

Article

Transition to Decarbonization-Oriented Urban Planning: Exploring Simplified Estimation Methods for the Emission Reduction Effects of Residential Induction

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Abstract

Urban areas, where diverse human activities take place, generate significant amounts of carbon dioxide. This study proposes a simplified method for estimating the reduction effects of carbon dioxide emissions from passenger transportation resulting from compact city measures, which are expected to contribute to reducing emissions in urban areas. In particular, this study contributes by introducing a distance-band-based estimation framework, enabling scenario-based analysis with reduced data requirements while retaining key spatial characteristics. This method enables planners to quickly assess whether the required CO₂ reduction levels can be achieved under given policy settings, thereby supporting evidence-based policy formulation. As an example of how this method could be applied in the policy formulation stage, it was applied to Toyohashi City, which faces the challenge of car dependency, a common problem in many regional cities. It was demonstrated that the scenario assuming the achievement of the targets for land use and transport measures outlined in municipal plans from 2022 to 2050 could reduce carbon dioxide emissions by over 40%. This research supports integrated consideration of urban and transportation measures at the planning and policy formulation stages, contributing to highlighting pathways toward sustainable urban development aimed at achieving carbon neutrality.

Keywords: carbon neutral; compact city model; land use planning; transport planning; sustainable urban development

1. Introduction

The transition to a carbon-neutral society by 2050 is a common goal of nations and regions worldwide [1]. It is an urgent priority to reduce carbon dioxide, the primary factor causing climate change [2], and to address the climate crisis, which intensifies and expands its impact year by year [3]. Urban areas are sites of diverse human activities and generate significant amounts of carbon dioxide [4]. Therefore, efforts to promote carbon neutrality in urban areas are essential, and the related fields of these efforts are wide-ranging [5]. These efforts include developing measures for constructing low-carbon housing and infrastructures [6,7]; energy policies such as facility development and system creation to promote renewable energy use [8,9]; transportation policies that enhance the efficiency of passenger and logistics flows and encourage a shift to lower-carbon transportation modes [10,11]; and land-use policies to form a compact city model by functionally locating and concentrating urban facilities and residential areas [12].



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The compact city model is expected to reduce carbon dioxide emissions by shortening car travel distances and promoting public transportation use [13,14]. Many countries around the world are paying attention to the compact city model—an environmentally friendly approach that moves away from unplanned, inefficient urban development and enables the efficient use of infrastructure and energy [4]. In Japan as the subject of this study, a compact city model has been promoted. This integrates transportation networks with urban development by concentrating urban functions such as healthcare, welfare, commerce, and residential areas along public transportation corridors and community hubs [15]. A significant number of studies have been conducted within Japan to clarify the impact of the compact city model on reducing carbon dioxide emissions in the transportation sector. Taniguchi et al. and Hirano et al. have analyzed the effects of urban structure and population density on carbon dioxide emissions [16,17]. Morimoto estimated the reduction in carbon dioxide emissions resulting from changes in the number and length of trips per transportation mode under different compact city scenarios [18]. Uchida et al. have estimated the effectiveness of compact city strategies in reducing automobile CO₂ emissions in a rural area by comparing them among medium-to-long-term scenarios, which combined the measures that consolidate living and residential functions to specific areas and promote public transportation usage, to discuss regional structures with low environmental impact [19].

Despite these academic advancements, the practical application of carbon reduction estimation in the formulation and revision of Location Normalization Plans (LNPs), one of the strategies for creating compact city models in Japan, remains underdeveloped [20]. This gap stems from a lack of accessible methodologies with which local planners can quantify and evaluate carbon reduction strategies within the framework of urban planning departments.

On the other hand, some research has focused on developing tools that help local governments and residents to intuitively understand and evaluate the effects of compact city models. This represents an attempt to link academic insights with practical work, such as formulating urban plans. For instance, Nakamichi et al. developed “Pictorial Archive of Japanese Ordinary Residential Zones” by classifying residential areas nationwide into 135 types based on basic information such as population density, land use regulations, and transportation conditions [21]. The archives contain characteristic values for each residential type, including total travel distance per person and mode share by transportation method. Furthermore, it has been proposed that the archives be utilized as a tool for considering policy on compact cities, which aims to reduce the environmental impact of transportation. This enables diverse stakeholders to share a unified vision of the urban structure, irrespective of technical expertise. Additionally, using the values of indicators compiled in the archive facilitates quantitative analysis, including the reduction of automobile fuel consumption. Therefore, it is important to advance research aiming to refine calculation methods for carbon dioxide emissions and develop practical approaches for quantitatively presenting the emissions reduction effect with simplified calculations.

This study aims to propose a method for estimating the effects of reducing carbon dioxide emissions from passenger transportation through promoting compact city models by residential induction (the strategic relocation of residents to designated zones). This method is developed to be practical for local governments, ensuring ease of data gathering, calculation, and result interpretation. This method enables planners to quickly assess whether the required CO₂ reduction levels can be achieved under given policy settings, thereby supporting evidence-based policy formulation. Developing a simplified quantitative evaluation of emissions reduction is expected to contribute to formulating land use plans and public transportation plans considering decarbonization. This study has

developed a methodology capable of estimating the effects of policy measures, with the application to Japanese cities. This methodology could also be applied to cities in other countries facing similar challenges of car dependency and limited data availability, where basic information such as population and area for each region, as well as transportation data including trip generation unit, origin–destination (OD) traffic volumes, and mode share, is available. This approach has the potential to support their efforts toward sustainable urban development and contribute to solving challenges faced by countries and regions that encounter difficulties in quantitatively evaluating CO₂ reduction effects through urban planning, particularly land-use policies, due to severe resource constraints, such as the lack of dedicated staff.

