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DEPARTMENT OF EARTHQUAKE RISK MANAGEMENT and URBAN RENOVATION
DIRECTORATE OF EARTHQUAKE AND GROUND RESEARCH

MEGACITY INDICATOR SYSTEM for DISASTER RISK MANAGEMENT

MegaİST
Megacity Indicator System for Disaster Risk Management

EXECUTIVE SUMMARY
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İÇİNDEKİLER

Contents

Abbreviations

IMM: İstanbul Metropolitan Municipality

JICA: The Study on A Disaster Prevention / Mitigation Basic Plan in Istanbul including Seismic Microzonationin the Republic of Turkey
MIS: Mega City Indicator System
IDEA: Inter-American Development Bank
EMI: Earthquake Megacities Initiative
CIMNE: International Center of Numerical Methods in Engineering of The Technical University of Catalonia
LDW: Logical Decision for Windows
DEZIM: Deprem ve Zemin İnceleme Müdürlüğü Directorate of Earthquake and Ground Analysis

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1. Introduction

After the 17 Agust 1999 and 12 November 1999 Marmara Earthquakes, the reality of the possible large earthquake threat to İstanbul take place more strkingly on the agenda. Large earthquake occurance in İstanbul is expected to expose unmanagable disaster losses in human life, physical structure, socio-economic life and environment.

İstanbul Metropolitan Municipality (IMM) accepts the notion of a multi-hazard approach in disaster prevention and risk management with projects such as Urban Geology of İstanbul, The Study on A Disaster Prevention / Mitigation Basic Plan in Istanbul including Seismic Microzonation in the Republic of Turkey (JICA Project), İstanbul Earthquake Master Plan, In disaster risk reduction studies – especially in disaster prone megacities – having so many priorities and determination of it uncertainly makes giving decisions difficult for managers.

"Mega City Indicator System" not only helps decision makers and managers develop logical strategies and make proper decions on risk mitigation in disaster prevention and risk management work but also enables transferring all information and risk factors to the stakeholders in the process of disaster prevention and risk management. Therefore, validation of the investments, disaster prevention and risk mitigation decisions are supported. Megacity Indicator System consists of three components:

1. "Urban Seismic Risk Index" where Physical Risks and Social vulnerabilities are evaluated.
2. "Coping Capacity Index" refers to the capacity after an earthquake emergency.
3. "Performance Based Tracking Process" analysed regarding certain performance criteria within the context of related IMM work.

The models and methodology referred to here as the "Megacity Indicators System" (MIS) approach was originally developed for the Inter-American Development Bank through the IDB-IDEA Indicators Program by Omar Cardona by the Institute of Environmental Studies (IDEA) of the National University of Colombia, Manizales (NUCM). Together with its partners at Manizales, the International Center of Numerical Methods in Engineering (CIMNE) of the Technical University of Catalonia, and local counterparts in the Philippines, EMI undertook a preliminary application of the MIS approach to megacities in Metro Manila. Besides the implementation in Metro Manila, many other related applications of the model have been undertaken by the IDEA-CIMNE team, and the methodology has been tested and evaluated in other cities and sub-national regions in Latin America and Europe, including Manizales (Colombia) Quito (Ecuador), Barcelona (Spain) and Lombardy region (Italy).

In June 2007, EMI and IMM renewed their cooperation agreement for the participation of IMM in the Cluster Cities Project and the 3cd Program. Under this agreement, EMI and IMM agreed to undertake a series of activities relevant to the implementation of the Istanbul Earthquake Master Plan (IEMP). A kickoff meeting involving officials from EMI, IMM and researchers from Karlsruhe University (CEDIM) and Bogazici University (CENDIM) took place in December 2007, where MIS project was discussed and a decision was taken to proceed with its implementation. After that MIS is undertaken within the *Directorate of Earthquake and Ground Analysis* of the IMM.

2. Aim, Target, Context

The main aim of the Megacity Indicator System is establishment of an "INDICATOR SYSTEM" in the process of Integrated Disaster Risk Management for every step in planning.

Determination of the most accurate Disaster Risk Management strategies, and defining priorities in allocating resources and investment decisions for decision makers and managers.

Track progress in certain time periods and validate accepted decisions.

Supporting communication and coordination among all concerned and related stakeholders and increase awareness on risk management.

