Quantifying the effect of natural disasters on the infrastructures and determination of disaster factor

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Natural disasters like earthquakes, floods, wind storms, etc, cause damage to the different types of the city infrastructures (water structures and networks, electricity structures and networks, roads networks, sewage structures and networks, telecommunications networks and public buildings). The allocation of financial resources in these cases needs a great effort from the decision makers to clarify the priority of the utilities and buildings for repairing. This study aims at developing a model to quantify the effect of a disaster to find out the arrangement of priorities to help the decision makers to make their decisions. This study is limited to infrastructures and governmental and public buildings only. First, the city or the affected area is divided into small areas according to the power of the disaster and the spread of the city (affected area). Second, an evaluation of the damage in the different types of utilities and governmental and public buildings are estimated for each area, and then an equivalent of damages and weights of utilities are calculated for each area. By introducing the population density and relative priority of the different types of utilities, and importance of the districts or the areas, the model to calculate the Disaster Factor (DF) is presented. The comparison between the different areas will be according to the DF. A case study is introduced to explain implementation of the model.

تسبب الكوارث الطبيعية مثل الزلازل والفيضانات و الرياح و العواصف.. الخ الكثير من الخسائر للبنى التحتية من منشات وشبكات مياه و كهرباء و طرق وصرف واتصالات. كما إنها تسبب الخسائر للعديد من المنشآت. عندما تصيب واحدة من هذه الكوارث إحدى المدن فان توجيه الأموال المحدودة للإصلاح يتطلب تحديد الأولويات مسبقا. وهذا ليس بالأمر اليسير على متخذي القرار نظرا لتشابك وتداخل البني التحتية وتعدد الخسائر في أجزائها. تهدف هذه الدراسة إلى تطوير نموذج يستخدم لتحويل نسب الخسائر في الأنواع المختلفة في البني التحتية إلى أرقام للمقارنة بين المساحات المختلفة لتحديد الأولويات. حيث يتم تقسيم المدينة المصابة إلى مساحات متناسبة مع الكثافة السكنية ومقدار التدهور في البني التحتية ثم تحديد درجة الأهمية للمساحات المختلفة ثم تقدير الخسائر في البني التحتية المختلفة ومن ثم تطبيق النموذج وحساب معامل الكارثة. تم في هذا البحث تطوير نموذج لحساب معامل الكارثة. وهو القيمة التي تعبر عن مدى الإصابة التي لحقت بهذه المساحة من المدينة. يتم تحديد الأولويات حسب معامل الكارثة حيث تعطى الأولوية للمعامل الأكبر. تقتصر الدراسة على البني التحتية و على المباني الحكومية والمباني العامة.

Keywords: Natural disaster, Earthquake, Infrastructure maintenance

1. Introduction

When natural disasters like earthquakes, thunderstorms, wind storms, floods, tsunamis, fires, hurricanes, tornados, etc, hit a city, most of the infrastructures and buildings will suffer serious damage. The damage caused by these natural disasters differ from area to another according to how far this area is from the center of the disaster. In the same area the effect of the disaster will vary from one infrastructure to another and from one building to another. When allocating limited resources to the affected areas, the decision makers face the problems of the priorities, which area needs its resources before the others. This depends mainly on the importance of the infrastructures and urgency of infrastructure repair and their extent of damage. The interlocking nature between the different types of infrastructures makes the problem more difficult. This study tries to find an objective description of the problem to help the decision makers make their decisions.

2. Literature review

2.1. Natural disaster and natural hazards

A natural disaster is the consequence of a natural hazard (e.g. volcanic eruption, earthquake,and landslide) which moves from potential in to an active phase, and as a result affects human activities. Human vulnerability, exacerbated by the lack of planning or lack of appropriate emergency management, leads to financial, structural, and human losses. The resulting loss depends on the capacity of the population to support or resist the disaster, their resilience [1]. This understanding is concentrated in the formulation: "disasters occur when hazards meet vulnerability [2]. A natural hazard will hence never result in a natural disaster in areas without vulnerability, e.g. strong earthquakes in uninhabited areas. The term natural has consequently been disputed because the events simply are not hazards or disasters without human involvement [3]. The degree of potential loss can also depend on the nature of the hazard itself, ranging from a single lightning strike, which threatens a very small area, to impact events, which have the potential to end civilization.