2. Estimation Methods

2.1. Background of Quantitative Evaluation in Japan

Despite aiming to reduce carbon dioxide emissions and achieve zero-carbon cities through compact city models, many Japanese local governments have not conducted verification or discussions based on specific numerical targets [20]. Most local governments evaluating their cities' low-carbon performance in LNP adopt "carbon dioxide emissions from automobiles per citizen" as an indicator. This preference is primarily attributable to the 'Handbook for Evaluating Urban Structure' provided by the Ministry of Land, Infrastructure, Transport and Tourism [22], which features this indicator as a standard reference. As evident from the evaluation criteria of established LNP and the handbook published by the Japanese government, the low-carbon performance of urban areas has been measured by the emissions reduction of transportation resulting from urban structural changes.

Then, in order to understand how the reduction effects of LNP are considered in the transportation sector, we reviewed the Local Government Action Plans for Global Warming Countermeasures (District Measures Edition), which include long-term goals for the transportation sector. The review focuses on 39 local governments in Aichi Prefecture, where the formulation of the plans can be confirmed on the Ministry of the Environment's website, reviewing whether a 2050 reduction target or emissions reduction measures for the transportation sector are included. As a result, only four municipalities have indicated targets for reducing carbon dioxide emissions in the transportation sector, while many local governments aim to achieve carbon neutrality or an 80% reduction from the base year by 2050. Even these four municipalities have not explicitly stated the implementation effects of their compact city initiatives, specifically the reduction effects of transportation-related carbon dioxide emissions, considering land use policies. This highlights the necessity of establishing methodologies to estimate the implementation effects of urban and transportation policies, aiming at decarbonization. Therefore, this study estimates the effects of compact city policies by focusing on carbon dioxide emissions from passenger transportation. It proposes a methodology to verify the synergistic effects of residential induction and transportation policies.

2.2. Estimation Method

The estimation formula for carbon dioxide emissions attributable to passenger transportation is defined as Equations (1)–(3), based on the equations established in the previous study (Figure 1) [23]. The number of trips, trip length, and share of travel are based on the data published as results of the Person Trip Survey (PT Survey).

$$E_i = \sum_k e^k \cdot L_i^k \quad (1)$$

$$L_i^k = \sum_l L_i^{lk} = \sum_l L_{ave_i}^l \cdot S_i^{lk} \cdot T_i^l \quad (2)$$

$$T_i^l = P_i^l \cdot pop_i \cdot a_i \quad (3)$$

E: Carbon Dioxide Emissions from Passenger Transportation [kg-CO₂/day]

e: Carbon Intensity [kg-CO₂/person · km]

L: Total Trip Length [person · km/day]

L_{ave}: Average Trip Length [person · km/trip]

S: Mode Share [%]

T: Number of Trips [trip/day]

P: Distance Band Ratio [%]

pop: Population [person]

a: Trip generation Unit [trip/person · day]

k: Transportation Modes (Trains, Buses, Cars, Two-wheeled vehicles, Walking)

l: Distance Band (Short: ~2 km, Middle: 2~10 km, Long: 10 km~)

i: Small Zone Number

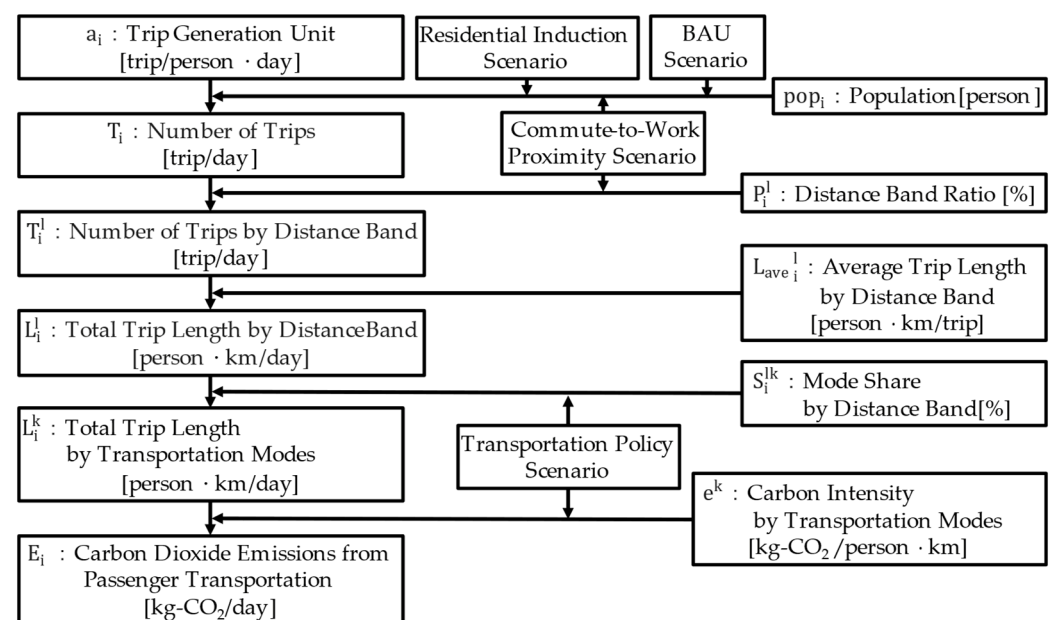


Figure 1. Flowchart for estimating CO₂ emissions in passenger transportation.

