shown in Fig. A. 7, which is a slightly rearranged version of the logic model presented in the literature [16], i.e., "output / implementation" was set as the solution, and "Key technology" was set between the solution and "Activities." This is because the extraction of key technologies for which targets should be set is one of the major objectives of this study. In addition, "Inputs/resources" and "Activities" were excluded from consideration because setting specific activities should be done by the proposer who puts forward a specific project when it becomes an MS Goal.

In this study, the above-mentioned "14 items for daily lives" that an ideal society should have are placed in the "impact" category, and the "outcomes" that constitute the realization of the "impact" are represented as goods, concepts, and services. "Solutions" were devised as a means to realize these outcomes, and the key fields of technology to realize the "solutions" were then each derived.

Table A. 9 summarizes the relationship of the solutions to the outcomes of the 14 items for daily lives. The solution shows that there is a technology that appears again and again. In summary, it was derived that the fields of technology associated with energy self-sufficiency, resource circulation, fully automated transportation, the five-sense communication, and houses as environment-building devices are the issues to be addressed.

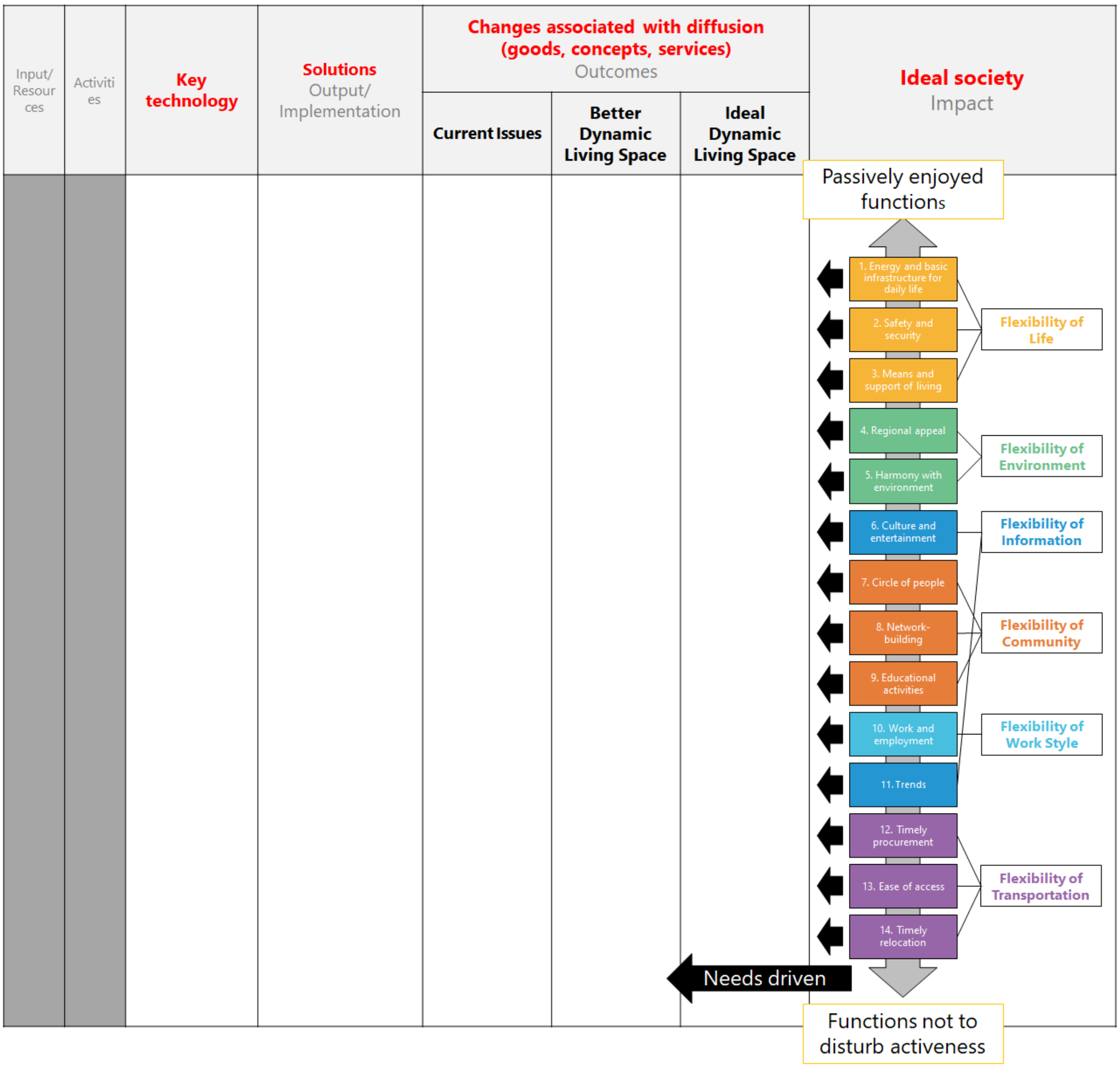


Fig. A. 7: Logic model template

Table A. 9: Outcomes and solutions related to the 14 items for daily lives

14 items for daily lives	Outcome	Solution
1. Energy/living infrastructure	● All life and transportation is powered by self-generated, environment-friendly energy ● All waste organic matter can be used for power generation ● As much water as needed can be obtained anywhere, anytime ● No more water than necessary is used	● Although there is a limit to securing physical space in dynamic life and life in space, etc., in the society where this proposed MS Goal has been achieved, comfortable living spaces will be realized not only by heat insulation and sound insulation but also by space arrangement.

	● You can move where and whenever you want	
2. Safety/security services	● Physical condition is managed and opportunities for emergency transport are decreasing ● Detailed disaster occurrence information and forecasts are provided according to where you live ● There is an extreme reduction in infrastructure that needs to be updated ● Information can be obtained automatically when you select the region, even without paying attention to a hazard map ● Police, fire, and emergency services that can respond at high speed even across wide areas ● Ability to detect and report abuse and other behavior in the home, even remotely ● Ability to deter crime across wide areas, even where there are no police stations ● Credit scores increase the number of people who try to behave well everywhere	● Services such as medical care and education will be mainly provided online, minimizing the need for physical travel. ● In addition to direct measurement using body contact devices, a body monitoring function will be developed for health maintenance using bodily waste and other materials to lower the risk of sudden death and reduce the number of emergency transport vehicles. ● Crime prevention will be achieved through remote danger detection and rapid response by robots ● To guard a wide area, automatic patrols and detection by drones, etc. will be carried out instead of human patrols ● Violent behavior (including neglect, etc.) in the home will be detected using body monitor functions
3. Living support services	● Access to a wide variety of shops and services, regardless of distance, enabling you to get the goods and services you need, when you need them ● High speed communication in urban areas and beyond ● External electromagnetic radiation due to increased wireless communication will	● For shopping, online ordering, automated delivery, or 3D modeling will eliminate the inconvenience of an on-demand shopping experience. ● On-demand fully automated transportation is developed making it possible to obtain what you need whenever you want, without any human intervention. ● By floating base stations in space and

	have no effect ● Life is no longer subject to unintended outside influences (noise, light pollution, etc.) ● Enjoying the outside view at any time and in any mood without any unintended outside influences	in the sky, high-speed, high-quality communications are achieved wherever you are. ● Indoor areas are electromagnetically shielded from the outside by shielding material, so there is no electromagnetic interference ● Noise from the outside world is shielded using metamaterials and other materials. ● The insides of homes become inorganic, by isolating them from the outside, but this is modulated by adjusting the properties of spaces (CO_2 concentration, humidity, temperature, airflow, and lighting) and by projecting images and sounds from the outside extracted only from the areas that you want to take in, thereby creating comfort.
4. Appeal of the locality	● A locality in which residents can feel happiness and self-affirmation regardless of how well it is known or how attractive it is to others ● An area where everyone can enjoy the scenery	● Technologies for measuring wellbeing of consumers in a society where this proposed MS Goal has been achieved ● Enjoy scenery that is more beautiful and dynamic than when seen with the naked eye
5. Harmony with the natural environment	● The exterior of the house can blend in with any location ● Zero emissions ● No radio pollution to the outside occurs	● The expansion of our sphere of activity to date has been achieved in exchange for adverse effects on the global environment and other living organisms, and we are now facing problems such as abnormal weather and resource depletion. ● From now on, we need a way to develop in harmony with the natural environment, other organisms, and other humans. ● Currently, the policy is such that convenience is sacrificed to some extent, such as laws that limit CO_2

		emissions and rules that restrict the use of plastics. ● In order to harmonize with the global environment and other living organisms in the ideal IPA/DLS society, autonomous circulation of electricity, water, and waste disposal will be realized in each residential unit. In addition, to harmonize with other humans, a high-quality and stable high-speed wireless communication environment will be realized with electromagnetic radiation control technology, and in order to protect the natural landscape, the appearance of residences will blend in with any place.
6. Unexpected discoveries and encounters 7. Easy access to the people, products, and ideas that are being talked about	● You can live in the city, in the mountains, in the desert, or under the sea without changing your standard of living ● You will be able to learn about the attractions of whatever place you are in, without looking them up	● Improving the accuracy of various types of sensing, mapping the community
8. Opportunities to meet people (interesting and diverse people) 9. Access to job information (meeting people)	● A meeting place where coincidence is guaranteed, even if far apart, is provided in both physical and virtual space ● Even remotely, the conversation is very real ● Understanding the surrounding environment without talking on the phone ● Communities like cafes and bars are realized in virtual reality	● Until now, communities have been rooted in the land, such as families, schools, and companies, but online networking will enable the establishment of a wider range of communities and create new value. In an ideal IPA/DLS society, people can share their space with others (including the five senses) regardless of their location.
10. People who	● You can go to any school you	● There are a variety of ways to

want to receive education can receive it when they want	want, no matter where you live ● You can learn all subjects in a school in a virtual space with a very high sense of reality ● Advanced education is available at any age, and anyone can become a teacher	participate in educational institutions, such as moving closer to the school itself, fast transportation to the school from remote areas, remote participation, and the use of avatars. ● By means of sensory transmission, students can experience the same kind of education as being in a classroom, even if they are participating as an avatar. ● It provides a platform where anyone can get an advanced education at any age and anyone can become a teacher.
11. Ability to choose a job one desires	● The commuting area extends to the entire country, giving you more options ● Any job can be done remotely ● Equipment and materials needed for the job are delivered immediately on demand ● In almost all occupations, work and location are no longer related, and the concept of work location is eliminated ● Employers accept remote working as the norm ● You can assign various tasks in a quest-like manner ● Primary industries, such as agriculture, can be carried out in any environment	● Field work will be done by robots (not only automated, but also remotely operated), and most human work will be possible online ● Avatars are utilized and senses are transmitted in real time, so work can be done remotely as if you were in the field ● Work sites, residences, and the delivery bases of necessary goods are far away from each other, so there is no hassle in arranging delivery with the delivery system linked to work details ● In houses, etc., it is possible to re-create the work environment itself, and to experience a place without having to move there ● Proposals for work will be made taking into account ability and residential conditions, and sub-work and remuneration will be calculated without making the employee aware of the hourly rate
12. No restrictions on what you desire or can access	● Fresh fish, restaurant food, and set meals are available wherever you are ● The same goods and services	● No matter how many things you can do online, you won't be able to do without tangible items, such as food and daily necessities, but you will be

13. Easy access to things + resulting peace of mind	are available everywhere, whether in the city or on a desert island ● Objects can be moved automatically between arbitrary multiple points without human intervention ● You can get supplies when you need them (day or night, without waiting)	able to obtain most things without waiting, which is better than transportation and on-demand manufacturing. ● Automated delivery is possible while protecting privacy, using a technology that encrypts one's location and delivers only the information needed for a particular service to the person who needs it
14. Ability to travel at any time you want	● You can travel day and night with no waiting time ● No heavy rains, floods, storms, and short travel time ● No matter where you live in the world, things can be delivered to you with pinpoint accuracy ● Instead of moving luggage around, it is "life itself" that will move	● Personal rapid transit is available for safe travel at all times ● Means of high-speed transportation always select the optimal route, taking into account not only efficiency but also noise to the surroundings, and actively maintain quietness in the internal environment ● Moving works by comparing what is at the next location with what is here now and only moving the difference

A.5 Consideration of living space and life vision in the society after this proposed MS Goal was achieved

In this section, we show the results of our study of the vision of the kind of living space and life of the future when this proposed MS Goal was achieved.

The first step was to identify and quantify the infrastructure needed for life. In identifying the infrastructure necessary for human life, in addition to listing the components of a typical house, we focused on the component systems of the International Space Station as a good example of an autonomous circulation system. Fig. A. 8 summarizes the results of the study of infrastructure on the space station, infrastructure in current general housing, and infrastructure that will be a component of the IPA. Among the components of IPA, communication and telecom control will be discussed in detail in a separate study, and the analysis of the other components shows that the largest deviations from the current situation are water supply, electricity supply, and house structure.

With respect to these, supply is currently land-bound. There are two solutions for freeing us from these constraints—one by transportation and the other by circulation. In other words, in the case of water, it is necessary to transport and store the required amount of drinking water starting from the existing (or new) water supply and sewerage system, and either transport and treat the wastewater or recycle the wastewater into drinking water at the household level. In the case of electricity, it is unlikely that transmission from existing power plants and substations can be easily expanded, so it will be necessary to carry filled batteries or generate electricity on a household basis, e.g., through solar power. For the structure of the house, technology to transport the whole house or to construct it easily, such as 3D molding is likely to be necessary. In practice, the balance between transport and circulation will be determined as a result of the optimization of the cost and energy of each. Toward the study, the weight of the equipment required as a component of IPA and the required amount of water and electricity are listed as shown in

Table A. 10.

