Disparity of Density in the Age of Mobility

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High mobility has promoted the concentration of people's aggregation in urban areas. As people pursue areas with higher density, gentrification and sprawl become more serious. Disadvantaged people are then pushed out of urban centers. Conversely, as mobility increases, the disadvantaged may also migrate in pursuit of their desired density. As a result, disparities relative to density and housing may shrink. Hence, migration is a complex system.

agent-based model migration disparity of density

1. Introduction

Mobility is a new paradigm that can be used to understand the changing world ^{[1][2]}. The increasing convenience of transportation has changed people's lives. People have enjoyed the development of cars, airplanes, and other modes of transportation, and of railways and roads. Many people now have access to such means of transportation. Hence, people now have the option to live and work wherever they choose and, hence, broaden their social relationships ^{[3][4][5]}. The distinction between work and leisure has become blurred. Owing to the development of tourism, people now travel greater distances with more frequency. Tourism has now become part of some people's jobs and has changed their lifestyles ^{[6][7]}. The spread of information and communication technology (ICT) has also contributed to higher mobility. Owing to smartphones and social networking services, people can stay connected to their distant relatives and friends and obtain the information necessary for them to travel to their desired locations ^{[8][9]}. Social relationships through social networking services are critical not only in migration but also in tourism ^{[10][11][12]}. By contrast, as evidenced by war and environmental refugees, not all people migrate by choice. People need to be aware of the disparity between those who have the privilege to migrate and those who do not. For example, people with health problems and the poor are excluded not only from the use of private vehicles but also from public transport and ICTs. This negatively affects their mobility and, hence, the general well-being of the disadvantaged ^[13].

This research focuses on the concentration of people in urban areas caused by increased mobility. People tend to migrate to or visit urban areas in search of higher income and opportunities for jobs and leisure in both developed and developing countries ^{[14][15][16][17][18][19][20]}. As transportation and ICT become more widespread, concentration in urban areas will likely strengthen. People from a wider range of areas, both domestic and international, are more likely to be attracted to urban areas. However, capital investment in large cities is mainly aimed at attracting large corporations and tourists, and housing development has not caught up. People see gentrification in many urban areas where low-income residents are forced to live in poor housing conditions. In some cases, they are evicted because they cannot afford to live in the area ^{[21][22][23][24][25][26]}. Even if poor residents could live in gentrified areas,

which attract multinational corporations and tourists, inequalities often increase. This is because financial and information workers earn high incomes, while unskilled service workers are placed in low-income situations ^{[27][28]}. The high densities of urban areas also cause problems such as crime ^{[29][30]}. While the wealthy can protect themselves from such risks by, for instance, living in condominiums, the poor have to endure not only poor living conditions but also deteriorating public safety. People with low incomes, illnesses, disabilities, or limited access to ICTs are forced into situations of poverty, isolation, and other disadvantages in urban areas built on the premise of high mobility. Even if the poor may reside in urban areas, stores and public transportation are less available in areas with high concentrations of poor people, making their lives more difficult ^{[31][32][33]}. Further globalization may lead to super-gentrification, wherein not only the poor but also the middle class will find living in urban areas difficult ^{[34][35]}. With justice in mind after COVID-19, disparities in urban areas should be corrected ^[36].

The rise in mobility does not only result in migration to urban areas. Migrations from urban to rural areas have also become easier. Owing to the natural beauty of rural areas, rural tourism remains popular. People are increasingly becoming attracted to such nature-rich rural areas. Owing to the blurring of the boundaries between tourism and migration, lifestyle migrants, who seek a more relaxed life in rural areas, may increase ^{[37][38][39]}. In the past, only global elites could freely select multiple areas for their residence and their jobs ^{[40][41]}. However, now, the number of digital nomads—people who work and live while traveling the globe—is increasing ^{[42][43]}. However, this way of life is not open to all people, and there may be disparities in peoples' options to move to rural areas.

In summary, the push factor for migration is the cost of living associated with high density, and the pull factor is the density that people seek. Different people have different tolerance for density costs and different opinions about density, so the problem becomes a complex system. Furthermore, the migration of people, the resulting changes in density, and the disparities found therein are complex systems that interact with each other. Hence, these systems are difficult to understand intuitively. Responding to these issues, this researach considers the relationship between mobility, density, and disparity using an agent-based model (ABM).

2. Disparity of Density in the Age of Mobility Using an Agent-Based Model

Many ABMs that tackle migration have been developed. These ABMs assume that agents seek economic opportunity or income. Agents are expected to gather in urban areas, where economic opportunities and incomes are more available ^{[44][45][46][47]}. This concentration of people in urban areas results in higher living costs (e.g., rent), which is associated with higher density. This may result in reinforced disparities in a residential location. Wealthier people can tolerate higher densities, while the poor are typically evicted to the periphery ^{[48][49]}.

When people migrate, they do not necessarily do so to maximize economic opportunities. Some people move to a new area owing to certain features of the living environment (e.g., neighborhood, amenities, and level of public safety). People migrate to areas where they can walk or cycle to work, enjoy rich natural environments while doing the work they want, or raise their children comfortably. Some people aim to move to environments that were considered inferior but would allow them to meet a more diverse range of neighbors. Hence, ABMs that assume

that people migrate based on preferences other than economic opportunity have also been developed. The models assume that agents make migration decisions based on their potential neighbors, ethnicities, jobs, or incomes. Moreover, agents are assumed to migrate based on other factors (e.g., housing prices, available transportation, commuting time to offices, and the potential networks available) ^{[50][51][52][53][54][55][56][57]}.

Types of preferred living environments should vary among people. Population density can be considered an indicator that influences living conditions, including economic opportunities. Generally, in higher-density areas, residents are more likely to gain higher incomes, but they also incur higher living costs. In lower-density areas, residents often enjoy living environments of natural beauty. Different people have different ideas about the type of density they are looking for. People could be assumed to seek their ideal population density. Their opinions about density will change in their interactions with others and with the environment. Some people seek to maximize economic opportunities, while others value other aspects of the living environment. Disparities among people may affect the differences in preference. As a result, one would expect self-organized changes in density and opinion, and disparity among people. Density would change dynamically as people migrate through a change in their opinions.

In this regard, people focus on the opinion formation model as a kind of ABM. The model assumes each agent has its own opinion and that this opinion changes in a bottom-up manner owing to interactions with other agents. Agents' opinions are represented by continuous variables. Agents change their opinions minutely through interactions with other agents. The model assumes that if the distance between their own opinion and that of the other agent is within a certain threshold, the opinion will move closer to the latter. If it is away from the threshold, the opinion will not change or, for instance, will contrast with that of the other agent. Depending on the assumptions, different outcomes have been predicted. These include cases wherein the opinions of all agents converge to one, wherein several opinions are juxtaposed, and wherein extreme opinions or polarizations emerge [58][59][60][61][62][63][64][65][66].

Few studies have explored the migration of agents as an effect of their opinions. Gracia-Lazaro et al. ^[67] created an ABM wherein agents change their tolerance threshold for migration depending on their interaction with other agents, assuming that agents leave when they are surrounded by neighbors whose opinions are different from theirs. Cai et al. ^[68] constructed an ABM wherein agents decide to migrate between urban and rural areas not only because of economic opportunities but also owing to the influence of other agents tied to the social network. In some social networks, the number of agents moving between the city and the countryside becomes too large. Alraddadi et al. ^[69] found that if agents become spatially closer to and distant from agents with similar and different opinions, respectively, then more opinion clusters emerge.

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