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Topics: Strategic management of evidence-based health and medical care policy: How to use new Digital Big Data in health care system

<Review>

Accessibility to medical care in case of major disasters

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Abstract

When the 2011 Tohoku Earthquake occurred in Japan, the term *unforeseen* was often used to describe the scale of the disaster. As symbolized by this, it has become evident that the accumulated plans based on the concepts of risk management, including disaster prevention, disaster reduction, and disaster preparation, were not sufficient to prepare for major disasters. Therefore, reconsidering these issues from the viewpoint of crisis management will surely become very significant in the future.

As is well known, the accessibility to various local facilities decreases in the event of a disaster, and the degree increases as the scale of the disaster becomes larger. Furthermore, the limited supply of a service can easily cause a situation in which not all consumers can receive the service. Especially for local facilities, where high demand rises in cases of emergency, it is important to consider the scale of its impact and have ways to assess the degree of change and locations. Medical service is one of the services that will incur increased demand in the event of an emergency such as a disaster. Therefore, realistically speaking, the "availability" of facilities, which means the change in accessibility to medical facilities as well as the possibility of receiving medical service in the event of a disaster, will be very significant issues.

In this paper, changes in accessibility are examined with a focus on access to medical facilities in the event of a disaster. Also, based on the actual condition that most emergency transportation for injured and ill people in the event of a disaster is by general-purpose car, ideal transportation behavior is discussed. Specifically, with the advanced emergency medical care facilities in the disaster area of Miyagi Prefecture as a target, the change in accessibility before and after the earthquake is analyzed, while the capacity of these facilities is assumed to analyze the accessibility to available facilities when a simultaneous outbreak of injured and ill people occurs. For the analysis, accessibility is substituted by road distance; the Geographic Information System (GIS) is used to measure road distance.

The result of analysis showed that the average travel distance to advanced emergency medical facilities after the earthquake increased by 12% in all of Miyagi Prefecture after the earthquake. Also, it indicated that following a guided plan could lead to reducing the travel distance by 30% in comparison to search type behavior.

keywords: disaster, emergency transportation, accessibility, network distance, GIS, Miyagi

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I. Introduction

Earthquakes are well known in Japan. As many seismic disasters happened in the past, including the Great Hanshin-Awaji Earthquake of 1995, the Mid-Niigata Prefecture Earthquake of 2004, and the Tohoku Earthquake of 2011, there is a constant demand for plans with risk management concepts such as disaster protection, disaster reduction, and disaster preparation.

However, due to unpredictability of disasters, dealing with disasters only with the concept of risk management is not possible. Therefore, the management concept in the event of a disaster, which is the idea of crisis management, becomes important.

As we know, accessibility to various local facilities decreases in the event of a disaster. As the scale of a disaster becomes larger, its impact on accessibility increases. Especially regarding local facilities where high demand rises in the event of an emergency, it is important to have ways to predict and assess the degree and location of changes while taking the degree of impact into account. Also, limited supply can easily cause a situation in which not all consumers can receive the service. Therefore, it is also important to prepare ways to predict and assess such a situation.

Medical service is one of the services that will have increased demand in the event of an emergency such as a disaster. Therefore, realistically speaking, along with the possibility of receiving medical service, the change in accessibility to medical facilities in the event of a disaster is also another very significant issue. Based on these factors, discussing crisis management from a viewpoint of accessibility is considered to contribute to creating a response plan for expected major disasters in the future.

There are a wide range of existing research papers that discuss medical service from the viewpoint of accessibility and earthquakes, such as a study evaluating accessibility to medical service in ordinary times, a study investigating behavior characteristics of injured and ill people in ambulance placement during a disaster, and also a study on simulation model building based on those. For example, Satoh [1] conducted an evaluation analysis of the relationship between medical facilities and users by spatial accessibility, which is road distance, based on the recognition that guaranteeing access to medical facilities within a constant level of spatial and time distance is important in building a sustainable health care system. Based on understanding the significance of utilizing expressways in improving accessibility from the scene of injury or illness to medical facilities, Orita et al [2]. analyzed ideal expressway construction and improvement from the viewpoint of emergency transportation. Among the study cases investigating the behavior characteristics of injured and ill people, Sugimoto [3] and Ukai et al [4]. pointed out the characteristics of injured and ill people as having a tendency to rush to nearby medical facilities instead of going to ones at somewhat greater distance. Also, while taking such behavior characteristics of injured and ill people into account, Koike et al [5]. focused on the transportation system in the event of a disaster and proposed a method to predict the number of injured and ill people visiting each medical facility. Utilizing information and a chain-of-command structure that set regulations for treating injured and ill people as the key factors to smoothly operate an emergency medical transportation system, Baba et al [6]. developed a simulation model of an emergency medical transportation system that corresponds to a widespread disaster.

