A REVIEW OF EMERGENCY ROADS IN ISTANBUL: PAST, CURRENT AND FUTURE

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ABSTRACT
In case of earthquakes, floods, fires, and landslides, access to the disaster area is vital via transportation modes, either road or rail, marine, and airways to save people and reduce the causalities. In this respect, the transportation planning process is crucial in evaluating the systems' road capacity and demand conditions to plan an efficient and effective emergency master plan. During the disaster management process, the worst scenario considers mobility that will occur before, during, and after the disasters. The location choices of disaster management centers and logistic activity areas, as well as meeting points that will be used in an emergency, are determined, and positioned according to the status of emergency transportation routes. This study reviews the Istanbul emergency road conditions in terms of their capacity, damaged position, and requirements for an earthquake. It illustrates past, current, and future circumstances of emergency roads in Istanbul by using building data to estimate the possibility of the closure of emergency roads. ArcMAP program is used for analyzing the emergency road capacity and damaged position. Building conditions are determined by using the Istanbul Metropolitan Municipality data. Besides, Japan International Cooperation Agency (JICA) and Megacity Indicator System for Disaster Risk Management (MegaIST) reports also give tremendous information during the preparation of emergency road analysis. Based on the investigation, the conditions of the emergency roads in Istanbul are evaluated, and suggestions for future development are made to highlight the conditions. According to the results, it determines that many roads will be closed in a possible earthquake because of the buildings located near emergency roads.

Keywords: Emergency Road, Earthquake, Disaster Management

1.0 INTRODUCTION
Due to rapid urbanization with a high density of buildings in metropolitan areas such as Istanbul, İzmir, and Hatay in Turkiye, the risk of human causalities and economic destruction increases notably because of disasters like earthquakes, floods, or fires. Identifying and optimizing rescue and emergency routes is considered one of the issues that can play an essential role in reducing disaster risks. Considering safety at all planning levels, there has been a reduction in the vulnerability of urban communities against earthquakes. If emergency road plans are implemented and managed successfully, it will decrease the casualties and damage rates.

Emergency vehicles and staff must reach the disaster area immediately because losing time causes irreversible results. At this point, road, rail, sea, and airways play a vital role in many issues, such as search, rescue, aid, communication, and evacuation, providing the mobility needed after a disaster. Any circumstance that will cause the closure of emergency roads or prevent their use should be determined and eliminated in advance. One of the most important goals of disaster management is to ensure that transportation is not interrupted in the event of a possible disaster. The road widths should have been a certain standard to achieve continuous access to the place. In addition, it is vital to identify the debris of the buildings that collapsed due to the earthquake and the areas where the debris will be thrown on the road (IMM, 2018).

Moreover, areas required for landing and take-off of aircraft critical for emergency response (such as helicopters, unmanned aerial vehicles (UAVs), drones) and safety strips on emergency roads are required. In addition to these conditions, emergency roads are the routes of infrastructures such as electricity, water, and natural gas under the roads (IMM, 2012). Therefore, emergency roads are also crucial for responding to other disasters such as fire, flood, and explosion in case of damage and closure of emergency roads and other buildings on the roads after the earthquake.

Another important task of the emergency road is to deliver the foods and goods needed in emergency logistics to the necessary places quickly, rapidly, and safely.

The Disaster and Emergency Management Presidency (AFAD), Turkish Red Crescent, and Turkish Armed Forces are responsible for emergency logistics throughout Turkiye, and Afet Koordinasyon Merkezi/Disaster Coordination Center (AKOM) is authorised for Istanbul. Istanbul has four emergency logistics support centers and over one thousand gathering points, camping areas, tent sides, health centers, and institutional places. These centers are on emergency transportation routes (Fig. 1) (IMM, 2018).

Fig. 1: Location of emergency roads, logistic centers, and gathering points in Istanbul. (Source: The map is drawn based on IMM data, 2022)

According to the Turkish Statistical Institute (TUIK) data for 2022, approximately 15.8 million people live in the Istanbul metropolitan area, and it expects that the population will reach 17 million by the year 2025, depending on different population estimations (TurkStat, 2023). Many infrastructures such as transportation, energy, communication, and service facilities should be either newly built or existing ones should be developed to make the current urbanization sustainable and to provide sufficient mobility for the city in the event of a possible disaster. As a result of this situation, it is vital to take the necessary precautions to prevent deaths and reduce the damage caused by disasters in the city infrastructure.

Emergency roads determined within the scope of the "*The Study on A Disaster Prevention/Mitigation Basic Plan in Istanbul, Including Seismic Microzonation in the Republic of Turkey*" within the Istanbul metropolitan area conducted by JICA in 2002, and current situation, projections and what needs to be done were presented to the relevant institutions in the form of a report. In 2009, the "*Megacity Indicator System for Disaster Risk Management (MegaIST)*" was prepared based on the work carried out in 2002 by the Istanbul Metropolitan Municipality (IMM). Considering the geological circumstances, construction conditions, and

building quality of Istanbul, when the possible destructions that the city will encounter in a possible earthquake are simulated using different models, even according to the most optimistic scenario, thousands of buildings are expected to be destroyed, in Turkiye's largest metropolitan settlement. It has been determined that some of the buildings mentioned above and roadside structures are on the emergency roads. In both studies, emergency roads are critical before, during, and after the possible earthquake.

2.0 LITERATURE REVIEW

Natural events and manufactured activities turn into a disaster, and it could disrupt the condition of transportation roads. The period after the disaster occurs is divided into two stages: short-term and long-term actions, depending on the interventions to be made. In the short term, road blockage may jeopardize emergency operations such as search and rescue, evacuation of victims, and distribution of emergency supplies (Almeida, et al., 2022). In this case, opening closed transportation roads constitutes one of the priority tasks.

