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Original Research

Co-development of Low-speed Electric Community Buses for Local Area Revitalization

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Abstract

This paper describes the development of low-speed electric community buses (LSECBs) designed by the author's group and their spread situation in Japan. LSECBs are electric vehicles that can travel on public roads at speeds of less than 5.56 m/s (20 km/h). The university, local

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government, local businesses, and residents with a co-design approach developed the LSECBs. They have various advantages such as safety due to low speed and low energy consumption. In particular, the LSECBs have features not found in ordinary vehicles, such as the ability to friendly talk with other passengers in the vehicle and to see the surroundings. The purpose of using LSECBs is mostly for sightseeing, but they are also used to enhance the mobility of elderly people in the community. In Japan, public transportation plans are formulated by each local government, but local governments with weak finances do not provide sufficient financial support to the companies responsible for public transportation. As a result, public transportation services have been reduced or eliminated due to the business conditions of private companies, and many elderly people with reduced mobility, called "people with shopping difficulties," have been left behind. Under these situations, it is necessary to discuss what kind of contribution LSECBs can make. Moreover, the LSECBs require special driving methods so as not to cause traffic congestion when mixed with other ordinal vehicles. In this paper, we report on the development concept, features of the LSECBs, their special driving method, positioning as a transportation policy, and their potential as stainable mobility.

Keywords
Global warming; sustainable mobility; low-speed mobility; electric vehicle; safety; co-design; co-development

1. Introduction

1.1 Background

Global warming is entering a critical stage of a climate crisis and urging us to significantly transform the national economy, industrial structure, and lifestyles. Much research has been conducted on environmental changes associated with global warming, and various future projections have been made [1, 2]. IPCC's Working Group I, which discusses the physical science basis, in its sixth assessment report [3], used the word "equivocal" to describe the impact of human activities on global warming as, '*It is clear that human impacts are warming the atmosphere, oceans and land*.' Many efforts have been made to prevent global warming, and scenarios have been proposed to significantly reduce CO_2 emissions from various sectors [4-6]. The transportation sector is also strongly required to reduce CO_2 emissions, and various assessments about the CO_2 emissions from the transportation sector are underway [7, 8]. In the IPCC Sixth Assessment Report, Working Group III: Mitigation of Climate Change, mitigation measures in the transportation sector include reducing demand, combining electric vehicles with low- and zero-emission electricity, and using low-carbon hydrogen and biofuels in shipping and aviation [9]. Introducing electric vehicles (EVs) has been considered to reduce CO_2 emissions in the transportation sector, and a specific analysis has been conducted to determine their effectiveness [10, 11]. The shift from internal combustion engine vehicles to EVs has been reported to be progressing rapidly [12-14]. However, it has been suggested that EVs cannot significantly reduce CO_2 emissions in countries with high CO_2 emission coefficients from power generation and that the widespread use of EVs may lead to an increase in CO_2 [15].

The World Business Council for Sustainable Development (WBCSD) defined sustainable mobility as '*Sustainable Mobility is the ability to meet society's need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future*' in the report titled "The Sustainable Mobility Project" at 2002 [16]. And the United Nations Economic Commission for Europe (UNECE) described it as '*Sustainable Mobility focusses on how to move people and goods efficiently, safely, securely, affordably and in an environmentally friendly manner using inland transportation*' in the report titled "Sustainable Mobility and Smart Connectivity" [17]. As shown here, sustainable mobility involves many disciplines, including sustainable city design, an easily accessible and environmentally friendly mobility system, a shift to low-carbon vehicles, and policies to induce it [18, 19]. In addition, various attempts at sustainable mobility research can be seen, such as car sharing using small EVs [20], combining with MaaS [21, 22], and utilization of renewable energy [23-25]. Furthermore, regarding MaaS, the concept of sustainable MaaS (S-MaaS) has been proposed [26, 27]. These studies highlight the importance of local governments' participation, the service design of MaaS companies, and the governance of related organizations as necessary components for implementing S-MaaS in society. In addition, an analysis of the economic returns, environmental benefits, and social benefits concerning sustainable mobility has been conducted [28].

In contrast to conventional vehicles, very small and slow vehicles that can only be used as a means of transportation within a limited area are often called new mobility. For example, one- or two-seater EVs were called micro-EV [24, 29] or neighborhood-mobility [30, 31]. Slow electric vehicles have been developed as sustainable motilities [24, 32]. Such new mobility may be a vehicle that meets the requirements of sustainable mobility.

The Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) of Japan were introduced in 2018 to promote the use of electric vehicles that can travel on public roads at speeds of less than 5.56 m/s and can seat four or more people, calling them "Green Slow Mobility (GSM) ," in various area. MLIT describes the five characteristics of GSM as Green, Slow, Safety, Small, and Open, and suggests various ways to utilize it [33]. These GSMs are included golf-cart-type vehicles that can be driven on public roads and LSECBs, which will be introduced in this paper.

