Transition into a Mobile Society through Next-generation Mobility

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This paper presents an important viewpoint of the next generation mobility in urban area. From the points in the design of sustainable transportation system, selection of transportation mode, technology with design of institutional arrangements, and urban design are discussed. Finally the direction of technical development is shown for next generation mobility.

Key Words*: mobility, transportation, vehicle, personal mobility, autonomous driving*

1. Preface

Over 200 years have passed since the invention of motive power during the Industrial Revolution, and nearly 100 years since the birth of a practical motor vehicle. During that time until now, humans have made multiple inventions associated with transportation, including railroads for public transit, personal vehicles such as motorbikes and cars, and the number of choices for transportation methods has expanded greatly. In these 200 years, we have become adept at using these new vehicles, and through generations have gained the knowledge and realization of how to use these inventions, and what problems arise with their use. The 20th century can be said to be the "age of the automobile"; its invention altered people's lives dramatically and enabled the growth of enormous industries, creating a more abundant society. At the same time, great advancements were made in telegraph technology. With the ease of information transmission, communication could be made instantaneously, without the need to transport anything or even to actually move. This created a massive revolution within society.

Currently, in the 21st century, when we consider the relationship of intelligent human beings with our evolved methods of transportation and information transmission, it is unthinkable that people will continue to use the same mechanisms from the 20th century. It is important that we choose the right methods of transportation for the right situations and build new mobility technologies fused with the technological developments of information transmission. We are now able to do what our predecessors could have only dreamed of, such as gather detailed information on individuals and independent means of transportation in a split second, analyze massive amounts of data to extract features, and provide information in real time. And it doesn't stop at information provision. In fact, we are nearing the supplementation of our own abilities to actualize further control intervention. In other words, the initiative to unite humans, vehicles and infrastructure using information transmission, also described as ITS, is being restructured into yet a newer, more evolved form.

The space upon Earth is limited, and the energies we can use are unable to be used endlessly. Humans are still powerless against catastrophic natural disasters. We have precisely recognized these facts about our societal environment, and have therefore acquired the knowledge of how to build infrastructure such as roads, and how we should manage and maintain what we have built.

Automobile transportation is extremely convenient, but due to the safety as well as the difficulty of handling multiple demands within a limited transportation capacity, it can be said that the prioritization of convenience has undermined the negative side, such as traffic accidents. In Japan, the shift into an aging society stresses the importance of creating a mobility society that takes into account the structural age ratio of the population.

Logistics has become a major issue alongside human migration. The issue is primarily to devise a transport system efficient enough in time, labor and cost as it is in energy, and where no humans are necessary. From this point of view, I would like to introduce my personal opinion about technological review and systematic design for creating the mobility society of future generations.

2. A Sustainable Traffic System

When we think of what it takes to meet next-generation mobility, the formation of a sustainable traffic system comes to mind. The basic requirements for a traffic system are human migration and goods transport, the implementations of which must be desirable for both society and the users of the traffic system, and which by themselves cause no harm.

For a sustainable traffic system, I offer three main points; safety and security, lessening environmental load, and comfort and health. Safety is a top priority for all traffic systems, and it is vital that safety be promoted for the traffic system itself, in order to ensure its secure utilization and allow society to feel at ease. Lessening the environmental load entails energy conservation to reduce CO_2 emissions to the best of our ability. When we think of environmental issues, CO_2 usually comes to mind, but the past public hazard of exhaust gas from automobiles and the matter of noise pollution have once again started to be emphasized as well. It is important that we thoroughly consider the influence of the traffic system on subjects other than its users.

The reason for the previously stated issues is that unfortunately, the performance of the current traffic system is not enough. Merely deciding the negative angles of the current system will not achieve the desired mobility. We must also consider the issues of comfort and health.