A natural hazard is a situation which has the potential to create an event that has an effect on people. They result from natural processes in the environment and some natural hazards are related - earthquakes can result in tsunamis, and so on. The natural hazards types are geological, hydrological, climatic and fire.

Geological (Avalanche, Earthquke, Lahar, Landslides, Mudflows, Sinkholes, Volcanic eruption). The main disaster that may badly affect infrastructure is an earthquake. It is a phenomenon that results from a sudden release of stored energy that radiates seismic waves. At the Earth's surface, earthquakes may manifest themselves by a shaking or displacement of the ground and sometimes tsunamis. Ninety percent of all earthquakes - and 81% of the largest - occur around the 40,000km long Pacific Ring of Fire, which roughly bounds the Pacific Plate. Many earthquakes happen each day, few of which are large enough to cause significant damage.

Hydrological: Example are: Flood, Maelstrom, and Tsunam.

Climatic: Examples are:Blizzard, Hailstorm, Heat wave, Hurricanes, Ice storm , and Tornado.

Fire.

2.2. Emergency management

Emergency management or disaster management is the discipline of dealing with and avoiding risks [4]. It is a discipline that involves preparing, supporting, and rebuilding society when natural or human-made disasters occur. Actions taken depend in part on perceptions of risk of those exposed [2]. Effective emergency management relies on thorough integration of emergency plans at all levels of government and non-government involvement.

2.3. Phases and professional activities

The nature of emergency management is highly dependent on economic and social conditions local to the emergency, or disaster. This is true to the extent that some disaster relief experts such as Fred Cuny have noted that in a sense the only real disasters are economic [5]. Experts, such as Cuny, have long noted that the cycle of emergency management must include long-term work on infrastructure, public awareness, and even human justice issues. This is particularly important in developing nations. The process of emergency management involves four phases: mitigation, preparedness, response, and recovery.

2.3.1. Mitigation

Mitigation efforts attempt to prevent hazards from developing into disasters altogether, or to reduce the effects of disasters when they occur. The mitigation phase differs from the other phases because it focuses on long-term measures for reducing or eliminating risk [4]. The implementation of mitigation strategies can be considered a part of the recovery process if applied after a disaster occurs. However, even if applied as part of recovery efforts, actions that reduce or eliminate risk over time are still considered mitigation efforts [4]. A precursor activity to the mitigation is the identification of risks. Physical risk assessment refers to the process of identifying and evaluating hazards [1]. In risk assessment, various hazards (e.g. earthquakes, floods, riots) within a certain area are identified. Each hazard poses a risk to the population within the area assessed [2].

2.3.2. Preparedness

In the preparedness phase, emergency managers develop plans of action for when the disaster strikes.

2.3.3. Response

The response phase includes the mobilization of the necessary emergency services and first responders in the disaster area. A well rehearsed emergency plan developed as part of the preparedness phase enables efficient coordination of rescue efforts [3]. Emergency plan rehearsal is essential to achieve optimal output with limited resources. Depending on injuries sustained by the victim, outside temperature, and victim access to air and water, the vast majority of those affected by a disaster will die within 72 hours after impact [6].

2.3.4. Recovery

The aim of the recovery phase is to restore the affected area to its previous state. It differs from the response phase in its focus; recovery efforts are concerned with issues and decisions that must be made after immediate needs are addressed [1]. Recovery efforts are primarily concerned with actions that involve rebuilding destroyed property, re-employment, and the repair of other essential infrastructure [4]. An important aspect of effective recovery efforts is taking advantage of a ‘window of opportunity [3]. This study focuses on recovery.

2.4. Natural disaster in Saudi Arabia

Fig. 1 show a rsult of study done by Higgan and Tablib [7] to categorize the disaster in Saudi Arabia during the last decade.

3. Aim of the study

The study aims at developing a model to quantify the effect of the natural disaster in the different areas of a stricken city to help the decision makers make their decision regarding allocation of the limited resources. The study is limited to the public infrastructures (utilities) and the governmental and public buildings. These infrastructures include water structure and networks, electrical structural and networks, sewage structures and networks, road networks and bridges, and telephone structures and networks.

3.1. Assumptions

The following assumptions were considered to develop the model. Some of these assumptions can be changed according to the judgment of decision makers such as population factor assumption and the priorities assumptions. These changes will not affect the developed model if the decision makers use the new assumption as a base.

The density of population will be taken per 100m^2 to obtain a suitable number that can be used in comparing different areas.