Earthquakes are one of the most devastating natural disasters in the world, and unfortunately, it is impossible to know where they occur before they happen. All around the world, many public and private institutions, non-governmental organizations (NGOs), companies, and offices have prepared many disasters prevention, master plans, action programs, or disaster salvaging centers. So, the standard method to reduce the damage of an earthquake is disaster prevention through research, monitoring, dissemination of information, and education (Tzeng, et al., 2007).

In disaster management organizations, determining the necessary resources in advance, determining optimum resource allocation programs, and planning for repairing blocked road networks in emergencies are essential in the preparation phase (Hosseini, et al., 2023). When an earthquake occurs in a place, effective disaster management programs for rescue and delivery of food and goods can reduce the causalities and injuries. Besides, combining all relevant institutions, offices, information centers, and other logistic centers is essential. So, determining the best emergency transportation routes for evacuation and delivering medical aids and other necessities is vital (Tzeng, et al., 2007).

Natural disasters, like earthquakes and floods, have caused many casualties and damaged thousands of buildings, properties, and infrastructures. These disasters highlight the function of urban disaster prevention and mitigation (Wei, et al., 2021). Emergency routes have a critical role in the post-earthquake emergency phase, where they constitute one of the main elements of the transportation system in storing rescue teams, first aid teams, or exempts that need to be evacuated (Gehl, et al., 2022). So, emergency roads are vital for urban life, whether a disaster occurs or not. For this reason, in case of a collapse of a building on the side of the road, a road width should be at least 12 meters, allowing a minimum road width of 3 meters so that vehicle traffic can pass on the road (Buldurur & Kurucu, 2015).

GIS programs are globally top-rated; in particular, GIS programs organize and simulate network analysis and disaster management processes (Dunn, 1992). An essential advantage of GIS programs is that they allow spatial and network-based queries in analysis along with data entries. Turkiye is located geologically in an earthquake zone; thousands of earthquakes occur annually, either minor or intense. The latter are devastating; thousands died or were injured due to earthquakes.

3.0 METHODOLOGY

This study aims to analyze the status of the emergency transportation roads, developed for Istanbul in 2002 by JICA-IMM after the earthquake in Kocaeli in 1999, and updated as MegaIST

in 2009. This status was examined under the context of the Istanbul Environmental Plan study that was revised between 2016-2018. The data obtained in the studies carried out in 2002 for JICA and 2009 for MegaIST evaluates the building risk analysis reports prepared by IMM. It reveals the status of the building stock and the situation of the risky buildings on the emergency roads of Istanbul, examined by the geographic information system (GIS) ArcMAP query program. In the case of demolition of buildings, it has been tried to reveal which regions in Istanbul carry the most significant risk.

The data produced by the IMM in the study of the building status determination were used in the analysis. There are more than 1.3 million units in Istanbul, but in this study, only the buildings in bad condition are evaluated regarding road blockage. In the analysis, the road blockage issue was examined in terms of road widths, locations of buildings along the road, and heights. Road widths are divided into three classes: roads narrower than 10 meters, roads between 10 to 20 meters, and roads wider than 20 meters. The heights of the buildings were calculated depending on the number of floors and floor heights and were associated with the road widths. If the height of the building is higher than the road width, then the ArcMAP GIS program calculates how much of the road would be covered in case of building collapse. The analysis outputs were compared with JICA and MegaIST data results to determine which roads would be closed in a possible earthquake in Istanbul.

4.0 EMERGENCY ROADS IN ISTANBUL

Istanbul has a colossal emergency road capacity, nearly 12.000 km in length (Figure 1). According to the GIS analysis, it is determined that risky buildings in 112 neighborhoods on the European side and 40 neighborhoods on the Anatolian side directly and negatively affect the emergency roads (IMM, 2018). The heights of the buildings on the border of the emergency roads calculated assume that these buildings collapsed on the road due to an earthquake depending on their heights and the road closure conditions determined. According to the analysis, there are 5,214 buildings located on the side of the emergency road in Istanbul in poor condition. As a matter of fact, two buildings in Zeytinburnu and Beyoğlu, among the buildings identified within the scope of the study, were demolished in 2017, and the roads with the destroyed building in Seyitnizam and Dolapdere Streets could not be used within 6 to12 hours. A similar situation occurred in the İzmir earthquake, and after the earthquake, the roads were closed; unfortunately, AFAD could not reach the place for nearly 6 to 7 hours due to the closing of the roads. Figure 2 shows examples of road blockage due to collapsed buildings.

Fig. 2: Blocked roads in Adıyaman after Kahramanmaraş earthquakes in 2023.

Kahramanmaraş earthquakes were a big tragedy in terms of emergency road conditions. The earthquake affected 11 provinces, and unfortunately, the rescue teams and other staff could not reach the cities for up to 24 to 36 hours. Thus, emergency roads have a critical role during and after disasters.

4.1. JICA Project

JICA and IMM prepared "*The Study on A Disaster Prevention/Mitigation Basic Plan in Istanbul, Including Seismic Microzonation in the Republic of Turkey*" in 2002. The study aims to prevent the possible damage of earthquakes in İstanbul, and it suggests a comprehensive framework to eliminate the demolition. One of the components of the study is to determine the emergency roads in Istanbul (Figure 3); therefore, it has been proposed to establish and strengthen the appropriate emergency transportation network so that it can be used effectively in all emergency response activities.