On one hand, from the view of the hardware and software of which mobility is comprised, what would the ideal sustainable traffic system be? The leading role in mobility is, of course, people. For the distribution of goods, it is the goods being transported. For both of these, there must be a mix of vehicles and infrastructure. More specifically, there must be a cooperation and fusion of these three elements (**Fig. 1**). These elements did not adequately cooperate within the original traffic system, and this led to the occurrence of various problems. If the traffic capacity of traffic infrastructure (roads) is large enough and transport density is low, people may drive as they please without any major problems. However, when there are not just vehicles, but pedestrians, motorcycles and bicycles all sharing a limited traffic space, traffic control and rules become a necessity. Traffic signals at intersections work to adjust the traffic demands for travel in different directions. For traffic with different directional goals, there would be no need for traffic signals if each designated space was isolated, but it would be nearly impossible to create a solid separation on every road as is done on highways. Therefore, exclusive time frames are allocated to allow sharing of time. For the question of how to manage the signals, past records of traffic data and real-time traffic demands must be measured to select suitable timing. If this is not done in a way which suits actual traffic conditions, it may lead to road congestion or accidents. Drivers cannot be expected to handle unanticipated occurrences. This configuration involves providing drivers with accurate information depending on the make-up of the infrastructure, as well as sensing the whereabouts of pedestrians and other automobiles to provide information. It also involves dynamically managing traffic controls, such as traffic signals, according to traffic information, and even more desirably, according to the organization of road infrastructure Lastly, there are methods such as changing the number of automobile lanes to reflect demand.

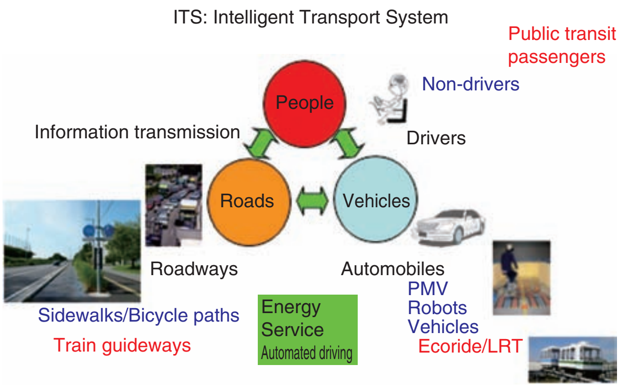

Fig. 1 Next-generation mobility and concept of ITS

The current method of traffic lights, in which a given length of time is appropriated for specific requests, would ideally shift to traffic control where individual courses and speeds are assigned in order to avoid collisions, and stopping is avoided as much as possible. The traffic lights infixed within the infrastructure would not have to be visually confirmed by the driver; inner-car signals and automated driving would be used to intelligently guide drivers. Looking at the evolution of the railroad trajectory traffic system throughout history, we can see the implementation of totally automated driving within visual manual operation, automated stop devices in case a traffic signal is overlooked, and automatic train control devices using inner-car traffic signals, which regulate speed to avoid collisions.

ITS is a trial in the unification of humans, vehicles and infrastructure using information transmission technologies, with ongoing research and development and practical implementation. I believe it is time we start creating even higher ideals and objectives.

3. Selection of Traffic Mode

Next-generation mobility is a sustainable system, fusing people, vehicles and infrastructure through the transmission of information, and acting as an evaluation indicator of safety and security, environmental load reduction, and comfort and health. I would like to consider the policies and assessments for actualizing this concept. The evaluation of traffic systems is broken down into two parts; user opinion and societal opinion, and these views may run counter to one another. To users, the highest merit is in a system that allows them to move easily and privately wherever and whenever they please. For this reason, users favor private vehicles that they themselves own, for individual, door-to-door movement. However, from the view of society, the use of private vehicles for every transportation need is, unfortunately, unrealistic within urban space.

For efficiently utilizing a limited amount of traffic space, users of small-size vehicles are at an advantage, and from the viewpoint of safety and a lower environmental load, a transportation system of large-capacity vehicles shared by many passengers is more beneficial; the two are not equivalent from the perspective of comfort and convenience. There are those who believe that riding trains is better than driving individually, and that public transportation becomes necessary in instances where those who usually use a private vehicle are unable to do so. The basic purpose of the existence of driving management through the shared use of a vehicle by multiple people is to fulfill a societal request; rather than constructing mobility in cities based solely on personal automobiles, the reality is that fusion with a public transportation system is more rational in terms of societal expense and social receptivity.