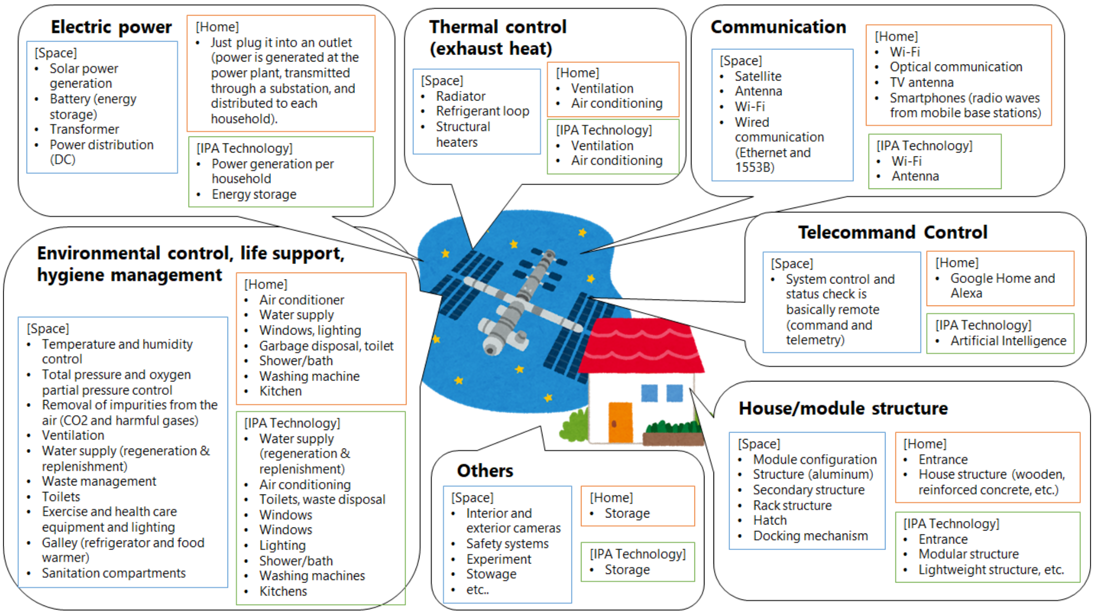


Fig. A. 8: Brainstorming results of infrastructure and IPA components of the space station and current typical housing (Created with reference to [166][167])

Table A. 10: IPA components and their weight, power requirements, etc.

Major items	Sub items	Equipment weight	Supply weight (water)	Supply weight (food)	Supply weight (others)	Power consumption	Waste weight	Remarks
Living room module	Sleep, Spend the daytime	0	2 kg/person/day (Drinking water)	1.5 kg/person/day (Lunch box including containers)		0	0.918 kg/person/day	
	Baggage claim	(Part of the house structure)	0	0	0		0	
	Air conditioner	25 kg	0	0	0	2000 Wh/day	0	Panasonics, air conditioner CS-221DFR https://panasonic.jp/aircon/p-db/CS-221DFRS_spec.html (in Japanese)
	Bed	7kg (futon)	0	0	0	0	0	Nitori, futon for single https://www.nitori-net.jp/ec/product/7543176s/ (in Japanese)
	Overall structure	1,500 kg	0	0	0	0	0	12 ft container http://container.jp/container_12.html (in Japanese)
Water area Module	Toilet	17~20 kg (if ceramics, 25kg)	4.8 kg/time (feces)	0	0	190 Wh/day	3kg sewage + 1.8kg washing water (Disposal)	Panasonic, tankless toilet, S160 https://sumai.panasonic.jp/toilet/alauno/alauno-s160/spec/ (in Japanese)
	Shower/bath	Shower (faucet + head): 2.8 kg Bathtub: 28 kg	(90 kg/person/day)	0	0	0	(Water 90kg/person/day) (regeneration)	
	Refrigerator	32 kg	0	0	0	816 Wh/day	0	Panasonic, Refrigerator, 2 doors 138L type, NR-B14DW https://panasonic.jp/reizo/p-db/NR-B14DW_spec.html (in Japanese)
	Air conditioner	25 kg	0	0	0	2000 Wh/day	0	
	Washing machine	28 kg	(114 kg/time (Capacity: 5 kg)	0	Detergent	100 Wh/day	(Water 114kg/time) (regeneration)	Assuming once a day. Panasonic, full automatic washing machine NA-F50B14 https://panasonic.jp/wash/p-db/NA-F50B14_spec.html (in Japanese)
	Washbasin	60 kg	(13 kg/person/day)	0	0	0	(13 kg/person/day) (regeneration)	WOTA WOSH https://wota.co.jp/wosh/spec/ (in Japanese)
	Water treatment equipment	82 kg	(-4 kg/min (regeneration))	0	0	500VA (533 Wh/day assuming 500 W regeneration time of 64 min/day)	0	WOTA BOX https://wota.co.jp/wota-box/spec/ (in Japanese)
	Kitchen		(38 kg/person/day)	0	0	0	(38kg/person/day) (regeneration)	
	Overall structure	1,500 kg	0	0	0	0	0	12 ft container http://container.jp/container_12.html (in Japanese)
	Water tank	10.5 kg	0	0	0	0	0	Store 255 L/person/day of regeneration for one day
Total		Approx. 3,300 kg	6.8 kg/person/day	1.5 kg/person/day		5,639 Wh/day	5.72 kg/person/day	

We also made a trial calculation of the energy consumption of ordinary households and whether it is possible to cover them with solar power generation. First, from the Ministry of the Environment's "2017 Survey of Statistics on CO2 Emissions in the Household Sector (Confirmed Values)" [168], the annual energy consumption and composition ratio per household by region were reconstructed. It is summarized in Table A. 11.

Table A. 11: Annual energy consumption per household by region and its composition ratio

	[kWh / household・year]	(Giga-Jour Converted energy composition ratio)				[%]
	Electricity	Electricity	City Gas	LP Gas	kerosene	total
Hokkaido	3,906	27.5	8.2	5.1	59.3	100
Tohoku	4,994	38.4	6.9	9.4	45.3	100
Kanto Koshin	3,833	44.8	36.2	8.3	10.6	100
Hokuriku	6,333	49.4	14.9	6.2	29.5	100
Tokai	4,464	49.1	26.0	12.2	12.6	100
Kinki	4,108	48.2	39.8	4.2	7.9	100
Chugoku	5,164	59.5	11.5	13.0	16.0	100
Shikoku	5,153	61.0	6.0	15.7	17.3	100

Kyushu	4,669	59.1	11.1	14.6	15.2	100
Okinawa	3,942	67.7	3.4	21.8	7.1	100
Nationwide	4,322	46.9	25.3	9.0	18.8	100

Based on Table A. 11, the numerical value converted for each energy type and the annual estimated power generation amount [169] of the published commercial photovoltaic power generation system are compared as shown in. In Hokkaido, Tohoku, and Hokuriku, there is a shortage of about 10% or less, but as for the annual power generation amount, even with the current commercial products, it can be expected that the power generation amount of one ordinary household will be generated by solar power generation.

Table A. 12: Annual energy consumption per household by region and estimated annual power generation possible with solar power generation

	Power Conversion [kWh/household･year]	Estimated annual power generation [kWh/household･year]	
Hokkaido	14,204	12,752	Sapporo
Tohoku	13,005	12,833	Sendai
Kanto-Koshin	8,556	12,313	Tokyo
Hokuriku	12,820	11,740	Kanazawa
Tokai	9,092	13,884	Nagoya
Kinki	8,523	12,870	Osaka
Chugoku	8,679	13,740	Hiroshima
Shikoku	8,448	13,749	Takamatsu
Kyushu	7,900	12,941	Fukuoka
Okinawa	5,823	13,024	Naha
Nationwide	9,215	-	-

However, the amount of solar radiation fluctuates throughout the year. For example, Fig. A. 9: Annual fluctuation of solar radiation in Kanazawa shows a graph of annual fluctuations in the amount of solar radiation near Kanazawa City. This figure is based on the data obtained from the database on solar radiation provided by the New Energy and Industrial Technology Development Organization [170] It can be seen that the fluctuation in the amount of solar radiation during the year is quite large. In addition, it has been pointed out that the amount of solar power generated fluctuates significantly even during the day [171], and at present, there is a strong awareness of countermeasures against this fluctuation. In any case, the technical key to utilizing natural energy is to absorb fluctuations and enable efficient use throughout the year.

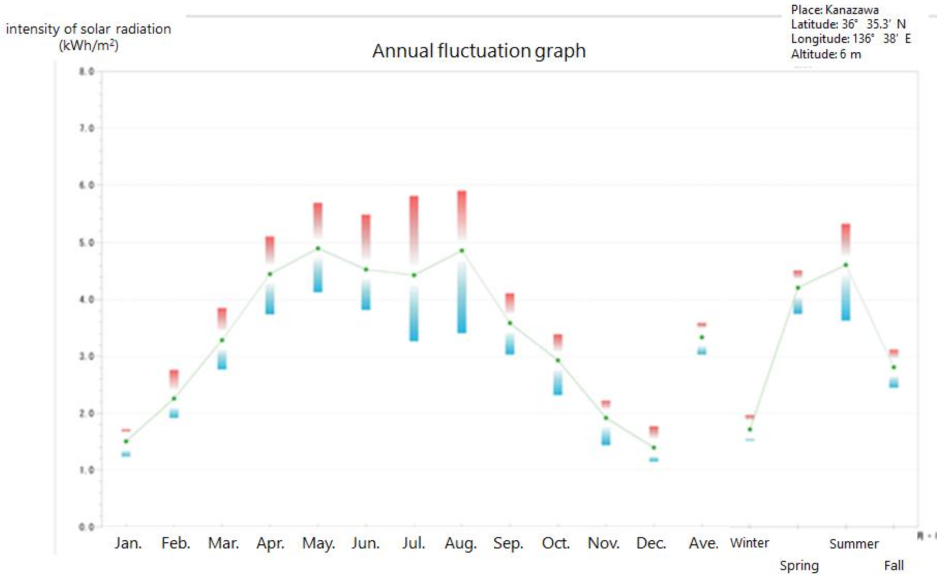


Fig. A. 9: Annual fluctuation of solar radiation in Kanazawa [170]

A.6 Examples of automated rapid transit solutions: unmanned aerial vehicles

Consider unmanned aircraft as an example of an automated rapid transit solution. The two most important factors in determining the performance of an aircraft are payload and transport distance. In this section, we consider the aircraft that will be responsible for individual transportation to private homes in daily life in 2050. First, the target value of the loading capacity is determined from the form of transportation service. Next, target values for transportation distances are established by modeling the distribution of intercity distances and the range to be reached. Then, in order to consider the suitability of this aircraft example with the means of transportation that exist in the world, the results of a survey of the current loading capacity and transportation distance for each transportation machine are shown [172]. Finally, we present the results of a conceptual study on the extent to which the performance of UAVs can be improved by increasing battery performance, since batteries are one of the key technologies for longer and larger transport distances.

A.6.1 Survey of required loading capacity

First of all, a society in which this proposed MS Goal is realized must be able to carry the minimum necessary commodities for daily life, such as water and food, as well as associated waste and luxury goods.

In this study, the minimum amount of goods necessary for daily life was clarified from the viewpoint of living space. The details are shown in A.6. The total of each element is 261.8 kg/person-day of water, 1.5 kg/person-day of food, and 259.8 kg/person-day of waste. In practice, the water and food would need to be transported to the residence and then the waste would need to be transported to the disposal site. Taking this into account, future transport should carry a maximum of 263.3 kg/person-day of water and food combined at one time. It may be divided into multiple times or multiple planes. However, if it must be divided into multiple times or multiple planes, the degree of freedom may be reduced. Therefore 263.3 kg is set as one of the target values.

In addition, it is necessary to be able to obtain luxury goods as typified by online shopping and food delivery, which has become increasingly frequent in recent years, without any problems. Since it is not possible to obtain individual data on the transport weight of luxury goods, we instead investigated what weight of cargo is expected by studying the transport standards of several shipping companies. The transportation standards for each carrier are shown in Table A. 13. All international shipments are limited to a maximum of 70 kg per piece, while domestic shipments are limited to 20-30 kg per piece, except for large items. The results of this study suggest that it is sufficient to carry 30 kg for the transportation of domestic luxury goods and other products.

Table A. 13: Transportation standards of transport companies

Types	Restrictions (*for all three sides)	Citation
Yamato Delivery Service	~25 kg Up to 160 cm in total*	https://www.kuronekoyamato.co.jp/ytc/search/payment/size/ (in Japanese)
Yamato Delivery Service for large size	~30 kg Up to 200 cm in total*	
Sagawa Delivery Service	~30 kg Up to 160 cm in total*	https://www.sagawa-exp.co.jp/service/takuhai/ (in Japanese)
Sagawa Delivery Service for large size	~50 kg Up to 260 cm in total*	
Kangaroo Delivery Service	~20 kg Up to 130 cm in total*	https://www.seino.co.jp/seino/service/domestic/takuhai/ (in Japanese)
Fukutsu Delivery Service	~30 kg Up to 160 cm in total*	https://corp.fukutsu.co.jp/service/f-takuhai/index.html (in Japanese)
UPS	~70 kg Up to 400 cm in total*	https://www.ups.com/jp/ja/help-center/packaging-and-supplies/weight-size.page (in Japanese)
DHL Express Worldwide	~70 kg Up to 400 cm in total*	https://www.dhl.co.jp/content/dam/downloads/jp/express/ja/shipping/weights_and_dimensions/weights_and_dimensions_jp_ja.pdf (in Japanese)
FedEx Express International	~68 kg Up to 330 cm in total*	http://www.fedex.com/downloads/jp/packagingtips/howtopack.pdf (in Japanese)

Altough we could not clearly define the weight limit of food delivery because delivery companies do not impose weight limits, we considered a carrying capacity of about 25 kg to be sufficient for food delivery purposes. This is because a load capacity of 10 kg to 25 kg are the mainstream when using various commercially available delivery bags. We set 30 kg as one of the target values for transportable weight, taking into account the weight of the courier service. This weight is also the limit weight that an individual can easily handle.

Based on the above considerations, we conclude that the target values for transportable weight are 263.3 kg and 30 kg.

A.6.2 Investigation of required cruising range

Next, we considered the transport distance. Since goods are basically concentrated in cities, if they can be transported to any place between cities, it would be possible to transport any goods located in cities to any place. Therefore, in this study, the distance between cities was used as the requirement for transportation distance. By their nature, cities are the terminus of supply chains, so transporting goods further by air from cities would be inefficient. However, they can be used as a guide in terms of the usability of transportation means.