- Spatial Unit of the Estimation

This study estimates carbon dioxide emissions from passenger transportation at the small zone level, which is the unit of measurement in the PT Survey of Japan.

- Trip Generation Unit

The trip generation unit is defined as the gross generation unit, which is the total number of trips per day divided by the night-time population.

- Distance Band Ratio

The values representing travel characteristics, such as average trip length and mode share, are provided for each distance range and small zone after stratifying trips by distance range. Distance bands are divided into three groups: short distance (less than 2 km), medium distance (2 km or more but less than 10 km), and long distance (10 km or more).

The trip length used for stratifying trips is the distance connecting the centroid of the small zone for each origin–destination (OD) pair, where the origin is the target city. The

number of trips per OD pair is based on the distributed traffic volume from the PT Survey results. The centroids of the small zones are calculated using the polygon data for these zones from the PT Survey, which is publicly available as Digital National Land Information, and QGIS's centroid calculation function. The centroid distances between small zones are calculated using the latitude and longitude data of the centroids exported from QGIS 3.40 'Bratislava'. In the case of internal trips departing from and arriving within the same zone, the travel distance is set as the radius of a circle with an area equal to the small zone's area, referencing prior research [24]. The areas of small zones are determined using QGIS functions.

Finally, the distance band ratio for each small zone is calculated by dividing the total number of trips within distance band *l* by the total number of trips originating from small zone *i*.

- **Average Trip Length**

For trips originating from zone *i*, the total trip length for each OD pair is calculated by multiplying the trip length by the number of trips. The sum of these total trip lengths is aggregated by distance band to calculate the total trip length per distance band. This total trip length is divided by the total number of trips per distance band to obtain the average trip distance of distance band *l* in zone *i*.

- **Mode Share**

For mode share, it uses the mode share values for OD pairs originating from zone *i*, calculated by distance band.

- **Carbon Intensity**

The carbon intensities for trains, buses, cars (GV), and EVs are shown in Table 1.

Table 1. Carbon intensity of trains, buses and cars.

Transport Mode		Intensity
Trains	Carbon dioxide emissions from operating [kg-CO ₂ /person · km]	0.018
Buses	Carbon dioxide emissions from operating [kg-CO ₂ /person · km]	0.054
Cars	Gasoline	Carbon dioxide emissions from driving [kg-CO ₂ /person · km]
		0.108
		Power consumption for driving [kWh/person · km]
		0.108
Electric	Carbon intensity for electricity [kg-CO ₂ /kWh]	0.61
	Carbon dioxide emissions from driving [kg-CO ₂ /person · km]	0.066

The discharge intensity of GV/EVs varies depending on the number of passengers. The carbon intensities are calculated using the average occupancy rate of 1.29 passengers per vehicle in the Tokai region on weekdays, as reported in the 2021 National Road and Street Traffic Survey.

Two-wheeled vehicles include motorcycles, scooters, and bicycles. Since it is impossible to determine which mode was used, we assume bicycle use and set the intensity to 0. The intensity for walking is also set to 0.

2.3. Concept of Estimation Method

This estimation method enables the expression of regional characteristics at a certain level while keeping calculations and results interpretation easy by considering traffic characteristics for each small zone and distance band.

Mesh units, or administrative district units applying consistent variables across city areas, can be considered as spatial units. However, this method adopts small zone units, which reduces calculation workload compared to mesh units and facilitates interpretation of results, while incorporating the spatial and traffic characteristics of individual regions and transit routes, which could not be addressed by simplified models using standardized indicators across the city. Furthermore, introducing distance band rates enables consideration of differences in mode shares between short-distance and long-distance trips. It also simplifies value calculation compared to estimating per OD pair and mitigates the problem requiring exclusion of data with extremely small sample sizes.

Rather than using origin–destination (OD) based approaches to characterize traffic behavior by OD pair, introducing distance bands allows traffic behavior to be viewed as a characteristic of the origin area, decoupled from the destination. This design reduces the dimensionality of the problem and enables more stable manipulation of travel behavior in scenario analysis without requiring detailed OD matrices. This provides a framework for integrating discussions on transportation policy and land use policy.

This estimation method focuses on capturing regional traffic characteristics through small zones and distance bands, ensuring a practical calculation process. While the model assumes current travel behaviors and does not account for micro-level changes such as shifts in travel trends due to relocation of destination facilities, increases in public transportation usage resulting from improved service levels, or improvements to specific road network improvements, these details are considered outside the scope of our macro-scale strategic evaluation. By simplifying the complex data requirements of traditional models, this approach reduces the computational workload and functions as an accessible tool for urban planners. This allows for cross-departmental decision-making within local governments, enabling planners to quantitatively evaluate the decarbonization potential of land-use policies at the early stages of planning.

2.4. Subject of Estimation

This paper applies a methodology to a city in a case study to estimate the impact of changes in carbon dioxide emissions resulting from population growth or decline, changes in trip numbers due to residential induction, and changes in trip length, mode share, and carbon intensity resulting from transportation policy implementation.

The subject city for applying the estimation method is Toyohashi City (Figure 2). Toyohashi City is located in southeastern Aichi Prefecture, with a population of 364,221 (on September 2025) and an area of 262.05 km². The public transportation network in Toyohashi City is organized radially around Toyohashi Station, with Shinkansen (bullet train), four railway lines, and a tram operating. Furthermore, route buses and community transport services are operated.