Nevertheless, the transformation of lifestyles including the proliferation of EVs does not proceed without creating public acceptance. Furthermore, it is important to enlighten the public concerning the benefit of renewable energy-based transportation on local economic vitalization. In this respect, GSM is understood to have a special potential of creating a public platform not only to open public eyes to electric mobility but also for conceptual change from linear progress of chasing efficiency and speed to sustainability transformation. Developing such a platform should be the task of the public sector. So, the authors initiated a slow-mobility-based regional public transportation initiative in Kiryu city, Gunma prefecture, in 2011. The LSECB developed through this initiative continues to be produced in Kiryu city and is being introduced in other parts of Japan.

1.2 Objective

This paper introduces the design concept of LSECB developed as safe and sustainable transportation [24, 34, 35]. The LSECB was developed as a co-design involving universities, local governments, residents, and local businesses is described. And we discuss that the co-design process is important to accept the LSECB in the community. In addition, the safe operation method in the region and the road conditions where the LSECB can be operated are summarized. Finally, we evaluate that the LSECBs are effective in vitalizing depopulated and aging communities, tourist areas, and shopping districts through the used situation in various areas.

2. Co-development of LSECB

The concept of LSECB was born out of the JST-RISTEX (Japan Science and Technology Agency - Research Institute of Science and Technology for Society) R&D program “Community-based Actions against Global Warming and Environmental Degradation,” which was implemented from FY2008 to FY2013 [36, 37]. This R&D program aimed to push forward low carbon transitions through community-based socio-technical innovation developed by “co-design and co-development approach” in contrast with the conventional top-down, one-way, and technology-pushed approaches. This approach also aimed at a comprehensive solution to various localized problems arising from high CO_2 emission systems. To ensure a co-design and co-development approach, it is significant to involve wider local stakeholders in a transition project from the scenario design stage (i.e., co-design) through the implementation process (i.e., co-development). In the implementation process, it is also important to utilize locally accessible, but effective technologies based on local climate as well as financial capacity (i.e., appropriate/alternative technologies), and locally available resources (including human resources). Eventually, the LSECB project became a symbolic community-based socio-technical innovation challenge for the R&D program as described before.

2.1 Concept Building of LSECB

In the RISTEX R&D project, a low-speed vehicle was initially chosen to reduce development costs. The choice of low-speed vehicle, rather, not only allows for lower development costs but also allows passengers to take their time to enjoy the surrounding scenery and reduces the number of fatalities from traffic accidents. Tokushi Nakashima proposed such an idea, currently, the President/CEO of Global Mobility Service Inc. The low-speed vehicle’s idea greatly changed the values of the R&D members, who at that time viewed EVs as a substitute for conventional gasoline-engine vehicles. Developed in this project was not just a means of transportation, but a new vehicle that would become a symbol of a low-carbon society and even change the things of community building. Thus, the first LSECB concept was created.

2.2 Co-design and Co-development of LSECB

The "Road Transport Vehicle Act" sets a safety standard for road vehicles in Japan. Under this law, some regulations are relaxed for vehicles with a maximum speed of fewer than 5.56 m/s. For example, a vehicle may be driven on public roads even if it is not equipped with a seat belt. Therefore, the maximum speed of LSECB was set at speeds of less than 5.56 m/s to apply the deregulation of the “Road Transport Vehicles Act."

It has been shown that the mortality rate is very low when traveling at speeds of less than 5.56 m/s. Figure 1 shows the mortality rate for danger perception speed based on 2017 data from the National Police Agency, Traffic Bureau of Japan [38]. Here, the danger perception speed is defined as the driving speed immediately before the driver perceives danger and takes danger avoidance measures such as braking or steering operation. And the mortality rate is defined as the following equation.

$$Mortality\ rate=\frac{Number\ of\ fatal\ traffic\ accidents}{Number\ of\ fatal\ and\ injury\ accidents}\times 100\ (\%)$$