Urban Centre Database[16] was used for data on how cities were defined, their location, population, and area. In this database there are 13,135 cities (= "Urban Centre" or UC) around the world, with a total population of 3.54 billion people living in UCs. Using this database, we calculated the distance to the nearest UC for UCs around the world and created a histogram (Fig. A. 10). It is clear that most UCs have a neighboring UC within 100 km. Although there are some UCs with adjacent UCs that are more than 500 km away, they are omitted from the graph because they are very few. The median distance is 21.7 km and the 95th percentile is 109.5 km. If we use the 95th percentile as a representative value (as is commonly done), we can say that UCs exist within approximately 109.5 km of each other, and for transportation, the ability to cover this distance could be a useful criterion, because 95% of UCs can be connected. Since 95% of the UCs have neighboring UCs closer than 109.5 km, we assume that the UCs are located most densely at intervals of 109.5 km, as the most stringent condition for connecting them (Fig. A. 11). If we set the cruising range of 109.5 km as the performance that can tie these together, we can see that there will be a blank area in the center. To be able to fly the maximum diagonal distance of the hexagon to make up for this, i.e., to be able to go back and forth anywhere from the center to the edge of the hexagon, a range of 126.4 km is required. Furthermore, considering the possibility of a problem at the destination UC requiring the aircraft to divert to the next UC (even a passenger aircraft might divert to another airport if the runway is blocked), we concluded that the range should be doubled to 252.8 km. Fig. A. 12 shows the locations of the UCs scattered around the world and the black circles with diameters of 252.8 km, 1,000 km, and 2,000 km centered on each UC plotted on the world map. Note that the size of the circles is not exact because the Mercator diagram method is used. Fig. A. 12 (b) shows the approximate transportation range that can be covered by the range of 252.8 km defined above. This shows that UCs are connected by transportation, and goods can be transported to many UC-surrounding lands. On the other hand, it can be seen from the figure that deserts such as the Sahara and the Gobi are non-transportable areas. Furthermore, apart from deserts, there is also the inability to connect the Mediterranean from north to south, and the existence of areas of land where transport is impossible near the center of each continent. Therefore, ideally, longer transport distances would be required. Fig. A. 12 (c) and Fig. A. 12 (d) illustrate circles with diameters of about 1,000 km and 2,000 km, respectively. If the range were 1000 km, it would be able to cover the Mediterranean Sea as a transportable area, and except for small islands in the Pacific Ocean, etc., it would be possible to cover almost everything except deserts and areas near the North and South Poles. Furthermore, if the range were 2,000 km, it would be possible to completely cover the islands, central Australia, the North Pole, and everything except areas near the South Pole. Based on the results of these studies, three targets were finally set for the cruising range: 252.8 km, 1,000 km, and 2,000 km.

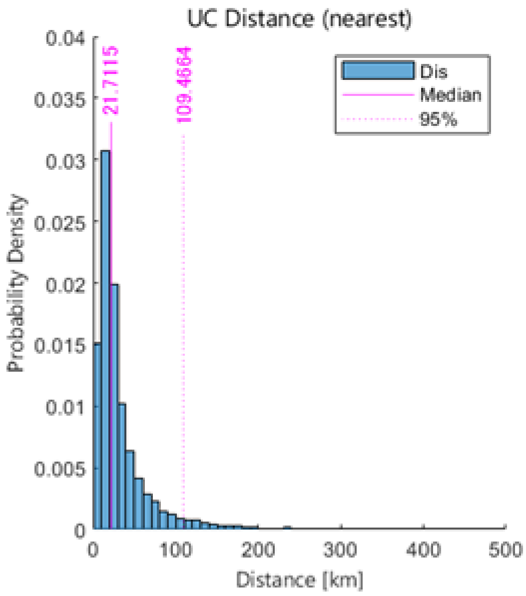


Fig. A. 10: Histogram of the minimum distance between “Urban Centres” (UCs)

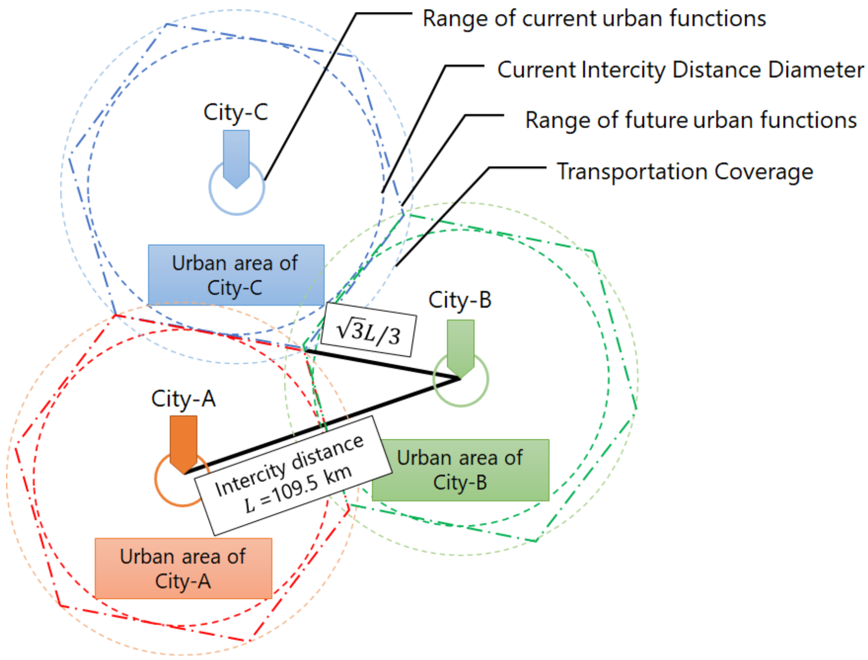
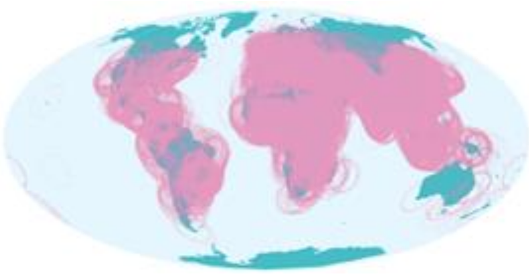


Fig. A. 11: City layout image

(a) Urban Centre (UC) location

(b) 252.8 km diameter range centered on UC

(c) 1,000 km diameter range centered on UC



(d) A 2,000 km diameter range centered on the UC

Fig. A. 12: Extent of land occupied by circles of different diameters centered on Urban Centres (UCs) (tetradecimal method)

A.6.3 Loading capacity and transport distance of various transport machines

The types of transport machinery surveyed and the number of data are shown in Table A. 14. Fig. A. 13: also shows a double logarithmic graph of the aggregated data. The results show that there are two modes of transport, air transport and ground and sea transport. Since ground and marine transportation is not utilized to the performance limit of each transportation machine, the upper part of this band could be visualized as an appropriate area in terms of profitability and usability. The data shows that air transportation is a viable form of transportation, despite the fact that loading capacity is low for the transportation distance.

Table A. 14: Types of transport machine surveyed and number of reference data[172]

Transportation equipment	No. of data points
Ship	9
Aircraft	10
Helicopter	4
Train	1
Road vehicles	6
Motorcycles/bicycles	4
Multicopter	9
UAV	7

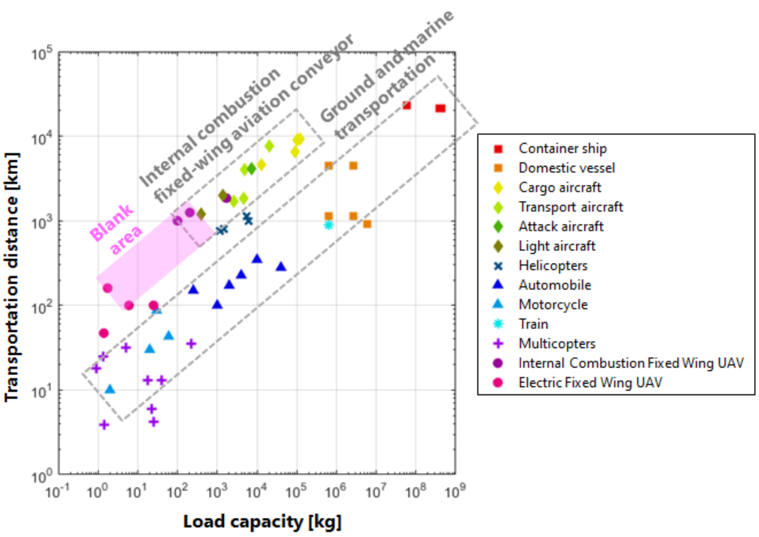


Fig. A. 13: Range and payload of each transport machine (partially modified figure published in Ref. [172])

In general, there are three main reasons why air transport is chosen[173]. The first is the characteristics of the items to be transported. High speed and easy temperature control make it suitable for transporting medical supplies and foodstuffs for which humidity, temperature and freshness are important. It is also less prone to shocks and vibrations than trucks and ships, making it suitable for transporting precision equipment and valuable items. Another advantage is the ability to transport items with short product cycles, such as digital home appliances and LCD panels, at high speed. The second is for strategic reasons. The advantage of this is that new products can be introduced to the market in a timely manner to secure market share. In addition, although the amount of cargo transported per aircraft is smaller than for ships, the number of flights is very large, so by transporting cargo sequentially without storing it, the cost of building and maintaining storage facilities such as warehouses is eliminated, and the total cost can be kept low. In addition, high-speed, high-frequency transportation of clothing, semiconductors, PCs, mobile phones, and other items with high unit prices can improve the turnover of funds. The third is time constraints. Air transport, which is many times faster than other means of transport, is chosen as a means of emergency shipment in unforeseen circumstances, such as production delays. It is also used as an emergency shipping method when the demand for a product is very high and the product is in short supply. These three factors are the reasons why air transport is at least viable in terms of payload for the same transport distance.

On the other hand, air transport is characterized by a longer transport distance for the same payload compared to ground and sea transport. It indicates that air transport wins in terms of distance per hour due to the speed. Considering these characteristics of air transportation, it is inferred that air transportation with excellent on-demand characteristics is suitable for the society of 2050, and the air transportation band in the figure is the suitable area for the society of 2050. On the other hand, since air transportation is not suitable for mass transportation, it is expected that railways and road vehicles will continue to be used with existing infrastructure for transportation between delivery points.

It should be noted that multicopters currently exist in the same realm as motorcycles, and do not have the generally accepted advantages of air transport. They are no different from motorcycles except that they can take off and land vertically. Newer models tend to be plotted in the upper right of the graph along the ground and marine transport bands, but not out of the bands. Furthermore, considering that helicopters exist somewhere between air transport and ground/marine transport, it is assumed that multicopters will not be included in the air transport band in the future, which is not optimal for the vision of society in 2050 from the viewpoint of on-demand convenience. However, compared to fixed-wing aircraft, multicopters are easier to control and handle.

In recent years, electric fixed-wing UAVs capable of vertical take-off and landing and internal combustion fixed-wing UAVs have begun to be developed, and they are gradually beginning to fill the blank areas in the air transport band shown in Fig. A. 13:. In general, fixed-wing aircraft are characterized by superior payload, fuel efficiency, and speed compared to multicopters. On the other hand, it is difficult to combine their performance with vertical takeoff and landing functions, and they are more difficult to control. Therefore, it can be said that there are currently few aircraft that can fly in this area. However, this area has a loading capacity of a few kilograms to a few hundred kilograms, which is between that of a motorcycle, light truck, and 2-ton truck, and a transportation distance of a few hundred kilometers to a few thousand kilometers. Therefore, it can be said to be small-scale transportation compared to existing air transportation such as passenger planes and light aircraft. From the perspective of transportation to individual homes, however, it is considered a favorable area. It can be seen as small-scale transport compared to existing air transport with passenger planes and light aircraft. Therefore, it is expected that unmanned aerial vehicles will be built in the future that will achieve the target values specified in this section.

A.6.4 Increased transportation distance due to improved battery performance

So far, we have estimated the transport weight and range required for the social vision. The technical feasibility of these is explained in this section. For environmental reasons, the feasibility of an electric fixed-wing UAV, rather than a UAV with an internal combustion engine, will be examined.

The question of transportation weight is related to the size of the aircraft, so basically it can be achieved by utilizing larger aircraft. Thus, this is not a serious problem in terms of feasibility. However, the size of the aircraft cannot be too large in relation to the size of ground equipment and in terms of public acceptance. Since acceptability depends on the appearance of the aircraft and the situation at the time, it is difficult to examine it quantitatively, so it will not be treated in detail in this study. However, for example, EHang is developing air mobility with a payload of 220 kg [174], and aircraft with a payload of 300 kg have begun to be developed as shown in Fig. A. 13:. Therefore, it can be said that the feasibility including acceptability is not low.

As for cruising range, we are studying the feasibility of fixed-wing aircraft in the future, taking into account the current performance of electric fixed-wing UAVs and battery performance. For more details on the derivation process and the equations used, please refer to[172]. Fig. A. 14: shows the results of the study. The horizontal axis shows the total weight of the aircraft, and the vertical axis shows the cruising distance (transport distance). The five black curves represent the total weight of the aircraft less the battery weight, i.e., the line where the total weight of the aircraft structure and payload is constant. From this, we can say that if we want to carry a payload of 30 kg, we need to place the design point of the aircraft to the lower right of the 30 kg curve on the graph. It is also important to note that increasing the total weight, or battery weight, will increase the cruising range, but increasing the battery weight beyond a certain point will not increase the cruising range any further. This means that the benefit of the increased power supply capacity due to the bigger battery cannot outweigh the disadvantage of the increased weight. This means that a range of only 219 km can be achieved with the performance of lithium-ion batteries as currently used in drones (weight energy density 156 Wh/kg). The range can be increased by reducing aerodynamic drag in terms of airframe performance, and by improving energy density in terms of battery performance. The light blue line in the figure represents an estimate when the gravimetric energy density of the lithium-ion battery is improved to the theoretical value of 662 Wh/kg[175]. In this case, the cruising range limit increases to 929 km. However, the cruising range of 1,000 km and 2,000 km set in the previous section cannot be achieved. We can conclude, therefore, that the development of next-generation batteries and the improvement of aircraft aerodynamic performance will be necessary in the future. The four black lines are the result of estimating the cost of recharging the battery for one flight based on the capacity of the battery, assuming an electricity price of 25 JPY/kWh. The point where the 100-circle straight line and the 30 kg black curve intersect corresponds to an approximate cruising range of 100 km and a total weight of about 55 kg It indicates that a 55 kg aircraft, including payload and battery weight, costs 100 JPY to fly 100 km. It should be noted that this study focuses on the power consumption during horizontal flight. Power consumption is higher during takeoff and landing. However, the time required for takeoff and landing is short compared to the time required during horizontal flight, so this is not a major problem.