Regarding spatial units, Toyohashi City is divided into 15 small zones in PT Survey: small zone numbers 15001–15004, 15101–15106, and 15201–15205. The small zones containing 50% of the residential induction areas designated by LNP of Toyohashi City are defined as residential induction areas in this study and shaded in gray. The distance band ratio and mode share for each small zone, calculated using results from the 6th Chukyo Metropolitan Area Person Trip Survey conducted by Chukyo Metropolitan Area Transportation Planning Council in 2022 [25], are shown in Figures 3 and 4.

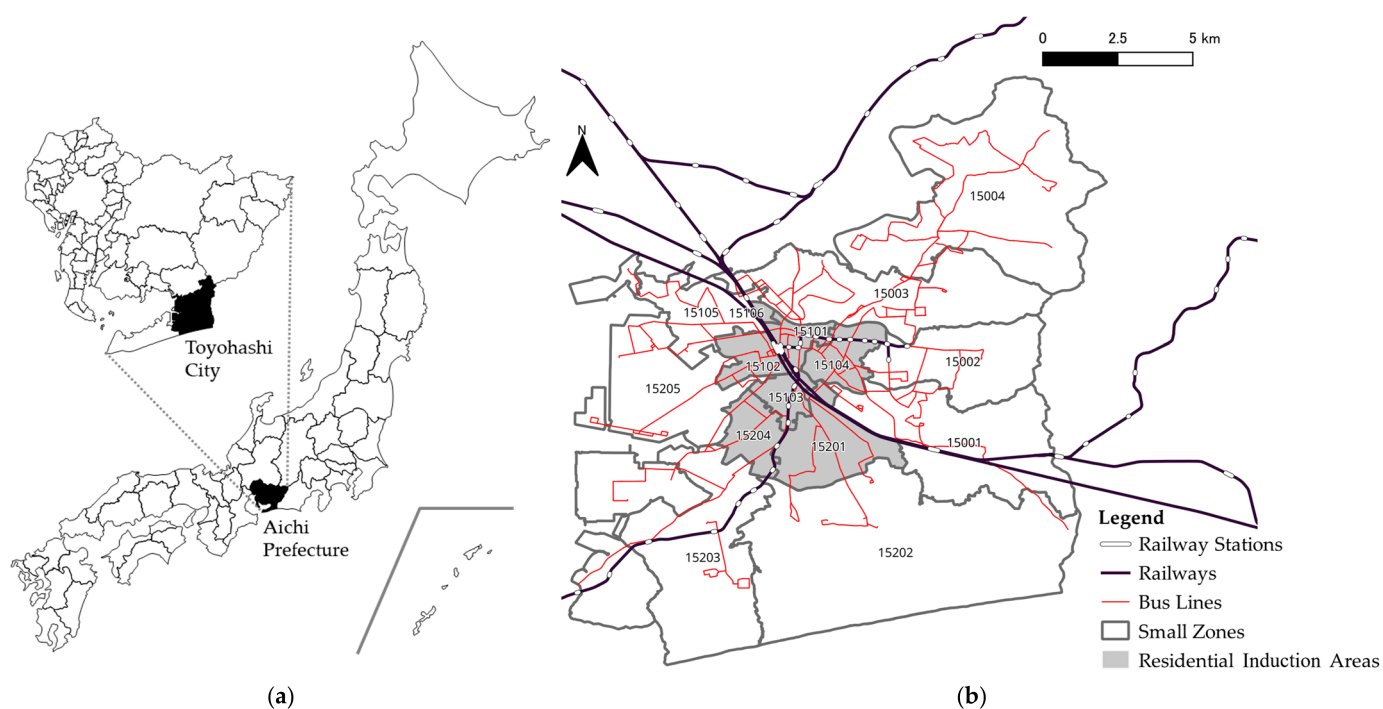


Figure 2. (a) Location of Toyohashi, subject to estimates. (b) An overview map of Toyohashi.