If the damage in any of the utilities structures is equal to or greater than 70%, the structure will be useless and non-rehabitable and the decision would be to develop a new structure.

A scale of five is used to develop the weights of priorities. This is suitable to judge the importance or the priority of the items. The decision makers can easily give weights among: strong; very strong; weak; very weak, or moderate. The given priorities or weights can be changed according to the decision makers and this will not affect the application of the developed model.

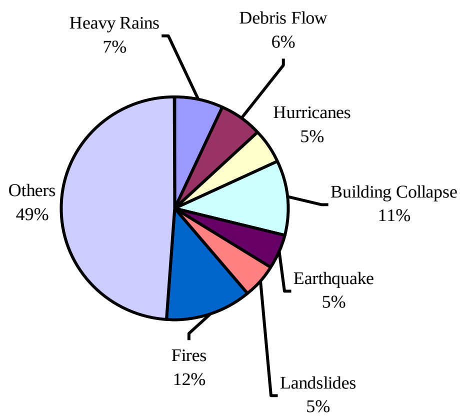

Fig. 1. Natural disaster in Saudi Arabia during the last decade - Average occurance 32.62 times (Higgan and Talib-1998).

4. Methodology

The main idea of the methodology is to divide the bitten city into areas and then define a number expressing the disaster called Disaster Factor (DF) for each area of the city by considering the damages due to the disaster in all types of utilities and public buildings. This number is calculated for the different areas of the city considering the most effective variables in these areas. Selecting the priorities for the different parts of a certain infrastructure or utility and among different types of utilities is carried out by a questionnaire.

The questionnaire was designed and distributed to 287 Engineers of different engineering disciplines and different titles. Two hundred and one questionnaires were collected and analyzed.

5. Questionnaire

5.1. Description of the questionnaire

The main aim of the questionnaire was to get the logical arrangements of the priorities for the different parts of same utility, governmental and public buildings, and relative priorities between different utilities. So, a simple questionnaire was used and simple analysis was carried out. The results of the questionnaire do not affect developing the model equation but helps to understand it. The questionnaire is in Appendix A.

5.2. Sample size and description

The questionnaire was distributed to 287 Engineers in different disciplines, and 201 forms were collected with response rate 70%. The reason for this high rate is the simplicity of the questionnaire and most of them were distributed and collected by hand.

5.3. Analysis of the questionnaire

Level of Education (5 Ph.D., 8 M.Sc., 4 M.Eng., 184 B.Sc.).

Engineers' Disciplines (Civil 127, Electrical 27, Mechanical 25, Architectural 12, Industrial, 7, Chemical 3).

The averages were calculated for each question after excluding 5% of maximum values and 5% of the minimum values. The results are presented as percentages in Tables 1 through 7 in the right columns. These percentages represent the ratio between the number of Engineers who agreed with this arrangement (rank) to the total number of the sample. Experience and logical sense governed the results of the questionnaire.

6. Developing the model

6.1. Zoning of stroked areas

When a natural disaster strikes a city, the consequent damages differ according to many factors such as: the power of the disaster; how far is the city from the center of the disaster; the distribution of the population; and the type of utility. Some zones are affected much more than others. To quantify the effect of the disaster, the city has to be divided into small areas. These areas are defined according to the experience of the decision makers; the areas of 200m×200m up to 1000m×1000m are suitable. The chosen areas depend upon the extent of damage. The more excessive the damages, the smaller are the area considered. These areas are named A1, A2, …An. In this study, a developed model is used to rearrange these areas according to the compound damages and priorities.

6.1.1. Power of the disaster

The Power or Force of the disaster can be expressed using their scientific parameters and scales. For earthquakes the scale is Richter and for storms, the scale is the speed of the air, for Tsunamis, the scale is how far the bitten city is from the sea, for Fires, the scale is how far from the center of the fire. If all the city is subjected to a disaster equally, a relative number equals to one is used in the model.

6.1.2. Population

The more the population, the higher the risk will be. The density of population can be expressed by population factor P. P is the number of people per certain area. To make the output of the model in feeling numbers, a certain area will be taken 100 i.e. an area of 10m × 10m. Make P_1 the highest density of population, P_2 less population, etc. e.g. in a district of 5000 people with an area of 1 km^2, then P= 5000/(100×100)= 0.5, this factor will help in developing the Disaster Factor as will be seen later.