From the results of the above discussion, it can be concluded that the transportation in the vision of society described by the logic model can be established if the aerodynamic performance of the aircraft itself and the battery performance are improved. As for batteries, various new forms of batteries are being developed as shown by[175], and their realization is awaited.

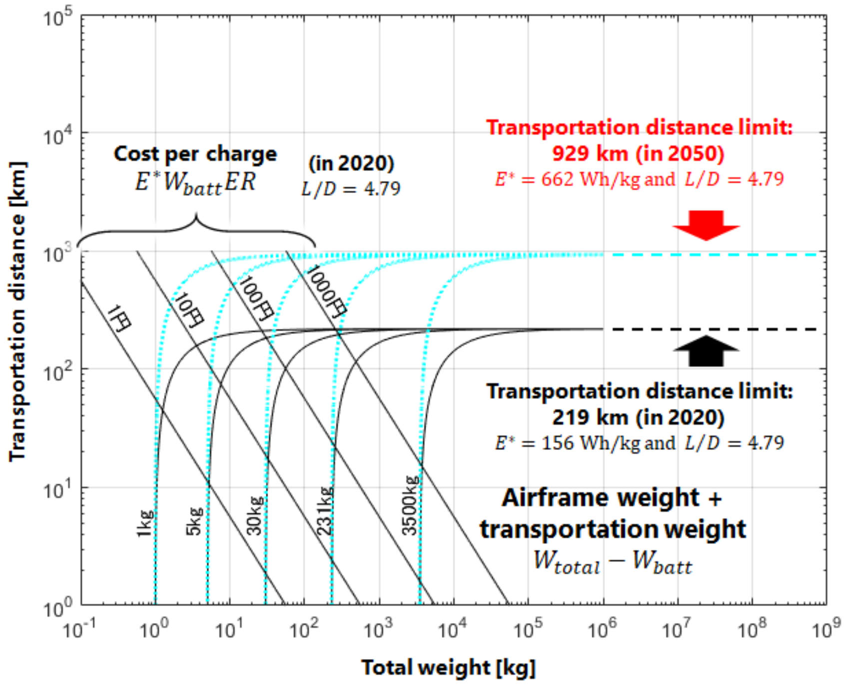


Fig. A. 14: Range and gross aircraft weight estimates

A.7 Operation system of aircraft in automated rapid transit

One ambitious, broad vision for realizing an efficient and low-cost drone transportation system would be to build an unmanned transportation system. At the drone logistics demonstration experiment in Goto City (September 2019, January 2020, November 2020), two operators and at least two person (one person each at takeoff and landing points A and B) operated. In other words, we delivered packages up to four times a day with four or more people. In this case, even if only the labor cost is considered, the labor cost for one person x one day is added to the transportation cost for each transportation. In the transportation of daily necessities such as food and water, the transportation cost is not a practical price.

In light of this, an important aspect of future technological development will be how to establish an operation system that is as close to unmanned as possible, without direct human intervention.

Table A. 15: Relationship between the state of facilities development around drone logistics and the assumed operation system

	Basic Flight Operation Level 3	Automatic Flight with Drone Port Gate with Required Authorization in Level 3	Automatic Flight with Drone Port Gate with Required Authorization in Level 4	Autonomous Flight
Level of operation	Level3 (Beyond Visual Line of Sight (BVLOS) flight over an unpopulated area)	Level 3	Level 4 (BVLOS flight over a populated area)	Level 4
Method of flight operation	Automatic flight based on waypoints	Automatic flight based on waypoints	Automatic flight based on waypoints	**Autonomous flight (includes dynamic obstacle avoidance)**
Number of operators	1	1	1	0-1 (1 person can operate multiple drones)
Port camera/Weather observation equipment	Yes	Yes	Yes	Yes
Port fence	No	Yes	Yes	Yes
Port gate (Require authorization)	No	Yes	Yes	Yes
Number of staff needed at drop off port	1 at each drop off port	0	0	0

A.7.1 Flight Operation: A system that allows one operator to manage multiple aircraft simultaneously.

By increasing the number of aircraft that can be operated and managed by one operator at a time, more efficient operations can be achieved. However, there is a limit to the number of aircraft that can be managed if relying on human vision and other abilities. Therefore, it is vital that the aircraft be equipped with technology to control the operation of the aircraft automatically to some extent. Therefore, the technologies which should be installed and developed are automatic collision avoidance function of aircraft, fully automatic takeoff and landing, and a system that enables air traffic control for unmanned aircraft. In addition, the environment which should be improved is Secure land for takeoff and landing, a house/building that allows landing on the roof area, and a communication network for the aircraft covering the entire airway.

A.7.2 Takeoff and landing sites: reduced staffing at takeoff and landing sites Automatic loading and unloading of cargo at take-off and landing points and the automatic

Automatic loading and unloading of cargo at take-off and landing points and the automatic inspection function of the aircraft are important technologies. This is because there is a human cost involved and the delivery will be limited to locations where personnel are available to handle the unloading if personnel are needed to board and unload cargo at take-off and landing points. Therefore, the technologies which should be installed are automatic loading of luggage and automatic inspection of the airframe. In addition, the environment which should be maintained is the standardization of luggage size.

A.8 Required communication characteristics and network configuration

A.8.1 Perception for the communication of the five senses

The quantity of information and time perception required to communicate the five senses is as follows.

Quantity of information:

・Vision[176]: The resolution of the human eye is 576 Mpixels (cf: 8K video is 33.18 million pixels).

・Hearing[177]: Audible range: 20 Hz to 20 kHz

Assuming a sampling frequency of 40 kHz and a quantization bit rate of 32 bits, the bit rate is 1,280 kbps = 160 kB/s (derivation method: 40 kHz x 32 bits = 1,280 kbps = 160 kB/s, 8 bits = 1 byte)

Time perception[39]:

・Vision: 30 to 40 ms = 25 to 33.3 fps (games are around 144 fps[178])

・Hearing: 3 to 5 ms

・Touch: 10 ms

From the above, visual information is the largest in terms of quantity, so visual information is the largest factor that puts most pressure on the communication speed. In addition, since auditory response is the fastest, the limit of discomfort is considered to be determined by the transmission of delayed information. Therefore, as a communication network configuration for the transmission of the five senses, auditory information, which is highly sensitive to delays, can be transmitted over wireless lines using drones, etc., and visual information, which is relatively tolerant of delays but requires large-capacity transmission, could be transmitted over terrestrial lines using optical fibers, which have large capacity but large delays in routing. In other words, the configuration is such that only auditory information is transmitted first via the drone, while visual information is transmitted via optical fiber.

A.8.2 Derivation of the communication speed and delay required for five-sense communication

In this section, we describe the results of calculating the communication speed and the communication delay required for two people far away from each other to realize the same perception in virtual space as in physical space, without any discomfort in the virtual space. However, consider the case where there is no brain-machine interface.

In the case of transmitting a 24-bit color image of 576 Mpixels (1 frame) at 144 fps as visual information data, it becomes

576 Mpixels/frame x 24 bits x 144 fps = 1.99 Tbps

This required transmission speed is about 100 times greater than the maximum transmission speed of 5G, of 10 Gbps[179]. The figures are also considered to be highly relevant, since [180] states that the era of 1 Tbps per person will arrive around 2040.

Next, we derive the required communication delay. Here, we assume that the speed of sound at room temperature is 340 m/s and the speed of light is constant at 3×108 m/s, and that information can be transmitted at the speed of light. In the following, we consider the case where information can be transmitted over a linear distance and via a one-hop relay station.

◯ When information can be transmitted in a straight line distance (Fig. A. 15)

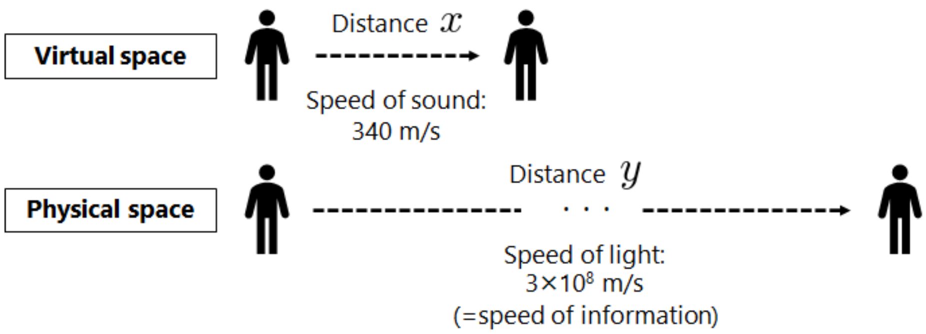


Fig. A. 15: When information can be transmitted over a straight line distance

To avoid auditory discomfort in auditory virtual spaces, this distance is considered to be the limit of discomfort, due to delay, because the auditory response is fastest, as shown in A.8.1. The arrival of audio information in the physical space must be faster than the arrival of sound in the virtual space. From this condition, the constraint of the distance between two people in physical and virtual space is obtained. Therefore, in order to prevent discomfort from occurring, the following must be satisfied.

$$\frac{\text{Distance in virtual space}}{\text{Speed of sound}} \geq \frac{\text{Distance in physical space}}{\text{Speed of light}}$$

If this condition is not met, the sound is not transmitted in the virtual space in the same way as in the physical space, and the sound arrives late. If the distance in virtual space is x and the distance in physical space is y, we get

$$\frac{x}{340\ \text{m/s}} \geq \frac{y}{3 \times 10^8\ \text{m/s}} \qquad \text{(Eq. 1)}$$

Here, if radius $r_{ls} \coloneqq 3 \times 10^8\ \text{m/s} / 340\ \text{m/s} = 8.824 \times 10^5$, this condition can be described as

$$y \leq r_{ls} x$$

This region can be illustrated as in Fig. A. 16.

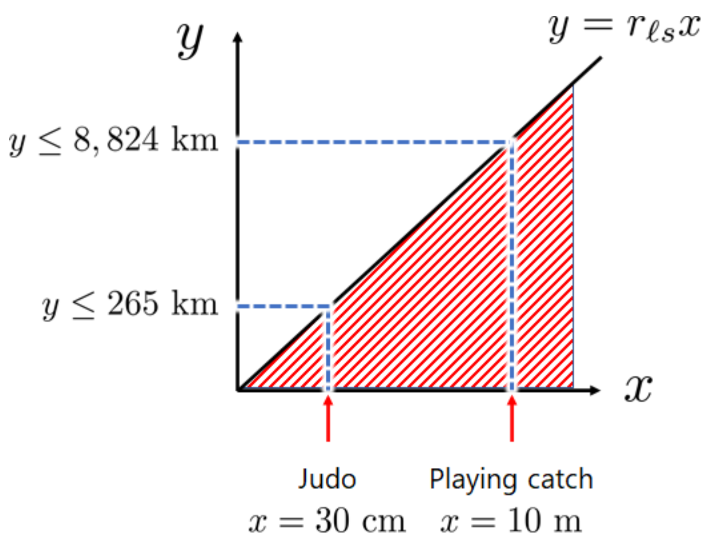


Fig. A. 16: Illustration of the domain of inequality conditions (when information can be transmitted over a straight-line distance)

Examples are given below for the conditions shown in Fig. A. 16.

Example 1: At a distance of 10 m in virtual space, the time taken for the sound to arrive is

$$\frac{10 \text{ m}}{340 \text{ m/s}} = 29.4 \text{ ms}$$

Therefore, when experiencing sound transmission in virtual space, hearing will be uncomfortable if the distance between the two is greater than the following value

$$8.824 \times 10^5 \times 10 \text{ m} = 8{,}824 \text{ km}$$

Thus, applications that are performed 10 m apart in virtual space, such as catching a ball, are possible. If the distance in physical space is less than 8,824 km, the system can compensate for it and make it feel like you are 10 m away in virtual space.

Example 2: In the case of an application that is conducted at a distance of about 30 cm in virtual space (e.g., short-distance sports such as judo), Fig. A. 16 shows that hearing discomfort occurs if the user is not within 265 km in physical space (from Tokyo Station, Nagoya, Toyama, and Niigata cities are all within a range of 265 km).

Example 3: With the farthest person on the earth, i.e., someone at a distance of only 20,000 km (the earth's circumference of 40,000 km/2), if you are not further apart than the following distance in virtual space, your hearing will be uncomfortable.

$$\frac{20{,}000 \text{ km}}{8.824 \times 10^5} = 22.7 \text{ m}$$

Example 4: The delay limit for controlling a realistic avatar can be thought of as the round trip between where you are and where the avatar is. Taking into account the time perception of the fastest response hearing (3 ms), you will no longer feel the delay when manipulating the avatar if the distance between you and the avatar satisfies the following equation, i.e., = 450 km.

$$\frac{2 \times \text{physical distance between person and avatar}}{3 \times 10^8 \text{ m/s}} = 3 \text{ ms}$$

In other words, the avatar must be within 450 km of its own position in physical space to be uncomfortable.