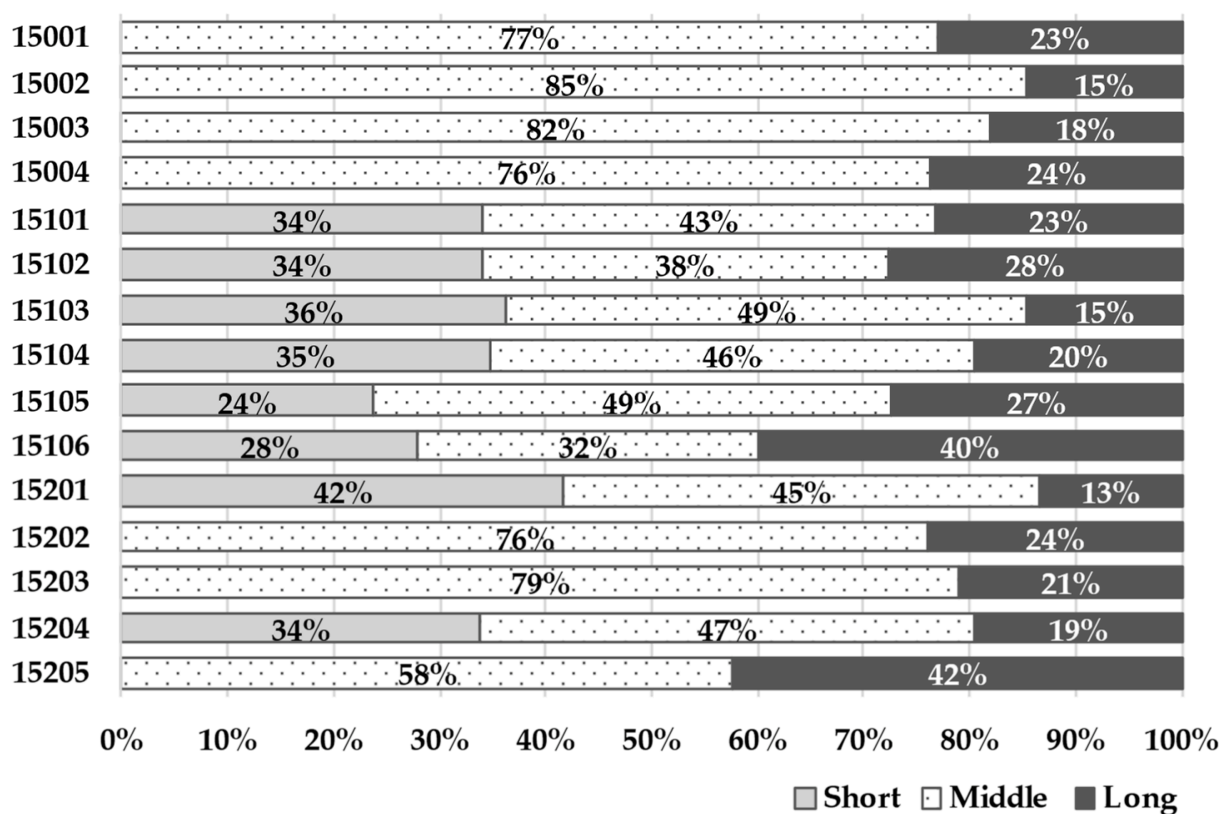


Figure 3. The distance band ratio in Toyohashi.

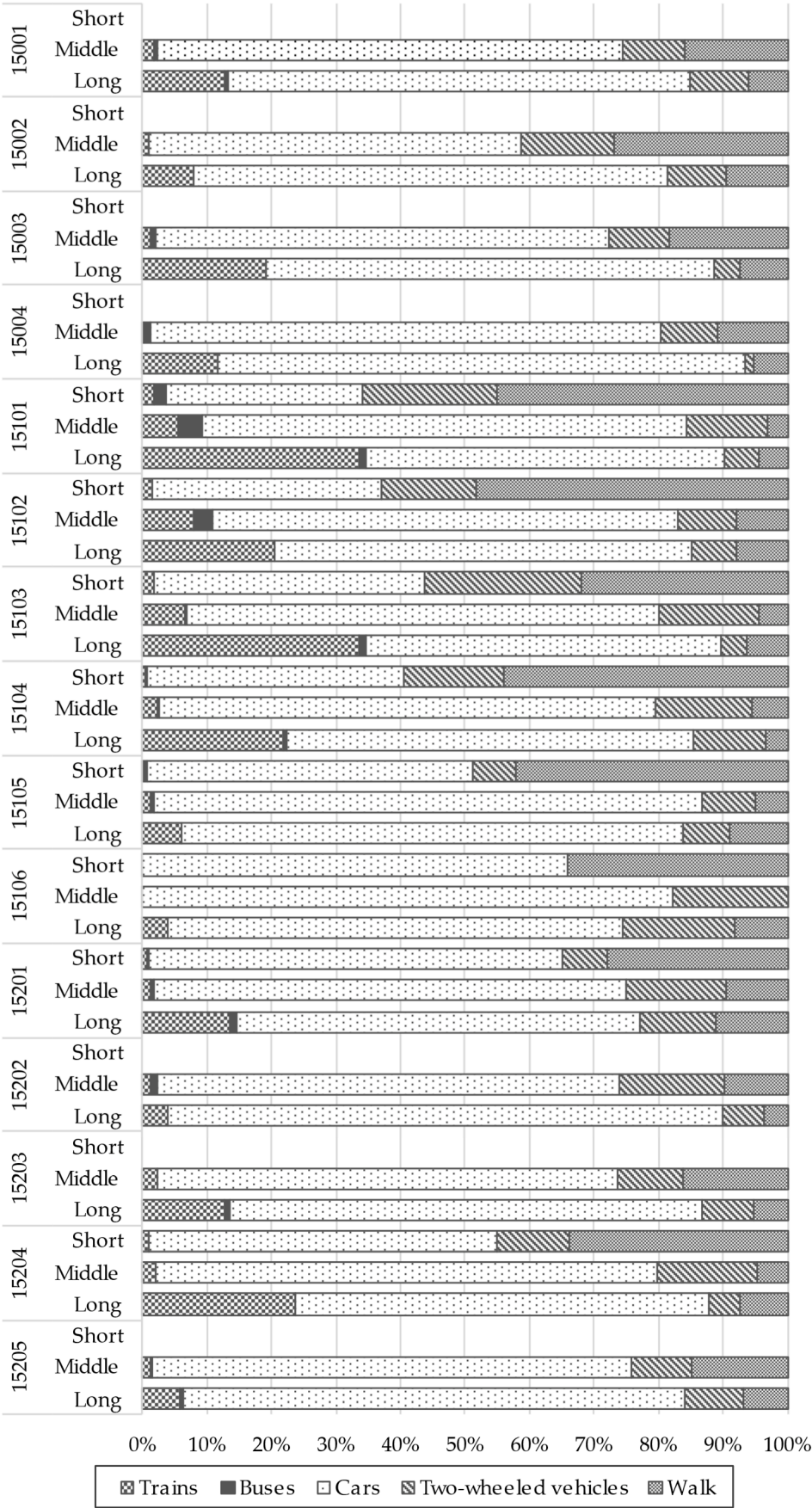


Figure 4. The mode share in Toyohashi.