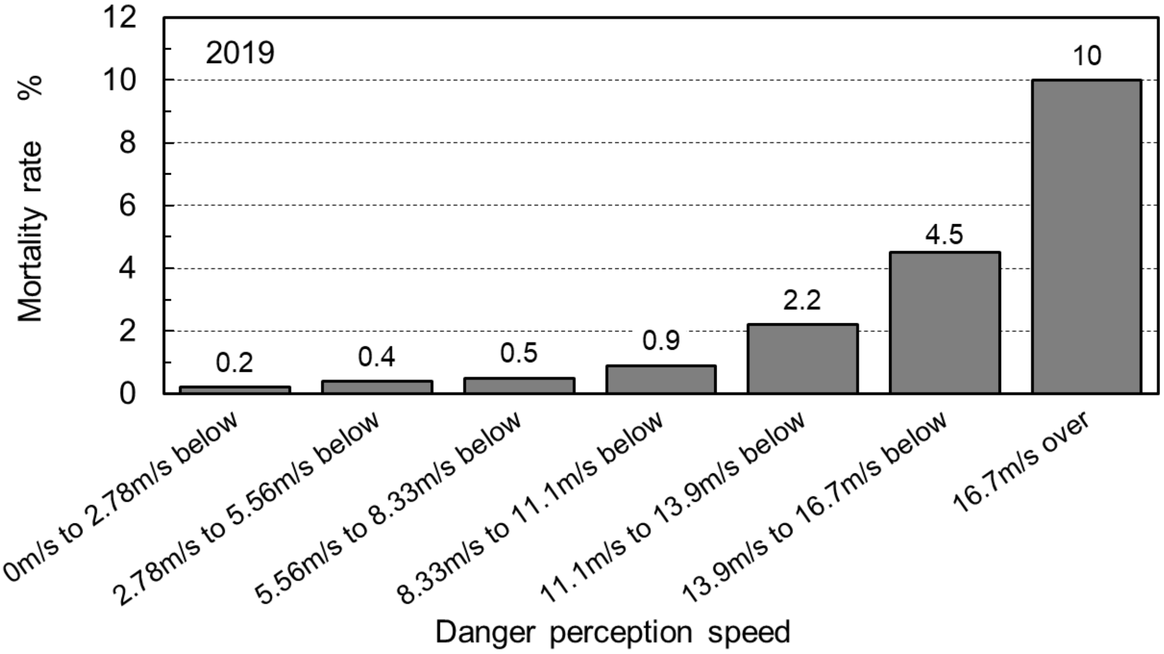

Figure 1 Mortality rate vs danger perception speed [38].

The result shows that the mortality rate is lower at speeds below 5.56 m/s than at higher speeds. It should be noted, however, that the number of accidents is higher at lower danger perception speeds [38].

Before the start of actually designing the LSECB, it was tested whether the LSECB would be an obstacle to the traffic flow in the city area. For this test, a small conventional bus was rented to drive at low speeds on city streets. To conduct this test, the Gunma University and the local government, Kiryu city in Gunma Prefecture, cooperated in obtaining the consent of the local police. As a result, it was confirmed that no major troubles would arise by paying attention to driving methods (driving methods will be described later).

The specific property required for the LSECB was co-designed by R&D members in the RISTEX program, universities, and related companies. The required properties listed were as follows:

(1) The maximum speed is less than 5.56 m/s, which allows for a clear view of the surroundings.
(2) Eliminating side windows allows, passengers can sense the external environment directly.
(3) The buses have long seats for 10 passengers and are face-to-face for easy onboard communication.
(4) Utilizing the in-wheel motors and small-diameter wheels of light motor vehicles, a low floor is achieved to easily ride for elderly persons.
(5) The width of the bus should be smaller than that of a full-standard bus so that it can easily pass other vehicles.

(6) The bus should be able to charge by a 100 V household power supply.

(7) The battery should be able to removable and replaceable.

To develop the LSECB at a low cost, we decided to use the small in-wheel motor of a micro-EV [24, 29]. A venture company developed this small in-wheel motor, Thinktogether Co., Ltd, a member of the "Next Generation EV Research Society" at Gunma University. This technology was improved to develop a low-speed-torque-type drive system with sufficient gear strength to drive at a maximum speed of fewer than 5.56 m/s. All of the vehicle’s exterior and interior specifications, as well as the drive system, were designed by Thinktogether Co., Ltd. Considering the number of passengers and the hill climbing performance required on local roads, the number of wheels was set to eight (four per each side). A photograph of the first model is shown in Figure 2. The completed vehicle has a unique style with eight wheels and should symbolize sustainable mobility. This LSECB was named eCOM-8.

Figure 2 Developed LSECB (eCOM-8).

Various methods of steering the eight wheels were investigated. Finally, the Ackermann-Jeantaud scheme, in which the center of rotation is placed on the extension of the rear axle, was applied to the front six wheels [39-41]. By this mechanism, the front six wheels had different steering angles as shown in Figure 3. The steering mechanism was realized in the lever ratio of the mechanical linkage to give different steering angles for all six wheels. The seats of LSECB are wooden facing-type benches for easy talking as shown in Figure 4.

Figure 3 Steering angles of six wheels.

