DEVELOPING A NATIONAL RISK PROFILE
FOR
THE LEBANON

DRAFT

by

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Acknowledgements

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Executive Summary

This report is the third in a series of report funded by the UNDP and SDC, and carried out by the author, for the Presidency of the Council of Ministers in Lebanon. The first report provided a summary and discussion on disaster risk losses in Lebanon. The second report provided an identification of Lebanon's national critical infrastructure followed by a discussion on the current state of resilience of Lebanon's national critical infrastructure. This report provides an analysis of the risk profile in Lebanon including hazard, exposure and vulnerability mapping. The remaining report will present a draft national strategy for Disaster Risk Reduction within Lebanon, for discussion by various stakeholders. Where applicable, each of these reports will also provide a discussion on the interaction of the main global risk drivers (environmental degradation, rapid urbanization, poor governance and poverty) with the topic under consideration (i.e. disaster losses, infrastructure, hazards, exposure, vulnerability, risks and strategies for risk reduction).

As various low and middle income third-world countries continue to strive to meet development goals, it becomes crucial to comprehend the multi-faceted manner in which disaster risk interacts with the development process. Indeed, on the one hand, disaster risk is being driven by various manifestations of unchecked development including environmental degradation, rapid urbanization and poverty which is leading to an increase in the frequency and intensity of disaster risk. Disaster risk reduction may be achieved most effectively through integrating DRR efforts in development planning and private investment planning. However, a prerequisite to this integration is the availability of a national risk profile for the country, showing spatial variability of hazards, exposure and vulnerabilities. Therefore, it is important to collate and analyse data related to hazards, exposure

and vulnerabilities, corresponding to the main hazards within the country (earthquakes, tsunamis, forest fires, storms and floods).

Against this background, the UNDP commissioned the author to carry-out this study with the objective of developing a National Risk Profile for The Lebanon.

Some of the salient conclusions of the study are discussed below, while a more detailed discussion is available within the body of the report and in Chapter 7:

There is a need to adopt an approach that can capture the economic, social, physical, natural and institutional factors that contribute to vulnerability corresponding to various hazards. By adopting such an approach, rather than simply focusing on physical vulnerability, it was possible to capture the following salient representations of risk:

- **The earthquake risk to nurseries is critical** due to a combination of factors shaping vulnerability including lack of clear mandates leading to no effort or intervention in this regard.
- **Earthquake risk is critical** in illegal settlements and refugee camps which show a concentration of non-engineered houses – where the latter is usually ignored when assessing the seismic safety of buildings.
- **Earthquake risk is critical** in settlements near hazardous installations, whether those have encroached on areas near hazardous installations, or those where factories have illegally located in residential areas.
- **Earthquake risk is critical** in housing units with old tenancy agreements where various factors including ownership issues interact to shape an extreme picture of seismic risk.

- **Earthquake risk is critical in Beirut and Tripoli,** which witness a high degree of exposure and concentration of factors contributing to vulnerability.
- **There is an urgent need to develop tsunami hazard intensity maps,** showing expected wave height and expected inland inundation, due to the high level of exposure along the Lebanese coast as represented by a concentration of the population, trading establishments, industrial establishment and touristic establishments amongst others.
- **Earthquake and tsunami risk is critical in the four main cities along the coast, Beirut, Tripoli, Sidon and Tyre.**
- **The agriculture sector is particularly vulnerable to flooding hazards,** and the livelihood of agriculture workers is also particularly vulnerable to flooding hazard, particularly in those Cazas where agriculture forms the sole source of income.
- Forest fires continue to pose a risk to the livelihoods of citizens which depend on crops and trees particularly along the western plains of Lebanon.

1 Introduction

1.1 Background

Efforts are being increasingly targeted towards meeting the development millennium goals on a worldwide scale. At the same time it is becoming apparent that disaster risk losses (both human and economic) may be aggravated by unchecked urban development, environmental degradation, poor governance and poverty; and in turn may hinder the development process. Against this background there is an increased need to intensify disaster risk reduction efforts, a prerequisite of which is the availability of a national risk profile showing the spatial variation of hazards, exposure and vulnerabilities.

While various countries are embarking on developing their own national risk profiles, it is important to comprehend the challenges of such an undertaking within developing counties in general and the Lebanese context in particular where data is scarce and information sharing mechanisms are lacking.

To this end, effort is directed at making use of existing data on hazards and exposures to arrive at a risk picture. The risk picture is a preliminary one which is in need of continuous updating as more reliable data becomes available and as risk and exposure evolve. However, notwithstanding limitations in data, it is necessary that a national risk profile be produced so that efforts can be directed at incorporating it into the development process. Once this is done, it becomes part of the risk management process to update the risk profile as more data become available or as conditions evolve.

1.2 Objectives

The principal objective of this study is to undertake an analysis of the spatial variation of hazards, exposures and risks within Lebanon. To achieve the above objective, the following tasks were carried out:

- Carry out a review of international methodologies for developing national risk profiles.
- Carry out a review and analysis of available data on hazards in Lebanon.
- Carry out a review and analysis on available data of exposed elements in Lebanon.
- Carry out analyses to arrive at a preliminary picture of vulnerabilities within Lebanon.
- Analyse available data on hazards, exposure and vulnerability to arrive at a preliminary picture of risk within Lebanon.
- Draw conclusions and identify areas where future efforts must be directed in order to improve data collation, analysis and the overall quality of the national risk profile.

1.3 Scope and Layout

1.3.1 Scope of Hazards

The focus of this study is on the exposure and risk corresponding to the following hazards:

- Earthquakes.
- Tsunamis.
- Floods.
- Forest fires.

1.3.2 On Terminology

Six terms are frequently used in this report, namely critical facilities / critical infrastructure, resilience, hazard, risk, exposure and vulnerability. Definitions of these terms are shown below, in alphabetical order, based on the terminology developed by the United Nations International Strategy for Disaster Reduction (UNISDR) [1]:

Critical Facilities: The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or a community, both in routine circumstances and in extreme circumstances of an emergency.

Lebanese Context: Infrastructure in Lebanon gains additional criticality due to the large public debt which will place excessive burdens on the budget, and possibility to invest in development initiatives, in case of future significant destruction to existing infrastructure. As such the level of production to be afforded to critical infrastructure should be based on a national stakeholder participatory approach.

Exposure: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Lebanese Context: Data on exposure is significantly limited. For example, the only and latest national census for the Lebanese population was carried out in 1932. Reliance has to be made on various studies based on different samples.

Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Lebanese Context: In the context of this study, earthquakes, tsunamis, floods and forest fires will be considered.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, respond to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Lebanese Context: Resilience of infrastructure in Lebanon, and worldwide, is a function of component based attributes such as reliability and strength, and system based attributes for the network as a whole including redundancy and ability to fulfil their role in response and recovery efforts, including the avoidance of hampering these efforts. Within the Lebanese context, so far, emphasis has been placed on response and less on the remaining three elements.

Risk: The combination of the probability of an event and its negative consequences.

Lebanese Context: The production of accurate risk maps requires the existence of hazard intensity maps which include data on both the severity and probability of particular events occurring. This data is not yet available for all hazards under consideration.

Vulnerability: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Lebanese Context: It is important to look at all factors that contribute to vulnerability including social, economic, physical, natural and institutional vulnerability. As in many developing and third world countries, it is envisaged that the above dimensions of vulnerability will be concentrated in certain areas.

1.3.3 Layout

The remainder of this report is divided into five main sections. Section 2 provides a brief overview of the methodology adopted in this study. Section 3 and Section 4 address the exposure and vulnerability to seismic and tsunami risk respectively. Section 5 assesses the exposure and risk to flooding hazards, while section 6 assesses the exposure and risk to forest fires. Finally, Section 7 provides conclusions of the study. Recommendations will be part of a separate report on the development of national risk reduction strategy for Lebanon.

In the context of this study, and for purposes of succinctness, the term disaster risk management is used to imply all the phases related to disaster risk reduction which includes: prevention, reduction, mitigation, rehabilitation, reconstruction and relief, as well as the capacities, skills and institutions necessary for carrying out disaster risk reduction activities.

1.4 Limitations

It should be recognized that this is the first instant in time when such a study has been carried out within Lebanon. Inevitably, such a study on developing a national risk profile is as accurate as the accuracy of the data that it is collating and analysing. To this end, the following challenges in data collation have been identified and highlighted for possible corrective interventions in future efforts:

1. In general, there is significant overlap in the authorities that are requested to collate data at the centralised level (council for development and reconstruction - CDR and central administration of statistics - CAS), sectoral level (ministry and trade /professional organisation level) and local (municipality /

local NGO) levels. This, in turn, makes it very difficult to determine the responsibility to collate data.

2. There is a lack of political will on collating certain types of "sensitive" data (such as population demographics, place of residence, etc) due to a "perceived apprehension", that this may be used for political purposes by various sectarian factions.

3. However, the paucity of reliable, up-to-date data should be seen within a broader context. Namely that there is limited demand for such data, in turn implying limited progress in development, implementation and monitoring of national development plans. This is a major challenge as the eventual objective (and success) of any disaster risk management profiles, recommendations and strategy is their incorporation in national and sectoral development plans.

2 Methodology

2.1 Introduction

The national risk profile of any country is composed of the following elements:

- A hazard profile showing the variation of various hazards within the country.
- An exposure assessment showing the type, number and economic value (if possible / applicable) of the elements exposed to the hazard under consideration.
- A vulnerability assessment taking into account the physical, social, economic, institutional and natural (alternatively referred to as environmental) factors which may increase (or decrease) the susceptibility (or resilience) of a community (or element at risk) to the negative impact of hazards.

According to the above definition, the basic function of risk may be divided into three components, namely hazard, exposure and vulnerability. This may be represented conceptually using the following equation:

Risk = Hazard ✖ Vulnerability ✖ Elements at Risk

In this manner, risk is obtained using an Exposure, Vulnerability and Risk Assessment (EVRA) approach that combines the spatial and quantitative variation of the above factors to arrive at a risk picture. In the context of this study, the vulnerability assessment attempts to capture the factors that may increase or decrease vulnerability (and so decrease or increase resilience).

2.2 Exposure Assessment

The objective of the exposure assessment is to quantify the exposed population, livelihoods and economic assets located in hazard prone areas. This inevitably requires a definition of the economic and other sectors which will be included in the scope of the exposure assessment.

Table 1 shows the sectors included in the exposure assessment, namely the educational, financial, health, population, real estate, transportation, government, industrial, telecommunications, energy, water, emergency services, tourism, and heritage sectors. These are identical to the sectors considered in the assessment of the resilience of the national critical infrastructure produced in an earlier report [15].

The accuracy of the exposure assessment is determined to a large degree by the level and accuracy of existing data. The exposure assessment will in turn provide input to the vulnerability and risk assessment process.

Table 1 *Sectors considered in the Exposure Assessment*

Sector	Defence and Emergency Response	Economic security and Livelihoods	Public Health and Safety
Telecommunication and information networks	✖	✖	
Energy	✖	✖	
Banking / finance		✖	
Transportation	✖	✖	
Water			
Emergency Services			
Government			
Health Services			
National defence	✖		
Law enforcement			
Food / agriculture			
Manufacturing		✖	
Chemical			

Sector	Defence and Emergency Response	Economic security and Livelihoods	Public Health and Safety
Special events			✖
Power plants			
Postal / shipping			
National monuments / Icons			✖

2.3 Vulnerability Assessment

Vulnerability assessment is amongst the most critical steps in the quantification of risk assessment since it includes the following dimensions:

- Physical factors affecting vulnerability.
- Social factors affecting vulnerability.
- Economic factors affecting vulnerability.
- Institutional factors affecting vulnerability.
- Natural (environmental) factors affecting vulnerability.

In this report, an attempt will be made to determine the various factors affecting vulnerability in order to arrive at a realistic risk profile. In addition, an attempt will be made to assess the effect of ignoring the latter four dimension of vulnerability on the overall risk picture.

2.4 Types of Hazards

The EVRA methodology depends to a large degree on the national hazard assessment. A main challenge is that hazard assessments in Lebanon are limited to hazard prone area maps and rarely produce hazard intensity maps.

Another challenge is that there is a need to develop a rationale for setting the level of severity of the hazardous events (and return period of the event under consideration) for which the exposure and vulnerability assessment is going to be carried out. Such a rationale should include differentiation between critical infrastructure

installations, which must be afforded a higher degree of reliability and protection, and ordinary structures. Furthermore, such a rationale should elaborate reasons behind any differences in the severity of the various hazardous events against which the exposed elements must be protected. Table 2 shows the criteria currently being used in the protection of various exposed elements.