However, even though these studies were reviewed, there are still only a few that assume and consider a behavior scenario based on the transportation behavior characteristics of injured and ill people. As pointed out by Nakano et al [7]. and Kosaka [8], specifically, considering the high ratio of using general-purpose cars for transporting injured and ill people in the event of a disaster, it is relevant to conduct accessibility evaluation based on a transportation behavior scenario that takes such a fact into account. Therefore, while learning about the circumstances of a major disaster from past cases such as the Tohoku Earthquake, this study emphasizes the significance of proposing a new management method for transportation behavior. Also, the results of analysis of accessibility changes before and after the earthquake are shown, and a method to improve efficiency in transporting injured and ill people is proposed. Understanding accessibility changes in the damaged area is considered to be a helpful record for support and recovery of other areas that face disasters in the future, thus contributing to the discussion of crisis management. Moreover, through focusing on a shortage of supply in goods and service that becomes a big problem in the event of a disaster, proposing an analysis method for the availability of medical service and accessibility to available medical facilities will also contribute to further developing the crisis management discussion.

II. Accessibility change before and after the Tohoku Earthquake

Still vivid in most people's memories, serious damage was caused by tsunami in the Tohoku Earthquake. On March 11, 2011, a major earthquake of magnitude 9.0 hit eastern Japan and brought widespread damage to the coastal Tohoku and Kanto region. With its tremendous power, the tsunami swept away every kind of building, including houses. Regarding medical facilities, which experience a sharp increase in demand in the event of a natural disaster, many in the area were shut down due to the damage caused by the earthquake and tsunami. As a result, it created major problems for injured and ill people to receive medical care.

Miyagi Prefecture, the target area of this study, is one of the major disaster areas affected by the Tohoku Earthquake. Examining to the coastal region hit by the tsunami, the geographical feature of the northern part is ria coastline that stretches south from Iwate Prefecture; part of Kesennuma City, Minamisanriku Town, and Ishinomaki City are in the indented landform. Urban areas in such a landform tend to experience decreased accessibility after a disaster.

The southern part of the coastal region is made up of the Sendai Plain. Since there is nothing separating the Pacific Ocean and the urban area, the tsunami hit a wide range of coastal areas of Sendai City, Natori City, and Iwanuma City. As in the northern coastal region, many medical facilities in these areas were shut down. However, considering the possibility of replacing them with the medical facilities in the areas that escaped damage from the tsunami after the earthquake, we can imagine that the decrease in accessibility was not as serious as in the northern coastal region.

Factors that have a major impact on the change of accessibility before and after the earthquake are: (1) damaged traffic network, (2) loss of facilities, and (3) movement and change of population. Regarding (1), many areas had roads restored in the early stage, thus the impact was minimized. On the other hand, for (2) and (3), the dramatic changes in these factors are considered to have a great impact on the change in accessibility.

Also, in this study, the definition of “before the earthquake” is March 10, 2011, and “after the earthquake” is March 11, 2012.

1. Method of measuring accessibility

In this section, accessibility to advanced emergency medical facilities before and after the earthquake in Miyagi Prefecture is observed. To conduct the analysis, accessibility is represented by road distance. As pointed out by Satoh [1], it is generally ideal to evaluate accessibility to medical facilities by time distance. This is based on the viewpoint that there is spatial distance between the origin of demand and supply, which is between the location of injury or illness and the medical facility, and thus streets are used as the main mode of transportation for emergency medical care. Therefore, from this viewpoint, a road distance is used for the analysis in this paper.

Many of the advanced emergency medical facilities in Miyagi Prefecture are designated emergency hospitals. Because some of them participate on a rotating schedule, in the analysis it is necessary to take into account that the hospital in service changes every day. However, it should not be a problem to assume that all facilities will be operating in the event of a disaster. This study especially places emphasis on accessibility evaluation in the event of a major disaster, and thus it is assumed that all the facilities are in service. Although there were 75 advanced emergency medical facilities before the earthquake in Miyagi Prefecture, now there are 71 facilities, as 4 of them were shut down after the earthquake.

The population in demand is assumed as follows. First, for the basic population data, the half grid regional square, with the length of each side about 500 m, in the national population census, provided by the Ministry of Internal Affairs and Communications Statistics Bureau, is used for the population before the earthquake. For the data after the earthquake, the population of the area flooded by the tsunami is set as 0 for descriptive purposes while making a correction reflecting the number of residents in temporary housing. Also, within each grid, the location of representative points in each grid as the site of injury or illness is corrected by referring to the visible outline of buildings provided by the Geospatial Information Authority of Japan.

For the road network, the numerical map 25000 from the year 2002 was modified to create the original road network data in the target analysis period of March 10, 2011 and March 11, 2012.