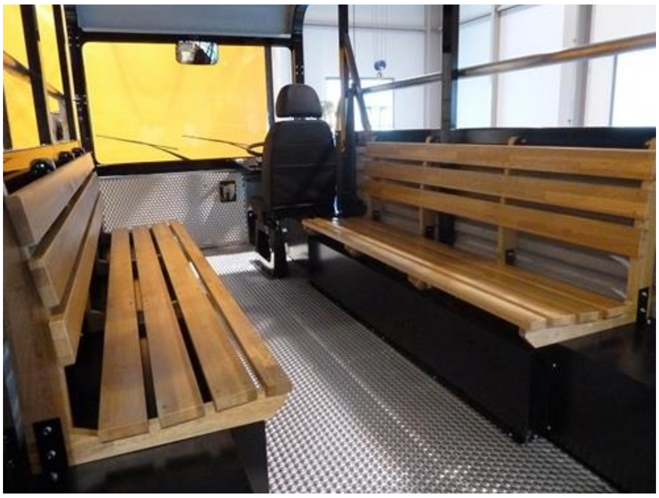

Figure 4 Wooden facing-type bench.

The battery used in LSECB is a 52 V lithium polymer battery with a current capacity of 3.6×10^5 C (100 A·h) and a battery capacity is 18.7 MJ (5.2 kW·h). The battery mass is approximately 50 kg and exchangeable by two persons (see Figure 5). The cruising range of electric vehicles has always been a challenge. Therefore, they are required to be equipped with batteries of as large a capacity as possible. However, the newly developed LSECB does not require a large-capacity battery because its primary application is low-speed driving in a small area. In addition, from the viewpoint of mass reduction, it is also significant to mount a relatively small battery. Therefore, we designed the LSECB batteries so that they can be manually replaced by two people as needed to extend the cruising range.

Figure 5 Exchangeable Li-polymer battery.

Four solar panels are mounted on the roof of the LSECB. The maximum power generation capacity is 0.56 kW, which is a DC-DC converter can automatically recharge to the lithium polymer battery. Figure 6 shows a block diagram of the power system of the LSECB. A 100 V outlet on the household power source is used for the battery charge. The battery is also supplied with power from solar panels mounted on top of the vehicle body and is managed by a battery management system (BMS). During driving, each in-wheel motor is driven by the power supplied by the battery. Signals from the accelerator pedal drive the in-wheel motors, and a motor controller independently controls each motor.

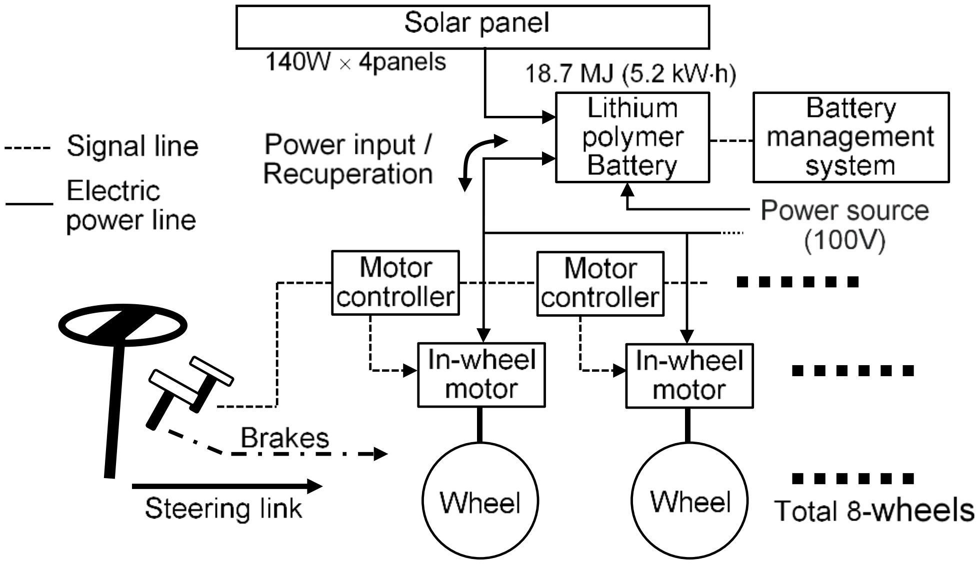

Figure 6 Block diagram of the power management system.

More than 20 companies around Kiryu city were involved in developing the LSECB. And as mentioned above, the design and development of the LSECB involved not only the developing and manufacturing companies, but also many other stakeholders, including universities and local governments. In addition, introducing the LSECB to the actual areas where it will be used requires the understanding the residents. In particular, it is important to build a consensus among residents driving the same route in regular vehicles to accept LSECB travel. Furthermore, to ensure continuous operation in the region, it is necessary to establish an operating company and a sustainable business model. This is a case of co-design and co-development by the local community for the building of sustainable transportation (see Figure 7). The concepts of co-design and co-production are extremely important in the development of various technologies and the implementation of the developed products in society. Research articles are also being published on various cases related to these concepts [42-44]. LSECB reported in this paper is one such example.