Table 2 *Scope of EVRA for Various Hazards and their Severity*

Type of Hazard	Criteria currently used in the country
Earthquake	10% exceedance in 50 years or (475 years)
Tsunami	Not used
Earthquake and Tsunami	Not used
Flood	Hazard prone areas
Forest Fire	Hazard prone areas

The lack of hazard intensity maps, which show the geographical distribution of the intensity of the hazard correspond to a particular annual probability of exceedance, poses a challenge for the vulnerability assessment since vulnerability corresponds to a particular level of severity. In view of the above, a qualitative vulnerability and risk assessment is carried out. Factors affecting the multi-faceted nature of vulnerability are identified and their geographical variation analyzed. This allows a qualitative estimation of vulnerability that takes into account both physical and non-physical factors and their contribution. This allows for the development of a risk profile and a national disaster risk reduction strategy to be incorporated within the development and planning for development.

As the disaster risk situation unfolds with the emergence of new data on hazards and exposure, and with the implementation of various disaster risk reduction initiatives, it becomes necessary to update the disaster risk profile. It is envisaged that such a task will need to be done on a regular basis every 3 to 5 years depending on developments.

2.5 Application of EVRA

The application of the EVRA methodology provides a framework showing linkages and interactions between hazards, exposure and vulnerabilities (including various factors affecting vulnerability). In particular, the following points should be recognized regarding the application of the ERVA methodology:

- The hazard assessment refers to hazard prone area maps. And the vulnerability and risk assessment are based on these maps. There is a need to update the risk profile once hazard intensity maps become available for the various hazards. This will allow for a more accurate assessment of vulnerabilities based on the intensity, and corresponding return periods, of various hazards.
- Data on exposure is limited in both quantity and quality. For example, data on population numbers are not available as the last full census dates back to the year 1932. Similarly data on economic sectors is not complete in terms of years and geographic coverage.
- Several factors are identified under each of the five main headings of factors affecting vulnerabilities (physical, social, economic, natural, and institutional). Each one of these factors is influenced by several sub-factors. Data on some of these sub-factors is limited in both quality and quantity.
- The ERVA provides a basic framework for understanding linkages between hazards, exposure and vulnerabilities. As more data becomes available on any of these three components, there is a need to update the risk profile using the framework discussed in this report.

3 Earthquake Hazard, Exposure, Vulnerability and Risk Assessment

3.1 Introduction

Over the past centuries, cities lying within the current borders of Lebanon, as many cities along the Eastern coast of the Mediterranean, were subjected to variety of earthquakes in some instances coupled with destructive Tsunami waves, as indeed happened in Berytus (modern day Beirut) in 551 CE. In order to understand the current risk in the country, and the vulnerability of the various sectors to the earthquake hazard, it is necessary to map exposure, vulnerability and risk corresponding to earthquake hazard in Lebanon.

The sectors included in the study include the education, health, transportation, communication, financial, tourism, government buildings, national heritage, emergency response, industrial, housing, water and wastewater, energy and agriculture.

It should be recognized that one of the main challenges in the determination of the seismic risk the country is subjected to, is the determination of the seismic event for which the risk profile is going to be calculated. This should ideally be based on a national consensus process, which takes place through a national committee representing all stakeholders. However such a committee is yet to be formed for various reasons related to risk governance, the lack of a risk accountability framework and the volatile political situation in the country and the region acting as a backdrop against which this study is taking place.

3.2 Hazard Assessment

Earthquake hazard maps in Lebanon are restricted to hazard prone area maps as reported earlier in the country situation analysis report on risk assessment [2]. Figure 1 shows the earthquake hazard prone area map produced by the council for development and reconstruction [3], as part of general principles for developing master plans for landuse

purposes, where it can be seen that seismic hazard is referred to as seismic risk. It can also be seen that Lebanon is divided into four seismic zones where the seismic hazard is considered as very high, high, medium and low.

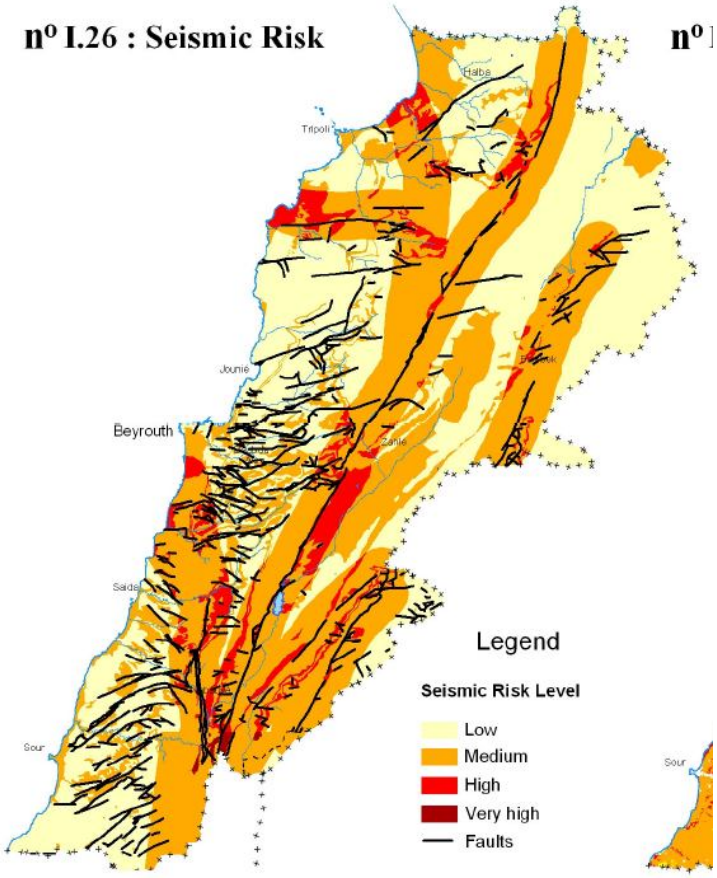

Figure 1 *Seismic Hazard Prone Area Map*

On the other hand the public safety decree 14293 [4] issued in 2005 defined the whole of Lebanon as a seismic zone equivalent to Zone IIB in the American UBC Code for 1997, with a peak ground acceleration of 0.2g corresponding to an annual probability of exceedance of 475 years.

3.3 Exposure Assessment

3.3.1 Methodology for Exposure Assessment

Different methods are available to carry out the exposure assessment for a particular country corresponding to a certain hazard. The most suitable method will depend on the following factors:

- The detailed scope of the assessment.
- The type of the hazard.
- The available data.
- The allocated resources for the assessment.
- The objectives of the risk assessment itself.

In the context of this study, the main objective is to show the linkages between hazards, exposure of elements at risk, vulnerability and risk. Due to the lack of hazard intensity maps, and the paucity of data on some of the factors affecting vulnerability, a qualitative methodology will be adopted.

3.3.2 Elements at Risk

It is assumed that the whole of Lebanon is subjected to earthquake hazard, as indicated by both the public safety decree [4] and the National Physical Master Plan for the Lebanese Territory [3]. The exposed elements to the earthquake hazard include the population and various critical national infrastructures.

3.3.3 Population

Figure 2 shows the distribution of population per Caza according to statistics carried out in 1996 [5].

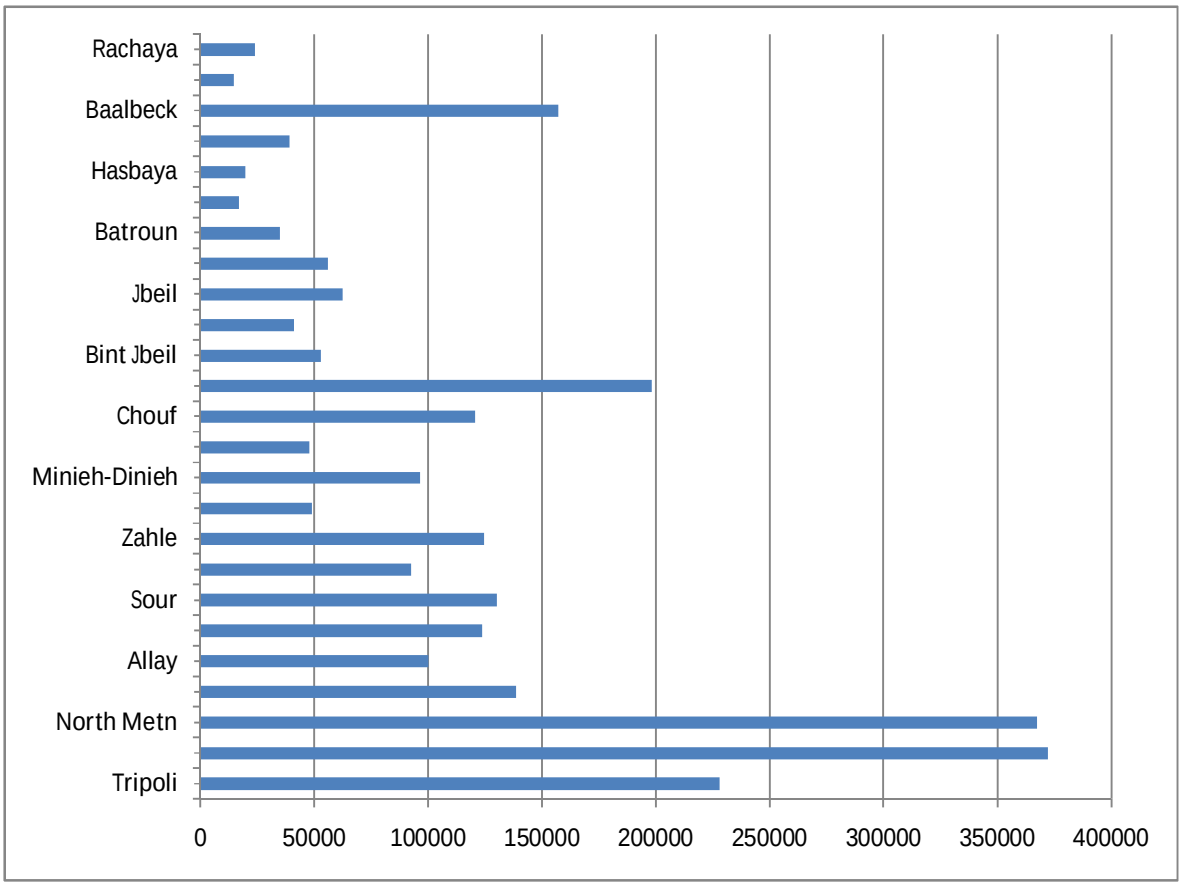

Figure 2 *Population Exposed to Earthquake Hazard with respect to Cazas*

Figure 3 shows the dependent population (in absolute numbers) which corresponds to two categories between 0 and 14 and above 65 years old. This is important as disaster loss statistics show that the dependent population are more susceptible to disaster risk since they are less mobile, more susceptible to disease, and often have fewer resources at their disposal. Hence areas with low dependent populations should be prepared in terms of civil society, NGOs, local communities and emergency responders for a higher need for prompt intervention.