Combining rail transit systems, namely buses, railroads, subways and LRT (light rail transit), etc. and the fusion of the public transportation system with automobiles requires individual, easy-to-use vehicles as its hardware, such as bicycles and the more evolved PMV (personal mobility vehicle) (**Fig. 2**). It is also important to provide users with precise information, maintain park-and-rides where drivers park their cars and transfer seamlessly to public transit, and continue to evolve on-demand service for public transportation.

Existing automobiles have only a small carrying capacity, whereas the public rail transit system must generate greater carrying capacity as its investments are large. Consequently, due to the large transportation efficiency gap between these two, seamless mobility seems unlikely be achieved. From the perspective of passengers transported per area and traffic density, it is vital to construct a comprehensive traffic system with public transit such as LRT and buses, and go more

Fig. 2 Example of PMV (Segway® and Winglet)

compact than just lightweight vehicles for personal mobility, into a category in between these and motorized bicycles. That is to say, we must create ultra-compact mobility, creating a category of the PMV which lies somewhere between bicycles and motorized vehicles, but is easier to use than bicycles.

Even for rail transit systems, a more compact form is desired over large infrastructure for railroads and subways. Development is continuing for LRT, which runs on road surfaces in Europe and the Americas, and is achieving results in Japanese cities such Toyama. By upgrading LRT and giving it the same performance on sharply curved passages as automobiles, we can understand the necessity of an energy-conserving, lightweight automatic trajectory system such as Ecoride (**Fig. 3**), which has technological developments to expand its public use to that of buses, and makes good use of sky sidewalks and the upper space center median.

There is then the need to build an environment able to seamlessly utilize these new modes of transportation, using IT/ITS technologies. Streamlined hardware will not be utilized unless it comes with conveniences and incentives for use.

Fig. 3 Low cost/energy-saving/high frequency/auto-drive trajectory system “Eco-ride”

4. Technology and System Design

When considering the design of mobility, it is expected that an optimum system be built from a logical perspective, but there is another important point that must be regarded from among the problems of traffic. This is the social organization of laws and regulations, and that of insurance. No matter how idyllic a traffic system is created, Japan dictates that its laws and regulations of safety standards, the Road Traffic Act, and the Railroad Operation Act must be satisfied within each respective system in order to use them. It is most important that we take this into account when considering mobility design.

It is widely believed that traffic systems should essentially be created freely, judging by the history of traffic system development. However, in Japan, due to the Meiji Restoration, transport that had relied mainly on travel by foot was revolutionized into travel by trains and automobiles. These technologies are unfortunately not of Japanese creation, although Japan became number one in World production, practical use and technology. Regarding system design, effects of bureaucratic sectiondism or stereotype remains strong, and attitudes are conservative towards new modes of transportation.

Social systems naturally restructure and improve according to the evolution of society. If a new invention is used, new rules pertaining to it are created. The difficulty is in how those rules should be changed to fulfill social receptivity, as well as in the speed of policy transformation.

It takes time before innovative changes are acknowledged by society, and this will not happen by natural course alone; a vision must be created, and demonstrated to be beneficial evolution to society. Passengers, transportation providers, business operators, and industry, as well as a country's government and local authorities must collaborate to create this vision and implement it. In this light, industry-government-academia cooperation is extremely important, and neutral organizations such as universities are also anticipated to play a role. The Advanced Mobility Research Center to which I belong works not only in research and development to plant the seeds of basic technology and advanced technology, but also promotes regional cooperation and the fusion of industry-government-academia. I would like to continue to formulate new frameworks for achieving ideals, in addition to simply performing cooperative research.

5. Design for Urban Space

For practical next-generation mobility, the design of the urban space to be introduced is also significant. There is the viewpoint of mobility that matches existing road space, but to achieve the ideal vision, the existence of infrastructure and lifestyle are important as well.