◯ If information is transmitted via a 1-hop relay station (Fig. A. 17)

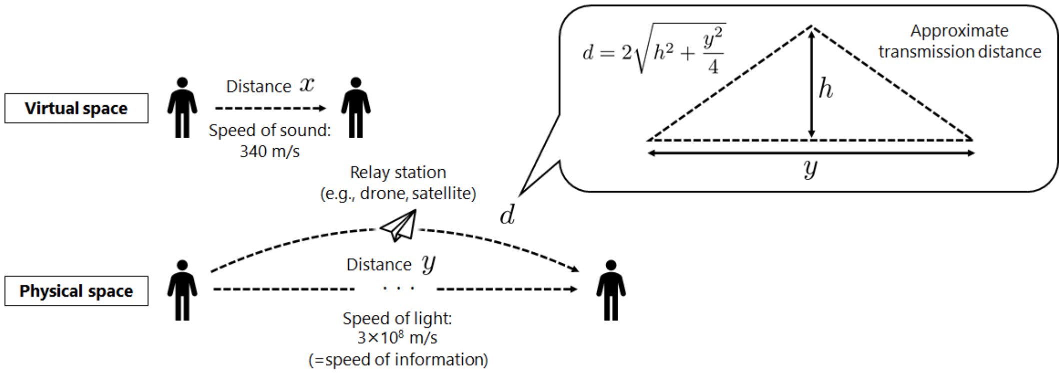


Fig. A. 17: Problem setup (if information is transmitted via a 1-hop relay station)

Next, consider the case where information is transmitted via a 1-hop relay station. If the altitude of the relay station is h and the transmission distance in physical space through the relay station is d, then the condition for not causing discomfort can be expressed as

$$\frac{x}{340 \text{ m/s}} \geq \frac{d}{3 \times 10^8 \text{ m/s}}$$

$$d \leq r_{ls} x$$

Here, the transmission distance through the drone is

$$d = 2\sqrt{h^2 + \frac{y^2}{4}}$$

So, the condition is

$$\frac{x^2}{(2h/r_{ls})^2} - \frac{y^2}{(2h)^2} \leq 1 \qquad \text{(Eq. 2)}$$

This inequality represents a hyperbola and can be illustrated as in Fig. A. 18. Here

$$a = \frac{2h}{r_{ls}}$$

represents the lower limit of the distance in physical space that does not cause discomfort in virtual space. Thus, discomfort will always occur below this distance. For an altitude of the relay station of 1 km, a = 2.27 mm, of 10 km, a = 2.27 cm, and of 100 km, the limit comes to a = 22.7 cm.

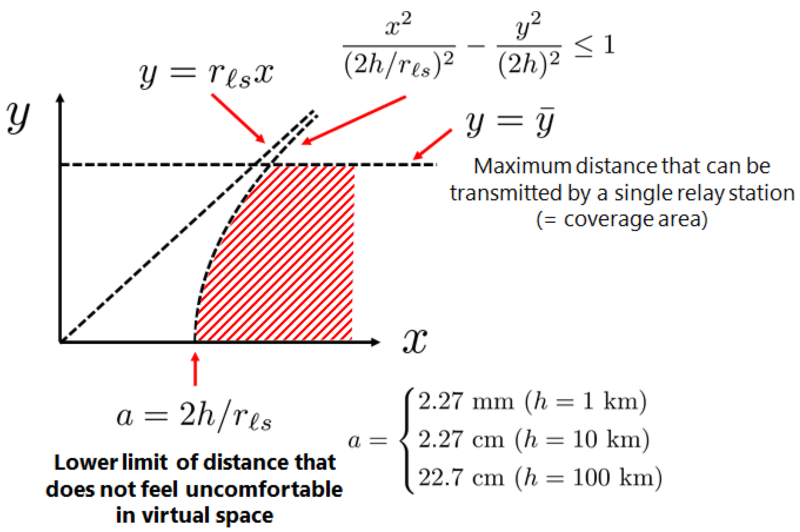


Fig. A. 18: Illustration of the region of inequality conditions (when information is transmitted via a 1-hop relay station)

From the relationship derived in this section, we can specifically calculate the relationship between distance and delay limit in virtual and real space.

■ Deriving the "limit of virtual space" from the "demand for physical space"

・The longest distance in Japan: 3,000 km (Shiretoko Cape Lighthouse to Yonaguni Island) is close to the lower limit of distance that does not cause discomfort.

(If direct communication is possible: transmission distance: 3,000 km, delay: 0.01 s): 3.4 m in virtual space (using Eq. 1)

(In the case of a relay station capable of 1-hop transmission, with coverage):

If the altitude of the relay station is 1,000 km (transmission distance: 3,606 km, delay: 0.012 s): 4.1 m in virtual space (using Eq. 2)

■ Deriving the "limit of virtual space" from the "demand for physical space"

・Assuming a use case of conversation in virtual space (assumed at approx. 2 m)

(If direct communication is possible): within 1,765 km in physical space (using Eq. 1)

(In the case of a relay station capable of 1-hop transmission, with coverage)

If the lower limit of the distance that is comfortable in virtual space = 2 m, the altitude is 882 km

If the relay station has an altitude of 822 km: within 499 km in physical space (using Eq. 2)

A.8.3 Terrestrial circuit network (visual information base) necessary to realize five-sense communication

Compare the transmission speed required for five-sense communication calculated above with the transmission speed required for Internet communication for everyone in 2020. In 2020, assuming 100 Mbps per household (best-effort type maximum), 51.2 Tbps (for a xN access network) will be required in the core network, based on the same calculation as above. Therefore, based on the required transmission rate required per household, we can see that 5 Tbps/100 Mbps = 50 times the transmission capacity is required.

In this section, we describe the terrestrial circuit network to realize five-sense communication as described in A.8.1 and A.8.2. However, as mentioned in A.8.2, it is assumed that the network transmits visual information that requires high-capacity transmission.

As described in A.6.2, the distance between cities in the proposed MS Goal is assumed to be 109.5 km. In this section, we set up a concrete scenario and show the results of calculations on the transmission speed required in the core network when everyone communicates with the five senses.

In this section, we focus on Japan and assume that the total population is dispersed and gathered in each UC (Urban Centre). Japan has 109 UCs, with a population in 2050 estimated to be about 100 million [181], which means that about 1 million people live in each UC. In the following, we use Hachioji City, Tokyo (pop.: 576,000; area: 186.4 km2; pop. density: 3,091 ppl/km2; no. of households: 253,000; no. of towns/subdivisions: 199) and Machida City, Tokyo (population: 434,000; area: 71.5 km2; pop. density (pop: 434,000, area: 71.5 km2, pop. density: 6071 persons/km2, no. of households: 200,000, no. of towns/subdivisions: 186) as sample cases to calculate the required capacity of the core network.

If the number of household members is assumed to be 2.5 (national average), the transmission speed of 2 Tbps × 2.5 = 5 Tbps per ONU (Optical Network Unit: optical line termination device on the user side, Fig. A.16) is needed because the transmission speed required for five-sense communication per person is 2 Tbps, as shown in 1.4.3. Therefore, since the number of ONUs that can be accommodated per OLT (Optical Line Terminal) is 128 [182], each OLT must be able to handle 5 Tbps × 128 = 640 Tbps. Here, since Hachioji City and Machida City have a total of 453,000 households, if the number of base stations per access network is assumed to be 4,000 (approx. number of households/ONU capacity), 640 Tbps × 4,000 = 2,560 Pbps = 2.56 Ebps is necessary per access network. Therefore, the core network must be able to transmit 2.56 Ebps (Fig. A. 19). However, this is the required speed for just one access network, so depending on the network structure, a transmission speed that bundles multiple access networks may be required. The transmission speed required for the core network varies depending on the number of ONUs that one OLT can accommodate and the number of access networks that the core network can accommodate.

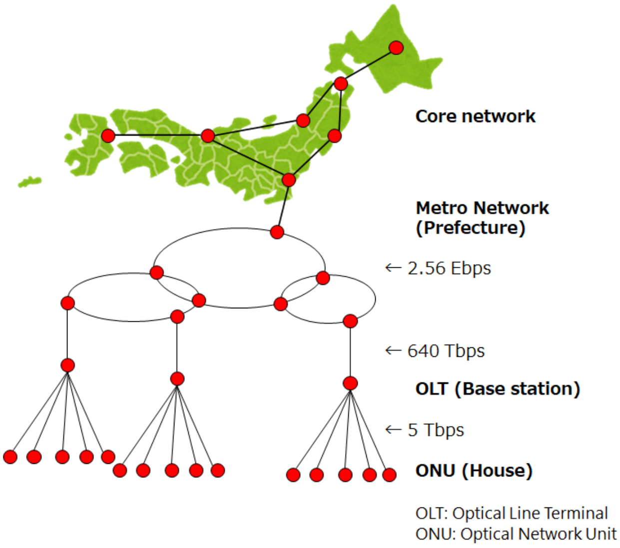


Fig. A. 19: Hierarchical structure of a wide-area optical network

Compare the transmission speed required for five-sense communication calculated above with the transmission speed required for Internet communication for everyone in 2020. In 2020, assuming 100 Mbps per household (best-effort type maximum), 51.2 Tbps (for a xN access network) will be required in the core network, based on the same calculation as above. Therefore, based on the required transmission rate required per household, we can see that 5 Tbps/100 Mbps = 50 times the transmission capacity is required.

Fig. A. 20 shows a roadmap of optoelectronics-related technologies. This figure suggests that we can expect zetabit-km transmission per link to be realized by 2050. Assuming that zetabit transmission is established in 2050 and transmits 109.5 km, the transfer rate will be

$$1 \times 10^9 \text{ Tbps·km/link} / 109.5 \text{ km} = 9.1 \text{ Ebps} / \text{link}$$

The necessary transmission capacity for five-sense communication is 2.56 Ebps, and it likely to be highly feasible from the viewpoint of the optical line because the order or magnitude agrees.

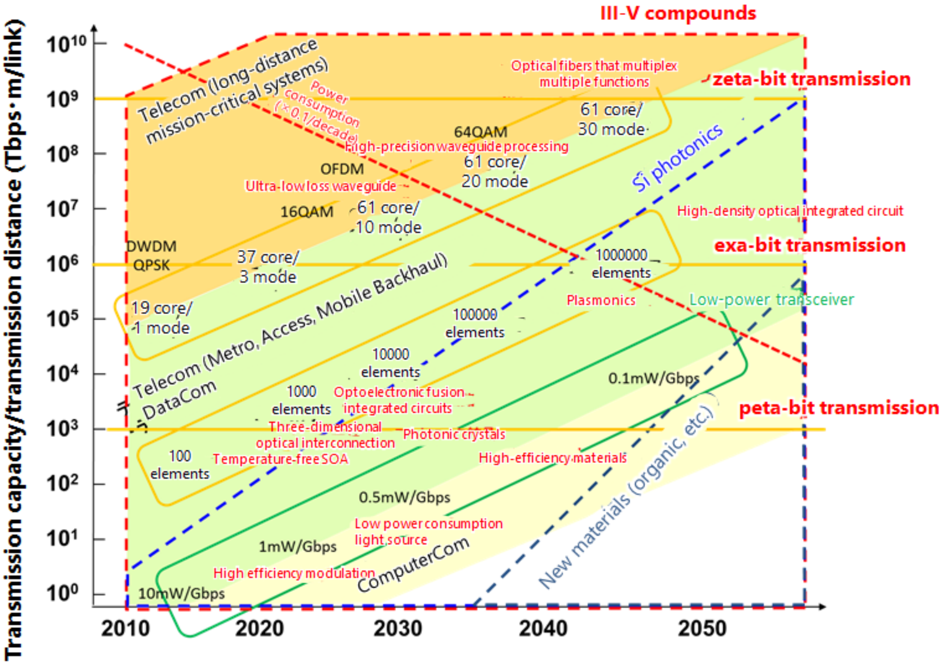


Fig. A. 20: Technology roadmap for optoelectronics[183]

A.8.4 Drone relay network (auditory information base) necessary to realize five-sense communication

In this section, we describe the drone relay network to realize five-sense communication, as described in A.8.1 and A.8.2. However, as mentioned in A.8.2, we assume that the network transmits auditory information with a high sensitivity to delay.

If the communication is within the same metro network or access network, the effect of the delay is less than 0.5 ms (metro network diameter up to 100 km) because the routing is almost unchanged because of the all-optical switch routing by ROADM (Reconfigurable Optical Add/Drop Multiplexer). In addition, when leaving the network sphere, there is a delay due to packet switching by the router. In particular, the delay between the OLT and the ONU is significant because the OLT is an inexpensive piece of equipment and employs a communication method that uses frequency sharing and time division. Based on the above, it is more likely that direct communication to a base station close to the access network will reduce the delay.

Assuming that the number of stations in the access network is 40 (approx. 1/10 of the total number of towns/subdivisions in Hachioji City and Machida City = 385/10), the average density of stations is 6.5 km2 /unit (= 257.9 km2/40 stations in the total area of Hachioji City and Machida City). In other words, a single station covers an area of about 2.5 km square (Fig. A. 21).Fig. A.18).

If we try to reduce the delay to less than 1 ms, which is the time perception of hearing, it is difficult to transmit signals that satisfy the above delay requirements using radio waves below 57 GHz because the 5G NR (New Radio) standard requires 10 ms per frame and 1 ms per time slot due to the tradeoff with multipath radio waves. In this paper, we will discuss how to achieve the above requirements. Therefore, to reduce the delay to less than 1 ms, spatial optical communication with a larger subcarrier space, higher directivity, and less susceptibility to multipath is considered to be an effective option.

In the case of a drone relay with spatial optical communication, if the height of the drone is 150 m, based on current regulations, and the beam spread angle is about 45 degrees, it can cover about 300 m x 300 m (Fig. A. 21). In addition, further drone spacing is considered to be impractical in terms of attitude control stability, beam control, and laser beam diffusion. The beam spread angle is assumed to be about 45 degrees because the shallower the angle, the less effective the light-receiving area, resulting in worse S/N and lower throughput.

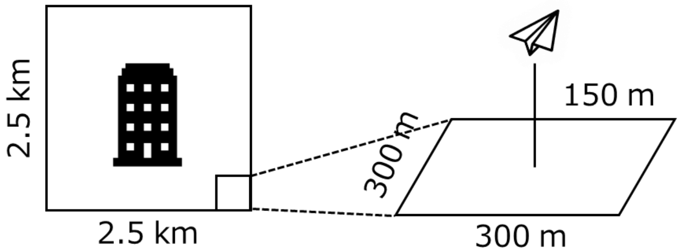


Fig. A. 21: Relationship between access network station buildings and drone coverage

This will determine the communication capacity required for the drone. It would take a total of 81 drones to cover a square of about 2.5 km on each side with drones capable of covering an area of 300 m x 300 m. In other words, the total number of drones required is

Total area 257.9 km2/Coverage area per station 6.5 km2 x 81 units = 3,214 drones.