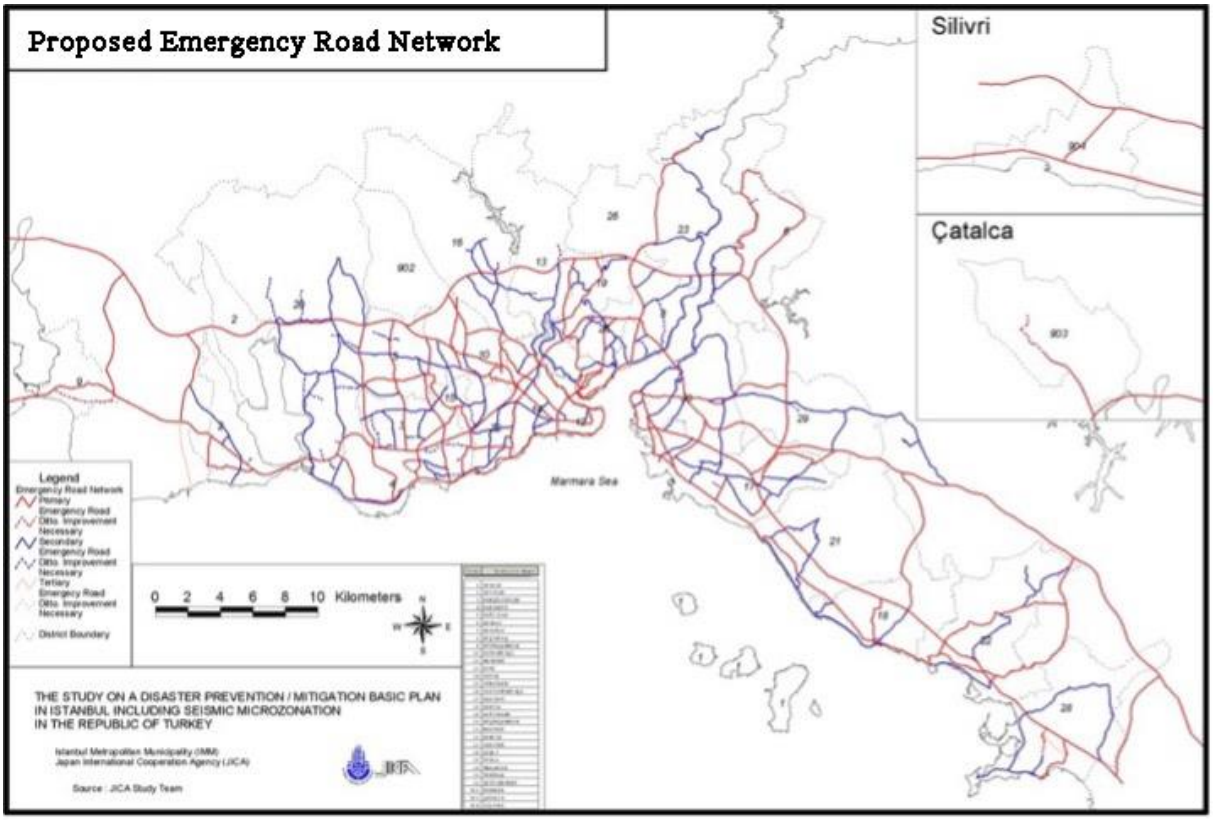

Fig. 3: İstanbul emergency roads based on JICA study.
Source: (JICA, 2002)

The study produced a model, and all scenarios were evaluated based on this model. Roads were classified according to their widths. It was assumed that the collapse of roadside buildings due to the earthquake significantly reduced the efficiency of the roads, especially the narrow roads which were affected more, disrupting efficient transport, and causing traffic congestion (JICA, 2002). Fig. 4, Fig. 5 and Fig 6 point out the road blockage based on the JICA study.

The study offers six leading suggestions for an efficient emergency network. To sum up, the emergency road plan should be upgraded depending on changes in land use distribution, and public relations, purposes, network, and regulations of the emergency road plan should be regulated, locating warning signals showing the emergency road and indicating that the parking is controlled on the road, making retrofit projects in weak buildings such as disaster management centers and response centers, making wider the narrow roads, strengthening the weak bridges, overpasses and other infrastructural structures (JICA, 2002).