Supporting information on the risk profile of the city to the domestic and foreign investors.

Sharing, understanding and documenting the knowledge on the similar and related applications carryied out by different institutions is aimed.

3. Method

Megacity Indicator System consists of three different and complementary components therefore it is possible to evaluate the disaster risk mitigation actions in an integrated way.

- Urban Seismic Risk Index
- Coping Capacity Index
- Disaster Risk Management Index

After a possible earthquake, physical damages caused by building and infrastructure and social vulnerability structure forms the "Urban Seismic Risk" and identifies the risk structure of the city.

PHYSICAL RISK INDICATORS

- Number of Damaged Buildings (Heavy damage, Moderately damage, Slight Damage, No damage)
- Nuber of Death-Injured (Death, Seriously injured, Moderately injured, Slightly injured)
- Number of Fire outbreak (Number of Flammable buildings, Number of damage to wooden buildings)
- Water and waste water pipe damage
- Natural gas pipe damage

SOCIAL VULNERABILITY INDICATORS

- Social fragility factors
  - Family structure
  - Poverty
  - Disability

- › Unemployment
- › Land ownership
- Resillience Factors
  - › Solidarity
  - › Mobility
  - › Education
  - › Access to health services
  - › Community awareness

According to system approach, after the risk structure of the city is determined, the coping capacity and management capability of the İstanbul Metropolitan Municipality with disaster is determined with certain indicators. Authorization area and duties of İBB is the identifying fact in determination of the indicators. Otherwise the it is inevitable that the indicators diverge from reality. In this study, Urban Seismic Risk is taken into consideration for whole İstanbul, however "Coping Capacity" indicators are designed fr IMM. In this regard, coping capacity of IMM after an earthquake emergency is evaluated.

COPING CAPACITY INDICATORS

- Rescue and Relief Capacity
  - › Search and Rescue Capacity
  - › Fire Fighting Capacity
  - › Burial Capacity
- Kapasitesi Shelter Site Support Capacity
  - › Bread Distribution Capacity
  - › Water Distribution Capacity
  - › Food Distribution Capacity
- Debris Removal Capacity
- Lifeline Restoration Capacity
  - › İSKİ Emergency Response Capacity
  - › İGDAŞ Emergency Response Capacity

The last step in the Megacity Indicator System is conducting PERFORMANCE BASED ADMINISTRATIVE TRACKING PROCESS for following Disaster Risk Management Applications in certain time periods with performance indicators. In the Administrative tracking process, qualitative indicators are used instead of quantitative indicators to evaluate the operational and organizational performance of İBB. These indicators consists of the ones like Legal and Institutional Arrangements, Preparedness and Risk Reduction Activities, Readiness to Respond and Recover, emergency management, rehabilitation,education and coordination,resource management.

4. Application

Four important steps are followed in establishing Megacity Indicator System for Disaster Risk Management.

- Determination of the indicators
  - ➢ Obtaining of data

- Data Analysis

- Determining stakeholders
    - Stakeholder workshops
    - Validation and update of data

- Calculation
    - Total Physical Risk
    - Social Vulnerability
    - Institutional Coping Capacity
        - Supply Data
        - Calculation of Demand
        - Accessibility analysis
        - Capacity calculation
    - Weighting of Indicators
    - Expert and Stakeholder Opinnions (Survey)
    - Evaluation of the data in Logical Decisions Soytware
- Documentation and share
    - GIS Maps
    - MIS Report
    - Sharing with stakeholders and related institutions.

Megacity Indicator System which is defined above with general properties and conducted in accordance with aim, target, context and planning steps is completed except social vulnerability that is planned to be carryied out in 2012. The required data for completing social vulnerability component will be able to be obtained by the Directorate of Strategic Planning with "Social Structure Survey at household level". After all the components are finalized, "Performance based Administrative Tracking Process" will be started.

5. Physical Risks

The physical risk indicators in this study are derived from 2009 "Updating Loss Estimations of the Probable Earthquake in Istanbul Study" within the context of "Production of Microzonation Report and Maps for Asian Side Project. All damage data were calculated with ELER (Earthquake Loss Estimation Routine) methodology and software. ELER is developed for the rapid estimation of earthquake shaking and losses in the Euro –Mediterranean region under the EU FP-6 NERIES Project. In GIS database the numbers are similar to the average values. It must be noted that these values are calculated in a grid basis (400X600m). Therefore in order to obtain district based results, the grid based numbers are aggregated.