There is the concept of the *compact city*. When the use of automobiles is assumed, cities will be constructed with ever-expanding suburban areas large enough to hold shopping centers, etc. in order to lessen the migration burden and ensure car space. On the other hand, if public transit and PMVs are assumed as the core transportation, a much more compact living sphere can be achieved. In European cities, there are older urban areas surrounded by castle walls; it is that kind of mobility from which the "compact city" concept is maintained. In the United States as well, a contemplation of the problems within suburban cities such as Los Angeles has led to the development of an urban area centered on a public transportation system. The number of cities is growing where free public transit is being offered as a city service.

There is not just human transportation, but also the transport of goods that must be considered. I would like to discuss the structure of a rational system of establishing city life, for which there must be not only inflow of necessary commodities supplied to the city, but an outflow of waste materials such as garbage as well. As logistics does not concern human migration, I believe an unmanned system would be quite effective; it is vital that automated operation technology evolves to suit this kind of logistics technology as well.

6. Direction of Technological Development

Next-generation mobility originates from the above discussions. One promising formula encompasses not only automobiles acknowledged within the existing system, but more compact vehicles, as well as the seamless combination of the PMV and an evolved public transportation system. Friendliness to both people and the environment is also important to the dynamic force of next-generation mobility. There are prominent ideas for electronic vehicles as well as compact mobility which stress human power utilizing electronic assist technology as most influential. Another technological revolution lies with automated operation technology.

Within the realm of safety and security, there must be balance between active safety and passive safety. Autonomous systems will be diffused as an active safety technology for automobiles, which will evolve with vehicle infrastructure and inter-vehicle communication. Automobiles and traffic infrastructure will be connected to a network through communication technology, and information from traffic movement to automobile and driver facts will be stored in a massive database. The policy for the effective use of this "big data" is progressing rapidly, and a new business is being born alongside the advancement of technology. Information gathered by telematics is analyzed in real time, and it is believed that this may achieve better driving skill and education for drivers, along with serving to prevent accidents. If automobiles can act as "probe cars", sensing their surroundings, and if each car and driver is provided with the appropriate information, the use of a system linking infrastructure with information automobiles will become common knowledge. Road-to-vehicle communication technologies are advantageous as their effects will come soon after their implementation, but it is necessary to examine the pros and cons of too much investment into infrastructure. As this issue deals with IT devices and automobiles, the extent of progress may vary, and this may lead to problems when the time comes for updating inner-vehicle installations. This raises the discussion on how to update IT devices invested into infrastructure, and whether it would be better to invest in automobiles rather than infrastructure. VICS and ETC held the leading initiative ten years ago, but these technologies become obsolete unless renewed. Therefore, a structure must be built which actively promotes autonomous safety support systems and inter-vehicle communication. I am currently working to improve safety in Hiroshima through the provision of information using inter-vehicle communication between tramways and passenger vehicles. Inter-vehicle communication cannot be effective if there are vehicles not equipped to provide it. If we can create vehicles that can be clearly differentiated regardless of who looks at them, namely if inter-vehicle communication equipment can be installed on tramways, the incentive to install this equipment will grow for drivers who wish to protect themselves against accidents involving tramways.

By contrast, with ultra-compact mobility and PMVs, the merits of compactness, light weight and low-cost are lost upon the installation of high-level safety devices. When the road is shared, passive security becomes an issue in regard to compatibility. A new concept must be considered, in which the burden of safety is placed on large-mass, relatively dangerous automobiles with high motive energy.

Driving a car will forever be a sovereign right of people. However, I believe that together with the progress of automated technology, there will come a time when we must seriously consider policies for the application of automatic driving depending on place of use, conditions of use and the situation. Situations easy to introduce automatic driving include single-purpose spaces and unmanned vehicles. This can be achieved inside parking lots and the guide paths on which unmanned vehicles travel, and for single-purpose roads used for vehicles transporting goods. Another objective of this plan is to obtain a consensus on drivers' sovereign rights concerning automatic driving.