6.1.3. Governmental and public buildings

This study considered the governmental and public buildings only. The scale that is considered in measuring the disaster factor is the importance of the building. A scale of five will be considered in this study G_1 through G_5. G_1 is the most important building while G_5 is the least important one. Table 1 shows the scale for the governmental and public buildings.

This percentage represents the ratio between the number of Engineers who agreed with this rank of the utility to the total number of the sample.

6.1.4. Water utilities (W)

Water utilities which include water treatment plants, water pump stations, and water networks are the most important utilities in the city. The model of the disaster has to include the Water utilities (W). W_1 thru W_2 is a scale of five to evaluate the importance of the utility part as sown in table 2. W_1 is the most important while W_5 is the least one. For a zone having different forms of water utility damage, an equivalent weight has to be calculated.

Equivalent weight and damages: The equivalent weights and damages will be calculated for the all types of utilities. The Letter W here is used for the weights not only for the water utilities but also for all types of utilities, as will be shown in the case study. For the same area that has different types of one utility i.e. W_1, W_2, W_3,..etc., an equivalent weight should be considered as in the following equation. Assume the percentage of damages for the different types W_1, W_2, ..ect. are d_1, $d2$,..etc., then,

$$W_e = \frac{W_1 d_1 + W_2 d_2 + ... + W_5 d_5}{\sum_{i=1}^{5} d_i} . \qquad (1)$$

Where:
W_1 through W_5 = Different forms of utilities
d_1 through d_5 = The damage accompanied to the different forms of utilities.
W_e is the equivalent weight, and
d_e is the equivalent damage (d_e) will be.

Table 1
Arrangement of priorities in governmental and public buildings

Scale	Priority	Weight	Buildings	Percent.*
G_1	1	5	Hospitals, fire stations	95%
G_2	2	4	Police stations, public housing	77%
G_3	3	3	Schools, universities,	83%
G_4	4	2	Ministries and governorate buildings	80%
G_5	5	1	Malls, hotels, parks, and other public buildings	94%

Table 2
Arrangement of priorities in water utilities

Scale	Priority	Weight	Water utility part	%
W_1	1	5	Dams, water treatment plants, pumping stations with damage less than 25%, main pipes 1000mm or larger	83%
W_2	2	4	Dams, water treatment plants, pumping stations with damage higher than 25% and less than 50% approximately, main pipes 800-1000mm.	86%
W_3	3	3	Dams, water treatment plants, pumping stations with damage higher than 50% and less than 75% approximately,	81%
W_4	4	2	Pipes between 800-500 mm.	78%
W_5	5	1	Pipes less than 500 mm.	84%

$$d_e = \frac{W_1 d_1 + W_2 d_2 + ... + W_5 d_5}{\sum_{i=1}^{5} W_i} . \quad (2)$$

Introducing the weights of W_1 through W_5, then

$$d_e = \frac{5d_1 + 4d_2 + 3d_3 + 2d_4 + d_5}{15} . \quad (3)$$

These two equivalent amounts will be considered in determination of Disaster Factor.

Eqs. (2 and 3) are same for the other utilities.

6.1.5. Swage utility (S)

The same scale of five (S_1 thru S_5) is considered to evaluate the importance of the utility part
as shown in table 3. For the same areas has different types of swage utilities, the same concept of eqs. (1 through 4) will be followed.

6.1.6. Electrical utility (E)

The same concepts are applied here, and table 4 is for scale and priority for electrical utilities.

6.1.7. Roads (R)

Same concepts will be considered in roads and table 5 is used.

6.1.8. Telephone (T)

Same Concepts and table 6 is used.

7. Disaster Factor

7.1. Definition

DF is a factor that can measure the severity of the disaster and give an objective scale for the subjective description of the disaster. It can help the government create a numbered picture of the disaster in the different areas. DF is calculated for each area. The suitable area will be taken 500 m^2 as mentioned before which may have variable effects of the disaster among them. Other dimensions of these areas can be considered according to the density and severity of the disaster, buildings, utilities, and people. For each area, the following information have to be collected.