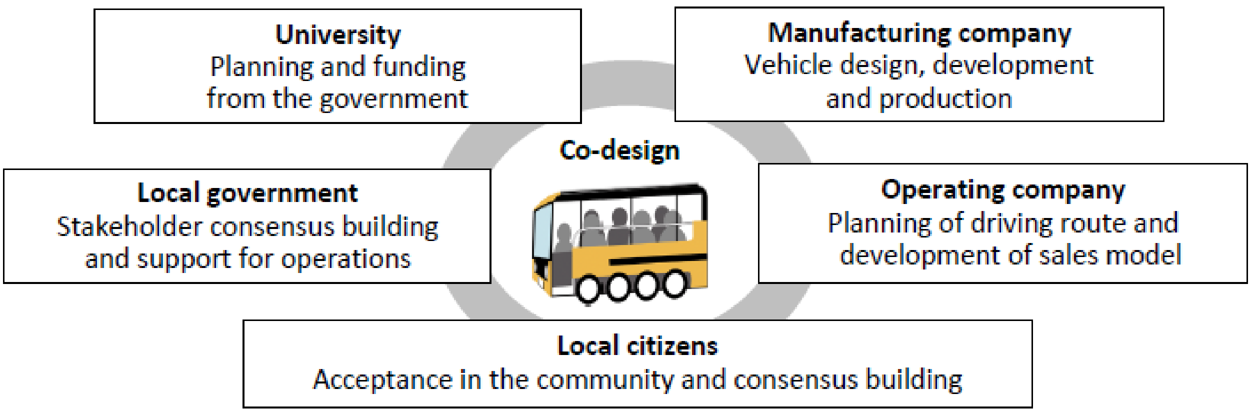

Figure 7 Co-design through the collaboration of various sectors.

2.3 Development of a Driving Method for LSECBs

LSECBs traveling at low speeds on public roads require special driving maneuvers when in mixed traffic with other vehicles. Figure 8 shows an example of a typical driving maneuver (in Japan, vehicles drive on the left side of the road). If there are several general vehicles behind the LSECB, the LSECB stops on the shoulder of the road. This operation avoids congestion and other problems associated with low-speed driving. It is necessary to select a travel route on a road that is wide enough for following vehicles to overtake safely. Such a method is not necessary on low-speed routes with many traffic signals. The body length of the LSECB is approximately 4.5 m. Suppose it is assumed that the body length of the following vehicle is 4 m. In that case, the distance between vehicles is 5 m and the overtaking speed is 5.56 m/s, the distance required for overtaking is 18.5 m, and the time required can be calculated as 3.3 seconds. Therefore, the road must have good visibility so vehicles in the oncoming lane can see sufficiently well.

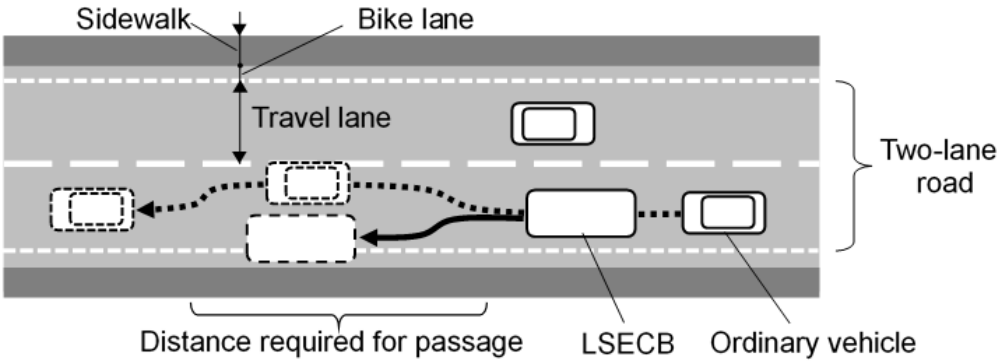

Figure 8 Typical two-lane road and passing pattern of vehicle.

In addition, to prevent traffic problems, it is extremely important that the residents, who use the roads, are fully aware that LSECBs are driving on local roads, and that they accept the introduction of such vehicles. In other words, it is very important to build a consensus among the local government, residents, and operators to introduce such a new mobility system.