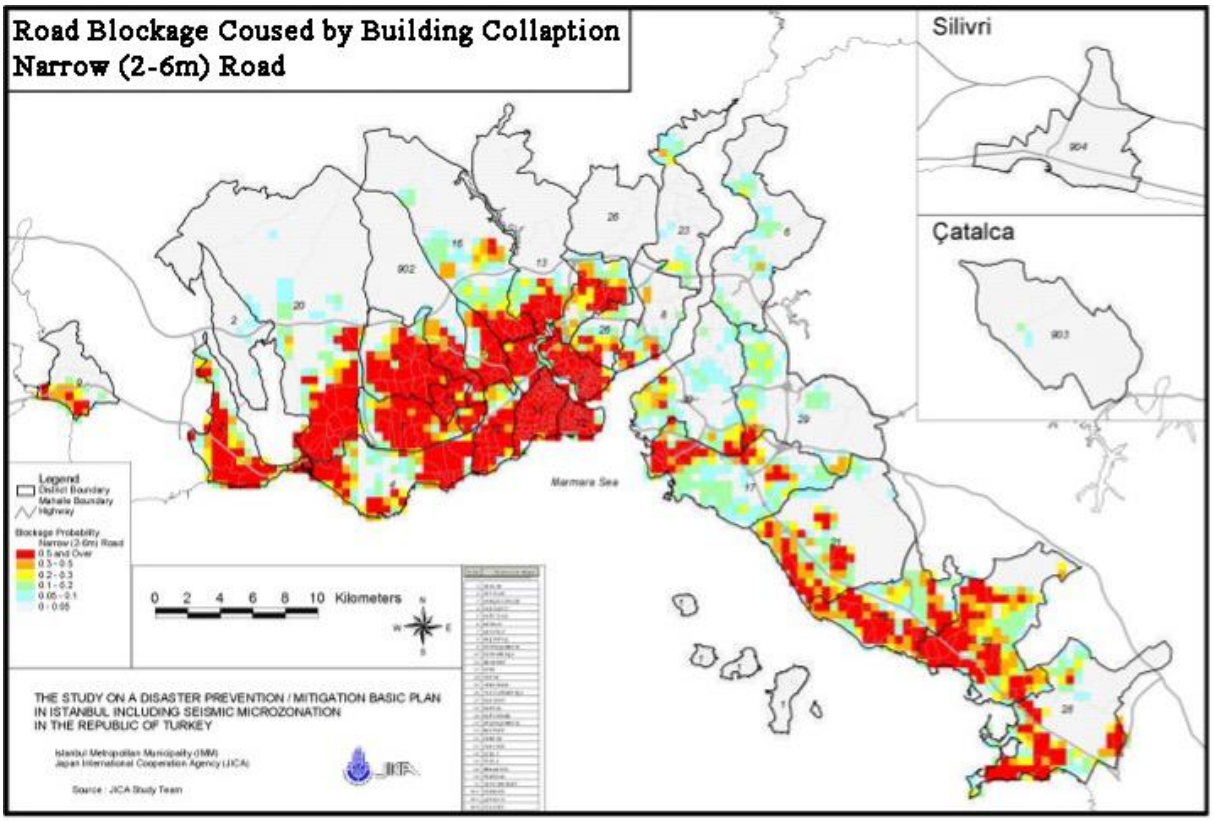

Fig. 4: Narrow Road (2-6 m) blockage caused by building collapse on İstanbul emergency roads
Source: (JICA, 2002)

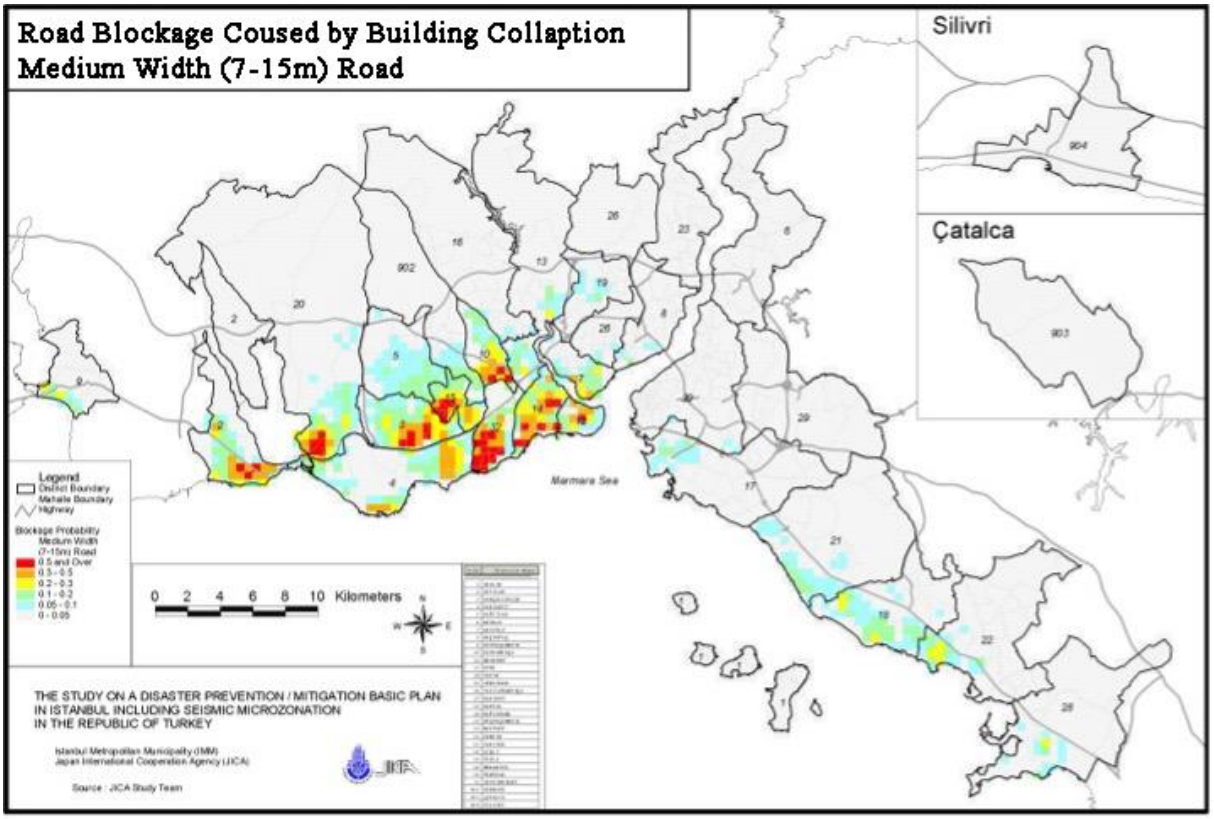

Fig. 5: Medium-width Road (7-15 m) blockage caused by building collapse on İstanbul emergency roads
Source: (JICA, 2002)