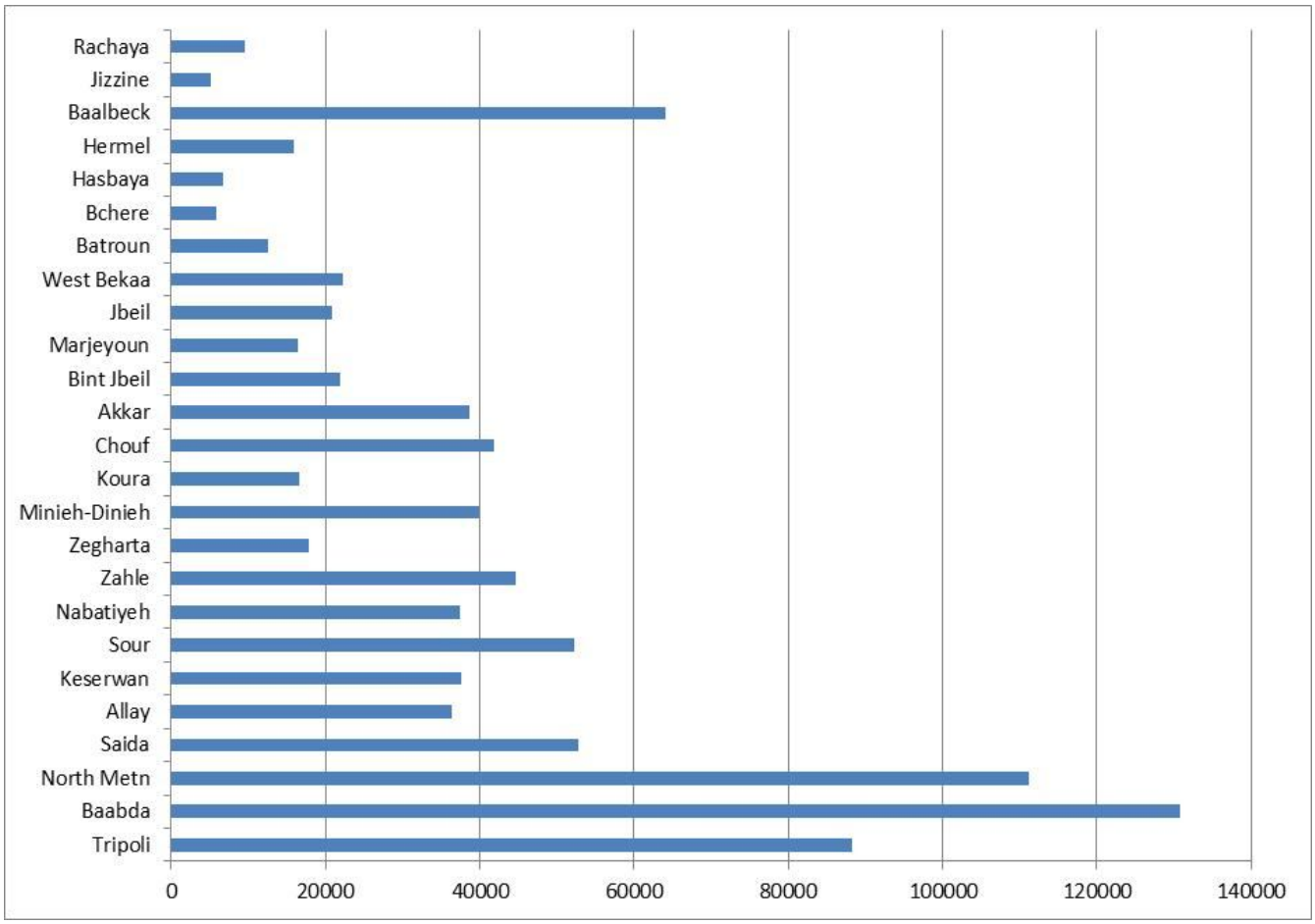

Figure 3 *Dependent Population (0-14 years and above 65 years) Exposed to Earthquake Hazard with respect to Cazas*

Figure 4 shows the distribution of the working age population subjected to earthquake hazard per Caza.

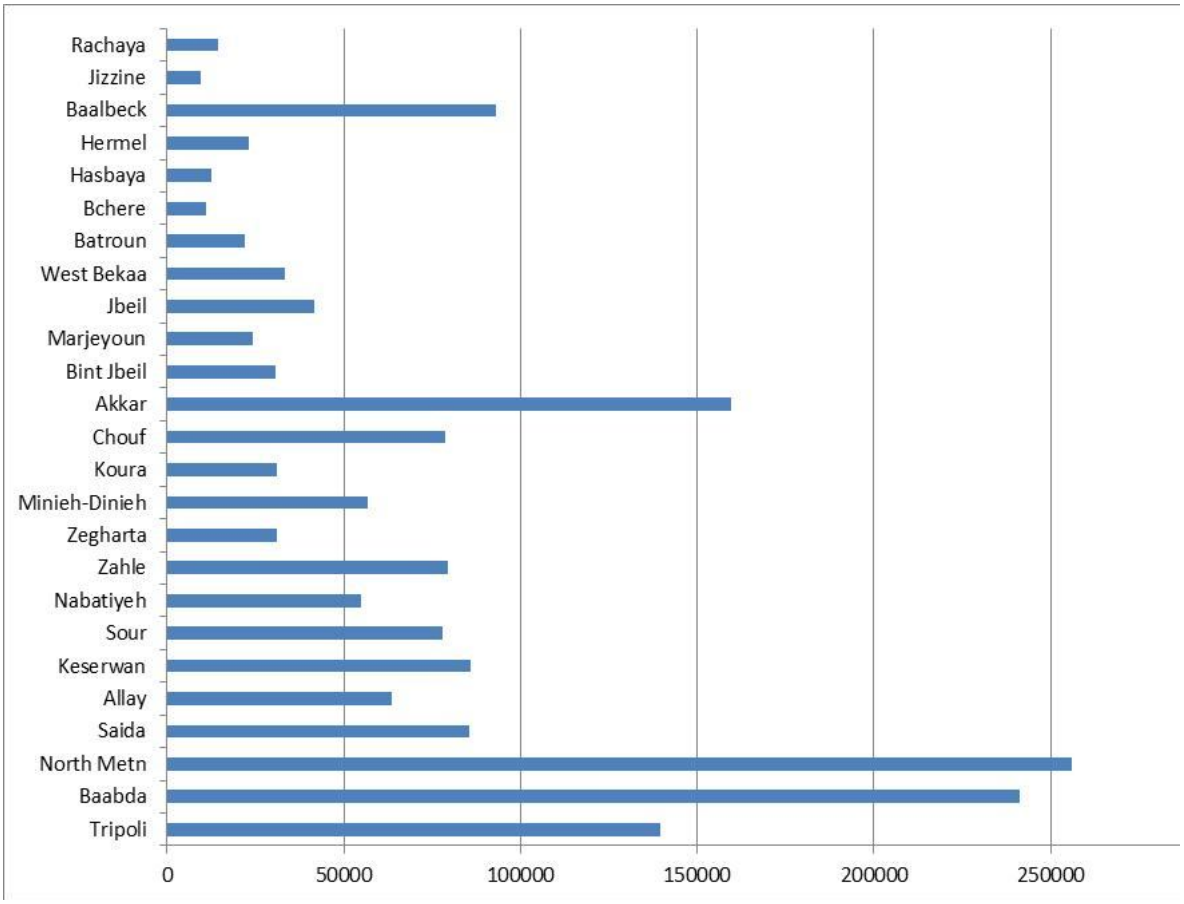

Figure 4 *Working Age Population (between 14 years and 65 years) Exposed to Earthquake Hazard with respect to Cazas*

More recent data is related to governorate rather than Caza as for example in the 2007 nationwide study on livelihood of households [6]. Table 3 shows the projected population growth grouped by Mohafazas for 2030 obtained from the National Physical Master Plan for the Lebanese Territory (NPMPLT) published in December 2005 [3] by the Council for Development and Reconstruction. It can be seen that a population increase of approximately 30% is expected over a thirty year period, thereby significantly increasing the percentage of population exposed to all hazards in general, and earthquake hazards in particular which affects all Lebanese territory.

Table 3 *Projected population growth by groups of Mohafaza for 2030*

	Population in 1997	Population in 2030	Growth %
Beirut and Mount Lebanon	1,910,896	2,310,000	21.22
North and Akkar	807,204	1,410,000	41.18
South and Nabatiyeh	747,477	1,040,000	37.93
Beqaa and Baalbeck-Hermel	539,448	740,000	38.90
LEBANON	**4,005,025**	**5,230,000**	**30.79**

Table 4 shows the projected distribution of population by groups of Mohafaza for 2030 as obtained from National Physical Master Plan for the Lebanese Territory (NPMPLT) [3], where it can be seen that Beirut and its suburbs will continue to attract more than 40% of the population.

Table 4 *Projected distribution of population by groups of Mohafaza for 2030*

	Population in 2030		% in 2000
Beirut and Mount Lebanon	2,310,000	44.2%	47.3%
North and Akkar	1,140,000	21.8%	20.4%
South and Nabatiyeh	1,040,000	19.9%	18.9%
Beqaa and Baalbeck-Hermel	740,000	14.1%	13.4%
LEBANON	**5,230,000**	**100.0%**	**100.0%**

The percentage of citizens living in large agglomerations, within each governorate, can also be seen from Table 5 shows the proportion of inhabitants in agglomerations in 2000 and 2030 as obtained from National Physical Master Plan for the Lebanese Territory (NPMPLT) [3], where it can be seen that the trend for living in large agglomerations

will continue to increase in the next 20 years, albeit with varying degrees across the various governorates.

Table 5 *Proportion of inhabitants in agglomerations in 2000 and 2030*

Geographic Entities	2000			2030		
	Total Population	Population in large agglomerations		Total Population	Population in agglomerations	
Beirut and Mount Lebanon	1,911,00	1,651,000	86%	2,310,000	1,990,000	86%
North and Akkar	807,000	385,000	48%	1,140,000	620,000	54%
South and Nabatiyeh	747,000	327,000	44%	1,040,000	490,000	48%
Beqaa and Baalbeck-Hermel	539,000	181,000	34%	740,000	300,000	40%
LEBANON	**4,005,000**	**2,544,000**	**64%**	**5,230,000**	**3,400,000**	**65%**

In addition, UN HABITAT statistics [7] show that 87% of the Lebanese population live in urban centres and 64% live in five main cities (Beirut, Tripoli, Sidon, Tyre and Zahle).

3.3.4 Health Sector

Table 6 shows the distribution of hospitals, beds in service, and hospitals and beds under construction as per The Atlas of Lebanon [8] produced by the CDR in 2004, based on data collated in 2002.

Table 6 *Distribution of Hospitals of Lebanon within Governorates [8]*

Governorate	Private and public hospitals and hospital beds, including those under construction and rehabilitation							
	Hospitals in Service			No. of Beds			Hospitals in preparation	Beds in preparation
	PB[1]	PR[2]	T[3]	PB	PR	T	Public	Public
North Lebanon	1	23	24	40	1567	1607	3	335
Mount Lebanon	3	55	58	250	1815	2065	4	245
Beirut	1	28	29	14	2354	2382	2	606
Bekaa	3	25	28	225	1478	1703	3	300
South Lebanon	4	25	29	236	1798	2034	4	300
	Notes: 1: PB refers to public hospitals. 2: PR refers to private hospitals. 3: T refers to total number of hospitals.							

Table 7 shows the number of doctors in Lebanon distributed across the different governorates [8].

Table 7 *Distribution of Doctors of Lebanon with Governorates [8]*

	Beirut	Mount Lebanon	South Lebanon	Bekaa	North Lebanon	Total
Number of doctors	2817	3211	1040	617	1015	8700
Percentage	32.38	36.91	11.95	7.09	11.67	100
Population	403338	1507561	747464	539463	807202	4005028
Number of inhabitants per doctor	143	469	719	874	795	460

Table 8 shows the Medical facilities licenses distribution by type and region as obtained from the study on Health Beyond Politics produced by the Ministry of Public Health in 2009 [9]. It should be recognized that in order to determine exposure and vulnerabilities it is necessary to look

at medical facilities beyond hospitals. For example, blood banks are important as their presence can reduce vulnerabilities in the wake of a large natural event. In addition imaging and other medical centres may contain radioactive material which if not protected properly may leak and increase the degree of vulnerabilities and risks in the area under consideration.

Table 8 *Medical facilities licenses: distribution by type and region (MOPH, Dec.2007)*

	Beirut	Mount Lebanon	North Lebanon	South Lebanon	Nabatiyeh	Bekaa	Total
Private Hospitals	21 (11.1%)	64 (33.9%)	34 (18.0%)	24 (12.7%)	10 (5.3%)	36 (19.0%)	189 (100%)
Public Hospitals	2 (6.7%)	6 (20.0%)	7 (23.3%)	4 (13.3%)	6 (20.0%)	5 (16.7%)	30 (100%)
Dispensaries	136 (12.5%	402 (37.1%	219 (20.2%	113 (10.4%)	63 (5.8%)	152 (14.0%)	1085 (100%)
Imaging Centres	27 (12.9%)	87 (41.6%)	38 (18.2%)	22 (10.5%)	8 (3.8%)	27 (12.9%)	209 (100%)
Medical Lab	45 (15.6%)	102 (35.5%	37 (12.8%)	30 (10.4%)	16 (5.5%)	59 (20.4%)	289 (100%)
Pathology Lab	6 (15.4%)	13 (33.3%)	7 (17.9%)	8 (20.5%)	1 (2.6%)	4 (10.3%)	39 (100%)
Blood Banks	5 (20.0%)	10 (40.0%)	5 (20.0%)	2 (8.0%)	0 (0.0%)	3 (12.0%)	25 (100%)
Dental Lab	41 (12.9%)	163 (51.1%	37 (11.6%)	37 (11.6%)	12 (3.8%)	29 (9.1%)	319 (100%)
Physiotherapy Centres	73 (16.6%)	208 (47.2%	83 (18.8%)	37 (8.4%)	13 (2.9%)	27 (6.1%)	441 (100%)
Prosthetic& orthotic workshops	3 (10.0%)	15 (50.0%)	6 (20.0%)	5 (16.7%)	0 (0.0%)	1 (3.3%)	30 (100%)

Table 9 shows the distribution of physicians by Mohafazas and specialties obtained from Health Beyond Politics [9].