5.1. Building Damage

In order to estimate the possible earthquake damages to buildings in urban areas, the results are used which are obtained by the Analytic Method that is the comparison of simplified models of the buildings and earthquake demand. Based on different methods, "completely damaged building" number change between 2,500 and 10,000. Unusable building number (comp + ext + mod) is varying between 100,000 and 190,000. This equals to the 10%-16% of the building stock. In GIS database the numbers are similar to the average values. It must be noted that these values are calculated in a grid basis (400X600m). Therefore in order to obtain district based results, the grid based numbers must be aggregated. This aggregation is made in GIS environment, transferring the grid values into districts.

5.2. Casualties

The major cause of casualties is building collapse. Deaths are caused by instant death under collapsed building structure, suffocation under collapsed roofs or walls, or trapped in collapsed building and not rescued promptly. The method used in HAZUS99 and HAZUS-MH Links direct relation between building damage and casualties death- injuries. Injuries are caused by non-structural damages where the structural damages are less furthermore there is possibility of high numbers of death where structural damages are heavy.

Injuries are evaluated under four main groups in HAZUS99 and HAZUS-MH.
1st level: outpatient treatment
2nd level: Short time treatment at hospitals
3rd level: Serious, long time treatment at hospitals
4th level: Injuries results in death

Produced results in estimation of the death and injuries using analytic method are such that 10000-30000 death and heavy-injury, 20000 – 60000 treatment at hospital, 50000-140000 light injuries.

5.3. Fire Outbreak Possibility

Istanbul has suffered from great fires repeatedly since its ancient days. The fire of 1782 reduced almost half of the city to ashes. The last great fires of Istanbul were the Hocapasa fire of 1865, the Beyoglu fire of 1870, and the Laleli fire of 1912. Over 100 fire outbreaks were reported in the Avcılar area due to the 1999 Izmit Earthquake and it is estimated that most of them occurred due to electric leakage. It is also reported that no fires spread to other buildings. After the 1912 fires, further constructions of wooden buildings in the city were prevented.

According to the inventory analysis in Microzonation project there are 3762 flammable and explosive containing building in Istanbul. 355 Moderate damage building, 59 extensive damage and 9 completely damaged building is determined according to the analytical method.

Wooden houses are included into the analysis in addition to the buildings that has flammable and explosive material. This data is obtained from JICA study.

5.4. Water Pipe and Sewage Pipe Damage

In water pipe damage, PGV is the main seismic parameter used to evaluate the damage of pipes. The pipe damage estimations are run using the HAZUS 1999 methodology.

Pipe damage types caused by seismic wave propagation are usually leakage or breakage.In loss estimation analysis it is considered that inspected damage at the joints of the pipes area due to 20% beakage and 80% leakage. Number of damages for water pipes with respect to peak ground velocity are 456 for water pipes and 1478 for sewage pipes.

The results are aggregated to district based format using a GIS software.

5.5. Natural Gas Pipe Damage

The number of damages to the natural gas pipes are 644 in terms of Peak Ground Velocity. Natural gas service boxes may be placed on ground floor or walls. Eventhough there is not a damage at natural gas line a leakage may occure and cause explosion. The inspection of the damage depends on the consideration of damage to the service boxes with very heavy damage and heavily damaged buildings and the half of moderate damage buildings. (The Study on A Disaster Prevention / Mitigation Basic Plan in Istanbul including Seismic Microzonationin the Republic of Turkey,2002)

According to our inventory, There is 515,248 natural gas service boxes in İstanbul. Building damage data calculated depending on analytic method and service box grid based data with 0.005 degree resolution is rationalized and below results are obtained. According to that total number of service box to be damaged is 16920.

As the intend of the respresentation of the results are district based, the results are modified to districts using GIS software.

5.6. Road Block Data

According to report belonging "Updating Loss Estimations of the Probable Earthquake in Istanbul Study", Building collapses cause the road block. In these analysis, "Completely" and "Extensive" damage degrees have been used for building damage. The roads have been divided into 3 classes with regard to their wideness. These are 2m-6m, 7m-15m, and roads with more than 16 m width. In the calculation, road width has been obtained by multiplying lane width number of lanes. Lane width has been taken as 2.5m in calculation. Closed road probability has been calculated for each 0.005 X 0.005 degree area. These data are distributed into district level as seen in the Table 16. In distribution process GIS data is referenced.