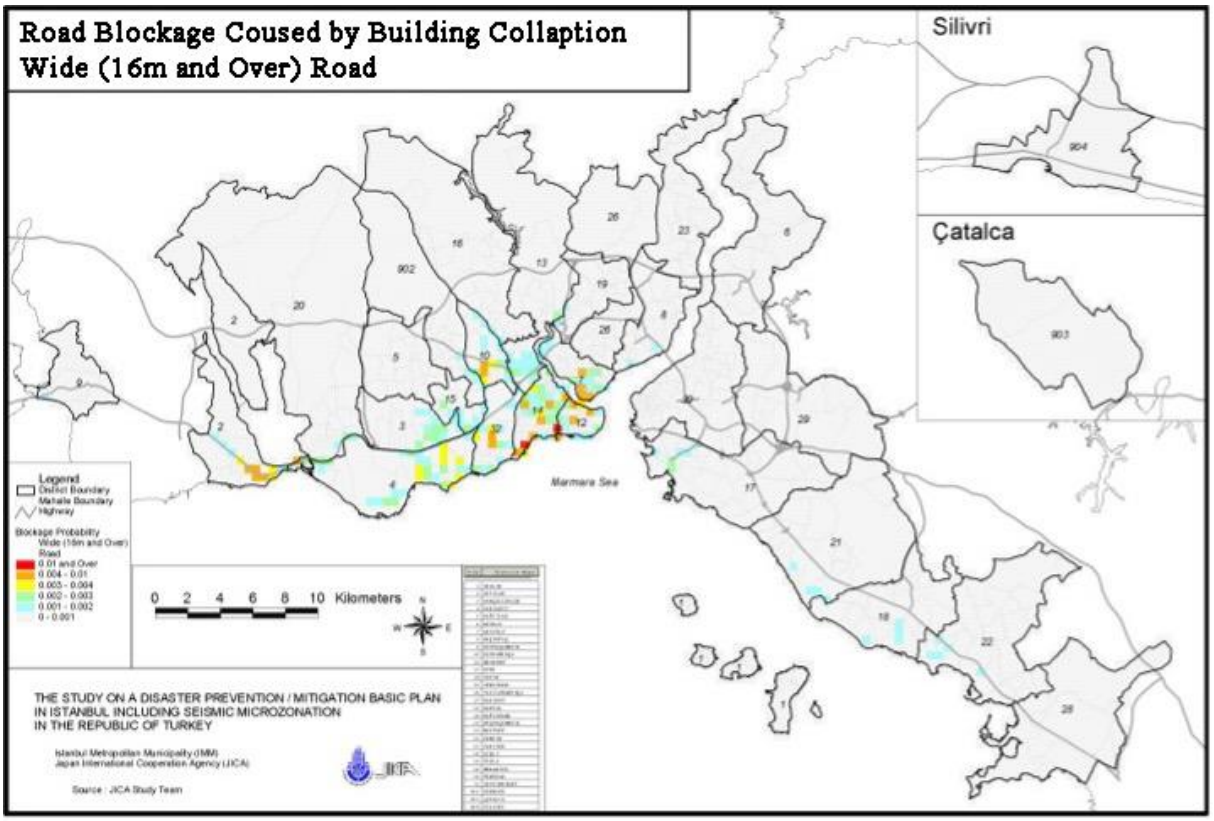

Fig. 6: Wide roads (16 m and over) blockage caused by building collapse on İstanbul emergency roads.
Source: (JICA, 2002)

4.2. MegaIST Project

MegaIST project is prepared to help decision-makers and governors develop correct strategies and take appropriate risk mitigation decisions in disaster prevention and risk management studies. MegaIST consists of three components, which are prepared to enable all risk information and risk elements to be transferred to all stakeholders in the disaster prevention and risk management process. These components are;

- "Urban Seismic Risk Index," where physical risks and social vulnerability are evaluated.
- "Struggle Capacity Index," which evaluates the capacity of the Istanbul Metropolitan Municipality to fight in an emergency after an earthquake.
- "Performance-Based Administrative Monitoring Process" analyzes the performance of Istanbul Metropolitan Municipality within the scope of related studies, considering specific criteria.

Road closure is defined in the MegaIST project as within the scope of updating possible earthquake damage, which is called the formation of passages with a width of less than 3 meters on the road due to the building's collapse. The project used mainly the JICA data and upgraded them within the 2009 data. In this project, the situation that will arise because of a possible earthquake can be evaluated systematically and analytically (Figure 7 and Figure 8), and it can be determined in which areas improvements should be made and at what levels the improvements should be made. Thus, it can be determined which areas are prioritized in reducing the disaster risk in Istanbul and what kind of work should be done in these areas.