Based on these data, road distance was measured with GIS, and the results were used to evaluate accessibility.

2. Results

The map of network distance before and after the earthquake is shown in figures 1 and 2. Naturally, areas close to the hospitals have a short distance for accessibility, while the accessibility decreases in areas far from the hospitals. The equidistance line is not in a simple circular form due to the drawing of the equidistance line by the road network. The polygon drawn at 5 km equidistant of the hospitals on the Oshika Peninsula in Ishinomaki City and the northwest edge of Miyagi Prefecture is more deformed and punctured than the one for hospitals around Sendai City. This is caused by the difference in maintenance conditions of the road network in these areas. Especially on the peninsula, areas with indentation and mountainous areas tend to have a higher detour ratio, indicated by the proportion of road distance to direct distance, thus accessibility evaluation by road distance becomes more significant.

A comparison of accessibility before and after the earthquake reflects the considerable impact of the shutdown of two facilities, the City of Ishinomaki Ogatsu Hospital and Shizugawa Public Hospital, in the coastal region in the north of Ishinomaki City. The urban areas in this region are especially scattered due to the topographical constraint of ria coasts, and thus there is a decrease in accessibility caused by the shutdown of one facility that

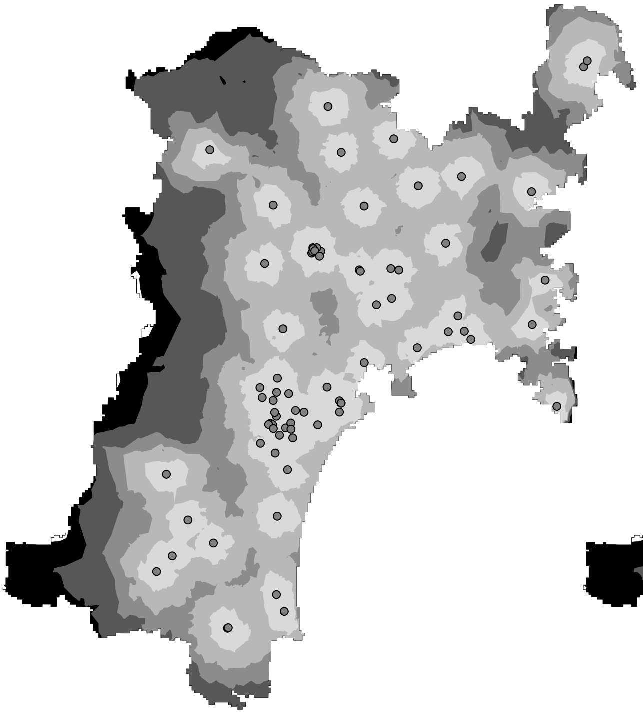


Figure 1

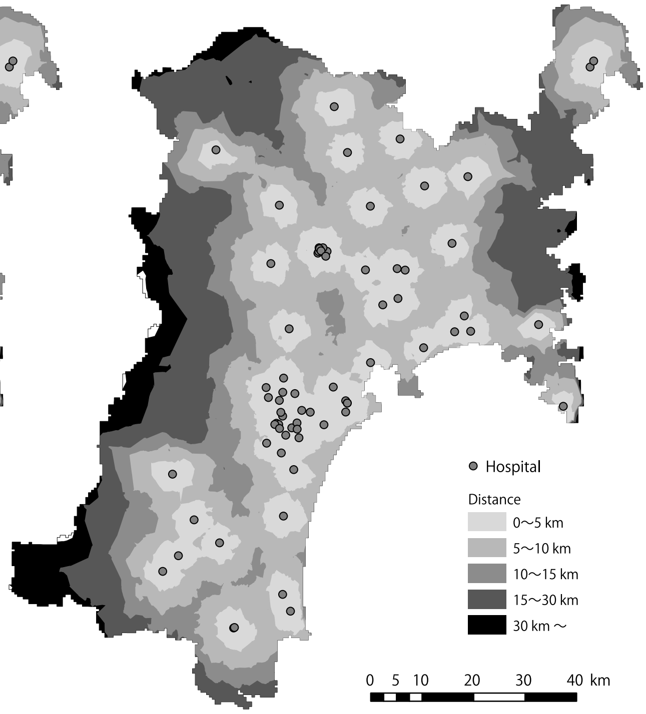
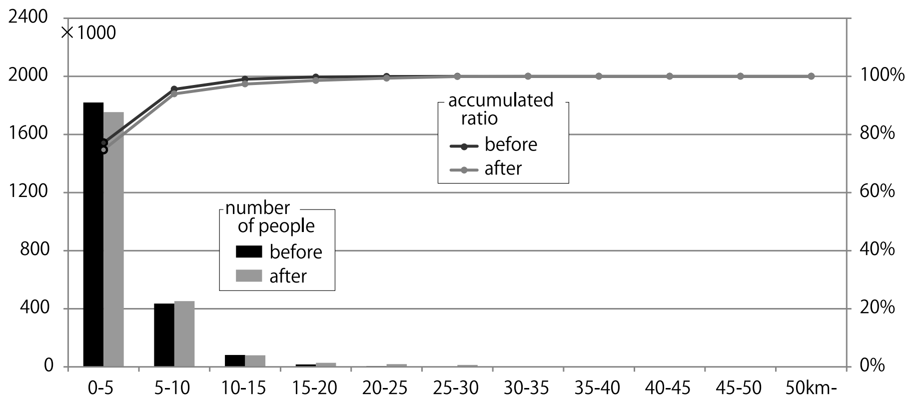