Table 3
Arrangement of priorities in sewage utilities

Scale	Priority	Weight	Sewage utility part	%
S_1	1	5	Swage treatment plants and pump stations with damage less than 25% approximately	78%
S_2	2	4	Swage treatment plants and pump stations with damage higher than 25% and less than 50% approximately	84%
S_3	3	3	Swage treatment plants and pump stations with damage between 50% and 75% approximately.	81%
S_4	4	2	Main Pipes 3000 mm or greater.	77%
S_5	5	1	Pipes less than 3000mm.	86%

Table 4
Arrangement of priorities in Electrical Utilities

Scale	Priority	Weight	Electrical utility part	%
E_1	1	5	Electrical power plant with damage less than 25% approximately.	84%
E_2	2	4	Electrical power plant with damage higher than 25% and less than 50% approximately.	79%
E_3	3	3	Electrical power plant with damage ranging from 50%-75%.	77%
E_4	4	2	Power line 66kv	79%
E_5	5	1	Power line 13.8kv	82%

Table 5
Arrangement of priorities in road utilities

Scale	Priority	Weight	Road utility part	%
R_1	1	5	Main roads, bridges and tunnels with damage less than 25%	90%
R_2	2	4	Main roads, bridges and tunnels with damage ranging from 25% -50%	86%
R_3	3	3	Secondary roads 1st level with damage 25%.	72%
R_4	4	2	Secondary roads 1st level with damage ranging from 25% and 50%.	71%
R_5	5	1	Secondary roads and bridges on 2nd level rods.	75%

Table 6
Arrangement of priorities in telephone utilities

Scale	Priority	Weight	Telephone utility part	%
T_1	1	5	Stations with damage less than 25%	72%
T_2	2	4	Stations with damage varying between 25%-50%	68%
T_3	3	3	Stations with damage varying between 50%-75%	74%
T_4	4	2	Main lines and towers	69
T_5	5	1	Secondary lines and towers	71

Population density: It will be expressed by number of people per 100m^2 area as described above.
Power or force of the disaster:
For earthquakes the scale is Richter.
For storms, the scale is the speed of the air.
For Tsunami, the scale is how far from the sea.

For Fire, the scale is how far from the center of the fire.

Importance of an area (I): It is a factor expressing the importance of the area and has to be considered in such a model. Some areas have special attention and importance such as military bases, diplomatic districts, and presidency areas. A relative judgment from the applicator of the model has to be used. The author suggests a number between 1.0 to the highest degree of importance to 0.1 to the desert areas.

8. The model

The model will collect all the variables mentioned in the previous sections. Eq. (4) represents the model which can be applied in different conditions.

$$DF = P \times F \times I \times \begin{pmatrix} (W_e \times d_{ew}) + (E_e \times d_{eE}) + (R_e \times d_{eR}) \\ + (S_e \times d_{eS}) + (T_e \times d_{eT}) + (G_e \times d_{eG}) \end{pmatrix} . \quad (4)$$

Where:

DF is the Disaster Factor,
P is the population density (person per 100 m^2),
F is the relative power of disaster, and
I is the importance factor.

W_e, E_e, R_e, S_e, T_e, are equivalent weights (priority) for water, electricity, roads, sewage, telecommunications utilities respectively.
G_e is the equivalent weight (priority for the governmental and public buildings.
d_e is the equivalent damages for the different utilities.

The equivalent weights and damages are calculated using eqs. (1 and 2).

8.1. Relative Priority (Pr)

It is a factor that allows combination between the different types of utilities to reach a specific distinguishing number between different areas. This Pr is subjective and can be judged with different manners in different cities. Table 7 shows the results of the questionnaire regarding the relative priority.

Because the sample does not represent the opinion of the member of the population, the rank or priority will be accepted but the percentage is not reliable. However, this will not affect the model and the decision makers can assume the suitable priority for each situation.

Table 7
Relative priority

Utility / Building	Priority	Percentage*
Water	1	96%
Electricity	2	76%
Sewage	3	72%
Roads	4	83%
Telephone	5	68%
Governmental and Public	6	89%

* This percentage represents the number of engineers agreed with this rank of the utility to the total number of sample.

The model has to be modified by introducing the relative priority

$$DF = P \times F \times I \times \begin{bmatrix} (\frac{W_e \times d_{eW}}{p_{rW}}) + (\frac{E_e \times d_{eE}}{p_{rE}}) + (\frac{R_e \times d_{eR}}{p_{rR}}) \\ + (\frac{S_e \times d_{eS}}{p_{rS}}) + (\frac{T_e \times d_{eT}}{p_{rT}}) + (\frac{G_e \times d_{eG}}{p_{rG}}) \end{bmatrix}. \quad (5)$$

Where:
$p_{rW}, p_{rE}, p_{rR}, p_{rS}, p_{rT}, p_{rG}$ are the relative priority between the different types of utilities (water, electricity, roads, sewage, telephone, and governmental buildings and can be taken 1- 6 respectively).