2.5. Scenario Setting

This method seeks to measure the reduction in carbon dioxide emissions resulting from changes in trip distance distribution and mode share caused by compact city policies. The primary outcomes of compact city models on passenger transportation can be summarized as two main effects: shorter trip lengths and an increase in the mode share of public transportation [17]. The concept of residential induction of LNPs involves concentrating the population in zones with many facilities, potentially serving as destinations and convenient public transportation, i.e., the small zones with short average trip lengths and high rates of public transportation use. The role of the LNPs is to define the scope of residential induction areas for population concentration and indicate the target level of population density.

On the other hand, measures that can change average trip length and mode share are not only compact city initiatives. Even without adopting a compact city model, there are other land-use policies that can shorten commutes by encouraging residents to move closer to their workplaces. Another alternative measure is transportation policies that increase the frequency of public transport operations to improve service levels and raise public transport mode share, and to reduce individual trips reliant on motorized vehicles. Since there are various available approaches, future urban visions and land-use policies should be considered with an estimation and comparison of emissions reduction effects based on differences in urban structure.

To utilize this methodology in the above estimates and comparisons, five scenarios are defined: BAU Scenario, LNP Target Achievement Scenario, Complete Location Induction Scenario, Commute-to-Work Proximity Scenario, and LNP Target plus Transportation Policy Target Achievement Scenario. We estimate carbon dioxide emissions for each scenario in 2050 and compare the reduction rates from the base year of 2022 (Supplementary Data).

- Scenario 1: BAU Scenario

The future population for 2050 is estimated to use the cohort-component method, which multiplies the population data from the 2015 and 2020 national censuses by survival rates and future net migration rates. Calculations used the National Institute for Land and Infrastructure Management's "Future Population and Household Projection Tool V3 (R2 National Census Compatible Version)" [26]. Scenarios 2 through 5 are also reflected in the same population changes as the BAU scenario.

- Scenario 2: LNP Target Achievement Scenario

This scenario assumes that residents outside the residential induction areas will relocate within these areas, achieving the LNP targets by 2050. Toyohashi City's LNP sets a target to concentrate 74% of the city population within the residential induction area. In order to simulate this scenario, populations are first allocated to each small zone based on the population distribution estimated for 2050, ensuring that the total population of the residential induction areas reaches 74% of the city population. Next, the population outside the area is adjusted by reducing it to keep the total number consistent.

- Scenario 3: Complete Location Induction Scenario

This scenario assumes that location induction will proceed more significantly than in the scenario of achieving LNP's targets. The assumption is that all households will rebuild their homes by 2050. This is because the average residential lifespan in Japan is approximately 30 years, and furthermore, the period from the year when the 6th Chukyo Metropolitan Area PT Survey was conducted to the decarbonization target year of 2050 is also approximately 30 years.

Residents outside the residential induction areas relocate to the induction areas when rebuilding their houses, setting an extreme scenario where all citizens live within the induction areas by 2050. This scenario explores the limits of carbon dioxide reduction achievable through location induction.

- Scenario 4: Commute-to-Work Proximity Scenario

This scenario assumes a shift to a commuter-friendly lifestyle by relocating to the small zone where the workplace is located. It seeks to understand the reduction in carbon dioxide emissions when commuting distances are shortened while locations remain dispersed, differing from the urban vision pursued by LNP that concentrates residences in areas with high public transportation accessibility.

It is assumed that each person makes one commute trip per day, equating the number of commute trips in the 6th Chukyo Metropolitan Area PT Survey to the number of commuters. The workplace is located within the destination small zone of the commute trip, and it is assumed that all commuters relocate from their origin small zone to the destination small zone. After the relocation of commuters, their commuting trip lengths are adjusted to be the same as internal trips.

- Scenario 5: LNP Target plus Transportation Policy Target Achievement Scenario

This scenario assumes the achievement of the transport policy targets set by Toyohashi City, in addition to the targets outlined in Scenario 2. The transport policy targets in this scenario are the 2030 targets for promoting public transport and bicycle use, and advancing next-generation vehicles, as outlined in the climate plan in Toyohashi City. Since the 2050 target has not been published, it is assumed that the 2030 target will be achieved by 2050. Toyohashi City has set the goal to maintain its daily public transportation ridership at the 2019 level. This scenario assumes that the number of trips on rail and bus services, which will decline due to population decrease, would be maintained by increasing the mode share. The increased share of rail and bus transport is offset by a corresponding reduction in the share of cars.

Furthermore, Toyohashi City aims to increase the share of bicycle users within urban development zones from the 2019 figure of 4.8% to 7.0% or higher. Therefore, it is assumed that shifting from automobile use to motorcycle use will increase the bicycle mode share by 45.8% from the current level.

In addition, a target of 135,400 next-generation vehicles registered has been established. Since the number of owned vehicles in Toyohashi City remains stable, it is assumed that the current figure of 235,000 vehicles will not change. This means that 57.6% of cars will transition to EVs.

3. Results

Figure 5 shows the reduction rates in passenger transport CO₂ emissions from the base year (2022) to 2050, assuming the changes in residential and transportation behavior outlined in each scenario are in place. Figure 6 shows the results of estimation.