Figure 2



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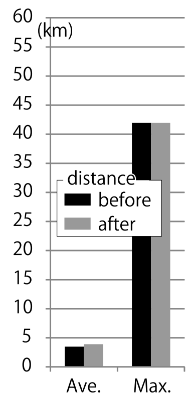


Figure 4

affects a large area. Although the City of Ishinomaki Hospital, which used to be in a location overlooking Ishinomaki Bay, has also been shut down due to damage by the tsunami, the impact of decreased accessibility in this area can be considered small since the neighborhood hospitals have been recovered.

A population histogram by distance zone is observed (see fig. 3). Before the earthquake, the number of people that had access to the advanced emergency medical facilities within 5 km was 1.82 million, or 77.1% of the total population. After the earthquake, it was reduced by 67,000 people to 1.753 million, or 74.7% of the total population. Between 5 km and 10 km, the number of people with access was about 435,000 (about 18%) before the earthquake, and about 453,000 (about 19%) after the earthquake.

Over 10 km, the number was 105,000 people (about 4.5%) before the earthquake, and 142,000 people (about 6.0%) after the earthquake. Over 30 km, the number was 560 people (0.02%) before the earthquake, and 2,459 people (0.10%) after the earthquake.

In general, the population histogram by distance zone showed a decrease in accessibility despite the small amount of change.

The average distance and the maximum distance are shown in figure 4. Before the earthquake, the average distance was 3.5 km, but it increased by 12% to 3.9 km after the earthquake. The maximum distance was 41.9 km for both, and this did not change. The decrease in accessibility was evident from the change in average distance.

3. Discussion

Multiple factors such as the change in population after the earthquake, the decrease in hospitals due to earthquake damage, and the missing road network contribute to the result of an over 10% increase in the average distance after the earthquake. However, a comparison of network distance maps before and after the earthquake from figures 1 and 2 shows an obvious increase in the traveling distance around the medical facilities that were shut down. Therefore, it can be said that a decrease in the number of medical facilities is a major cause of decreased accessibility.

Also, the big increase in the population forced to travel a long distance of over 10 km, 20 km, and 30 km is also a nonnegligible factor in the event of a disaster. This population is relatively small in the entire area. Moreover, a transportation route does not need to be limited to streets, since other modes, such as helicopter ambulance, can be suggested as an option if cost is left out of consideration. However, this does not mean that the residents of such areas can be ignored. In order to understand the problem, it is important to study the residents in areas with significantly low accessibility in a quantitative way. Therefore, the results of analysis for this section are significant in that aspect.

This analysis is related to advanced emergency medical facilities, and in the northern coastal region where urban areas are scattered along a ria coast, a few cases were seen where there was only one facility, so its shutdown affected a large area. On the other hand, when assuming validation in the category of a hospital instead of an advanced emergency medical facility, the number of target facilities in this region will likely increase. Due to the topographical constraints of this region, most functions tend to be concentrated in the compact urban area. Even with increased facilities, they will be damaged at the same time as a result of concentrated function, and thus there is a possibility that substitutability cannot be guaranteed despite the number of facilities. Robustness of accessibility, which is measured by the availability of a second facility in case the first facility is not available for some reason, is usually correlated with this substitutability. When functions are concentrated for the previously described reason, the robustness of accessibility drops significantly. In other words, the robustness of accessibility for tsunami damage is low in this region. Therefore, from the viewpoint of crisis management, it is necessary to keep this factor in mind and conduct research on a placement system for medical service hubs for other regions with the same topographic features.

The results of accessibility evaluation shown here are derived from all residents of Miyagi Prefecture as the population in demand. Regarding population, although the population change before and after the earthquake was reflected in the analysis, this is not the population in demand in terms of the number of injured and ill people who want to receive medical service at advanced emergency medical facilities. For example, the degree of damage in the event of a disaster may differ by area, so it is imagined that the rate of demand occurrence changes accordingly. Analyzing the number of injured and ill people in the event of a disaster as population in demand will be a necessary task in the future for discussing crisis management.