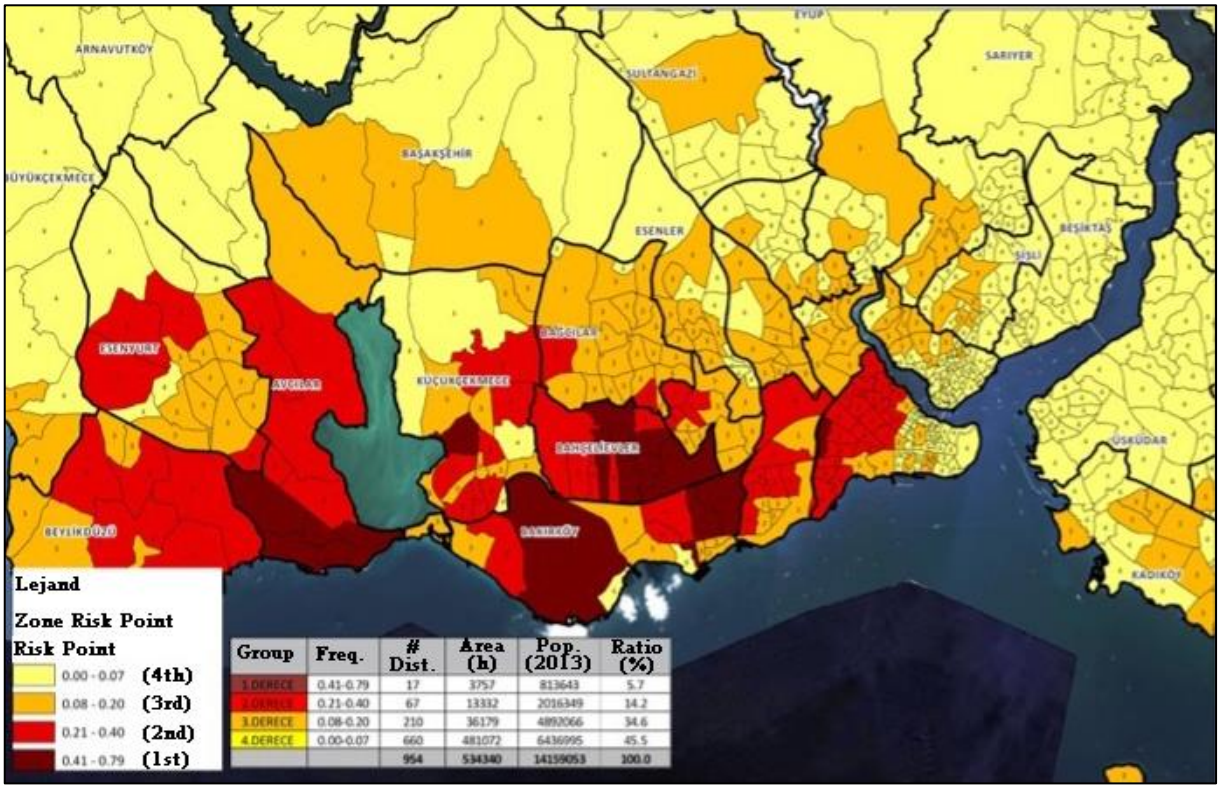

Fig. 7: Neighborhood risk points in terms of their capacity.
Source: (IMM, 2012)

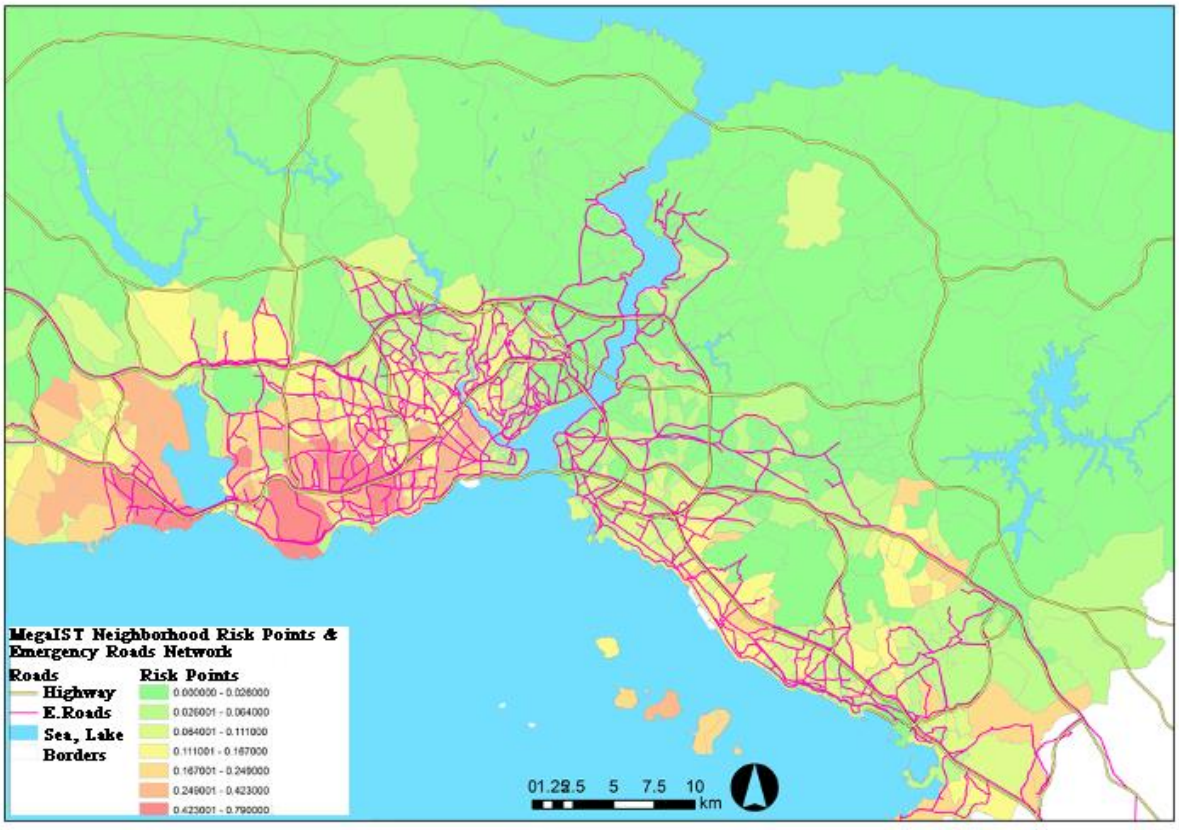

Fig. 8: Comparison of MegaIST neighborhood risk points and emergency roads.
Source: (IMM, 2012)

4.3. Istanbul Environmental Revision Plan

The Istanbul Environmental Revision Plan was conducted by IMM from 2016 to 2018. During the planning process, several issues were studied to prepare the city as a global trademark. Transportation title was one of the issues for solving the traffic problems, increasing mobility, and adopting grand projects like airports and highways to the plan decisions.

In the environmental plan study, a quantitative study was carried out to determine the closure of emergency roads. This study has simulated what happens in case of demolition of buildings in bad condition on the side of emergency roads. The buildings around the emergency roads over 12000 kilometers in Istanbul were evaluated (Figure 9). Conversely, the analysis did not include structures such as underpasses on the road.