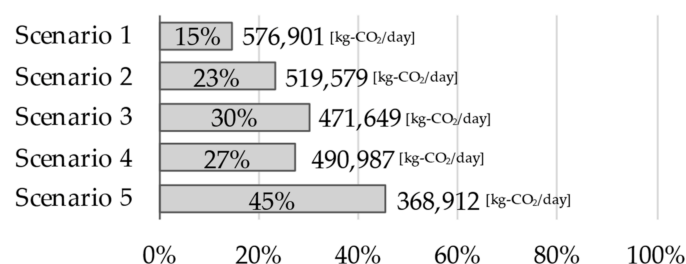


Figure 5. CO₂ reduction rate by 2050 and CO₂ emissions in 2050 under each scenario.

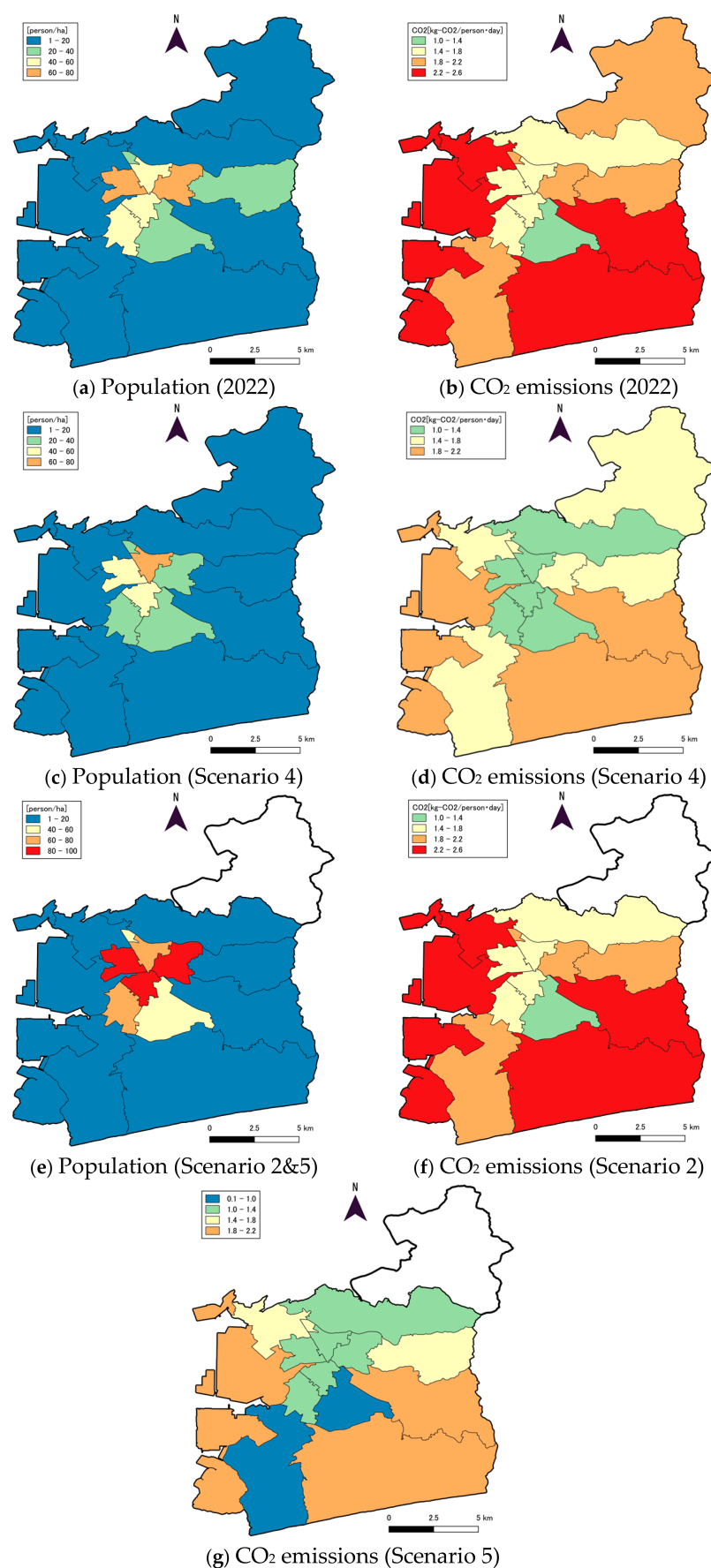


Figure 6. Spatial distribution of population and CO₂ emissions.

In Scenario 1, the population decreased in 12 out of 15 small zones. Since the number of trips decreases proportionally with population, the emissions were reduced by 15% relative to current levels. Scenario 2 achieves an 8% higher reduction effect than Scenario 1. This scenario assumes that residents relocate to areas with convenient public transportation without implementing transport policies, and that their transportation behavior changes at the new location. This can be considered a direct effect of location induction through the formulation of LNPs. Furthermore, Scenario 3 showed a 7% higher reduction effect than Scenario 2. Scenario 4 is the only scenario that assumes changes in trip length, and it is expected to achieve a 12% higher reduction in carbon dioxide emissions compared to Scenario 1.