2.4 Transportation Planning for Regional Implementation of LSECBs

To develop a sustainable mobility system and implement it in the region, it is necessary to design it with full consideration in transportation planning. In particular, it is important to discuss the population's consensus, the characteristics of the social structure, the time factor to reach the consensus, and the scale of the system to be implemented. In addition, the economic return, social advantage, environmental benefits, and the relationship between user demand and supply must be considered to maintain economic sustainability [28, 45, 46]. In Japan, public transportation use plans are developed by each local government. However, each local government with limited financial resources does not provide sufficient financial support to the companies responsible for public transportation. As a result, public transportation services are reduced or eliminated depending on the business conditions of private companies and leaving many elderly people with limited mobility, known as "people with shopping difficulties," behind [47]. Even if local buses were in regular operation in the community, in many cases, the elderly would be unable to access the bus stop. In this regard, LSECBs, which specialize in short-distance transportation, can be introduced as a transportation system on a scale that allows residents themselves to be involved in its operation. In Kiryu city in Gunma prefecture, where the LSECBs were introduced, the residents have started a plan to support short-distance transportation for the elderly in cooperation with the local social welfare council and town council. In particular, residents are participating in the efforts on a volunteer basis. This system has the potential to reduce the cost of operation. In addition, efforts to constantly increase the number of users are necessary to ensure sustainability. The regional introduction of such a small-scale transportation system is one of the realistic solutions for mobility support in an aging society.

Similarly, introducing LSECBs in tourist areas requires the cooperation of local stakeholders. In particular, local merchants and tourist associations could bear some operating costs, thereby reducing the cost of support from the local government. The collaboration model by local chambers of commerce and industry is also considerable. Introducing easy-to-handling vehicles such as LSECBs and collaboration among multiple stakeholders, including residents, local governments, social welfare councils, local chambers of commerce and industry, and local merchants are extremely important. Additionally, much coordination time is required to coordinate among these numerous stakeholders and build consensus. Finding and creating key people in the community to lead these processes is also important.

The potential limitations of LSECBs should be discussed. The service life of LSECBs is expected to be about ten years. However, compared to conventional vehicles, the travel miles of LSECBs during their service life are very few. Therefore, the service life of LSECBs may be longer. About the energy aspect, since LSECBs can travel 30-40 km on a full charge 18.7 MJ (5.2 kW·h), the ratio of electric power consumption is estimated to be 468 kJ/km to 623 kJ/km. These values are comparable to a normal EV [48, 49]. The LSECBs require about 5.2 kWh of electric power for a typical trip of about 40 km per day. Therefore, a large economic burden on power consumption is expected to be low. Rather, the aging of the drivers or the lack of operators is a major issue in ensuring the system's sustainability. In this regard, it is important to develop a cooperative system for the entire region, as mentioned above.

3. The Spread and Use of the LSECBs to Various Regions in Japan

3.1 SECB Lineup and Specifications

Four types of LSECBs have been developed to date. Table 1 shows the performance characteristics of each LSECB which is given the body name eCOM-(number of the tire), meaning electric community bus. The eCOM-4, eCOM-8^2, and eCOM-10 currently manufactured are all wheelchair-accessible. The eCOM-8^2 is a minor upgrade of the eCOM-8 in terms of design, size, minimum turning radius, etc. Depending on the region in which they are installed, LSECBs of various sizes can be selected depending on the purpose of the use of the local region in which they are introduced. All LSECBs use lithium polymer batteries and can be equipped with solar panels. And the batteries can be replaced manually.

Table 1 SECB lineup and specifications.

Body name	eCOM-8	cCOM-4	eCOM-8^2	cCOM-10
Photos				
Riding capacity	10	7	10	16
Overall length	4405 mm	3630 mm	4295 mm	4995 mm
Overall width	1900 mm	1640 mm	2000 mm	←
Overall height	2450 mm	1995 mm	2425 mm	←
Min. ground clearance	155 mm	150 mm	←	←
Min. turning radius	6200 mm	4000 mm	5000 mm	6000 mm
Tire size code	135/80R13	←	←	←
Vehicle mass	1160 kg	960 kg	1350 kg	2530 kg
Max. speed	Less than 5.56 m/s (20 km/h)	←	←	←
Max. climbing angle	0.26 rad (15 °)	0.16 rad (9 °)	0.23 rad (13 °)	0.21 rad (12 °)
Mileage per charge (Flat, less than 20 km/h)	40 km	50 km	60 km	50 km
Motor type	Brushless DC motor	←	←	←
Number of motors	8	4	8	10
Output power of single motor	1.3 kW	1.8 kW	←	←
Battery type	Lithium polymer battery	←	←	←
Battery capacity	18.7 MJ (5.2 kW·h)	20.9 MJ (5.8 kW·h)	41.4 MJ (11.5 kW·h)	←
Rated voltage	52 V	51 V	51 V	←
Solar panel (Option)	150 W × 4	100 W × 5	100 W × 6	←
Remarks	Currently, not manufactured	-	-	-

3.2 Spread of the LSECBs in Japan

Figure 9 shows a map of the areas where LSECBs have been introduced. Table 2 summarizes the areas where LSECBs are currently deployed and their usage status. In this table, a special type LSECB based on the eCOM-10, which appearance of the body is different, installed in Toshima city, Tokyo prefecture is added. In Kiryu city, Gunma prefecture, where the first LSECB was introduced, the LSECBs are used for many purposes. Social experiments using the LSECBs are currently being conducted in collaboration between the university, local government, and manufacturing companies. The autonomous LSECBs, developed jointly by Gunma University and the manufacturing companies, are used in the university and Oita prefecture.