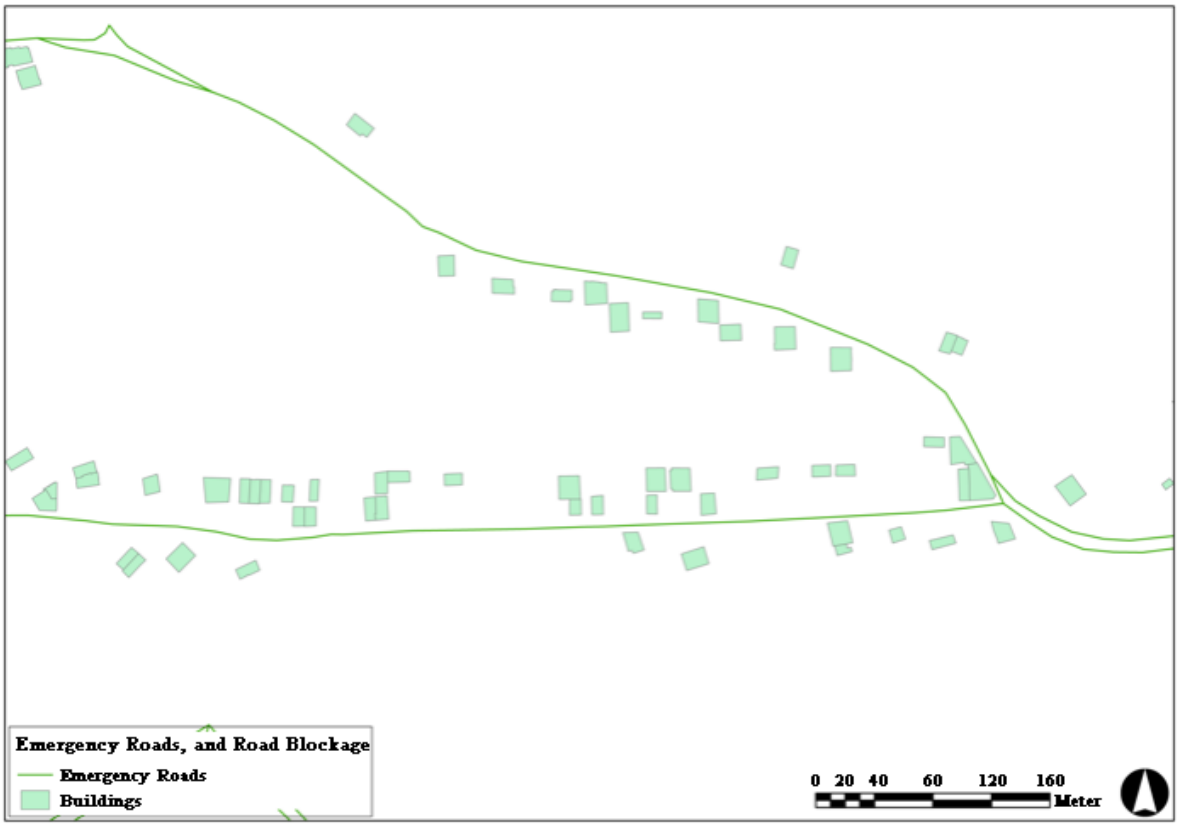

Fig. 9: Emergency roads and buildings position.
Source: The layout is drawn based on IMM data (2022)

The roads were classified according to their widths as less than 10 meters, between 10-20 meters, and over 20 meters, and the buildings' heights and the roads' widths were evaluated together (Figure 10).