Furthermore, considering demand and supply of service is a very significant issue in management discussions. The next section will highlight this issue and proceed with an analysis.

III. Efficiency improvement of the transportation scenario

In the event of a disaster, it is expected that many people will be injured and become ill at the same time. With the rise of heavy demand, many injured and ill people will rush to hospitals, which will cause hospitals to exceed their capacity on the supply side. This can create a situation in which some injured and ill people are rejected by hospitals. This means that not only “accessibility” but also “availability” of medical facilities become significant issues in the event of emergency.

The important factor here is that each medical facility has a capacity limit in accepting patients. The issue of capacity in each facility, which is probably not often a big problem in ordinary times, will become more apparent during the kinds of emergency discussed in this paper. There is a problem in how to define capacity. Also, a more realistic problem is that capacity can change according to operating policy and assessment of the situation by each facility. However, while keeping such problems in mind, creating an accessibility evaluation method that includes the capacity of medical facilities is considered to contribute to discussions of crisis management in the future.

Moreover, when the capacity of a facility is assumed in this way, it no longer means that injured and ill people can receive medical treatment by going to the closest facility. Therefore, behavior becomes different and more complicated from that discussed in section 2. Some people will be able to receive medical treatment at the closest facility, while others will only have their second- or third-closest facility available. Also, if it is not possible to predict which facility is available, people are expected to show behavior in which they will start searching from the closest facility. Thus, based on various possibilities of behavior scenarios in transporting injured and ill people, this paper suggests a method to improve transportation distance, which is accessibility, by elaborating a transportation scenario of injured and ill people and discussing its effect. This is also considered to give valuable insight to discussing crisis management from the viewpoint of accessibility to medical facilities.

1. Transporting injured and ill people

According to previous research [3], it is reported that transporting injured and ill people at the time of the 2007 earthquake in Japan, 13% of victims were transported by ambulance and 54% by general-purpose car. Although this ratio can change according to the type of disaster or the area, it can be said that most transportation is by general-purpose car.

When someone gets injured or falls ill and it is an urgent situation, most people do not check the availability of the medical facility they are heading to. If they are not accepted by the medical facility after arriving there, they will then head to the next closest hospital from there. Such transportation behavior, in which people keep searching for an available hospital, can possibly happen.

Therefore, transportation by general-purpose car runs the risk of increasing possibility of being rejected by medical facilities due to lack of capacity. In order to avoid this risk, it is efficient to pre-allocate hospitals for local residents when they get injured or fall ill during an emergency, although in reality this may not be absolutely guaranteed. If a situation is established where hospitals can absolutely accept patients, pre-allocating hospitals can save people from doing an unnecessary search, and thus will reduce traveling distance in transportation.

Based on such notions, this paper assumes two types of scenarios for transportation behavior of injured and ill people in cases of emergency, which are “Search Scenario” and “Pre-allocation Scenario,» and examines the difference in accessibility to advanced emergency medical facilities based on these scenarios.

The details of the two scenarios are as follows. In the Search Scenario, residents go to the closest hospital to search for availability. If they are rejected, they go to the next closest hospital from there. In this scenario, the distance becomes greater as they move every time they are rejected.

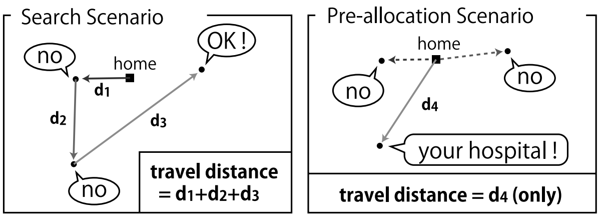


Figure 5

In the Pre-allocation Scenario, residents go to their pre-allocated hospitals. Specifically, the distance between an accident site and all medical facilities is measured in advance, and then a designated facility is determined according to the rule of which person closest to the medical facility has a higher priority in receiving medical care. This is different from the logic of minimizing transportation distance for all injured and ill people. Traffic behavior without complete information is expected in this scenario, and thus it is extremely difficult in the event of a disaster. However, this paper experimentally assumed this scenario because of its simple logic and ease of program creation.