Table 9 *Distribution of physicians by Mohafazas and specialty (2007)*

Mohafazas	Surgical Specialties	Medical Specialties	Paediatrics	General practice	Total Specialties	Total	%
Beirut	801	944	278	767	2790	2632	23.53
Mount Lebanon	1504	1550	445	1454	4953	4804	42.95
North Lebanon	400	379	238	452	1469	1494	13.36
South Lebanon	517	397	175	319	1408	1382	12.35
Bekaa	317	218	78	274	887	874	7.81
Total	**3539**	**3488**	**1214**	**3266**	**11507**	**11186**	**100**

Table 10 shows Physicians registered in the Lebanese Order of Physicians by country of graduation (2007) as obtained from Health Beyond Politics [9].

Table 10 *Physicians registered in the Lebanese Order of Physicians by country of graduation (2007)*

Graduation Country/Region	General Practitioners		Specialties	
	n	%	n	%
Lebanon	3945	40	2010	27.7
Eastern Europe	3085	31.4	1952	26.9
Western Europe	1405	14.3	2221	30.6
Arab Countries	1103	11.2	275	3.8
North America	59	0.6	692	9.5
Others	243	2.5	105	1.5
Total	**9840**	**100**	**7255**	**100**

Table 11 shows the Pharmacists and pharmacies per 10,000 inhabitants and by Mohafazas as obtained from Health Beyond Politics [9]. It should be recognized that pharmacies can reduce vulnerability if they are able to dispense medicine in the immediate aftermath of a large hazardous event. However, pharmacies can also increase exposure and vulnerabilities if not properly protected which may lead to a contamination of the nearby environment due to leakage of any contaminating chemicals.

Table 11 *Pharmacists and pharmacies per 10,000 inhabitants and by Mohafazas (2007)*

	Pharmacies			Drug Stores
	number	(%)	%00	number
Beirut	207	(10.7)	5.3	4
Mount Lebanon	896	(46.2)	5.97	12
North Lebanon	297	(15.3)	3.86	2
South Lebanon	201	(10.4)	5.01	1
Nabatiyeh	114	(5.8)	5.14	0
Beqaa	225	(11.6)	4.77	1
Total	**1940**	**(100)**	**5.17**	**20**

3.3.5 Housing Sector

Table 12 shows the evolution number of the population and housing in 1970, 1996 as obtained from the study on the Socio-Economic Situation in Lebanon, Status and Horizons, 2004 [5].

Table 12 *Developed number of people and housing in 1970, 1996*

	Number of population			Number of Housing		
Province	1970	1996	Percentage increase	1970	1996	Percentage increase
Beirut	474,870	407,403	-14	104,985	116,238	11
Mount Lebanon	833,055	1,145,458	38	199,975	463,583	132
North	364,935	670,609	84	79,976	179,278	124
Beqaa	203,520	399,890	96	56,062	121,305	183
South	249,945	488,468	95	42,910	184,427	229
Lebanon	2,126,325	3,111,828	46	483,908	1,064,831	120

Table 13 shows the evolution of population ratio and number of housing units according to the provinces for the years 1970-1996 as obtained from the study on the Socio-Economic Situation in Lebanon, Status and Horizons, 2004 [5].

Table 13 Evolution of population ratio and number of housing units according to the provinces for the years 1970-1996

Province	Percentage increase in housing units	Percentage increase in population number
Beirut	11	-14
Mount Lebanon	132	38
North	124	84
Bekaa	183	96
South	229	95

Table 14 shows the Distribution ratio of housing in 1970 -1996 as obtained from the study on the Socio-Economic Situation in Lebanon, Status and Horizons, 2004 [5].

Table 14 Evolution of population ratio and number of housing units according to the provinces for the years 1970-1996

	1970			1996		
Province	Population %	Housing %	No, of housing to per dwelling	Population %	Housing %	No, of housing to per dwelling
Beirut	22.3	21.7	4.5	13.1	10.9	3.5
Mount Lebanon	39.2	41.3	4.2	36.8	43.5	2.5
North	17.2	16.5	4.6	21.6	16.8	3.7
South	11.7	11.6	3.6	15.8	14.7	2.2
Beqaa	9.6	9.8	5.8	12.7	14.1	4.0
Lebanon	100	100	4.4	100	100	2.9

Table 15 shows the General state of buildings in Lebanon in 2004 as obtained from the CAS, Central Administration of statistics, [10].

Table 15 *General state of buildings in Lebanon in 2004*

Mohafaza/Caza	Houses	Other than houses	Mixed	Total	Unknown date of finishing	Finishing date ex ante 1950	Finishing date between 1951 & 1993	Finishing date ex post 1994	Total
Beirut	**6,680**	**2,852**	**7,749**	**18,336**	**3,651**	**5,542**	**8,238**	**905**	**18,336**
Baabda	19,112	3,561	11,379	**36,186**	4,903	2,957	25,361	2,965	**36,186**
Metn	22,263	4,502	10,368	**38,647**	5,001	3,414	28,242	1,990	**38,647**
Kesserouan	17,301	2,375	4,408	**24,873**	2,164	1,977	19,091	1,641	**24,873**
Jbeil	12,386	1,477	1,435	**15,782**	1,402	1,387	12,339	654	**15,782**
North Mount-Lebanon	**71,062**	**11,915**	**27,590**	**115,488**	**13,470**	**9,735**	**85,033**	**7,250**	**115,488**
Tripoli	3,691	1,302	4,824	**10,350**	2,007	2,280	5,262	801	**10,350**
Koura	8,122	1,091	1,404	**11,761**	2,031	1,641	6,827	1,262	**11,761**
Zghorta	7,972	999	1,386	**11,318**	2,006	1,028	7,148	1,136	**11,318**
Batroun	7,675	1,119	768	**10,689**	1,602	4,158	4,388	541	**10,689**
Aakkar	38,073	2,569	4,836	**46,631**	2,676	1,225	35,696	7,034	**46,631**
Bcharreh	3,618	415	407	**4,662**	296	103	4,119	144	**4,662**
Miyeh-Dennieh	11,772	916	2,395	**15,542**	1,463	1,245	11,536	1,298	**15,542**
Administrative North Lebanon and Akkar	**80,923**	**8,411**	**16,020**	**110,953**	**12,081**	**11,680**	**74,976**	**12,216**	**110,953**
Zahle	15,149	3,148	7,014	**26,623**	2,297	1,922	20,451	1,953	**26,623**
West Bekaa	8,302	1,053	4,049	**14,552**	1,648	781	11,030	1,093	**14,552**
Baalbek	35,672	4,326	6,554	**49,540**	5,656	2,509	37,043	4,332	**49,540**
Hermel	6,662	207	519	**7,530**	667	229	6,333	301	**7,530**
Rachaya	4,860	391	1,577	**7,135**	603	436	5,710	386	**7,135**
Bekaa	**70,645**	**9,125**	**19,713**	**105,380**	**10,871**	**5,877**	**80,567**	**8,065**	**105,380**
Saida	18,407	1,795	5,079	**26,757**	3,247	859	21,052	1,599	**26,757**
Tyre	22,319	2,726	6,168	**33,152**	4,430	1,346	23,892	3,484	**33,152**

Jezzine	5,577	367	739	**7,648**	1,483	636	5,223	306	**7,648**
South Lebanon	**46,303**	**4,888**	**11,986**	**67,557**	**9,160**	**2,841**	**50,167**	**5,389**	**67,557**
Nabatiyeh	17,956	1,402	3,625	**24,797**	3,217	1,236	18,189	2,155	**24,797**
Bent Jbeil	12,577	927	2,307	**17,256**	1,900	868	12,294	2,194	**17,256**
Marjaayoun	9,223	1,015	2,266	**13,569**	1,326	1,371	9,241	1,631	**13,569**
Hasbaya	4,116	513	1,725	**7,179**	1,178	537	4,685	779	**7,179**
Administrative Nabatiyeh	**43,872**	**3,857**	**9,923**	**62,801**	**7,621**	**4,012**	**44,409**	**6,759**	**62,801**
Lebanon	**319,485**	**41,048**	**92,981**	**480,515**	**56,854**	**39,687**	**343,390**	**40,584**	**480,515**

Table 16 Shows the Buildings, units and establishments in Lebanon in 2004 as obtained from the CAS, Central Administration of statistics, [10].

Table 16 *Buildings, units and establishments in Lebanon in 2004*

Mohafaza/Caza	Buildings	Units	Establishments
Beirut	18,336	156,801	25,504
Baabda	36,186	197,008	24,865
Metn	38,647	180,454	25,792
Kesserouan	24,873	88,705	10,080
Jbeil	15,782	32,085	3,528
North Mount-Lebanon	115,488	498,252	64,265
Tripoli	10,350	85,187	15,635
Koura	11,761	24,692	2,184
Zghorta	11,318	24,468	2,579
Batroun	10,689	17,349	1,865
Aakkar	46,631	70,326	8,223
Bcharreh	4,662	8,172	573
Miyeh-Dennieh	15,542	33,303	2,926

Administrative North Lebanon and Akkar	110,953	263,497	33,985
Zahle	26,623	61,771	10,045
West Bekaa	14,552	26,482	2,574
Baalbek	49,540	74,712	8,961
Hermel	7,530	9,265	725
Rachaya	7,135	10,811	740
Bekaa	105,380	183,041	23,045
Saida	26,757	76,895	8,664
Tyre	33,152	73,126	9,036
Jezzine	7,648	11,765	613
South Lebanon	67,557	161,786	18,313
Nabatiyeh	24,797	51,366	5,910
Bent Jbeil	17,256	27,812	2,168
Marjaayoun	13,569	22,095	1,913
Hasbaya	7,179	12,795	1,176
Administrative Nabatiyeh	62,801	114,068	11,167
Lebanon	480,515	1,377,445	176,279

3.3.6 Transportation Sector

The Transportation sector includes the followjng categories:

- The road network, which has been rehabilitated after the end of the civil war in Lebanon and the Israeli war in 2006.
- Bridges, the vast majority of which have been designed or rehabilitated after the end of the civil war. Furthermore, some of the bridges damaged during the Israeli war have been reconstructed. Bridges constructed after 1990 are being designed to resist a horizontal ground acceleration of 0.19g [15].

While non-synchronous motion is not being taken into account, the fact that most bridges in Lebanon do not have long spans mitigate against this oversight.

- Ports, where the main port is that of Beirut which consists of old and new buildings.
- Airport, where the main airport is the Rafiq Hariri Beirut International Airport.

3.3.7 Education Sector

Table 18 shows the students distribution with sector and levels of education, per governorate for the academic year 2009-2010 as obtained from CAS, Central Administration of statistics, Republic of Lebanon, 2011[10].