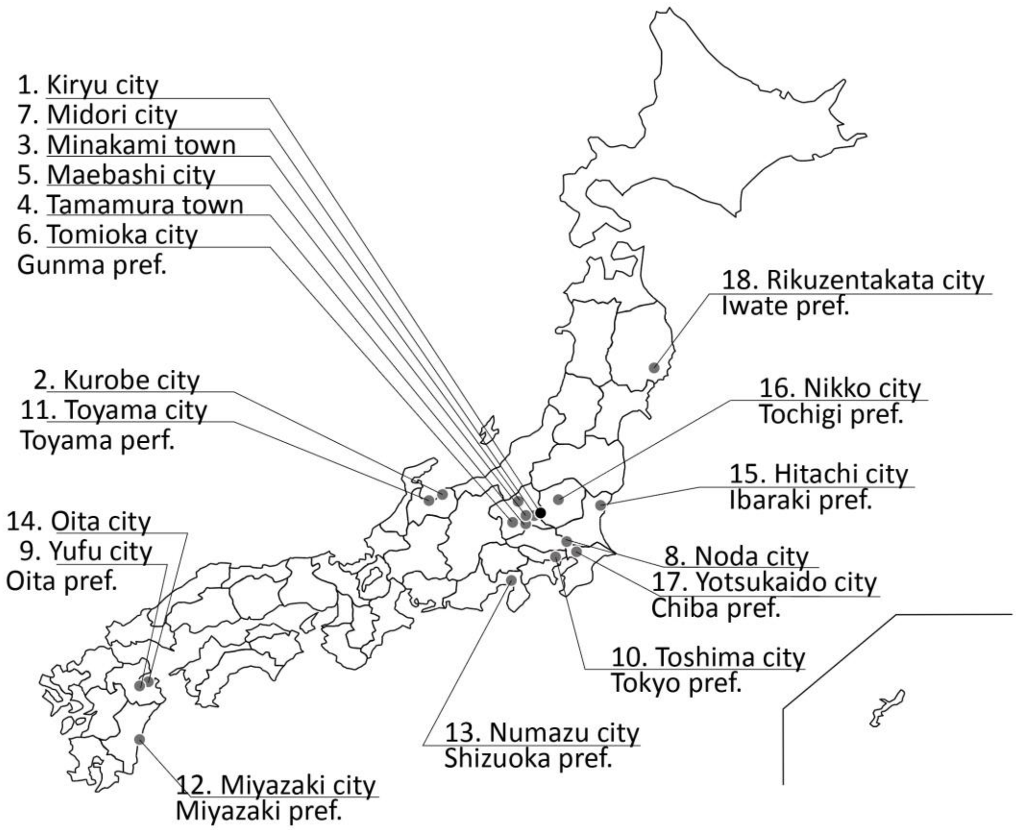

Figure 9 Map of areas where LSECBs have been introduced.

Table 2 Areas where LSECBs have been introduced and their main use.

	Introduced area of LSECBs	Year of first introducing	Body type and number of introductions	Purpose of utilization	Remarks
1	Kiryu city, Gunma pref.	2012	eCOM-8 × 5 eCOM-8^2 × 2 eCOM-4 × 1	Sightseeing use in the historical area, support for community outings, rental to the event, and demonstration tests	A manufacturing company is located in the city.
2	Kurobe city, Toyama perf.	2012	eCOM-8 × 3	Sightseeing use and shuttle service in hot-spring resort	
3	Minakami town, Gunma pref.	2014	eCOM-8 × 2	Sightseeing use of mountain area	