Scenarios 2 and 3 enable comparison of policy effectiveness based on differences in population density. Scenario 3 is a less realistic scenario, as it assumes that residents outside the residential induction area can relocate within the zone. The actual achievable reduction in carbon dioxide emissions is expected to be lower than the estimated value. However, even with a less probable high population density, the difference in effectiveness compared to Scenario 1 is only 15%. These results can be explained by the fact that even within residential induction areas, there are small zones and distance bands with high mode share for cars. In Scenarios 2 and 3, even when travel shifts from outside to within the residential induction area, car trips do not significantly reduce. Meanwhile, the reduction in commuting distances contributes to the decrease in car trips, leading to greater carbon dioxide reduction effects in Scenario 4. This is because the current share of car usage for commuting trips in Toyohashi City stands at a notable share of 72%. Finally, Scenario 5 was found to reduce emissions by 45% compared to current levels by promoting locational incentives while encouraging a shift to multiple modes of transportation and EVs. The scenario assumes a significant increase in the adoption of EVs, which have about half the carbon intensity of gasoline cars, leading to a significant reduction in emissions. Furthermore, by concentrating on population in residential induction areas where the lower-carbon transportation mode share, including public transport and bicycles, is relatively high, and then increasing the mode share, the synergistic effect of location induction and transport policies led to additional carbon dioxide reductions.

On the other hand, it must also be examined whether these policy goals—such as increasing the bicycle share by nearly 50% by 2050 and shifting nearly 60% of automobiles to electric vehicles—are achievable. Furthermore, achieving decarbonization requires an additional 55% reduction in carbon dioxide emissions by 2050 (compared to current levels). This suggests that more ambitious measures are needed beyond only reducing the car share. However, Toyohashi City has not yet presented a specific roadmap for the period after 2030. By comparing the scenarios, the CO₂ reduction effects of each policy are decomposed. The effects are shown as reduction rates compared to the current level. (i) The reduction effect of population changes is 15% (Scenario 1), (ii) the reduction effects of relocation and induction are 8% (Scenario 2—Scenario 1) and max. 15% (Scenario 3—Scenario 1), and (iii) the reduction effect of modal shift, including the transition to EVs, is 22% (Scenario 5—Scenario 2).

4. Discussion

Previous LNPs were formulated without evaluating whether the measures outlined in the plans could achieve the carbon dioxide reductions required to achieve decarbonization. This study proposed a simplified method for estimating the impact of changes in transport behavior on carbon dioxide emissions through residential induction. It aims to formulate LNPs and transport plans after verifying the emission-reducing effects of compact city promotion measures. This study assessed the application of this methodology to actual

planning and compared the reduction effects on carbon dioxide emissions when implementing locational induction measures with different population densities (Scenarios 2 and 3), locational induction measures that shorten trip lengths to destinations without adopting compact city models (Scenario 4), and compact city measures combining locational induction with transport initiatives (Scenario 5). The results revealed that residential induction policies alone yielded a modest 8% reduction compared to the BAU scenario. However, combining these land-use measures with transport policies significantly increased the mitigation potential to approximately 45% (an additional 22% reduction over Scenario 2). These results confirm that location induction and transport policy, which are expected to reduce carbon dioxide emissions through synergistic effects, require integrated policy formulation and goal setting rather than isolated planning within individual sectors.

This methodology defines the impact of compact city policies on the emissions from transportation as reductions in trip length and increases in the public transit mode share. This model enables the consideration of changes in distance distribution and mode share resulting from policy implementation while simplifying transportation demand forecasting. In order to simplify the analysis, it introduced the idea of considering trip characteristics by distance band rather than origin–destination pairs, adopting a meso-level analysis based on small zones. This allows representation of regional travel characteristics while maintaining ease of calculation and interpretation of results. While the simplified calculations constrain the prediction of dynamic behavioral shifts, they offer a baseline for comparing long-term urban scenarios. Furthermore, even if people relocate to another zone in response to the incentives, they may not always adopt the travel behavior of the zone they move to [27]. It is also necessary to consider methods for developing approaches and setting targets that include the rate of shift in transportation behavior after relocation. Cities are complex systems shaped by the interplay of various factors, including infrastructure costs and urban governance, in addition to environmental impacts. This estimation model is susceptible to the influence of uncertain factors such as changes in human behavior and technological innovation. Therefore, there is a trade-off between adopting simplified estimation methods and improving the accuracy of scenarios, depending on the expected level of change in the modal shift rate or the improvement rate of emissions intensity when evaluating policy effectiveness. A critical challenge for the future is to integrate these predictive scenarios into this methodology and explore ways to achieve the simplicity and accuracy required by planners.

Addressing climate change requires not only reducing carbon dioxide emissions but also considering adaptation measures to counter increasingly severe and frequent abnormal climates [28–30]. It is also emphasized that integrating mitigation and adaptation measures can lead to synergistic effects between both efforts [31]. While this study focuses on mitigation, the proposed methodology can be extended to integrate climate change adaptation strategies. For example, future research could evaluate scenarios that relocate residents from flood-prone peripheries to climate-resilient, low-carbon urban centers. Such an integrated approach would ensure that compact city policies not only achieve decarbonization but also enhance urban resilience against extreme weather events, providing a comprehensive framework for sustainable urban development.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18147162/s1>, Supplementary Data: the data used to apply the proposed estimation method to Toyohashi City and calculate CO₂ emissions are presented here.

Author Contributions: Conceptualization, C.S., H.K., F.X. and R.D.; methodology, C.S., H.K. and F.X.; software, C.S. and F.X.; validation, C.S.; formal analysis, C.S. and F.X.; investigation, C.S.; data curation, C.S.; writing—original draft preparation, C.S.; writing—review and editing, C.S., H.K., F.X.

and R.D.; visualization, C.S.; supervision, H.K.; project administration, C.S.; funding acquisition, C.S. and F.X. All authors have read and agreed to the published version of the manuscript.

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