8.2. How to apply the model

The idea of the model can be summarized in the following steps.

1. Divide the stricken city into areas according to the power of the disaster and the horizontal spread of the city. Areas of 300m×300 m or 500m×500m are suitable.
2. Define the population of the city and the distribution of this population among the areas defined in the previous point. Define the density of population of each area per 100 m2.
3. For each area define all the public utilities and governmental and public buildings.
4. Then, estimate the damage inflicted to each utility and building. Use a percentile to express the damage. For any item with a percentage more than 75%, consider that item unfixable.
5. Define the priority of each item of same utility according to tables from (1 through 6)
6. Calculate the equivalent weights for all types of utilities using eq. (1).
7. Calculate the equivalent damages for all types of utilities using eq. (2 or 3).
8. Define the power of the disaster from the national records.
9. Define the relative priority from table 7.
10. Estimate the importance factor of the area (district).
11. Calculate the disaster factor for each area by applying the model from eq. 5.
12. Rearrange the areas according to the values of DF.

The decision maker can allocate the limited resources according to DF obtained for each area. He can use different values other than those mentioned in the listed tables.

9. Case study

A virtual case is assumed to present the application of the model. Fig 2 shows four sections of a city hit by an earthquake with different areas as shown in the figure. Table 8 shows the measurements of the damages for different areas and utilities.

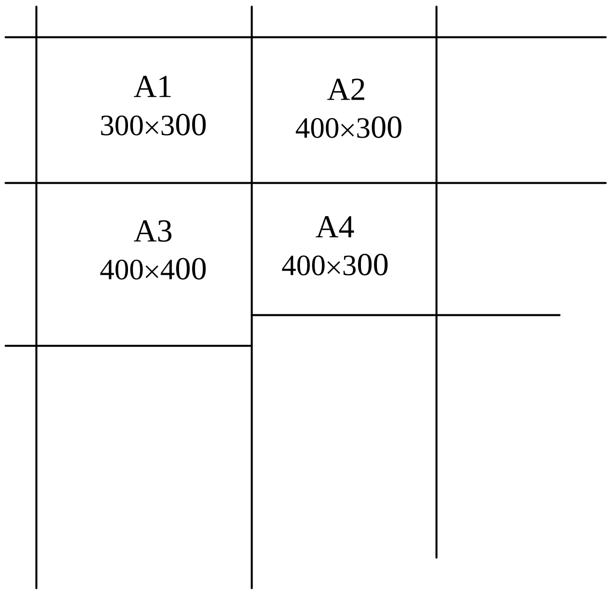

Fig. 2. Four areas for study.

10. Conclusions

When a natural disaster strikes a city, its infrastructure will be affected with different degrees of damage. Some utilities will be affected more than others and some areas will have problems more than others. The study aimed at quantifying the damage to enable the decision makers to direct their resources in rehabilitation of the affected utilities. The study was concerned about the public utilities (Water, Electricity, Sewage, Roads, Telephone) and governmental and public buildings. A model to calculate the Disaster Factor is presented. The Equation of the developed model includes all types of utilities, population density, Importance of the hit area, and the power of the disaster. The model introduced equivalent weights and equivalent damages for each utility and relative priorities for different utilities. The procedure for application of the model is introduced as well. Estimation of the hierarchy of degree of damages for the different parts of each utility and arrangement of the relative priorities of different utilities were obtained through a simple questionnaire developed for the study. A case study of a scenario of an earthquake hitting a city was presented.

As shown in the case study, the arrangement of the areas according to DF is A1, A2, A3, then A4.