2. Analysis

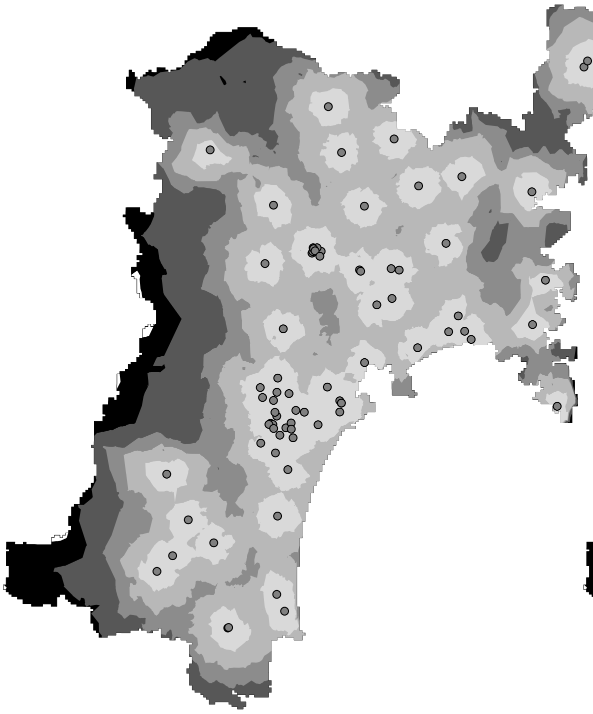
The analysis time for this section was set as 1 year after the earthquake. In order to discuss management right after the earthquake, detailed data such as the situation of medical facilities in operation or the number of injured and ill people at that time were necessary. However, since such data were difficult to obtain, this paper set 1 year after the earthquake as the evaluation time. Therefore, from the perspective of how management should be implemented to correspond to a future disaster while the local infrastructure is being repaired to a certain degree, the analysis in this chapter verifies the effects of a guided measure for transportation behavior. Although it is not a crisis management discussion in the event of a disaster, this kind of review method can be applied to simulate a disaster event.

The capacity, or acceptable number of patients, of each hospital in Miyagi Prefecture is calculated by allocating the number of emergency care patients per day to each hospital in accordance with the ratio of outpatients, which means substituting it with the estimated allotment number for emergency care per day in each hospital.

As in section 2 above, the site of injury or illness is the corrected grid representative point. The number of people in demand, which is the number of injured and ill people, is obtained as follows. First, the ratio of injured and ill people is calculated by dividing the number of emergency care per day by the population of Miyagi Prefecture. Then, to calculate the number of injured and ill people in each grid, the ratio of injured and ill people is multiplied by the population in each grid. This number of the injured and ill is only a temporary one based on the records for ordinary times. Also, there are some reports indicating increased emergency transportation after the earthquake, and thus the estimated population in demand needs to be reconsidered in the future.

Using the data above, the final selection of hospitals and transportation distance to reach them is obtained by the program that assumes each scenario.

Figures 6 and 7 are accessibility maps based on each



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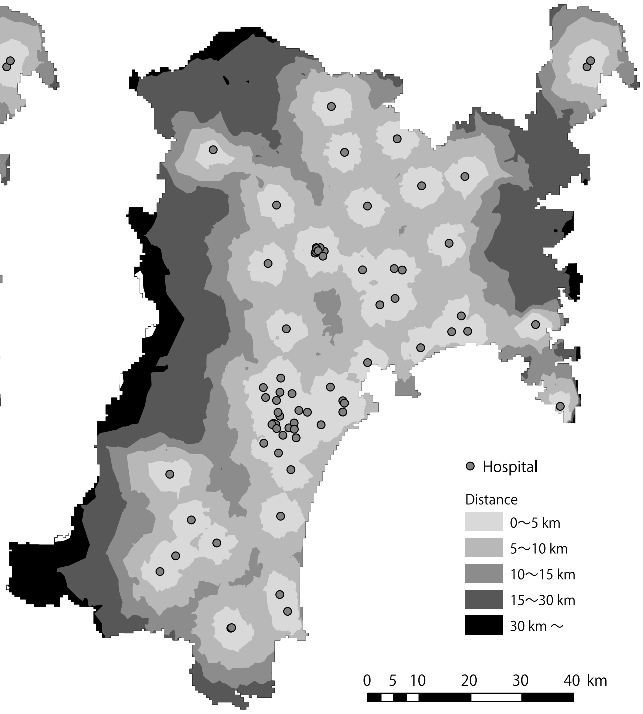

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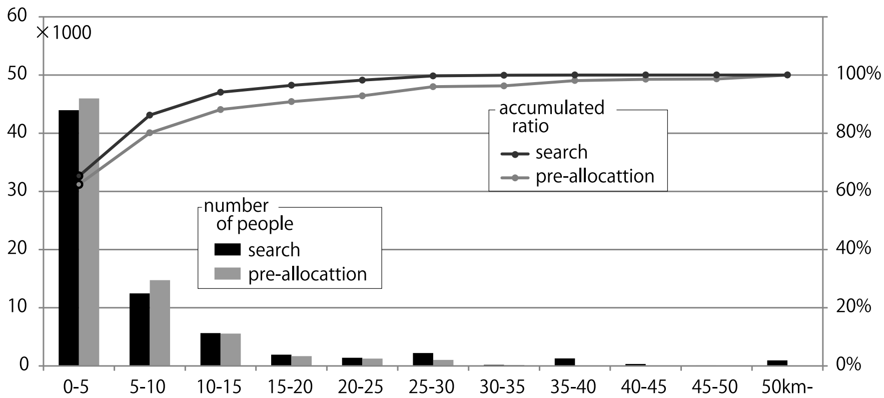