Table 18 *Students governorates distribution, per sectors and levels of education, for the academic year 2009-2010*

Mohafaza/ Caza	Public					Private Free			Private Non-Free					Private UNRWA					Sub Total
	1	**2**	**3**	**4**	**5**	**1**	**2**	**5**	1	2	3	4	5	1	2	3	4	5	
Beirut	1,588	6,813	4,832	4,277	17,510	1,190	3,984	5,174	10,905	21,390	11,375	9,795	53,465	-	1,614	761	597	2,972	79,121
Mount Lebanon/Beirut Suburbs	2,336	11,117	8,454	8,669	30,576	4,716	19,742	24,458	33,848	73,678	40,609	24,043	172,178	-	1,747	731	-	2,478	229,690
Mount Lebanon	2,685	9,370	6,934	7,246	26,235	2,402	7,018	9,420	13,162	28,995	14,681	8,320	65,158	1	594	348	143	1,086	101,899
North Mount-Lebanon	11,588	53,758	24,548	13,700	1.E+05	6,893	20,554	27,447	16,614	41,636	19,912	8,318	86,480	39	5,304	2,350	885	8,578	226,909
Bekaa	4,638	18,197	10,520	8,408	41,763	5,680	26,735	32,415	10,634	20,808	16,820	5,316	53,578	-	1,204	544	260	2,008	129,764
South Lebanon	4,186	17,066	11,527	8,111	40,890	1,799	12,786	14,585	9,683	18,489	10,384	4,434	42,990	61	9,521	4,435	1,511	15,528	113,993
Nabatiyeh	2,521	9,624	7,049	5,637	24,831	1,523	11,790	13,313	5,467	8,185	7,581	2,448	23,681	-	-	-	-	-	61,825
Total	29,542	125,945	73,864	56,048	3.E+05	24,203	1.E+05	126,812	100,313	213,181	121,362	62,674	497,530	101	19,984	9,169	3,396	32,650	942,391

1: before elementary, 2. Elementary 1 & 2, 3: intermediate, 4: Secondary, 5: total

Table 19 shows the distribution of the number of teachers by the sectors of education as obtained from CAS [10].

Table 19 *Distribution of the number of teachers by the sectors of education*

Mohafaza/Caza	Public				Private Free				Private Non-Free				Private UNRWA				Total			
	Ownership	Contract	Tribute	Total	Ownership	Contract	Tribute	Total	Ownership	Contract	Tribute	Total	Ownership	Contract	Tribute	Total	Ownership	Contract	Tribute	Total
Beirut	1,739	714	85	2,538	289	86	11	386	3,394	2,347	48	5,789	3	158	-	161	5,425	3,305	144	8,874
Mount Lebanon/Beirut Suburbs	4,103	714	62	4,879	982	314	18	1,314	8,118	6,147	130	14,395	-	139		139	13,203	7,314	210	20,727
Mount Lebanon	3,941	896	57	4,894	454	161	36	651	3,466	2,617	144	6,227	-	51	-	51	7,861	3,725	237	11,823
North Mount-Lebanon	6,935	4,552	270	1.E+05	1,010	248	29	1,287	4,099	2,626	109	6,834	4	386	2	392	12,048	7,812	410	20,270
Bekaa	3,795	2,111	193	6,099	1,257	326	50	1,633	2,149	1,755	96	4,000	25	92	-	117	7,226	4,284	339	11,849
South Lebanon	2,978	1,820	157	4,955	664	91	12	767	2,319	1,284	66	3,669	38	683	-	721	5,999	3,878	235	10,112
Nabatiyeh	2,459	1,004	138	3,601	594	125	16	735	1,204	770	29	2,003	-	-	-	-	4,257	1,899	183	6,339
Total	25,950	11,811	962	38,723	5,250	1,351	172	6,773	24,749	17,546	622	42,917	70	1,509	2	1,581	56,019	32,217	1,758	89,994

Table 20 shows the governorate distribution of students in the private vocational and technical education, according to the certificate and gender, for the academic year 2009-2010 as obtained from CAS [10].

Table 20 *Distribution of students in private vocational and technical education, according to the certification and gender, in the different governorates for the academic year 2009-2010*

Mohafaza/ Caza	Official Certificates												Total Official Certificates			Private certificate for 3 Months		Private certificate for one year		Students Sub Total		
	Professionalism		BP		BT		TS		TDS		LT											
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Total	Male	Female	Male	Female	Male	Female	Total
Beirut	90	-	235	71	-	-	1,745	1,164	201	212	-	-	2,271	1,447	3,718	321	572	828	633	3,420	2,652	6,072
Mount Lebanon/ Beirut Suburbs	22	-	1,126	656	123	13	6,632	4,463	1,644	1,978	104	59	9,651	7,169	16,820	815	1,434	2,980	2,624	13,446	11,227	24,673
Mount Lebanon	53	5	233	81	-	-	791	794	153	289	1	6	1,231	1,175	2,406	137	255	976	1,511	2,344	2,941	5,285
North Mount-Lebanon	171	12	1,337	523	-	9	2727	2.E+03	787	1,047	53	120	5,075	4,017	9,092	158	449	340	424	5,573	4,890	10,463
Bekaa	1	-	154	72	-	-	626	716	330	561	8	18	1,119	1,367	2,486	29	115	160	232	1,308	1,714	3,022
South Lebanon	-	-	422	159	-	-	1,227	1,099	258	435	-	3	1,907	1,696	3,603	124	191	1,257	620	3,288	2,507	5,795
Nabatieh	-	-	133	134	-	-	837	724	413	390	59	76	1,442	1,324	2,766	173	169	18	58	1,633	1,551	3,184
Total	337	17	3,640	1,696	123	22	14,585	11,266	3,786	4,912	225	282	22,696	18,195	40,891	1,757	3,185	6,559	6,102	31,012	27,482	58,494

Table 21 shows the distribution of students in public vocational and technical education according to the certificate and gender for the academic year 2009-2010 as obtained from CAS, [10].

Table 21 *Distributed students in public vocational and technical education, according to the certificate and gender, in the different governorates for the academic year 2009-2010*

Mohafaza/Caza	Official Certificates														Total Official Certificates		
	Professionalism		BP		BT		TS		TDS		LT		LET				
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Total
Mount Lebanon/Beirut Suburbs	-	-	203	60	171	17	2,108	1,494	1,756	1,872	607	536	-	-	4,845	3,979	8,824
Mount Lebanon	-	-	247	91	136	13	756	707	236	318	-	-	-	-	1,375	1,129	2,504
North Mount-Lebanon	68	-	888	591	235	1	2402	2.E+03	1,357	2,226	31	53	-	-	4,981	5,304	10,285
Bekaa	21	-	919	359	345	59	1,895	2,126	637	1,290	118	138	-	-	3,935	3,972	7,907
South Lebanon	-	-	275	111	169	-	1,276	1,280	125	268	-	-	-	-	1,845	1,659	3,504
Nabatiyeh	22	5	687	312	60	-	1,312	1,173	227	478	17	-	-	-	2,325	1,968	4,293
Total	111	5	3,219	1,524	1,116	90	9,749	9,213	4,338	6,452	773	727	-	-	19,306	18,011	37,317

Table 22 shows the private vocational and technical schools distribution in the governorates, and the distribution of teaches by gender and function, as obtained from CAS, 2011 [10].

Table 22 *Private Vocational and Technical Schools distribution and distribution of teachers by gender and function, in the governorates*

Mohafaza/Caza	Number of Schools	Educational and Administrative Staff					
		Gender			Function		
		Male	Female	Total	Administrative	Educational	Total
Beirut	42	365	275	640	83	557	640
Mount Lebanon/Beirut Suburbs	132	1,384	1,323	2,707	324	2,383	2,707
Mount Lebanon	39	254	317	571	84	487	571
North Mount-Lebanon	72	718	783	1,501	153	1,348	1,501
Bekaa	23	200	152	352	37	315	352
South Lebanon	35	421	325	746	57	689	746
Nabatiyeh	8	94	88	182	16	166	182
Total	351	3,436	3,263	6,699	754	5,945	6,699

Table 23 shows the public vocational and technical schools governorate distribution, and distribution of teachers by gender and function as obtained from CAS, 2011 [10].

Table 23 *Public Vocational and Technical Schools distribution and distribution of teachers by gender and function*

Mohafaza/Caza	Number of Schools	Educational and Administrative Staff						
		Gender			Function			
		Male	Female	Total	Administrative	Educational	Total	
Mount Lebanon/Beirut Suburbs	22	1,361	1,067	2,428	131	2,297	2,428	
Mount Lebanon	12	497	470	967	68	899	967	
North Mount-Lebanon	26	1,841	2,039	3,880	212	3,668	3,880	
Bekaa	22	1,586	1,232	2,818	185	2,633	2,818	
South Lebanon	9	649	401	1,050	48	1,002	1,050	
Nabatiyeh	14	765	594	1,359	75	1,284	1,359	
Total	105	6,699	5,803	12,502	719	11,783	12,502	

Table 24 shows distribution of public schools according to type of school and gender of students, for the academic year 2009 -2010 as obtained from CAS, 2011 [10].

Table 24 *Distributed number of general education schools to the provinces and education sectors, according to gender of their students for the academic year 2009-2010*

Mohafaza/Caza	Official				Private Free			Private Non-Free				Private UNRWA				Sub Total
	Girls	Boys	Mixed	Total	Girls	Mixed	Total	Girls	Boys	Mixed	Total	Girls	Boys	Mixed	Total	
Beirut	15	11	44	70	1	17	18	3	-	99	102	-	1	7	8	198
Mount Lebanon/Beirut Suburbs	10	9	90	109	-	70	70	1	5	313	319	3	1	3	7	505
Mount Lebanon	1	-	184	185	-	37	37	1	1	152	154	-	-	2	2	378
North Mount-Lebanon	52	32	368	452	-	77	77	1	1	192	194	3	3	12	18	741
Bekaa	7	2	244	253	-	92	92	1	-	144	145	-	-	5	5	495
South Lebanon	7	-	149	156	1	35	36	-	1	89	90	9	10	16	35	317
Nabatieh	1	-	139	140	-	39	39	-	-	69	69	-	-	-	-	248
Total	93	54	1,218	1,365	2	367	369	7	8	1,058	1,073	15	15	45	75	2,882

3.3.8 Energy Sector

Exposure in the energy sector is made up of three main components:

- Tank farms.
- Electric generation plants.
- Petrol stations scattered throughout the country.

Oil and Gas Installations

There are a number of tank farms and oil storage facilities scattered around the coast which have been built several decades ago.

Furthermore, there are tank farms to service the Rafiq Hariri Beirut International Airport.

In addition there are refineries in the North (Beddawi), and the South (Zahrani).

Electric Generation Plants

Electric Generation plants are located in the Zouk (Mount Lebanon), Deir Emar (North), and South (Karoun).

3.3.9 Public Buildings Sector

Table 25 shows the distribution of employed (aged 15 years and above) in both the public and private sectors, distributed according to governorates obtained from the socio economic study on households carried out in the aftermath of the 2006 war and published by the Ministry of Social Affairs in 2008 [6]. It can be seen that the public sector employs more than 175 thousand employees out of a total of 1.18 million employees. Furthermore, it can be seen that Mount Lebanon has the highest level of public sector employees, followed by the North and Bekaa.

Table 25 *Distribution of employed (aged 15 years and above) according to economic activity sector and regions*

Type of Economic activity sector	Beirut	Mount Lebanon	Dahiyeh	North	Bekaa	Less damaged cazas (south, saida, jezzine, hasbaya)	Most damaged cazas (south, Nabatiyeh, Sour, Bent Jbayl ,Marjaayoun)	Lebanon
Public	12456	47301	12267	45680	29541	12890	15856	175991
Private (declared enterprise)	89427	249063	83410	85118	59303	33904	47913	648138
Private (not declared enterprise)	25502	66759	26954	69395	32441	18291	43918	283260
Other	3209	2320	668	716	935	1222	1597	10667
No response	0	323	0	0	0	0	0	323
Total	130594	365766	123299	200909	122220	66307	109284	1118379

Table 26 shows the percentage distribution of employed (aged 15 years and above) according to type of economic activity sector and regions distributed according to governorates, as obtained from the socio economic study on households carried out in the aftermath of the 2006 war and published by the Ministry of Social Affairs in 2008 [6]. It can be seen that the percentage of employees working in the public sector (out of the total of employees working in a particular region) are the lowest for Beirut, Dahiyeh and Mount Lebanon.