4	Tamamura town, Gunma pref.	2015	eCOM-8 × 1	Utilization at events	
5	Maebashi city, Gunma pref.	2016	eCOM-10 × 1	Research for autonomous driving at Gunma university	Autonomous vehicle
6	Tomioka city, Gunma pref.	2017	eCOM-8 × 1	Sightseeing use in the world heritage area	World heritage “Tomioka silk mill and related sites”
7	Midori city, Gunma pref.	2017	eCOM-8 × 1	Sightseeing use in the city	
8	Noda city, Chiba pref.	2017	eCOM-8 × 2	For transportation to the temple	
9	Yufu city, Oita pref.	2019	eCOM-8^2 × 1	Scheduled service within the city	
10	Toshima city, Tokyo pref.	2019	eCOM-10 type special bus × 10	Sightseeing use in the city	Specially designed bus based on eCOM-10 drivetrain
11	Toyama city, Toyama pref.	2020	eCOM-8^2 × 1	Sightseeing use in the city	
12	Miyazaki city, Miyazaki pref.	2020	eCOM-8^2 × 2	Scheduled service within the city	
13	Numazu city, Shizuoka pref.	2020	eCOM-10 × 1	Scheduled service within the city	
14	Oita city, Oita pref.	2020	eCOM-10 × 3	Scheduled service within the city	2 autonomous vehicles
15	Hitachi city, Ibaraki pref.	2021	eCOM-8^2 × 1	Tours within the theme park	
16	Nikko city, Tochigi pref.	2022	eCOM-8^2 × 1	Sightseeing use in the world heritage area	World heritage “Shrines and temples of Nikko”
17	Yotsukaido city, Ciba pref.	2022	eCOM-4 × 1	Scheduled service within the city	
18	Rikizentakata city, Iwate pref.	2022	eCOM-4 × 2	Scheduled service within the city	

Figure 10 shows the percentage of the usage purposes of LSECBs. The most common use of LSECBs is in tourist areas for sightseeing. The next most common use is for regular service within the city and shopping area. The LSECBs are also used for events, rental businesses, research and development. In sightseeing areas, LSECBs can easily demonstrate their good features, such as seeing the scenery from inside the vehicle at a leisurely pace and engaging in conversation with other passengers. In addition, LSECBs, which do not emit exhaust gas directly, are effective in preserving the environment at tourist attractions and further contribute to making tourist attractions more attractive. The transportation system by LSCEBs is also suitable for events and sightseeing not only within local cities but also in relatively large areas such as tourist ports and port towns [46]. The LSECBs also operate as the scheduled service in areas not served by large local buses. Many of them are used by elderly people who have returned their driver's licenses and people without personal cars for shopping and hospital visits. It is very important to establish a system that enables elderly people to go out to improve their quality of life and revitalize the community. The purpose of conventional public transportation has been to transport many peoples as fast and as far as possible. LSECBs are not just for transporting people; they have the opposite property of transporting a small number of passengers close together at low speeds, but they are also very important, providing new values beyond transportation, such as enjoying conversation, taking in the surrounding scenery, and caring for the environment.

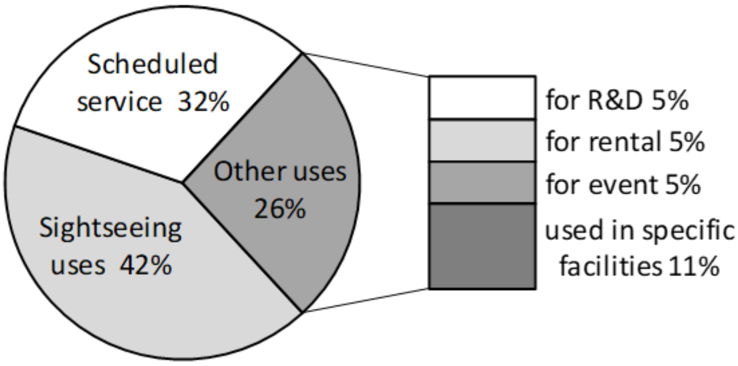

Figure 10 Percentage of various purposes of use.

4. Conclusions

This paper introduces the design concept of the LSECB, which was developed as safe and sustainable mobility. It also showed that the LSECB was developed as a co-design involving the university, local government, residents, and local businesses. And we also stated that for the LSECBs to be accepted in the community, it is important that a consensus building in the community through the co-design process. We also discussed how to operate the LSECBs safely in the region and the road conditions under which the LSECBs can operate. The effectiveness of LSECBs for revitalizing aging communities, tourist areas, and shopping districts was evaluated based on the results of their dissemination to various regions.

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Author Contributions

Kenji Amagai: Solving various issues related to the regional implementation of LSECBs, activities in the region, and compilation and writing of the entire paper. Hiroto Kotake: Solving various issues related to regional implementation of LSECBs, consensus building in the region, ascertainment of significance as the social science of results, and writing of the entire paper. Masahiro Munemura: Vehicle design, development, and manufacture of LSECBs. Sawako Shigeto: Conceptual design of LSECBs, management of LSECBs development projects. Masaaki Horio: Conceptual design of LSECBs, total management of LSECBs development projects.

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Competing Interests

The authors have declared that no competing interests exist.

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