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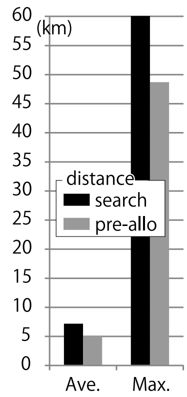

Figure 9

scenario. First, the Search Scenario map (fig. 6) shows a strong tendency for the distance to get shorter in the grid closer to the hospitals. On the other hand, for the grid that is far from the hospitals, some are rejected by nearby hospitals, and thus there is an increase in traveling distance. The risk of the Search Scenario, which is rejection by hospitals, is captured visually in this map. More specifically, in some parts of the region surrounding Minamisanriku Town in the northeast coastal area, the suburban area of inland Osaki City, and the region surrounding Kakuda City in the southeast coastal area, repeating a search for hospitals can lead to traveling distance over 30 km.

As shown in the map for the Pre-allocation Scenario (fig. 7), because designated hospitals are allocated in advance, the traveling distance for transportation tends to be shorter than in the Search Scenario. Also, compared to the map for the Search Scenario, it is evident that the area over 30 km decreases dramatically in the map for the Pre-allocation Scenario. Although there are some areas with increased distances compared to the Search Scenario, the general decrease in traveling distance indicates improvement in accessibility.

Second, the difference between accessibility in the two scenarios is examined through observing the population histogram by distance zone (fig. 8). Within 0–5 km, there are 44,000 people (62.4% of the total) for the Search Scenario, and 46,000 people (65.3%) for the Pre-allocation Scenario. There are more people in the Pre-allocation Scenario than the Search Scenario. The same result is shown for the number of injured and ill people within 5–10 km.

In the distance zone over 10 km, there are more people in the Search Scenario than the Pre-allocation Scenario. The total number of injured and ill people who were forced to use long-distance transportation of more than 10 km is 14,000 people (19.9% of the total) for the Search Scenario, and 10,000 people (13.8%) for the Pre-allocation Scenario. As shown here, the number of people in long-distance transportation decreases in the Pre-allocation Scenario.

In figure 9, the maximum distance and the average distance in each scenario are shown. For the average distance, the Search Scenario is 7.2 km, and the Pre-allocation Scenario is 5.1 km; thus the Pre-allocation Scenario is about 30% shorter than the Search Scenario. For the maximum distance, the Search Scenario is 84.0 km, and the Pre-allocation Scenario is 48.7 km; thus the Pre-allocation Scenario is about 42% shorter than the Search Scenario.

From the viewpoint of securing accessibility to medical services, it is an extremely important issue to decrease the number of injured and ill people in long-distance transportation. In that regard, bringing a guided plan such as the Pre-allocation Scenario is considered to be an effective method.

3. Discussion

In this section, two types of transportation activity scenarios were assumed, and the difference in accessibility for each was discussed. As a result, the Pre-allocation Scenario can accomplish a reduction in the average transportation distance by 30% compare to the Search Scenario, indicating the great effectiveness of a guided plan in improving accessibility for the time in which high demand occurs all at once. For the maximum distance, a greater improvement effect was shown. Even for the population who were forced to travel over 10 km, the Pre-allocation Scenario showed a reduction effect by 4,000 people (6%) compare to the Search Scenario. Therefore, in the situation in which demand rises all at once, carrying out this type of scenario is one effective management method.

On the other hand, there are many issues left in this analysis. Some are related to the precondition of calculations, such as a method of determining capacity at each hospital or a hypothesis method for the number of injured and ill people, while others are concerned with a way to choose a designated hospital in the Pre-allocation Scenario, assuming behavior without complete information, and many more. Especially, this paper incorporated a simple logic in which the proximity to facilities determines the priority of hospital choice in the Pre-allocation Scenario. However, this logic could cause a disadvantage to residents in areas that are forced to travel a long distance even in ordinary times. Therefore, discussing a suitable logic for crisis management, such as minimizing the total travel distance or attempting to minimize the population in long-distance travel, will be a key factor for this simulation to evolve.

Finally, the significance of accessibility evaluation with consideration of capacity is discussed through comparison of the results in section 2 and this section. From the results in section 2, data after the earthquake are used to compare the population ratio, average distance, and maximum distance in each distance zone.