Table 26 *Percentage distribution of employed (aged 15 years and above) according to economic activity sector and regions*

Type of Economic activity sector	Beirut	Mount Lebanon	Dahiyeh	North	Bekaa	Less damaged cazas in south (saida ,jezzine, hasbaya)	Most damaged cazas in South (Nabatiyeh, Sour, Bent Jbayl, Marjaayoun	Lebanon
Public	9.5	12.9	9.9	22.7	24.2	19.4	14.5	15.7

Private (declared enterprise)	68.5	68.1	67.6	42.4	48.5	51.1	43.8	58
Private (not declared enterprise)	19.5	18.3	21.9	34.5	26.5	27.6	40.2	25.3
Other	2.5	0.6	0.5	0.4	0.8	1.8	1.5	1
No response		0.1						0
Total	100	100	100	100	100	100	100	100

3.3.10 National Icons Sector

Lebanon is a country with a variety of national icons which are of significant importance to tourism, and perhaps more importantly to the Lebanese Psyche. Furthermore, several of these icons are on the UNESCO list of World Heritage Sites. National Icons are scattered across Lebanon, some in form of natural reserves and natural scenic sites such as the Jeita Grotto and others in form of archaeological sites which include but are not limited to:

- Roman Ruins of Baalbek
- Ruins of Byblos
- Ruins of Tyre
- Ruins of Sidon
- Beit El Dine Palace
- Jeita Natural Grotto
- Fortresses throughout the country including that of Tripoli in the North and Cheqief in the South.

All these are considered exposed to earthquake risk, especially since some of these structures (e.g. the columns of Baalbek) have been destroyed by previous earthquakes.

3.3.11 Tourism Sector

Figure 5 shows the tourism and leisure establishments as obtained from the Atlas of Lebanon , National Council for Scientific Research, 2012

[11], where it can be seen that a significant majority of hotels and restaurants lies on the coast along the main cities of Lebanon, the exception being Zahle which has a relatively large relative concentration of hotels and sectors while lying in the Bekaa valley.

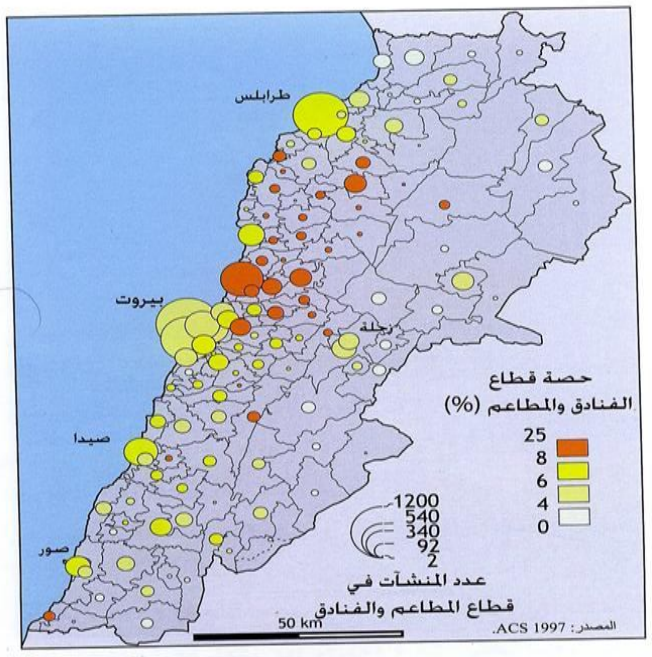

Figure 5 *Hotel and restaurant Distribution*

Figure 6 the distribution of hotels within Lebanon according to quality of service and number of rooms, while Figure 7 shows the distribution of restaurants within Lebanon according to regional percentage of large restaurants (servicing more than 250 customers) together with the total number of restaurants within the regions, as obtained from the Atlas of Lebanon , 2012 [11]. It can be seen that the exposure of this sector is concentrated along the coast, and in particular Beirut and Mount Lebanon.

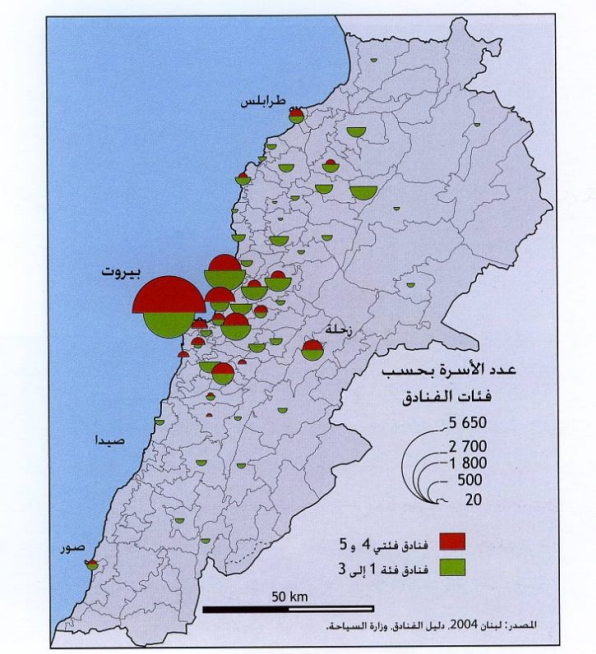

Figure 6 *Distribution of hotels, showing quality of service and number of rooms*

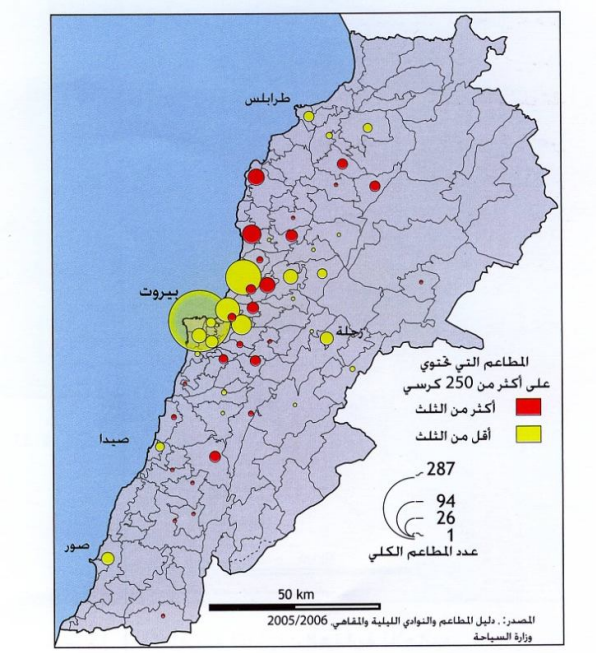

Figure 7 *Distribution of restaurants, showing quality of service and number of rooms*

3.3.12 Telecommunications Sector

Figure 8 shows the distribution of telecommunications infrastructure within Lebanon (telephone exchange locations and connections), where it can be seen that there is a larger degree of redundancy of

telephone exchanges long the coast rather than the internal governorates (Baalbek and Bekaa) [11].

By the year 2000, Lebanon had 19.49% fixed lines per 100 inhabitants compared to a world and European average of 17.19% and 56.2% [11]. However, there are large regional variations within this average number, with the expectation that remote areas will indicate lower penetration rates.

Similarly, the mobile penetration rate shows a value of 21.25% per 100 inhabitants, compared to a world and European average of 15.48% and 55.5% respectively [11]. Internet penetration rate for the year 2000 is 858 per 10000 inhabitants. [11].

It should be recognized that while fixed and mobile phone penetration rates have significance regarding evacuation, early warning and response, internet access has implication on awareness raising campaigns in addition to general socio-economic implications.

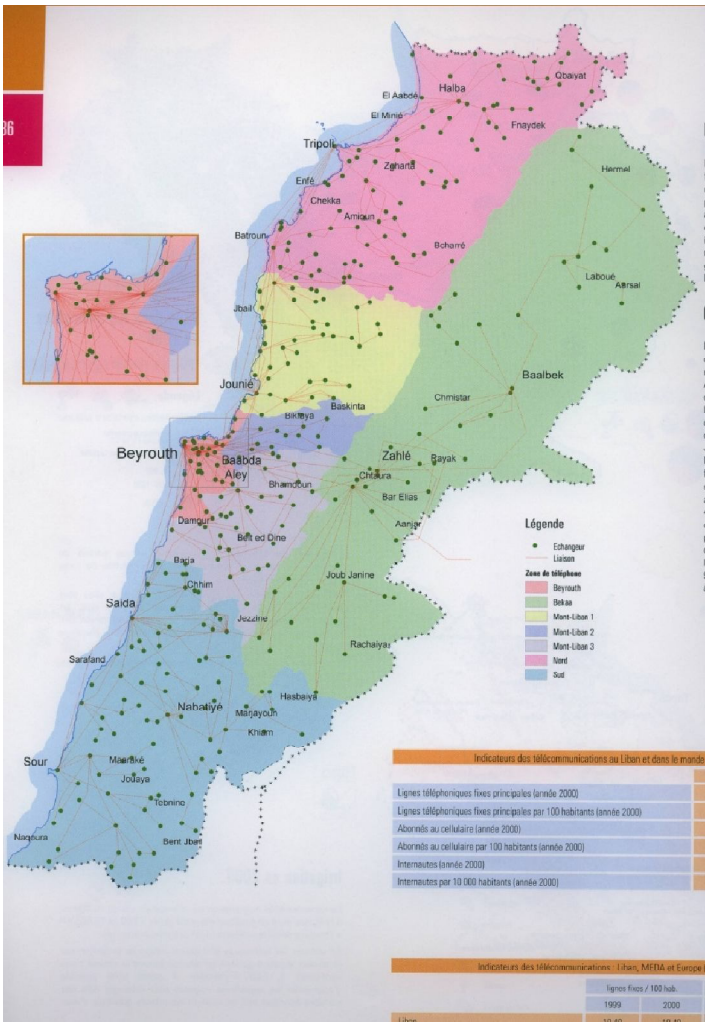

Figure 8 *Distribution of Telecommunication Infrastructure within Lebanon*

3.3.13 Water and Waste Water Sector

Table 27 shows the proposed dams of the Ministry of Energy and Water (MOEW) scheme as obtained from National Physical Master Plan for the Lebanese Territory (NPMPLT), 2005 [3].

Table 27 *Proposed dams of the MOEW scheme*

Proposed Dams	CAZA	Capacity (million m3)	Catchment	Spring	Notes
Shabrouh	Kesserouan	8	El – Kalb	Shabrouh	Under execution
Aassi	Baalbek	37	El-Aassi	El-Aassi	Started/should irrigate 6000 hectares

Bisri	Chouf	120	Awali	Awali	In current detailed study
Boqaata	Matn/Kesserouan	7	El-Kalb	Boqaata	Feasibility study started /promised for 2003
Dear Beashtar	Koura	55	Abou Ali	Abou Ali	To review feasibility
El-Hasbani / IBL Saqi	Hasbaya	50-100	El-Hasbani	El-Hasbani	Feasibility study started
Bared	Akkar/Minieh/Dinieh	40	El-Bared	El-Bared	Feasibility study started
Qarqaf	Akkar	20	Aarqa	Deviation Aarqa+ Wadi Jamous	Feasibility study started
Nahr el-Jaouz/ Qalaat el-Msailha	Batroun	9	El-Jaouz	El-Jaouz	Feasibility study started
Younine	Baalbek	5	Aassi	Deviation from Wadi Nahle	Feasibility study started
Janneh	Jbayl	30	Ibrahim	Ibrahim	Feasibility study started /unsuitable technical conditions
Noura et - Tahta	Akkar	70	El-Kabir	El-Kabir	Promised for 2005/only a part would be allocated to GOL
Azzounieh	Allay	4	Damour	Safa	Unsuitable Technical conditions
Massa	Zahle	8	Litany	Litany	Study not yet launched
Damour	Chouf	60	Damour	Damour	Study not yet launched
Iaal	Zghorta	10	Abou Ali	Deviation Abou Ali + Iaal	Study not yet launched
Khardali	Marjaayoun	128	Litany	Litany	Study not yet launched
Kfarsir	Tyre	12	Litany	Litany	Study not yet launched

Table 28 shows the proposed lakes of the MOEW Scheme as obtained from National Physical Master Plan for the Lebanese Territory (NPMPLT)

produced by the Council for Development and Reconstruction in 2005 [3].