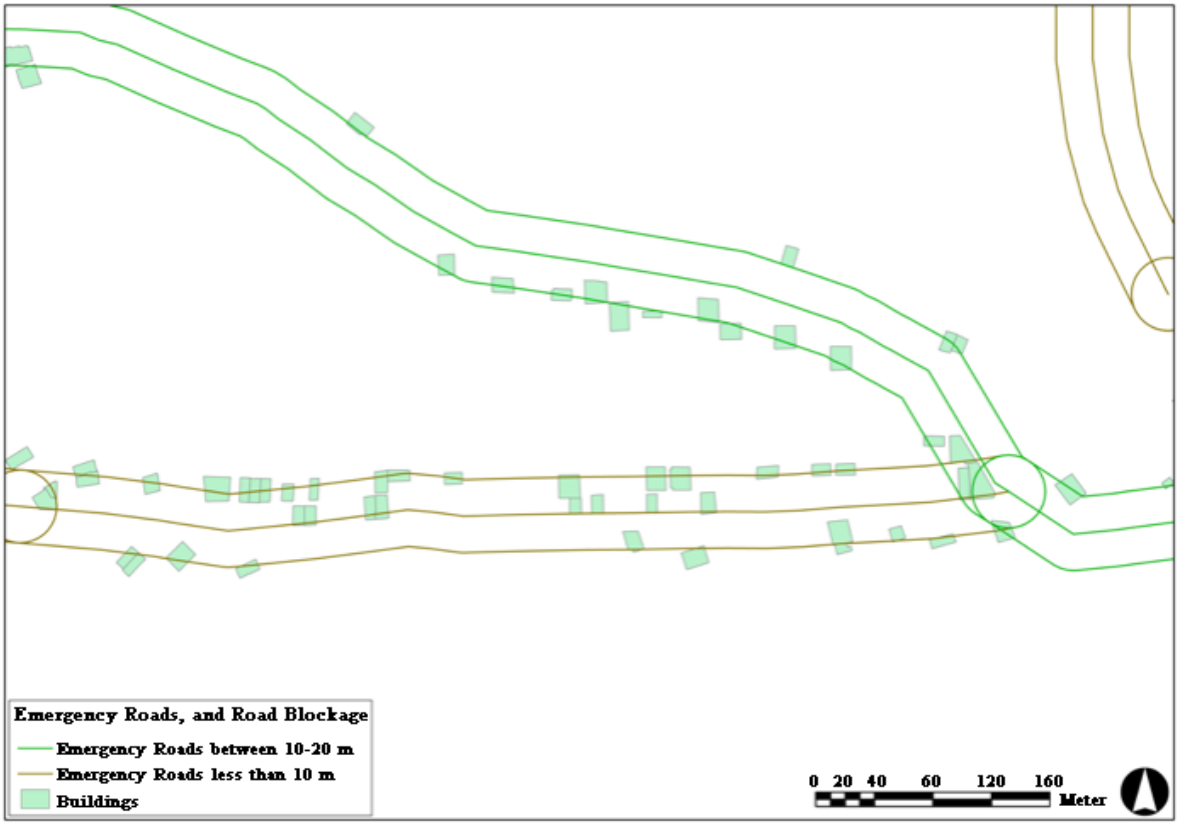

Fig. 10: Emergency roads and road blockage depending on building damage.
Source: The layout is drawn based on IMM data (2022)

If the height of a building is lower than the width of the road, it is assumed that when the building collapses, it will not completely block the road but damage it with respect to the road width. If the height of the building is lower than the width of the road, the rubble of the building would not be spread on the whole of the road. If the height of a building is over the width of the road, then it is anticipated that this building would block the road in case of collapse. The study examined the buildings in bad condition in Istanbul. However, some buildings which are in good condition also could collapse and block the roads, but they need to be studied. Another disadvantage of the buildings around the emergency roads is that if buildings in high-density and developing areas collapse, they can also damage the buildings that do not collapse, thus causing an obstacle in the emergency response.

5.0 DISCUSSION

One of the most important results of the study for Istanbul transportation systems is that emergency roads are not ready for an earthquake and are immediately checked and renewed in related studies. Otherwise, there will be difficulties in accessing the damaged or destroyed buildings, and the number of injuries and causalities will be much higher than expected.

Removing the car parking lots on the emergency roads and ensuring traffic flow is an essential component in disaster management and transportation studies to the disaster area. When on-road car park lots are not designed efficiently, they cause both financial and deaths in the event of a disaster. Cars left in these parking lots not only cause the road to be closed but also prevent first aid vehicles from passing. As a solution to this problem, it will be a valuable practice to produce car parking solutions at the neighborhood level and to solve the car parking areas in newly constructed buildings within the parcel apart from emergency roads. Thus, in case of a possible disaster, it will be possible to intervene quickly in a disaster area. Vehicle parking on emergency

roads in Istanbul is a big issue for disaster, and some of the ageing roadside structures need to be renewed. Besides, the abundance of risky buildings on the side of emergency roads was examined in detail, and suggestions were developed. It is stated that if the emergency roads are closed for the reasons stated above, it may lead to the collapse of the transportation system of an entire city. If relevant suggestions do not come true, it is seen that it will not be possible for the search and rescue teams, medical aid staff, and construction equipment used in the debris removal work to reach the disaster area. So, thousands of people who can be rescued alive from under the collapsed buildings will also be lost because of time losses. All in all, when the results are evaluated with the economic and social dimensions of the disaster, human casualties are also calculated at frightening levels.

In the study, administrative management, and economic components, which are the issues that directly affect the emergency roads, have yet to be examined in detail. A new management system was established in Turkiye after 2018; the pros and cons of the new system await studies and evaluation in terms of emergency roads. The fact that AFAD teams, which have modern search-and-rescue machines and other construction equipment, cannot reach the wreckage area for hours due to some buildings destroyed in the Bayraklı district as a result of the earthquake, that took place in the Aegean Sea off the coast of İzmir in 2020, and Kahramanmaraş earthquake in 2023 the traffic density on the emergency transportation road shows that there are still unclear points about disaster management that need to improve. Notwithstanding similar examples, disaster management and organization, together with emergency roads, should be handled and developed in a multidimensional way in social, economic, and administrative fields, not only at the administrative level but also by increasing people's awareness. The study also has some limitations regarding updated data for buildings and roads. In the reviewed articles, the building data belongs to 2013, and the road data belongs to 2018. So, the data needs to be updated with the current information in Istanbul.

6.0 CONCLUSION

In the last two decades, significant studies have been carried out in Turkiye, particularly in Istanbul, preventing disasters, reducing their effects and increasing institutional capacity. However, unfortunately, Istanbul could not reach the desired level in terms of creating a disaster-resistant city because of these studies. Thousands of buildings and infrastructure units are still waiting to be renewed, and planning and construction activities in new development areas prioritize concrete quality in terms of disaster resilience while other components are ignored.

In the studies carried out within the scope of both JICA, MegaIST, and the Istanbul Environmental Revision Plan, the conditions of the emergency roads were determined at a sufficient level, and the requirements were clarified. During the process, many requirements regarding both infrastructure and services were carried out for emergency roads. Based on the dynamic structure of Istanbul, the renewal plans prepared 15 to 20 years ago in the light of current data will enable managers and decision-makers to make more accurate applications.

Unfortunately, emergency roads in Istanbul cannot be used efficiently due to reasons such as parking on the road and being occupied by commercial units. One of the crucial components of solving this issue is to increase inspections, eliminate the relevant illegal occupations, and provide deterrent penalties.

If the solutions defined in the studies are implemented, the time to reach the debris will be reduced, and the casualties will decrease in a possible Istanbul earthquake. Besides, emergency roads will also maintain the connections not only for disasters but also for other necessities.

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