Table 8
Case study

Utility	Parts of utilities	Affected Areas				
		A1	A2	A3	A4	... Notes
Popu/Km^2		5600	3300	3750	1670	
Popu./100m^2		0.56	0.33	0.375	0.167	
Imp.		0.50	0.75	0.75	1.0	
Force		1	1	1	1	
Water utilities	Dam	-	-	-	-	
	Reg.	20% (w_1)	-	-	-	
	Treat.		25% (w_1)		50% (w_2)	
	Pump St.		20% (w_1)		20% (w_1)	
	Tanks	-	-	-	-	
	>1000 mm	10% (w_1)	5% (w_1)	15% (w_1)	10% (w_1)	
	800-500	10% (w_4)	20% (w_4)	5% (w_4)	5% (w_4)	
	< 500mm	25% (w_5)	20% (w_5)	-	10% (w_5)	
Eq. weight,	W_e	3.00	3.44	4.25	3.89	
damage	d_e	15	17.22	12.14	21.76	
Sewage Utilities	Treat.	-	-	50% (S_2)	20% (S_1)	
	Pump St.	-	-	30% (S_1)	20% (S_1)	
	>3000 mm			15% (S_4)	20% (S_4)	
	< 3000mm	25% (S_5)	30% (S_5)	-	-	
Eq. weight,	*Se*	1.00	1.00	4.00	4.00	
damage	*de*	25	30	34.55	20	
Elec. Util.	Power Pl.	60% (E_3)	-	-	-	
	Line 66kv	-	40% (E_4)	30% (E_4)	20% (E_4)	
	Line<13.8kv					
Eq. weight,	*Ee*	3.00	2.00	2.00	2.00	
damage	*de*	60	40	30	20	
Road	Bridges	-	50% (R_2)	-	-	
Util.	Main road	30% (R_2)	20% (R_2)		40% (R_2)	
Eq. weight,	*Re*	4.00	4.00		4.00	
damage	*de*	30	35		40	
Tel.	Station			30% (R_4)		
Util.	Main line	10% (R_4)	40% (R_4)	30% (R_4)	20% (R_4)	
Eq. weight,	T_e	2.00	2.00	2.00	2.00	
damage	d_e	10	40	30	20	
Gover. and		Hospital	Fire St.	Univ.	Ministry	
public blg.		15%	25%	20%	10%	
	G_e	5	5	2	1	
	d_e	15	25	20	10	
D.F		53.67	45.19	40.93	30.06	

Appendix

Questionnaire

Name:

Work Title:

Specialty:

Number of Years of Experience:

Education: Bachelor Master Doctorate

Age:

The following questionnaire will used in developing priorities of the different types of utilities. This will help the decision makers to select the way to allocate limited resources in case of disasters. Please use your personal judgment.

Group 1: Governmental and Public Buildings

In case of damage happened for governmental and public buildings, use your personal judgment to give the priority for repair and maintenance. Use a scale of five, 1 for the first priority, 2 second priority, .., and 5 for the last priority.

Hospitals □1st □2nd □3rd □4th □5th

Universities and Schools □1st □2nd □3rd □4th □5th

Public Arenas □1st □2nd □3rd □4th □5th

Police Stations □1st □2nd □3rd □4th □5th

Fire Stations □1st □2nd □3rd □4th □5th

Hotels □1st □2nd □3rd □4th □5th

Ministries and Governorate Buildings □1st □2nd □3rd □4th □5th

Malls □1st □2nd □3rd □4th □5th

Parks □1st □2nd □3rd □4th □5th

Public Housing □1st □2nd □3rd □4th □5th

Group 2: Water Utilities

In case of damage happened for water structures and networks, use your personal judgment to give the priority for repair and maintenance. Use a scale of five, 1 for the first priority, 2 second priority, .., and 5 for the last priority.

Dams and Regulators □1st □2nd □3rd □4th □5th

Water Treatment Plants □1st □2nd □3rd □4th □5th

Pump Stations □1st □2nd □3rd □4th □5th

Elevated Tanks □1st □2nd □3rd □4th □5th

Main pipes greater than 1000 mm □1st □2nd □3rd □4th □5th

Pipes than 800-1000 mm □1st □2nd □3rd □4th □5th

Pipes less than 800 mm □1st □2nd □3rd □4th □5th

In your opinion what is the percentage of damage in water structure that make the utility non-rehabilitable?

□50% □60% □70% □80% □90%

For the following damages define the priorities ?

Water Structures with 25% damage □1st □2nd □3rd □4th □5th

Water Structures with 50% damage □1st □2nd □3rd □4th □5th

Water Structures with 75% damage □1st □2nd □3rd □4th □5th

Pipes of diameters 1000 mm or greater □1st □2nd □3rd □4th □5th

Pipes of diameters 800-10000 mm □1st □2nd □3rd □4th □5th

Pipes of diameters less than 800 mm □1st □2nd □3rd □4th □5th

Group 3 : Sewage Utilities

In case of damage happened for Sewage structures and networks, use your personal judgment to give the priority for repair and maintenance. Use a scale of five, 1 for the first priority, 2 second priority, .., and 5 for the last priority.