That is, the number of people covered per drone would be

Population 1,010,000/3,214 aircraft = 314 persons per aircraft.

Then, the communication capacity required per drone to send voice data (1280 kbps = 1.28 Mbps calculated in A.8.1) would be

314 users/drone x 1.28 Mbps/person (voice data) x 2 (bidirectional) = 804 Mbps/drone.

The number of people a single base station can cover would be

Pop. density 3,914 persons/km2 (total of Hachioji City and Machida City) x 6.5 km2 of base station coverage = 25,441 people.

The voice data of 25,441 people needs to be aggregated and delivered directly to the base station, but hopping and aggregating will concentrate the communication traffic on the drones closest to the base station. In that case, the transmission rate the drone needs to handle is

25,441 persons x 1.28 Mbps/person x 2 (bidirectional) = 65 Gbps.

If four drones transmit to a single base station, the transmission rate per drone is

65 Gbps/4 = 16.3 Gbps

For example, if 100 drones capable of communicating with four directions simultaneously are arranged in a 10 x 10 grid, the network topology shown in Fig. A. 22 is currently known to be ideal.

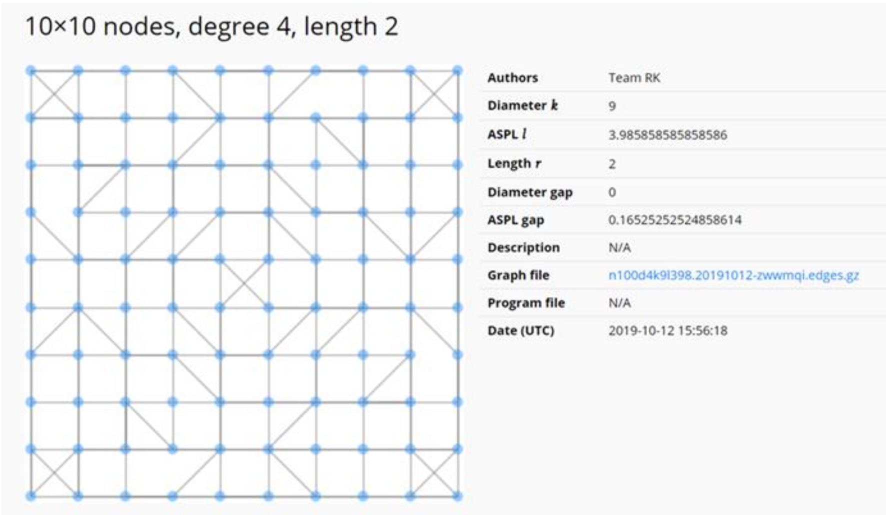


Fig. A. 22: Optimal topology with 100 nodes and 4 arms [184] (Note: this is not the global optimal solution because ASPLgap is non-zero.)

If a dwelling acts as a node for communication, the number of households in 6.5 km2 is approximately 13,000, but for simplicity we assume 10,000. If one drone has four optical communication terminals and can communicate in four directions simultaneously, it can transmit at a maximum of 99 hops with the topology shown in Fig. A. 23. If the maximum number of hops is 99, the maximum delay per node should be less than 10 μs (approx. 1 ms/99). If the number of nodes is 9,344 and one drone has six arms, i.e., it can communicate in six directions simultaneously, the topology in Fig. A. 24 allows transmission with a maximum of seven hops. In this case, the delay per node would be mitigated to 143 μs (approx. 1 ms/7). Since the network topology that minimizes the number of hops is derived by an algorithm based on the pseudo-annealing method, future developments in quantum computing may be able to provide an optimal topology even if the topology changes dynamically.

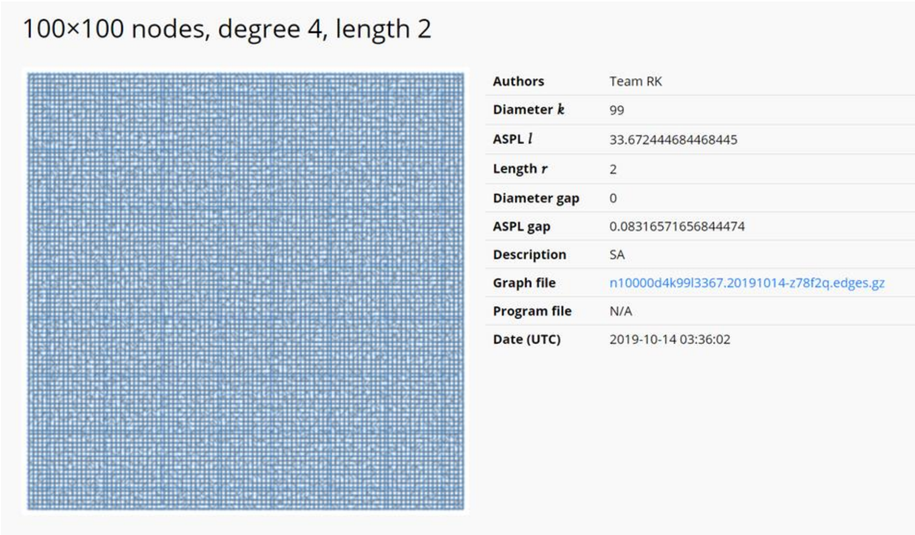


Fig. A. 23: Optimal network topology with 10,000 nodes and 4 free-space optical communication terminals[185]

Fig. A. 24: Optimal network topology with 9344 nodes and 6 free-space optical communication terminals[186]

A.9 Consideration of refrigerators in living spaces

Generally speaking, refrigerators generate power mainly by moving the compressor in response to the input of electrical signals, thereby changing the state of the refrigerant. The change in state of the refrigerant is accompanied by heat absorption and heat dissipation, causing temperature irregularities in the cooling circuit between the hot and cold sections. Cold air is created by cooling the air in the low-temperature section. Then by circulating the cold air, the food in the chamber is efficiently cooled. However, since the size of the chamber is fixed, the only way to improve the cooling efficiency further is to optimize cold air circulation or to turn on/off the input electric signal. It is often said that the fixed size of a refrigerator is sometimes useless and inconvenient from a long-term perspective, where several life events may occur. Therefore, IPA technology enables refrigerators that cool food by physically contacting it with a low-temperature biopolymer gel[187]. By using a gel that can be easily changed, the size of the refrigerator is not fixed, and it is possible to cool food at the optimum size according to the situation. The gel also serves to prevent food odor transfer by surrounding the food with the gel. As a future research challenge, it will be necessary to verify the cooling performance of the biopolymer gel and to examine the safety of the gel to ensure that it does not have any adverse effects on the human body, since it comes in direct contact with food.

A.10 Cost savings from applying IPA to water infrastructure

A.10.1 Current status and issues of water supply infrastructure

This proposed MS Goal will require the construction of independent water infrastructure. In most developed countries, water and sewerage infrastructure is in place throughout fixed settlements, providing access to safe water at all times. As of the end of FY2009, the total length of sewerage pipelines in Japan was 470,000 km, with maintenance and renewal work carried out on a daily basis. At the same time, some municipalities and businesses are facing issues related to the maintenance and management of the infrastructure that supports convenience, such as the aging of water pipes that were installed during the decades of rapid economic growth and the need to improve earthquake resistance. In particular, the water supply and sewerage business in Japan is of extremely high public interest, and the waterworks bureaus of local governments have taken on the responsibility of this business as a public enterprise, but the profitability of this business is severely challenging[188], and questions remain about its sustainability as tax revenues decline due to declining birthrates and aging populations and the outflow of population to urban areas.

A.10.2 Effectiveness of reducing the cost of maintaining water supply infrastructure

With the spread of IPA technology, if water supply facilities that were previously maintained and managed on an "area" basis as fixed infrastructure are now supplied on a "point" basis, there will be no need to maintain the same level of facilities as before, and IPA consumers will be disconnected from the existing water supply network. We therefore investigated the economic benefits of reducing water infrastructure if IPA living were to become widespread. Matsue City in Shimane Prefecture, which has a standard UC defined in Appendix A.2 spacing and population density in the UC survey, was used as a model. In addition, Matsue City has published the results of a trial calculation using the "Maintenance Cost Estimation

Software"[189] provided by the Ministry of Finance to local governments[190] and implemented the findings. Matsue City estimates that the maintenance costs shown in[190] will be required for the maintenance of the city's water and sewerage systems over the next 40 years.

Table A. 16: Water and wastewater maintenance costs in Matsue City. (Table drawn with information from [190][191].)

Items		Ownership Status	Maintenance and Management Costs		Construction Cost (Maintenance and management × 7/3)	Assumed Reduction	
			Total amount over the next 40 years	Annual average		Amount	Calculation assumption
Road	General	10,812,434 m²	135.54 billion Yen	3.39 billion Yen	316.3 billion Yen		
	Motorway	2,911 m²					
Bridges		84,662 m²	40.43 billion Yen	1.01 billion Yen	94.3 billion Yen		
Waterworks		933,660 m²	82.12 billion Yen	2.05 billion Yen	191.6 billion Yen	**-22.7 billion Yen**	80% reduction by infrastructure projection technology
Sewerage		952,799 m²	103.76 billion Yen	2.59 billion Yen	242.1 billion Yen	**-28.7 billion Yen**	90% reduction by infrastructure projection technology

Since the spread of IPA is expected to reduce maintenance costs by reducing the size of existing facilities, at least for water supply and sewerage, the economic effect was estimated assuming that IPA would be spread to 80% of households in 40 years. Although there are secondary effects such as lower new construction costs due to IPA and the dispersion of damage from natural disasters, the results show that simply reducing the maintenance costs of water and sewerage systems alone would result in a reduction of approximately ¥51.4 billion over 40 years (Table A. 16: Water and wastewater maintenance costs in Matsue City.). The annual maintenance cost is calculated as a quadratic function of the number of years elapsed, assuming that the diffusion rate increases in the latter half of the period, as shown in Fig. A. 25.

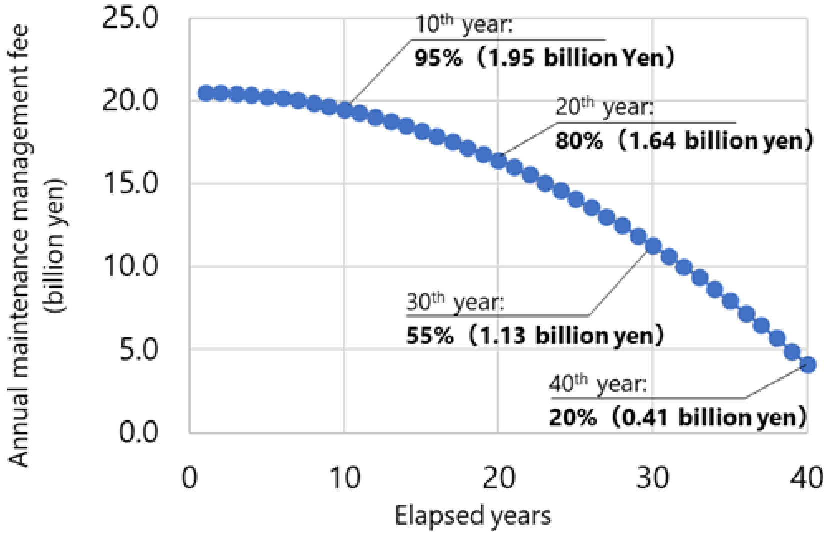
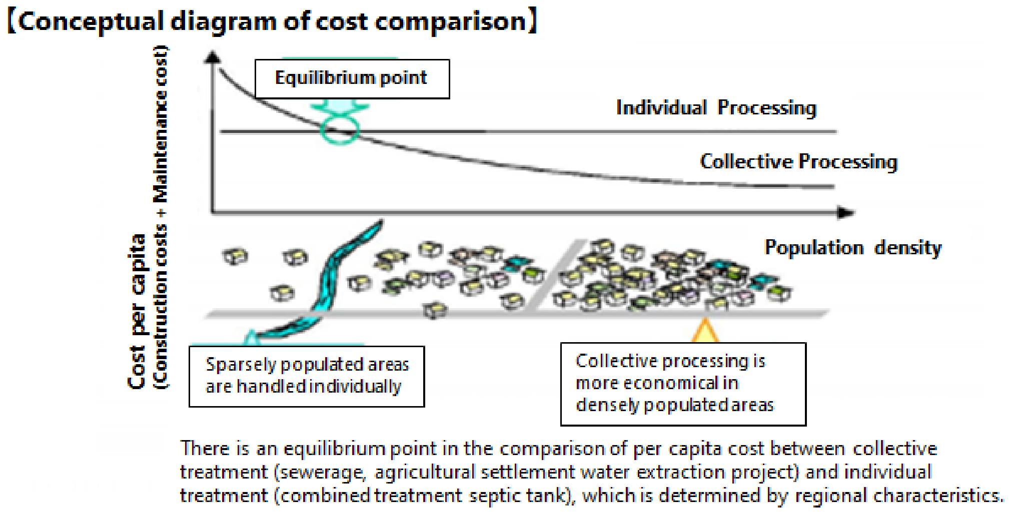


Fig. A. 25: Water supply and sewerage maintenance costs when IPA technology reaches 80% of households in Matsue City

Up until now, to provide services efficiently, water supply infrastructure has been developed on the premise that a certain size of population will settle down for a certain period of time, but under a declining population, some people believe that it would be cheaper overall to switch to individual treatment, such as installing combined treatment septic tanks, instead of connecting the water supply infrastructure to the existing network. With a declining population, however, there is also the idea that switching to individual treatment, such as installing combined treatment septic tanks, without connecting the water supply infrastructure to the existing network, would result in lower overall costs. (Fig. A. 26)



Source: Ministry of Land, Infrastructure, Transport and Tourism

Fig. A. 26: Conceptual diagram of cost comparison[192].

IPA technology is expected to give users more freedom in their lives. And by making existing infrastructure such as water and roads as unnecessary as possible, it might offer one solution to the current problem of limited maintenance due to lack of budget and manpower.