Table 28 *Proposed lakes of the MOEW Scheme*

Proposed lake	CAZA	Capacity (million m3)	Catchment	Spring	Notes
Yammouneh	Baalbek	1.5	Yammouneh	Yammouneh	Under Execution
Qaissamani	Baabda	0.55	Beirut		Under Execution
El-Habash	El-Matn	0.55	El – Kalb		Draft accomplished/promised for 2005
Qammouaa	Akkar	1	El-Aarqa		Feasibility study accomplished
Qatlab/Otlab	Akkar	1	El-Ostouane		Feasibility Study started
Kouashra	Akkar	0.35	El-Ostouane		Feasibility study started/existing dam 0.12Mm3
Sbat	Baalbek	0.70-1	Litany	Sbat	Feasibility Study Started
Jriban	Baalbek	0.70-1	Litany	Jribane	Feasibility Study Started
Balaa	Batroun	1	El-Jaouz		Feasibility Study Started/sensitive natural site
Laqlouq	Jbayl	0.80	El-Jaouz		Feasibility Study Started
Azzibe	Chouf	0.70	El-Awali		Feasibility Study Started
Maaser Chouf	Chouf	2	El-Awali		Feasibility Study Started
Brissa	Minieh/Dinieh	1.2	El-Bared		Promised before 2005
Rachaya	Rachaya	<1	El-Hasbani		
Lebaa	Jezzine	0.96	El Awali		
Kfarhouneh	Jezzine	1.20	Litany		

3.3.14 Financial Sector

Figure 9 Shows the development of the banking sector [11], where it can be seen that the number of banks decreased from 73 banks in the year 1999 to 61 banks in the year 2003. The average number of branches per bank remained in the region of ten for both years. metropolitan units area constitute 57% of the total in Lebanon and only 35 % of depositors But attracts 69 % of the value of deposits and grant 63 % of loans and 81 % of the value of loans disbursed.

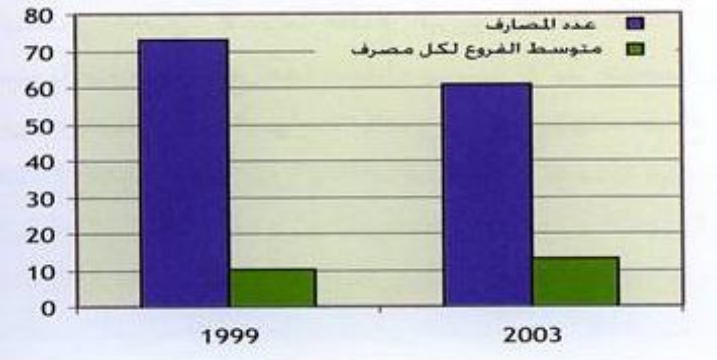

Figure 9 *The development of the banking sector*

Figure 10 shows the scarcity of the distribution of banks outside the centre may pause a challenge and increased vulnerability due to a possibility of a lack of access to bank in the aftermath of disaster, as will be discussed in future sections.

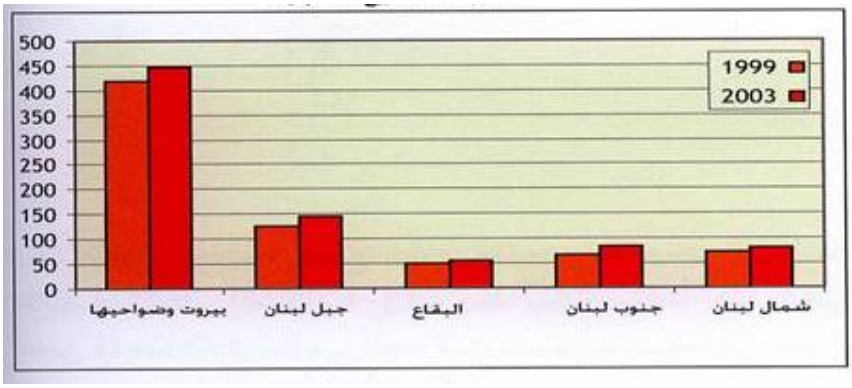

Figure 10 *The development of the banking sector*

3.3.15 Agriculture and Fisheries Sector

Table 29 shows the distribution of employed in the agriculture sector (aged 15 years and above) according to occupation within the various governorates, as obtained from the socio economic study on households carried out in the aftermath of the 2006 war and published by the Ministry of Social Affairs in 2008 [6]. It can be seen that a total of more than 52 thousand workers out of a total employed of 1.18 million work in the agriculture and fisheries sector. As will be seen in later sections, these are amongst the most vulnerable within society due to the presence and interaction of a variety of factors that contribute and acutely shape their vulnerabilities.

Table 29 *The distribution of employed (aged 15 years and above) according to occupation and regions*

Occupation	Beirut	Mount Lebanon	Dahiyeh	North	Bekaa	Less damaged cazas in south (saida, jezzine, hasbaya)	Most damaged cazas in south (Nabatiyeh, Sour, Bent Jbayl, Marjaayoun	Lebanon
General and Corporate Managers	14308	47811	11791	20769	15584	7760	14737	132760
Specialists	24473	43309	9257	13413	10430	5129	9408	115419
Intermediate professions	18482	42471	8356	17443	8524	6280	6495	108051
Office employees	14870	33513	10977	10045	5998	4484	4382	84269
Service sector workers	18234	54149	19993	11272	10309	7603	10389	131949
Agriculture and fishery workers	0	4161	477	17906	12299	4337	13350	52530
Skilled workers	14992	62290	24615	34969	17445	10521	23337	188169
Drivers	5595	29610	17239	14667	11788	6694	8148	93741
Unskilled workers	17777	30089	13670	32163	11381	8076	13529	126685
Armed forces	1602	18040	6924	28262	18463	5422	55105510	84223

Occupation	Beirut	Mount Lebanon	Dahiyeh	North	Bekaa	Less damaged cazas in south (saida, jezzine, hasbaya)	Most damaged cazas in south (Nabatiyeh, Sour, Bent Jbayl, Marjaayoun	Lebanon
No response	262	323	0	0	0	0	0	585
Total	130595	365766	123299	200909	122221	66306	109285	1118381

Table 30 Shows the percentage distribution of employed (aged 15 years and above) according to occupation governorates, as obtained from the socio economic study on households carried out in the aftermath of the 2006 war and published by the Ministry of Social Affairs in 2008 [6]. The governorates with the highest relative percentages of agriculture and fisheries workers are the South, Nabatiyeh, Bekaa and the North.

Table 30 *Percentage distribution of employed (aged 15 years and above) according to occupation and regions*

Occupation	Beirut	Mount Lebanon	Dahiyeh	North	Bekaa	Less damaged cazas in south (saida, jezzine, hasbaya)	Most damaged cazas in south (Nabatiyeh, Sour, Bent Jbayl, Marjaayoun)	Lebanon
General and Corporate Managers	11	13.1	9.6	10.3	12.8	11.7	13.5	11.9
Specialists	18.7	11.8	7.5	6.7	8.5	7.7	8.6	10.3
Intermediate professions	14.2	11.6	6.8	8.7	7	9.5	5.9	9.7
Office employees	11.4	9.2	8.9	5	4.9	6.8	4	7.5
Service sector workers	14	14.8	16.2	5.6	8.4	11.5	9.5	11.8
Agriculture and fishery workers		1.1	0.4	8.9	10.1	6.5	12.2	4.7
Skilled workers	11.5	17	20	17.4	14.3	15.9	21.4	16.8

Occupation	Beirut	Mount Lebanon	Dahiyeh	North	Bekaa	Less damaged cazas in south (saida, jezzine, hasbaya)	Most damaged cazas in south (Nabatiyeh, Sour, Bent Jbayl, Marjaayoun)	Lebanon
Drivers	4.3	8.1	14	7.3	9.6	10.1	7.5	8.4
Unskilled workers	13.6	8.2	11.1	16	9.3	12.2	12.4	11.3
Armed forces	1.2	4.9	5.6	14.1	15.1	8.2	5	7.5
No response	0.2	0.1	0	0	0	0	0	0.1
Total	100	100	100	100	100	100	100	100

The agriculture represented 6% of the GDP in year 2002 and comprising 7 % of the active labour force whereas in the year 1970 it represents about 9% of the GDP and compromising 19% of the active population [11]. This sharp decline in the employment of the agriculture sector is in sharp contrast to recommended pro-poor employment policies as referred to in the GAR 2011 [12].

Figure 11 shows the percentage of workers in the agriculture sector, with additional jobs in other sectors, as obtained from the Atlas of Lebanon, 2012 [11]. Despite the large number of workers who are engaged in other activities, except in the Bekaa and the South, it may not be directly concluded that this implies a reduction of vulnerability to an acceptable degree as will be discussed in future sections.

Furthermore, as a demonstration of the challenges facing data collation and analysis in Lebanon, the above report clearly states that the total number of agriculture workers is 194,000 according to 1999 census statistics, which is in contrast to the figures provided by slightly earlier studies [6] showing the total number of agriculture (and fisheries) workers as 52530 as shown in Table 29.

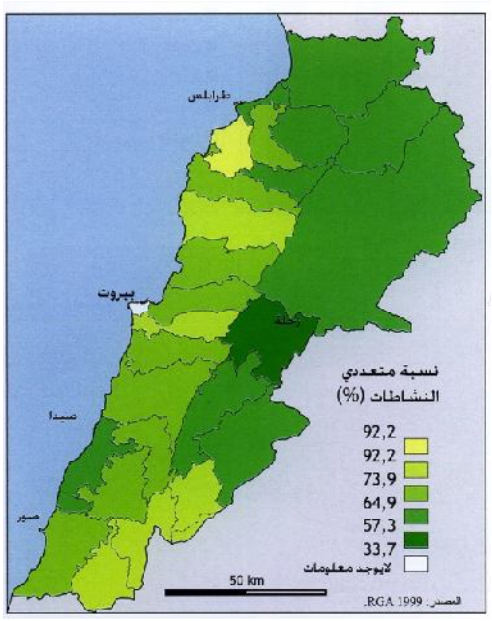

Figure 11 *Multiple Activities of workers in Agriculture*

3.3.16 Industrial Sector

The assessment of the exposure, and corresponding vulnerabilities and risks, within the industrial sector, especially those corresponding to the earthquake hazard, is particularly important. The main challenge is that many of these factories are situated illegally in residential buildings with no licensing or inspection procedures in place. The workers in the industrial sector are part of the skilled workers entry shown in Table 29 and Table 30.

Figure 12 shows the development of industry branches as obtained from the Atlas of Lebanon, 2012 [11], where it can be seen that in recent years (2002 – 1997) most areas continued the spiral downward trend registering a decline in activities except for a few sub-sectors which exhibited moderate growth (food, printing and jewellery industries).

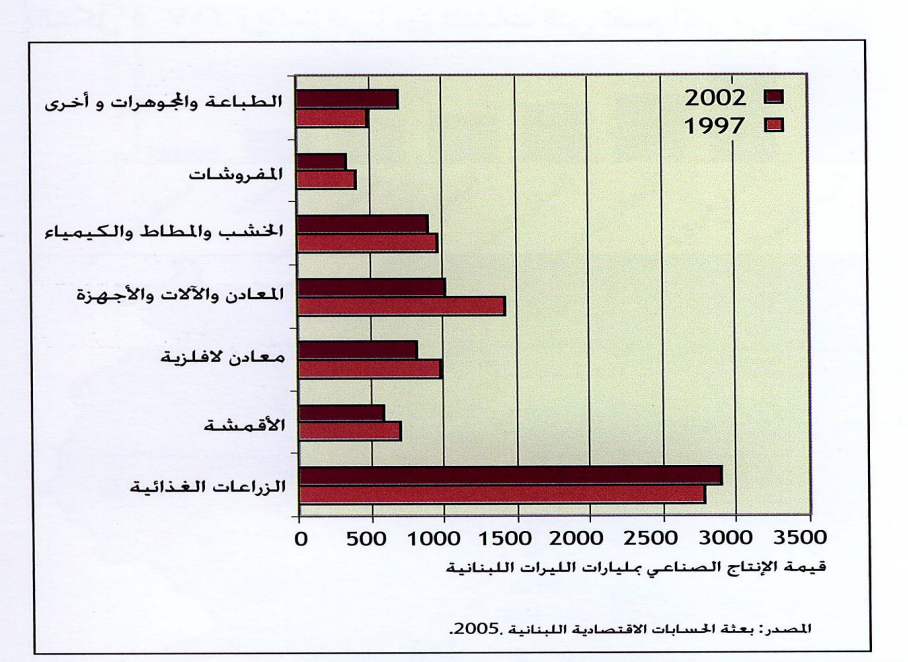

Figure 12 *Modern development of industry branches*

Figure 13 shows the industrial factories as obtained from the Atlas of Lebanon, 2012 [11], where the largest concentrations of industry factories can be seen in the eastern suburbs of Beirut and in the Tripoli area, mainly along the coast.

