An extended abstract (1,200-2,000 words in English)

■ Study objectives

The population of Japan has been declining since 2004 and the average age of the population is expected to become increasingly older. Consequently, the number of people aged 15 years and younger and the working-age population (aged 15 to 64 years) is expected to decline. Therefore, the formation of sustainable local communities is required in each region, and ensuring the sustainable provision of administrative services to support these communities is an important issue.

In this study, we consider the issue of one of these administrative services—emergency services provided by fire departments. The number of emergency calls in Japan has been increasing every year , and has about 1.94 times in the past 24 years (from 3.93 million calls in 1999 to 7.64 million calls in 2023), while the population has been decreasing. Moreover, the travel time from the fire station to the location requested by the ambulance has about 1.66 times in the past 21 years (from 6.2 minutes in 2001 to 10.3 minutes in 2022), and the travel time required to arrive at the hospital has about 1.65 times in the past 21 years (from 28.5 minutes in 2001 to 47.2 minutes in 2022), so the burden of emergency transport operations has increased significantly in recent years.

Emergency services must continue to fulfill their responsibility to protect the lives, health, and property of residents by promptly responding to changes in the environment affecting emergency services, such as the diversification and scale of disasters and accidents, the increasing complexity of urban structures, and the diversification of residents' needs. In this context, the following challenges arise: how to respond to the rapid increase in the number of emergency calls; how to ensure the level of residents' services, such as emergency transport, considering the limited number of personnel, facilities, equipment, and vehicles, and the severe financial situation in the case of multiple fire stations. This is important from the viewpoint of risk diversification and as well as to maintain the motivation of those who are engaged in the work.

■ Contributions of the paper

Shortening the travel time from the fire station to the location requested by the ambulance and required to arrive at the hospital not only reduces the burden of EMS transport operations, but also generates social benefits such as an increase in the lifesaving rate. In order to solve these various challenges, we think that it is very important to first quantify and demonstrate the burden of work undertaken by the fire departments. A qualitative discussion will tend to follow the existing policies, which will increase the possibility that discussions on the reorganization and integration of fire stations will not proceed. Moreover, in the case of multiple fire stations, it is important to think quantitatively about how to balance and distribute the work. This is important from the viewpoint of risk diversification and as well as to maintain the motivation of those who are engaged in the work. In

addition, it will provide very meaningful basic data for making policy decisions related to the reorganization and integration of fire stations.

■ Methods and data used

Based on this background, the purpose of this study is to quantitatively discuss the following topics, focusing on the Kochi City Fire Department, which includes one city -Kochi city- in Kochi prefecture in Japan.

Firstly, we constructed a system to calculate the travel time from the fire station to an emergency request located on a road network in Kochi City. The number of the links including a road network is 112,451, the number of nodes is 105,531.

Next, from the emergency transport operations occurred the Kochi City Fire Department in 2022. the ambulance travel log data are extracted. The number of emergency transports used in this analysis is 19,032. The number of ambulance travel log data used in this analysis is about 1.3 million data, including the latitude and longitude of the vehicle's current location, speed, direction, time and the ambulance status code. (ex. A) running from the fire station to the location requested by the ambulance, staying the location requested by the ambulance, B) running from the location requested by the ambulance to arrive at the hospital, and C) running from the hospital to the fire station) By matching these data, the location requested by the ambulance is identified. By using these constructed calculation systems, we can calculate which fire station is the closest to an ambulance request in Kochi City.

So, the total arrival time and the number of emergency transports for the Kochi City Fire Department (four stations, one branch station, and three sub-branch stations) can be quantitatively evaluated under the ideal situation in which 100% of the nearest emergency response teams can arrive at all locations requested by the ambulance. This means that changes in total arrival time and the number of emergency transports can also be quantitatively evaluated when the location of fire stations changes due to reorganization or consolidation of fire stations.

Ideally, the closest fire station would respond to all ambulance requests in Kochi City. However, it could be the case that there is a request for emergency transport in a large city in Kochi City and another emergency team is forced to provide this transport if the nearest emergency team is unable to respond. In this study, we defined this situation as "supporting emergency transport" and the ratio of the number of supporting emergency transports to the total number of emergency transports as the "supporting emergency transport ratio". We calculated the "supporting emergency transport ratio" in Kochi City Fire Department and it is possible to quantitatively grasp the disparity in the burden on fire departments. This can be used as an indicator to quantitatively consider how to distribute the workload in a well-balanced manner.

In this study, total transport time per fire station, firefighting unit, and time zone is calculated. The transport time is the sum of time running from the fire station to the location requested by the ambulance, time staying the location requested by the ambulance and time running from the location requested by the ambulance to arrive at the hospital and is an indicator of the workload of emergency transport. We summarize the issues that each station faces regarding workload, and propose measures to improve the assignment of units. The final goal is to study the optimization of EMS operations for the entire Kochi City Fire Department using quantitative indicators by comprehensively simulating the effects of station consolidation, relocation, and unit assignments.

■ Results and conclusions

Among the eight stations (four main stations, one branch station, and three sub-stations) in the Kochi City Fire Department, it was the Minami Main Station that presented the over-workload. The total transport time per firefighting unit was 86,044 minutes. The value is the highest among all firefighting units, especially between 9:00 and 21:00. Furthermore, the location of the Minami Main Station, which covers a wide area and is separated from other stations, made it difficult to improve the situation by reorganizing the stations. Furthermore, the arrival time at the hospital is longest among all firefighting units in all time zones, and it was possible to decreasing the workload per unit by working two firefighting units between 9:00 and 21:00.