A.11 Milestones, R&D themes, and effects on society of the proposed MS Goals corresponding to the scenes of achievement of the social vision

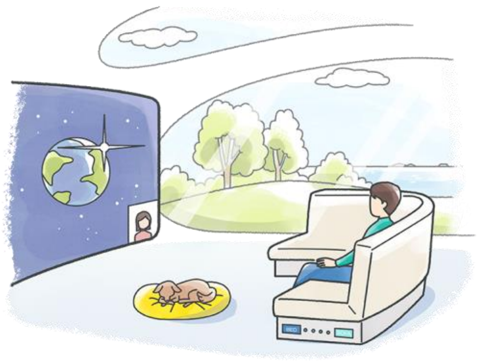
The technological milestones, R&D themes, and effects on society that can be imagined in connection with the achievement scenes shown in I.2 are shown in Table A. 17. These are summarized in III.2 as a series of flows.

Table A. 17: Technological milestones, R&D themes, and effects on society that can be imagined in connection with the achievement scenes

	(1) Milestones [2030] ・Power and water supplies will be separate and independent from the land. [2040] ・Environmentally friendly living will be possible by adding the function of complete self-sufficiency of electricity, etc.

	[2050] ・It will be possible to change the appearance of the house and blend in with the surroundings.
(2) R&D themes [2030] ・ Development of high-efficiency transparent solar panels. [2040] ・ Development of energy-creating and energy-storing systems. [2050] ・Development of an optical camouflage system that changes its appearance according to time, place, and scene.	(3) Effects on society [2030] ・Independent power and water infrastructures, except in certain areas and environments, will make it easier for people to move around. [2040] ・Self-sufficiency in electricity and water even in harsh regions and environments. [2050] ・The appearance of houses can be adapted to any place, and people can live without disturbing the local landscape.
	(1) Milestones [2030] ・The system can recycle relatively clean domestic wastewater (BOD 5 mg/L or less) from bathing and laundry to tap water (BOD 3 mg/L or less). Regeneration efficiency of 99% means that 82% of the water used is covered by regeneration. It can be circulated and used for cooking and drinking water. ・Each household can completely dispose of food waste and organic waste that does not emit toxic gases. [2040]

	・The system can recycle urine and dirty domestic wastewater (BOD 5 mg/L or higher) to the level of tap water. Assuming a recycling efficiency of 90%, 97.5% of the water used will be covered by recycling. It can be used for cooking and drinking water. ・Inorganic wastes and plastics can be recycled on a household basis. [2050] ・By increasing the amount of water to be recycled, all the water needed for daily life can be provided by circulation. ・All useful wastes are converted to resources, and the waste circulation/transportation system is optimized.
(2) R&D themes [2030] ・High efficiency reclamation system for low-BOD wastewater. ・Water disinfection and storage technology. ・Systematization of transportation and circulation treatment. ・Technology for converting waste into resources at the household level [2040] ・High-efficiency reclamation system for high-BOD wastewater. ・Establishment of a sustainable water reclamation system for air, rainwater, waste, etc. ・Wastewater quality monitoring technology. [2050]	(3) Effects on society [2030] ・Some water reclamation and waste treatment can be done at the household level, and is widespread in some areas, such as areas with declining populations. [2040] ・Some water and waste treatment will be transported, but most will be completed within households. [2050] ・The amount of water needed can be obtained anytime, anywhere. ・People can move to wherever they want, whenever they want.

・Optimization of resource circulation and automatic autonomy. ・ Construction of life with recyclable materials.	
	(1) Milestones [2030] ・More types of devices to project images in narrower areas [2040] ・Visual enjoyment by projecting the actual scenery over a wide area of the room. [2050] ・Wind and scent based on the projected scenery are transmitted to your sense of touch and smell, giving you the experience of being there.
(2) R&D themes [2030] ・Development of compact devices that can reproduce a variety of images. [2040] ・ Development of lighting and sound technologies that make the scenery more dynamic. [2050] ・Development of sensory experience space systems.	(3) Effects on society [2030] ・By projecting images into the living space, the stress caused by the small space can be alleviated. [2040] ・By realistically incorporating the exterior into the living space, the unique appearance of the local area can be enjoyed within the living space. [2050] ・Life is no longer subject to unintended external influences (noise, light pollution, etc.).

	・You can enjoy the outside scenery according to your time and mood without being affected by the unintended outside influences.
  	(1) Milestones [2030] ・Haptic communication will be added to the remote robot operation. ・The sensing technologies of taste and smell will be completed. ・Three-dimensional holograms with MR technology will be realized. ・It will be possible to create a space where people unconsciously feel comfortable [2040] ・In addition to vision and hearing, communication with the sense of touch has been completed. ・The actuation technology of the sense of taste and smell will be completed. ・Air-touch function will be realized. ・It will be possible to create a space that optimizes individual creativity. [2050] ・Five-sense communication is realized, and work can be done with the same quality as face-to-face. ・You can collaborate remotely as if you were there. ・It is possible to create an environment where you can access primary information at any time.
(2) R&D themes	(3) Effects on society

<table>
<tr>
<td>[2030]
・Highly realistic acoustic technology.
・Miniaturization and low-cost technology for taste and smell sensors.
・Fundamental research on the interaction between senses.
・Elucidation of the causal relationship between behavior and physiological responses in non-cognitive domains.

[2040]
・Miniaturization and low-cost technology for taste and smell actuators.
・Establishment and standardization of a safety evaluation index for sensory actuators.
・Theoretical clarification of the mechanism of creativity.

[2050]
・Technology to regenerate the five senses based on sensory interaction.
・Elucidation of the causal relationship between primary information and the designer's perception of it.</td>
<td>[2030]
・Primary industries, such as agriculture, can be conducted in any environment.
・The commuting zone will expand to the entire country, increasing the number of choices.

[2040]
・In almost all occupations, work and location are no longer related, and the concept of work location has been eliminated.
・Various jobs can be assigned like a quest.

[2050]
・Any job can be done remotely.
・Employers are accepting the idea of working remotely as the norm.</td>
</tr>
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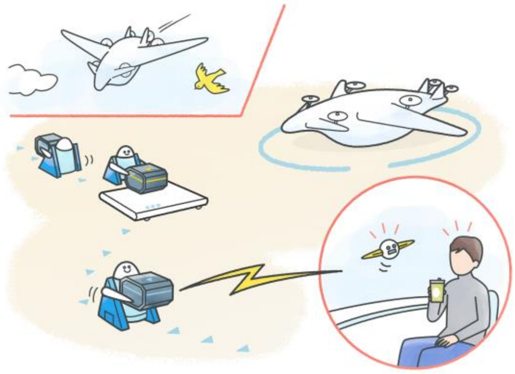
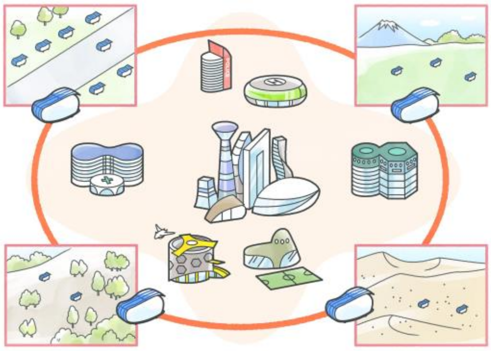
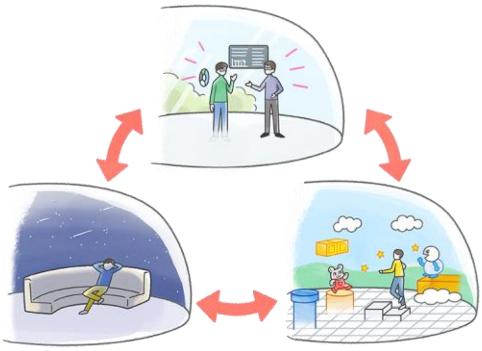
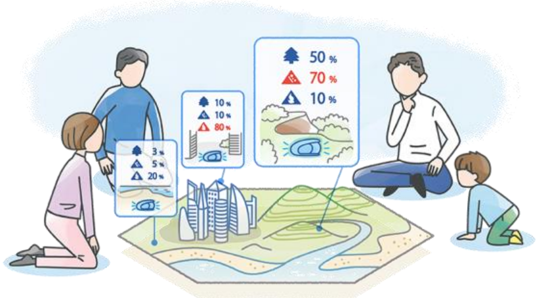
<td></td>
<td>(1) Milestones
[2030]
・Unmanned transport aircraft will be becoming increasingly common.
・Robots will be used to make transportation more unmanned. The robot will also be responsible for monitoring the traffic of transport aircraft.
・Field robots and unmanned devices can be operated remotely from anywhere.</td>
</tr>
</table>

	・Series hybrids and other internal combustion engines are being used to provide long range cruising. [2040] ・Field robots will become autonomous. ・Unmanned transporters will no longer be affected by weather and other factors, and the transport system will become completely unmanned. [2050] ・Improved battery performance will replace electric propulsion for transportation. ・The majority of unmanned vehicles will become autonomous, and fully automated transportation will become the norm.
(2) R&D themes [2030] ・Remote communication technology. ・Improving aerodynamic performance of unmanned transport aircraft [2040] ・Research and development of autonomous robots. ・Collision avoidance and weatherproof control technology for transport aircraft. [2050] ・Vertical takeoff and landing technology. ・Flight management systems. ・Battery performance improvement.	(3) Effects on society [2030] ・The ability to operate robots and transportation equipment remotely will enable people to work from any location, achieving the ubiquity of work. [2040] ・Robots working in the field will become more autonomous, reducing the burden of robot operation on people and giving them more time and peace of mind. [2050] ・The number of transports using on-demand transportation will increase, enabling rapid transportation no matter where you live, and allowing you to enjoy

	the convenience of cities regardless of where you live.
	(1) Milestones [2030] ・Decarbonization efforts will accelerate. ・Some areas of the city will be able to be reliably served only by renewable energy. ・Flying cars will be able to take off and land at various locations in the city. [2040] ・Gasoline cars will disappear. ・Automated land transport and automated air transport will begin to spread. [2050] ・A system that utilizes renewable energy and hydrogen will be now available for personal use. ・Everywhere on earth can be self-sufficient in energy.
(2) R&D themes [2030] ・Development of high-capacity and efficient energy storage technology. ・Methods of developing takeoff and landing sites in existing buildings and existing urban areas. [2040] ・The evolution of mobility that does not rely on fossil fuels.	(3) Effects on society [2030] Dependence on fossil fuels will be drastically reduced, and a society in which energy is stored and used will arrive. [2040] With a combination of land and air transport, you will be able to move fast to

・Technology for control and safety of unmanned aircraft. [2050] ・Development of portable energy storage technology using P2G. ・ Development of hydrogen-powered transport vehicles, etc.	where you want, when you want. [2050] Each household will be able to be self-sufficient in energy, and electricity will be off-grid, except for some large factories.
 	(1) Milestones [2030] ・A room to reproduce vision and hearing in 3D can be created. ・Some of the senses of taste and smell can be transmitted. ・You can manually switch between the work room, relaxation room, and game room. ・You can try on clothes in cyberspace. [2040] ・Most of the senses of taste and smell can be transmitted. ・The clerk's image and your image are projected in three dimensions, and you can communicate with them. ・Through the transmission of the sense of touch, the feel and texture of clothes can be confirmed. [2050] ・With the five senses communicating materialized, it has become possible to switch between the work room, the relaxation room, and the game room without being aware of it.

(2) R&D themes [2030] ・Improvement of transmission accuracy of tactile information. ・Miniaturization, low cost, high sensitivity, and high dynamic range of taste and smell sensors. ・Fundamental research on the interaction between senses. [2040] ・Development of tactile devices with high response speed and multi-point controllability. ・Development of compact, low-cost, and highly reproducible taste and smell actuators. ・Establishment and standardization of a safety evaluation index for sensory actuators. [2050] ・Technology to regenerate the five senses based on sensory interaction.	(3) R&D themes [2030] ・Improvement of transmission accuracy of tactile information. ・Miniaturization, low cost, high sensitivity, and high dynamic range of taste and smell sensors. ・Fundamental research on the interaction between senses. [2040] ・Development of tactile devices with high response speed and multi-point controllability. ・Development of compact, low-cost, and highly reproducible taste and smell actuators. ・Establishment and standardization of a safety evaluation index for sensory actuators. [2050] ・Technology to regenerate the five senses based on sensory interaction.
	(1) Milestones [2030] ・Hazard maps for flood, landslide, storm surge, tsunami risk information, roadside disaster prevention information, and land formation will be completed. ・The risk of multiple disasters occurring simultaneously can be examined. [2040] ・Information on typhoons, squalls, etc. will be added using data from ground IoT

	sensors and satellite observations. ・It is possible to estimate the probability of a disaster occurring in an area several hours to several days in advance. [2050] ・A unified platform and service will have been created to aggregate and share disaster risks from all locations.
(2) R&D themes [2030] ・Development of a system to quantitatively evaluate the disaster risk of a specific land by combining multiple disaster simulations. [2040] ・Development of technology to predict and provide information on disasters that may occur in people's living areas by aggregating information from a large number of sensors. [2050] ・Establishing a system to reproduce disaster situations in real time on a digital twin of a city and to rush to places where rescue and support are needed.	(3) Effects on society [2030] ・Detailed disaster occurrence information and forecasts will be provided according to where people live. [2040] ・Information on disaster risks will be automatically obtained when selecting land, without having to be aware of hazard maps. [2050] ・A police, fire, and ambulance system that can respond quickly to a disaster even in a wide area.

A.12 Conducting international workshops

If the social image becomes specialized for our country, the market for deploying the accompanying technology as a product becomes smaller and more expensive. In order to investigate the acceptability of the proposed vision of society in various countries around the world, we held an international workshop with the general public from the six major states of the world (the Americas, Europe, Africa, Asia, and Oceania), and Japanese nationals recruited from various parts of Japan. An international workshop was held.

A.12.1 Outline of international workshop

(a) Date and time: Sunday April 25, 10:00-12:00

(b) Format: Held online using Zoom and Miro (online whiteboard)

(c) Participants: 23 (Details are given in Table A. 18, Table A. 19: and Table A. 20) To focus on the generation that will be of working age in 2050, the participants were mainly in their 20s and 30s.