Pump Stations	□1st	□2nd	□3rd	□4th	□5th
Sewage Treatment Plants	□1st	□2nd	□3rd	□4th	□5th
Main pipes greater than 3000 mm	□1st	□2nd	□3rd	□4th	□5th
Pipes less than 3000 mm	□1st	□2nd	□3rd	□4th	□5th

In your opinion what is the percentage of damage in Sewage structures that make the utility non-rehabilitable?

□50% □60% □70% □80% □90%

For the following damages define the priorities?

Sewage Structures with 25% damage	□1st	□2nd	□3rd	□4th	□5th
Sewage Structures with 50% damage	□1st	□2nd	□3rd	□4th	□5th
Sewage Structures with 75% damage	□1st	□2nd	□3rd	□4th	□5th
Pipes of diameters 3000 mm or greater	□1st	□2nd	□3rd	□4th	□5th
Pipes of diameters less than 3000 mm	□1st	□2nd	□3rd	□4th	□5th

Group 4 : Electrical Utilities

In case of damage happened for Electrical Structures and networks, use your personal judgment to give the priority for repair and maintenance. Use a scale of five, 1 for the first priority, 2 second priority, .., and 5 for the last priority.

Electrical Power Plant	□1st	□2nd	□3rd	□4th	□5th
Power lines 66kv or greater	□1st	□2nd	□3rd	□4th	□5th
Power lines less than 66kv	□1st	□2nd	□3rd	□4th	□5th

In your opinion what is the percentage of damage in Electrical Generating Structures that make the utility non-rehabilitable?

□50% □60% □70% □80% □90%

For the following damages define the priorities ?

Electrical Plants with 25% damage	□1st	□2nd	□3rd	□4th	□5th
Electrical Plants with 50% damage	□1st	□2nd	□3rd	□4th	□5th
Electrical PLants with 75% damage	□1st	□2nd	□3rd	□4th	□5th
Power line 66kv or greater	□1st	□2nd	□3rd	□4th	□5th
Power line less tha 66kv	□1st	□2nd	□3rd	□4th	□5th

Group 5: Road Utilities

In case of damage happened for Road network and Road Structures (bridges –tunnels), use your personal judgment to give the priority for repair and maintenance. Use a scale of five, 1 for the first priority, 2 second priority, .., and 5 for the last priority.

Bridges	□1st	□2nd	□3rd	□4th	□5th
Tunnels	□1st	□2nd	□3rd	□4th	□5th
Main Roads	□1st	□2nd	□3rd	□4th	□5th
Secondary Roads	□1st	□2nd	□3rd	□4th	□5th

In your opinion what is the percentage of damage in roads and road structures that make the utility non-rehabilitable?

□50% □60% □70% □80% □90%

For the following damages define the priorities?

Bridges and main roads with 25% damage	□1st	□2nd	□3rd	□4th	□5th

Bridges and main roads with 50% damage □1st □2nd □3rd □4th □5th
Bridges and main roads with 75% damage □1st □2nd □3rd □4th □5th

Group 6: Telephone Utilities

In case of damage happened for Telephone line and structures and networks, use your personal judgment to give the priority for repair and maintenance. Use a scale of five, 1 for the first priority, 2 second priority, .., and 5 for the last priority.

Stations with damage less than 25% □1st □2nd □3rd □4th □5th
Stations with damage less than 50% □1st □2nd □3rd □4th □5th
Stations with damage less than 75% □1st □2nd □3rd □4th □5th
Main Tower for cell Phone. □1st □2nd □3rd □4th □5th
Secondary Tower for cell Phone. □1st □2nd □3rd □4th □5th

In your opinion what is the percentage of damage in Telephone centers that make the utility non-rehabilitable?

□50% □60% □70% □80% □90%

Group 7: Relative Priority

In the following table write a number expressing the relative priority for repair or relative importance using your personal judgment. Number 1 expressing the most important utility and number 6 is the least important one.

Utility	Importance (relative priority)
Water utilities	
Electrical utilities	
Sewage utilities	
Road utilities	
Telephone utilities	
Governmental and public buildings	
Total	100%

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