6. Municipality's Coping Capacity (CCi)

After a possible earthquake that may hit İstanbul, outcoming result requires too much resources. In these conditions and being in such an important city, both national and international may be mobilised for required servisces.

In this study the coping capacity indicators here are computed only for the Istanbul Metropolitan Municipality and do not represent the capacity of the city of Istanbul as a whole. In responding to a major event there will be a pool of domestic and international resources. This study neither assumes that for the coping capacity indicators which are calculated here, IMM will be the only organization responding, nor that it will be leading the response of other organizations. The coping capacity indicators simply provide the municipality with a planning tool to determine where it may be lacking resources and where it is meeting needs.

Capacity namely means the combination of the existing resources with types and quantities for an institution or organization to access targets. The coping capacity is the full managing skill and utilizing coping abilities with disasters and emergencies using the institutions' and organisations' resources. Including the disaster and emergency cases, Coping capacity continuously brings in awareness in normal case and requires resource and quality in management. Coping capacity contributes to the mitigation of disaster risks.

In the context of this Project, analysis are made with respect to the ratio between how much the services (supply) can be delivered with existing resources (demand) after a possible earthquake. With this aim, several areas are considered according to the principal responsibility of the municipality where support can be supplied and indicators are determined taking this into consideration. Here, supply is the whole of resources and the abilities of IMM in case of an emergency. Demand is the required resources and abilities for IMM to respond in the most efficient way.

Supply is the number of resources available in each district (e.g. the total number of trucks, and loaders necessary to remove the debris from a district area in 60 days), and Demand on resources is estimated based on the earthquake risk scenario and the department and directories concerned (e.g. The number of bread demand), Accessibility is used as a time-cost factor to account for the ease or difficulty of deploying the respective manpower and machinery for each district (e.g. the time it takes for the trucks to make trips to the closest landfill averaged over the entire district).

$$Capacity = \frac{Supply}{Demand} \times Accessibility$$

Supply analysis is based on the current manpower and equipment inventory of the IMM. Demand analysis is obtained from the outputs of ELER earthquake loss estimation software and depends on the calculation steps how these losses will be mitigated in the most efficient way. Capacities are calculated with the ratio of supply and demand for each indicator and multiplied by accessibility values.

One of the most important step of the Project is accessibility analysis. Acessibility is defined as the ratio between the pre-disaster and post-disaster ability to reach desired services. Pre-disaster accessibility is related to road width, speed of traffic flow, and slope. Post-disaster accessibility deprends on road blocks in addition to above stated parameters. Accessibility is calculated in terms of time and average values are calculated using Geographic Information Systems. Calculated values are multiplied by capacity values of districts.

Accessibility is calculated for all coping capacity indicators. These are

1. Rescue and Relief Capacity
    - Search and Rescue Capacity
    - Fire fighting Capacity
    - Burial Capacity
2. Debris Removal Capacity
3. Lifeline Restoration Capacity
    - İSKİ Response Capacity
    - İGDAŞ Response Capacity
3. Shelter Site Support Capacity
    - Bread Distribution Capacity (Halkekmek)
    - Food Distribution Capacity (IMM Logistical Centers and Social Facilities)
    - Water Distribution Capacity (Hamidiye)
    - Capacity of Planned Tent Area

Based on costs on a transportation network , accessibility values are calculated for each raster based 10m grid cell to a reference point. The input to accessibility model is

- İstanbul District Boundary
- İstanbul Road Network (Road width parameter)
- Rush hour traffic data (IMM Traffic Sensor Data)
- Road Block Data caused by debris
- Slope Map
- Service points that capacity stored.

6.1. Rescue and Relief Capacity

Rescue and relief activities consists of Works that has a wide range of activities. However, outstanding indicators when it is evaluated in the framework of authorities and responsibilities of IMM covers search and rescue, fire fighting and burial processes.

6.1.1. Search and Rescue Capacity

Search and rescue (S&R) is one of the most important factors in emergency management situation and it plays a vital role for human lives. On the other hand it is a very complex process to model and thus it is difficult to calculate the S&R capacity.