The population within 0–5 km is 74.7% if capacity is not taken into account, but it is 62.4% in the Search Scenario and 65.3% in the Pre-allocation Scenario, showing about 10% difference. The population over 10 km is 6.0% without consideration of capacity, 19.9% for the Search Scenario, and 13.3% for the Pre-allocation Scenario, showing about 7–14% difference as well. The average distance is 3.9 km, 7.2 km, and 5.1 km, respectively, while the maximum distance is 41.9 km, 84.0 km, and 48.7 km, respectively, showing a major difference. Even the demand is less than the supply in total. When considering how to manage an individual situation where demand exceeds capacity, which is crisis management, the accessibility analysis method that takes the capacity of a facility into account becomes necessary, as suggested here.

IV. Conclusion

In this paper, accessibility was evaluated and analyzed from the viewpoint of road distance while assuming two types of transportation behavior scenarios to examine ways to improve efficiency in transportation behavior. It became evident that: there is more than a 10% increase in the average traveling distance after an earthquake; in an emergency, when demand rises all at once and the capacity of facilities needs to be taken into account, transportation distance increases compared to ordinary times, as some people may have to choose a facility at a distance; and a guided plan in which designated hospitals are pre-allocated is clearly an effective way to improve accessibility.

However, some issues remain for the analysis method. In reality, access to the medical care system should be evaluated by time distance. Therefore, for more practical and realistic analysis, it is necessary to make an analysis by incorporating data for multiple traffic speeds. Also, in order to conduct more rigorous analysis for crisis management, it is ideal to predict the population in demand more practically by incorporating logic that can anticipate a variable degree of crisis related to the area's characteristics. Moreover, along with this prediction, it is necessary to develop a method to evaluate the capacity of medical facilities.

Based on the improvement of these preconditions for analysis, the research tasks ahead of this paper are: to assume sequentially occurring demands in the event of a disaster instead of only dealing with momentary demands; and building a system to process demands on the time axis that takes the passage of time and the capacity of facilities into account.

Along with a community medical plan, public administration and business operators dealing with medical services are required to further discuss medical service within a regional disaster prevention plan. For example, the transportation plan for injured and ill people mentioned in this paper is part of such a plan. As pointed out by the existing research,5 after closely investigating the actual condition of transporting injured and ill people by general-purpose cars to build a transportation behavior model, it is an urgent issue to suggest a method of predicting the numbers of injured and ill people along with a transportation plan as its dynamic. These are also other research tasks of this paper for the future.

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Accessibility to medical care in case of major disasters

大規模災害発生時のケアへのアクセシビリティ

抄録

東日本大震災の発災当時，わが国ではその災害規模に対してしばしば想定外という言葉が用いられた．これに象徴されるように，これまでに積み重ねてきた防災・減災・事前復興というリスクマネジメントの概念による計画のみでは，大災害の備えとして十分でないことが明らかになる中で，クライシスマネジメントの視点から問題を再考することが，今後非常に重要になってくるだろうことは想像に難くない．

周知の通り，災害発生時には様々な地域施設へのアクセシビリティが低下し，災害の規模が大きいほど，その度合いは大きくなる．そして，供給量には上限があり，需要者全員がサービスを受けられない事態が容易に起こり得る．特に緊急時に需要が大量に発生する地域施設については，その影響の大きさを考慮して，どの程度の変化がどこで起こるのか，把握する手段を持つことが重要となる．医療は，災害発生時のような非常時において需要が高まるサービスの一つである．医療施設へのアクセシビリティが災害時にどのように変化するのか，そして医療サービスが受けられるか，つまり施設のAvailabilityは，現実的には非常に重要な問題になる．

そこで本稿では，災害発生時における医療施設へのアクセスに着目して，そのアクセシビリティがどのように変化するか検証する．また，災害時の傷病者搬送は一般車によるものが多数を占めることがわかっており，その実態を踏まえて搬送行動の在り方を考究する．具体的には，被災地の宮城県を舞台に，2次救急医療施設を対象として，震災前後のアクセシビリティ変化を分析するとともに，それら医療施設のキャパシティを想定し，傷病者が同時大量発生する際の受療可能施設へのアクセシビリティの分析を行う．分析に際しては，アクセシビリティを道路距離と読み替え，geographic information system（GIS）を用いて道路距離を計測した．

分析の結果，震災後の２次救急医療施設への平均移動距離は，震災前と比べて宮城県全体で12%延びたこと，事前に割り当てられた病院に向かう誘導型施策に従えば，施設を探索して移動する行動と比べて30%の移動距離短縮につながることが示された．

キーワード：災害，救急搬送，アクセシビリティ，道路距離，地理情報システム，宮城県

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