The workshop consisted of three sessions, one in Japanese and two in English. At the beginning of the workshop, an overview of the proposal and the concept of this MS Goal proposal were introduced, and then specialist facilitators and graphic artists specializing in graphic recording[193] who illustrated the discussion in real time, facilitated an exchange of opinions.

Table A. 18: Composition of participants in the Japanese session.

No.	Nationality	Gender	Age group	Occupation
1	China	F	20	Researcher
2	Indonesia	M	20	Company employee
3	Japan	F	20	IT consultant
4	Japan	F	20	Dance instructor
5	Japan	F	30	Self-employed
6	Japan	F	20	Company employee
7	Japan	M	20	Web programmer
8	Japan	F	20	Pharmacist

Table A. 19: English session #1 Participant composition.

No.	Nationality	Gender	Age group	Occupation
1	Japan	M	40	Fragrance company (head of development)
2	Indonesia	F	20	Student
3	Zambia	F	30	Student
4	Colombia	M	20	Student
5	United States	F	30	NGO
6	Italia	M	30	Researcher
7	New Zealand	M	50	University teacher

Table A. 20: English session #2 Participant composition.

No.	Nationality	Gender	Age group	Occupation
1	Japan	M	30	Video editor
2	Indonesia	M	30	Engineer
3	Spain	F	30	Engineer
4	United States	M	20	English Teacher
5	Malaysia	F	30	Researcher
6	Russia	F	30	Artist
7	New Zealand	F	20	Student
8	India	F	20	Student

A.12.2 Results of the international workshop

In a post-workshop questionnaire, the participants rated the workshop on a scale of 1 to 5 (5 being the best). With an average score of 4.48, the workshop was rated highly. During the workshop and in the post-workshop questionnaire, the proposal was received very favorably, but there were also opinions about social issues that might arise with the implementation.

(a) Characteristic opinions of each session

In each session, many opinions were expressed based on the experiences of participants and social issues where they come from. The following were the main opinions.

(1) Japanese session

Benefits

・Support vulnerable populations whose access to employment opportunities and urban resources is limited by their area of residence.

・If applied to countries and regions with underdeveloped infrastructures, it could lower the barriers to installation of new infrastructure.

・People can live near places where they can pursue hobbies or study interests.

Disadvantages

・Loss of connection to the community, contributing to a risk of death by loneliness.

・There will be disparity between those who can use IPA and those who can't.

・In the event of a disaster or emergency, it is unclear who will be in charge of rescue and support.

(2) English session #1

Benefits

・Forming small groups with similar values can strengthen human connections.

・It will reduce land occupation and lead to a more equal society.
・As an island country, there is a large disparity between islands with cities and the rest of the country; this can be corrected.

Disadvantages

・Risk of losing community and of losing identity.
・Who will be responsible for providing a social safety net and how will it function?

(3) English session #2

Benefits

・Enables decentralized agriculture and diverse kinds of land use (free from intensive agriculture).
・Barren areas such as deserts can be utilized.

Disadvantages

・It allows anyone to enter natural environments, which can lead to environmental destruction.
・Who controls the movement/residence of each individual?

(b) Opinions that we believe should be addressed comprehensively

・Establishing a means of communication that shares all five senses

In both sessions, the possibility that the realization of IPA leads to a loss of community and a weakening of human relationships was pointed out. To increase the social acceptability of IPA technology, it is considered necessary to include in the package a means of enabling communication, like an actual face-to-face meeting. Such a means is also required to realize medical care and education in remote areas.

・In each of the sessions, the need to adapt to the situation where people reside in dispersed areas was pointed out with regard to administrative practices related to medical care, emergency medical services, education, taxation, and environmental conservation. Consideration should be given to methods of providing and regulating administrative services through patrols using drones and technologies that enable easy and safe identification of residence and residence history.

(c) Graphic records (references)

The following graphic recordings made during the workshop are shown in Fig. A. 27, Fig. A. 28, and Fig. A. 29 below.

Fig. A. 27: Japanese session graphic recording

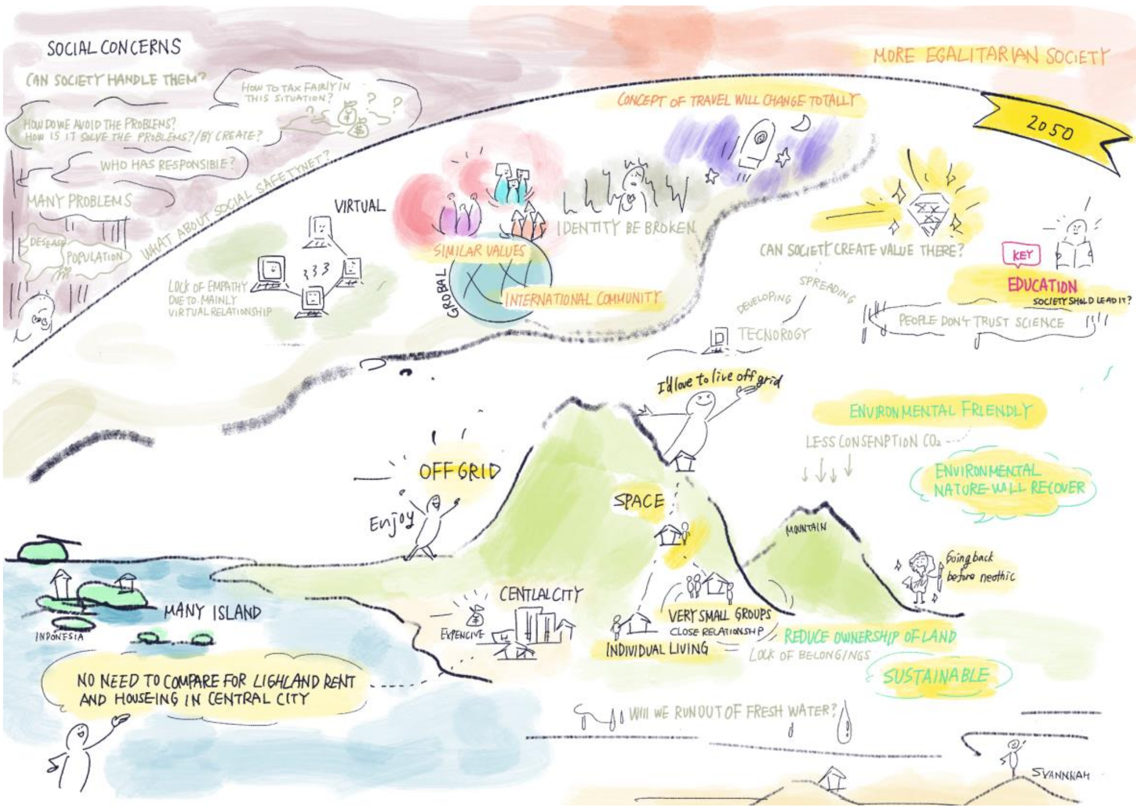


Fig. A. 28: English session #1 Graphic recording

Fig. A. 29: English session #2 Graphic recording

A.12.3 Conclusion

Despite the fact that the workshop participants had never met each other before, there was a lively exchange of opinions and the workshop was very valuable, because it brought together opinions that reflected the different situations in the places where the participants came from. In the future, the team will consider maximizing the advantages pointed out by the participants at the workshop, and also include solutions to the disadvantages in the team discussions. (Ref. III.5.)

A.13 Administrative services that enhance social acceptability where this proposed MS Goal is achieved

As mentioned in II and III, the social implementation of the technology to realize this MS Goal foresees a dramatic change in individual lifestyles, so the need for administrative services that are closely linked to people's lives will become more diverse and sophisticated, requiring a major shift on the administrative side. In light of this, we classified current administrative services provided to citizens into the following categories: "essential for daily life," "necessary for a safe and secure life," "necessary for maintaining life," "necessary for improving the quality of life," "removing barriers to life," and "administrative services such as taxes and certificates," respectively (Fig. A. 30).

The anxiety factors that arise under dynamic living were then organized as follows (Fig. A. 31). Under dynamic living, the increasing borderlessness and individualization of the community may lead to a deepening sense of isolation and problems that cannot be handled by the individual. Emergent community development and crime deterrent environments through government services are required.

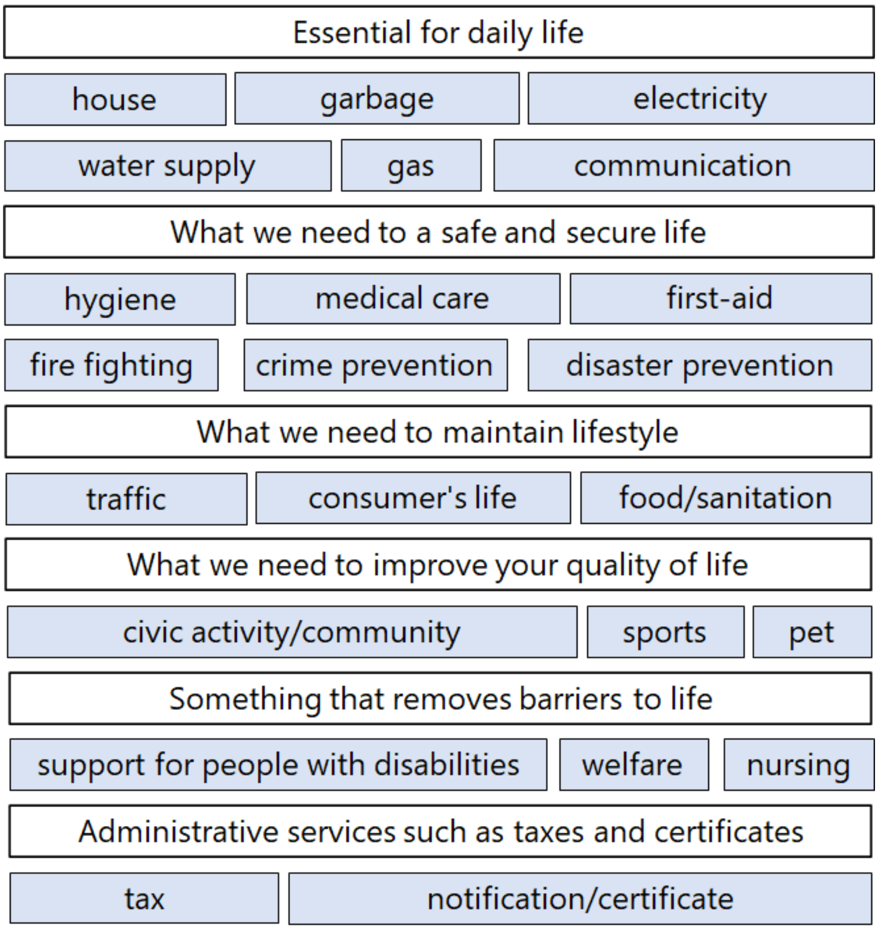


Fig. A. 30: Classification of administrative services

Community building

- Secure means of communication with family and friends
- Check the status of people living in the surrounding area
- Community for yourself and your children
- Difference between locals and migrants
- Local unwritten rules
- Carrying on local culture

Administrative Service Management

- Division of roles in administrative services
- Uniformity of service
- Police, fire, and first-aid jurisdictions

Free cross-border movement of people

- Immigration management
- Country's legal differences

Self-localization

- Privacy protection
- Personal identification
- Determining where to send mail, etc.

Safety

- Crime prevention
- Transportation Safety

Fig. A. 31: Anxiety under dynamic living

The main barriers to social implementation of the technology to realize this MS Goal (Table A. 21) are expected to be the difficulty in locating individuals and the difference in the adoption rate among municipalities (municipal difference). In living a dynamic life, it is an urgent issue to locate individuals who do not have a specific address, so that they can enjoy appropriate services and lead a comfortable life. Locating individuals is essential not only for purposes such as identifying the destination of mailings and supplies, but also for enabling governments to collect taxes from citizens and provide appropriate government services. However, although it is easy to identify locations by satellite positioning systems such as GPS (Global Positioning System), there is a strong concern about a surveillance society these days, and it is necessary to guarantee the privacy of individuals. Therefore, an effective approach may be to use technology that can leave a historical record without fear of falsification, such as blockchain, combined with a location information system (GIS: Geographic Information System).

This technology needs to be introduced uniformly, because a difference in the rate of adoption between municipalities due to financial resource problems could contribute to regional disparity. Ideally, the system should be introduced and managed by the national government and utilized at the basic municipal level.

Table A. 21: Key government services that alleviate anxiety about dynamic living and implementation issues

<table>
<tr><th>Common anxiety factors in dynamic living</th><th>Administrative issues for the anxiety</th><th>Solutions through government services</th><th>Management</th><th>Barriers to implementing the solution</th></tr>
<tr><td>Self-localization</td><td>* Mailing address
* Identification of taxpayers
* Concerns about a surveillance society
* Ensuring the privacy of individuals</td><td rowspan="2">History management using blockchain and other technologies</td><td rowspan="2">Utilized by municipalities under the management of the state government.</td><td rowspan="3">* The city is self-financed at 20%, and the other 80% is covered by subsidies and municipal bonds. The city also spends money on infrastructure, but there are many expenses that cannot be cut, such as aid for the needy and elderly.
* Population and area are currently included in the criteria for calculating the subsidy tax, but these criteria need to be changed.
* If the government adopts a dynamic tax system, there will be concerns about whether the necessary financial resources will be allocated to local government operations (e.g., personnel costs for administrative services, public debt costs).</td></tr>
<tr><td rowspan="3">Governing service management</td><td>* Address management</td></tr>
<tr><td>* Taxation method for local taxes, such as inhabitant tax</td><td>Dynamic Taxes</td><td>Utilized by municipalities under the management of the state government.</td></tr>
<tr><td>* Online acquisition of various certifications such as residence certificates</td><td>Virtual administration, full computerization of procedures for obtaining proof of residence, etc.</td><td>The state government</td><td></td></tr>
<tr><td>Environment and Sanitation</td><td>* Monitoring illegal dumping</td><td>Monitoring System</td><td>Municipalities</td><td>Ensuring personal privacy</td></tr>
<tr><td>Global move</td><td>* Immigration control at border crossings (personal identification)</td><td>Location information transmission system</td><td>The state government</td><td>Physical control against intrusion into territorial waters, etc.</td></tr>
</table>