Based on the consultation with IMM units, the most appropriate way of capacity estimation is taking basing the calculation on manpower. In the calculation of the required personel for search and rescue work international standarts used and evaluations are based on the number people under debris.
In general understanding the work is considered to be conducted by IMM Firebrigade personel and accessibility values of the service points are used.

6.1.2. Fire Fighting Capacity

With firefighting capacity it is meant to be evaluated that a possibble outbreak of fire extinguished after caused by a possible earthquake. In this scope, the outstanding responsible institution is IMM firebrigade.
Furthermore the computations are made for a targeted time of 24 hours for which all fire outbreaks following the earthquake should be extinguished. According to an earthquake scenario, it is considered that damages caused by fire outbreak is proportional to the facilities containing dangerous materials (flammable and explosive etc.,) and accessibility values are taken into consideration to calculate coping capacity values.

6.1.3. Burial Capacity

With burial capacity, it is evaluated that how much of the demand of the cemetry is supplied after a possible earthuqake. In the calculation steps, the ratio of the empty graveyard and the accessibilities to them and the number of deaths are analysed together.

6.2. Debris Removal Capacity

The efficient conductance of the post-disaster rehabilitation activities is directly related to the catering of the services to the disaster-prone areas. Therefore, it becomes important to remove debris at the shortest time that is caused by mainly damage to buildings and various other factors.
The estimated debris on the emergency road network should be temporarily removed to surrounding areas in order to re-open roads for emergency vehicle operations within 3 days is a critical role for İstanbul Metropolitan Municipality.

In this context, debris removal capacity covers the quickest removal of the debris after earthquake damages. The required data is **volume of the debris** calculated by using the scenario earthquake and the **required equipment (trucks and equipment)**.

6.3. Lifeline Restoration Capacity

Lifeline Restoration Capacity refers to evaluation of the mitigation of the risks with the response in the most efficient way after a possible earthquake. In this context, İSKİ and İGDAŞ stands for the responsible local authority at IMM.

6.3.1. İSKİ Recovery Capacity

ISKI (Istanbul Water and Sewage Administration) is the responsible unit that will be involved in repairing water and sewage pipe damages in the most efficient way after a possible Istanbul earthquake. Accordingly,after it is put forward as a result of the negotiations with İSKİ officials, the number of İSKİ damage staff that would intervene in teams to a damage is determined and the calculations are performed by the product of capacity values with accessibility of the İSKİ service points.

6.3.2. İGDAŞ Emergency Response Capacity

IGDAS (Istanbul Natural Gas Distribution Company) is the responsible unit that will be involved in natural gas pipe damages after a possible Istanbul earthquake. Accordingly, İGDAŞ damage repair staff will respond to the damages in teams, after it is put forward as a result of the negotiations with İGDAŞ officials, the number of İGDAŞ damage staff that would intervene in teams to a damage is determined and the calculations are performed by the product of capacity values with the accessibility of the İGDAŞ service points.

6.4. Shelter Site Support Capacity

During an emergency situation, it is necessary that different activities and responsibilities for support to shelter sites should be conducted. Within the context of this activities, the fields that IMM will take part is supporting food, bread and water. The SPHERE standarts are taken into consideration in the calculation of the demands. Accordingly, the responsible enterprises and the directorates are Halkekmek, Directorate of Social and Administrative Affairs and Hamidiye.

6.4.1. Bread Distribution Capacity

Bread distribution capacity, is designed to evaluate the proportion of the support of the produced Halkekmek bread for requirements of the people in the temporary shelters after a disaster. With this aim the production information of the factories are determined as a basis and accessibilities from this points to shelter site support areas where the tents are installed are taken into consideration for the calculation.

6.4.2. Food Distribution Capacity

Food Distribuiton Capacity is designed to evaluate the proportion of the support of the produced food bread for requirements of the people in the temporary shelters after a disaster. With this aim IMM social facilities, firebrigade kitchens, and logistical centers are regarded as main service points and accessibilities from this points to shelter site support areas where the tents are installed are taken into consideration for the calculation.

6.4.3. Water Distribution Capacity

Water Distribuiton Capacity is designed to evaluate the proportion of the support of the produced water for requirements of the people in the temporary shelters after a disaster. With this aim IMM enterprise records are regarded as main service points and accessibilities from this points to shelter site support areas where the tents are installed are taken into consideration for the calculation.