Within automatic driving technology, the "Autonomous Platooning Technology" project (**Fig. 4**) from the Development of Energy-Saving ITS Technology has been gathering attention in recent years, especially with its new achievements. This is a revolutionary project targeting commodity distribution on highways; three large trucks and one small truck operate in a line, with a mere 4 meters between each vehicle. With shortened inter-vehicle distance, air resistance is greatly reduced, contributing to energy conservation. With inter-vehicle distance so small, manual driving is impossible. To maintain an inter-vehicle distance of 4 meters, not only must there be feedback control which measures the distance, but there must also be speed and brake controls utilizing inter-vehicle communication. This distance also makes lane keeping in the trailing vehicles extremely difficult for manual steering control. Thus, cameras and laser radar are used to recognize white lines to create tracking control. This project aims for practical application in its use of existing market trucks, and is achieved with the installation of external sensors and actuators (**Fig. 5**).

Fig. 4 Autonomous platooning (NEDO Energy ITS Project)

Fig. 5 Technology development for auto-drive

In order to yield results for this project, it must be examined for social receptivity in its goal for application on highways. However, the project's utility has been crafted within the realm of possible practical use, and project investment is beneficial to the development of the technology. Pragmatic approaches have begun for application within trucks operating for the cleaning of tunnel lighting in highways within Central Nippon Expressway, the UBE exclusive high way Kosan Expressway (for transport by 60-ton doubles trailer on a private road of approx. 30 km) in Ube, Yamaguchi Prefecture, and for BRT (bus rapid transit) systems, which are one of the plans for bus conversion on local traffic lines. First, practical application must be promoted, with the goal of implementing automatic cruise for driver support. Lastly, the path will be opened for unmanned logistics systems and autonomous automatic cruising for compact vehicles and PMVs in low-population areas.

Electricity is the renewable energy desired for motive power, showing remarkable progress with the development of the HEV, PHEV, and EV. Suitable reforms are expected from innovations in battery technology, fuel cell technology, and wireless charging technology. Furthermore, it is widely accepted that compact vehicles and PMVs can be coupled with light weight and utilize human power. Electronic assist bicycles are activated basically the same as regular bicycles (human power), but use motive power when going uphill. This same idea has been established within the PMV as well. My group's proposed parallel 2-wheel method PMV, the Stavic-H, is a human-powered concept using motive power for stabilization (**Fig. 6**). In recent years, power assist systems have bloomed within automobiles, but the mechanics originating from power steering using human power alone may be revived due to weight-saving and structural innovations.

Besides this, there must be long-term considerations of aspects such as societal receptivity, adaptations for an aging society, and what must be done for future generations within an aging society. To establish businesses, it is best to develop technology considering not only proximal support for our own country, but also support for overseas development and the setting of global standards. Now, as the Japanese population shifts into decline, it has become evident that establishing businesses may not be possible without technological development targeted at world markets.

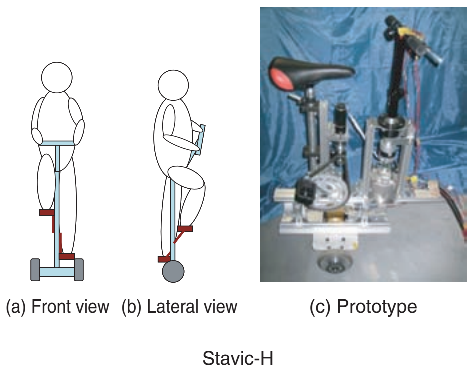

Fig. 6 Example of human-powered PMV "Stavic-H", currently being developed

7. Conclusion

I have introduced my thoughts considering the important aspects of next-generation mobility, although I have omitted some of the more detailed technologies and concrete images of mobility due to the wide range of topics available. Twenty years after the bursting of the economic bubble, Japan has been marginalized in growth, and we also face the challenge of recuperation from the East Japan earthquake on March 11, 2011. I believe that we do not have much time when it comes to next-generation mobility; I would like to build a concrete time schedule and road map, and get started on efforts for the