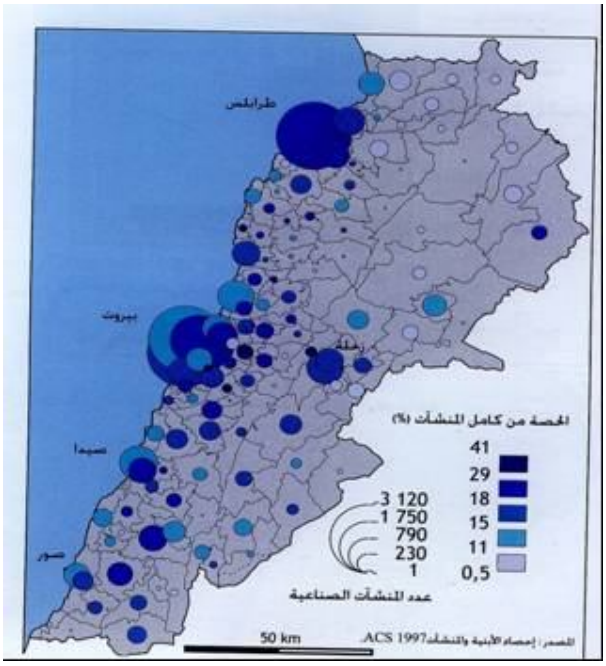

Figure 13 *Industrial Factories*

Figure 14 shows large industrial factories as obtained from the Atlas of Lebanon , 2012 [11], where it can be seen that Beirut and its suburbs dominates the factories with more than 20 employees. On the other hand, the Tripoli region shows a concentration of factories consisting of small and micro enterprises targeting mainly for the domestic market.

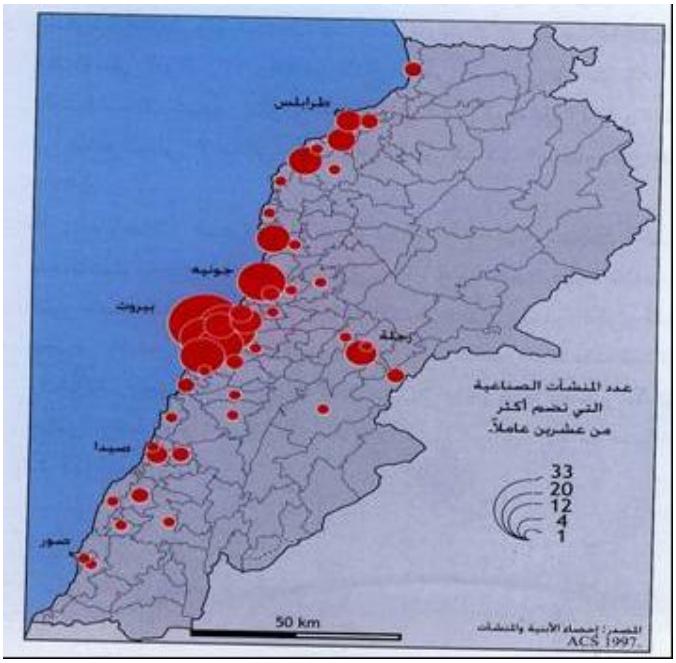

Figure 14 *Large Industrial Factories*

3.4 Sectoral Vulnerability and Risk Assessment

3.4.1 Introduction

While exposure determines the distribution of elements that *may* be subjected to a hazardous event, the vulnerability determines the consequence of them being exposed to such an event.

Earlier reports within the current project regarding disaster loss estimates [13] and [14] summarised the economic and social vulnerabilities of the Lebanese population in an attempt to assess the correlation between poverty and disaster losses. The two reports were based on two different datasets, the first collated by the army on behalf of the High Relief Committee and the second reflects the data on damages as reported by the Newspapers.

A third report within the current project addressed the issue of critical infrastructure within the country [15], including the level of resilience of the various critical infrastructure sectors. This section will address the vulnerability and resilience of selected sectors, making reference to the above reports where necessary.

3.4.2 Specification, Delineation and Enforcement of Landuse Guidelines

Before embarking on an analysis of sectoral vulnerabilities, it is important to review landuse management mandates and practices, as they are an important factor in shaping or reducing sectoral vulnerabilities.

Table 31 shows the distribution of responsibilities related to land management in Lebanon obtained from the UNHABITAT study on urban profile in Lebanon published in 2011 [7]. It can be seen that responsibilities related to land management are divided amongst nine directorates from several ministries.

Table 31 *Distribution of Responsibilities Related to Land Management in Lebanon*

Responsibility / Party	MOPWT (DGU)	MOE	MOA	MOC (DGA)	MOEW	MOIM	CDR	Religious Orders
National and use Master planning	X						x	
Protected areas management		x	x					
Forest management		x	x					
Urban Planning regulations	X							
Public maritime domain (coastal zone)	X							
Protection of cultural heritage				X				x
Protection of rivers and waterways	X	x			x			

Management of religious estates								x
Quarry sector		x			x	x		
MOPWT: Ministry of Public Works and Transportation, MOE: Ministry of the Environment, MOA: Ministry of Agriculture, MOC: Ministry of Culture, MOEW: Ministry of Energy and Water, MOIM: Ministry of Interior and Municipalities, CDR: Council for Development and reconstruction.								

In addition to the limited delineation of responsibilities, land use planning in Lebanon is subject to additional challenges. Indeed, few of the areas within Lebanon are covered by Master Plans for landuse recommendations and guidelines (see Table 32). Urban Master plans are primarily concentrated along the coast and in large agglomerations [7].

Table 32 *Areas covered by Master Plans in Lebanon*

Parameter	Percentage of Lebanese territories
Lebanese Territories covered by Urban Master Plans– Approved by the higher council of urban planning and decreed by the council of Ministers	10.3% (2000-2001)
Lebanese Territories covered by Urban Master Plans– Approved by the higher council of urban planning and yet to be decreed by the council of Ministers	16.2% (2004)
Unplanned and Only Partially Surveyed	83.8%
Demarcated, yet to be Surveyed	30%
Neither demarcated nor surveyed	20%

Table 33 summarises urban and slum characteristics of Lebanon as obtained from as obtained from the Lebanon Urban Profile produced by the UN HABITAT in 2011 [7].

Table 33 *Urban and Slums Characteristics of Lebanon*

Parameters	Description
Lebanon's Urban Population	87% (3,674,500) – UN HABITAT 2008 Statistics
Population living in Large Agglomerations	64% (2,703,000), mostly in Beirut and its surrounding suburbs, Tripoli, Saida, Tyre and Zahle - UN HABITAT 2008 Statistics.
Informal Settlements (non-engineered structures)	Two main waves (rural migrants in the 1950s, internally displaced during the civil war 1975-1990). Developed in cities fringes in Beirut and Tripoli in violation of construction codes and planning regulations. Slum to Urban ratio is 50% - UN HABITAT 2001 statistics.
Palestinian Camps	Refugee camps are historically the oldest slums of Beirut. These slums are located within and outside the city's municipal boundaries. Camps were organised for Armenian (1920s), Syriac (1920s) and Palestinian (1948) refugees with the help of international organisations, while Kurds occupied abandoned camps and deteriorating tenements in the city centre. There are a total of 12 Palestinian Camps in Lebanon serviced by UNRWA [16].
Palestinian Informal Gatherings	42 informal gatherings not serviced by UNRWA with limited services, accommodating around 35,000 refugees. Gatherings developed mainly around major cities of Tyre, Saida, North Lebanon, Bekaa and Mount Lebanon in descending order with respect to number of inhabitants [7].
Beirut Metropolitan Urban Area – Slum Characteristics	24 slums, 300,000 dwellers, 20% population

3.4.3 Health Sector

Nurseries

One of main sources of vulnerability within the country is the lack of clear mandates on a number of issues regarding disaster risk reduction. Regarding the health sector, an important issue is the safety of preschools and nurseries. According to Lebanese law, these are all considered as day care centres and as such are placed under the authority of the Ministry of Public Health. The latter do not have

experience in assessing the safety of schools or nurseries. They often benefit from the help of international organization such as the WHO who have accumulated experience in the field of hospitals and health, but not in the field of nurseries. The vulnerability of nurseries is further compounded by the presence of very young children, as indeed many accept toddlers less than one year old. In many cases these nurseries are several floors, while in other cases they occupy basements or upper floors in old buildings, all of which makes the response and evacuation very difficult. This vulnerability is further compounded by the fact that very little data exist on their establishments, a most operate without a licence.

Response Plans for Individual hospitals

On an individual installation level, a limited number of the installations have written emergency response plans providing instructions and SOPs for staff on how to behave during emergencies. Furthermore, training is rarely carried out according to international standards where the following consequence of training exercises and simulations are required:

- **Workshops** where all stakeholders, departments and personnel with a role to play in the risk management program and emergency response operations are represented and involved in writing / reviewing the plan / program.
- **Table-top exercises** where roles and responsibilities delineated in the plan and program are further refined and trained upon.
- **Control post exercises** where training on the plan takes place with personnel located within their respective departments (as would be the case in a real situation).
- **Field simulations** where training takes the form of a field simulation and where all or parts of the plan are tested in a free-

field unfolding time scenario or specific instance in time corresponding to certain stages within the response process.

However, most medical centres do have response experience (albeit not to earthquakes) and non-formalised plans and procedures on how to fulfil their roles during emergencies (assuming they are not damaged).

Strength and Resistance of Individual Hospitals

The vast majority of the hospitals in Lebanon have been built before 2005 when the public safety decree for earthquake and fire design was approved. The fact that the decree is yet to be implemented implies that even the hospitals built after 2005 are not necessarily built to resist earthquakes. Based on the above, it is possible to conclude that most hospitals are vulnerable to earthquake damage, and as a first step their degree of vulnerability must be assessed.

Sectoral Resilience Programs

On a sectoral level, there is a need to develop plans that will account for the following:

- Reduce interruption time to a minimum and ensure continuity of services offered to the public.
- Ensure resilience of the sector by developing sectoral resilience programs to meet the requirements in the strength, reliability, redundancy and response and recovery fields as detailed in the earlier report on the resilience of critical infrastructure [15].

The comments made regarding the sectoral resilience programs and the emergency response plans have been discussed in more detail in the earlier report on the state of resilience of critical infrastructure in Lebanon [15]. These comments are applicable to all sectors

considered in this study, while more detailed comments and discussion is provided in the above mentioned report.

3.4.4 Transportation Sector

The vulnerability of the transportation sector can be qualitatively assessed by examining the vulnerability of the following main components:

- **The road network**, which may be particularly vulnerable to landslides and liquefaction (depending on the foundation type). In addition, the road network is also vulnerable to cracking, opening and other types of deformations especially in the vicinity of the earthquake faults. In this regard, roads adjacent to faults and liquefaction areas are highly vulnerable.

- **Bridges**, which are considered vulnerable in case of an earthquake generating ground acceleration exceeding 0.l9g. While this may not be realistic for an earthquake with a design period of 475 years, it may be possible for earthquakes with design periods equivalent to an annual probability of exceedance of 2% in 50 years (as is considered by many countries which have recently completed a national risk profile exercise). This once again brings to the forefront the importance of having a national committee to set the limits of tolerable and intolerable risks and damages both to residential buildings and critical infrastructures.

- **Beirut Port** which contains large quantities of tanks with hazardous inventories as well as harbouring ships that contains hazardous materials. Many of the tanks within the port are not designed to resist earthquakes. Furthermore, most of the old buildings within the port have been build without any seismic deign considerations.

- **Airport** which has two new east and west runways designed twelve and fifteen years ago with a design life of twenty years, without seismic risk considerations. There are also two old runways designed without seismic risk considerations and whose design life has expired. Furthermore, the liquid storage tanks in the vicinity of the airport have been designed in 1984 without any seismic design considerations. The terminal building has a response plans in case of earthquakes but not in case of tsunamis (even though the runway and the airport are directly on the coast).

Within this sector, priority should be given to protecting hazardous tank farms against earthquakes and subsequent fires and explosions in case of leaks.

3.4.5 Housing Sector

The factors that play a role in determining the vulnerability of the housing sector include the following:

- **Age of housing**, where houses built prior to 2005 are not expected to be designed to resist earthquakes. Furthermore buildings older than 50 years old may be beyond their design life. In Lebanon where quality control and inspections during construction are rare and subject to corruption, it is possible that the *effective* design life of some buildings is below 50 years.

  Table 34 shows the distribution of families by the age of housing and the provinces in 1997 as obtained from the study on the socio economic condition in Lebanon [5]. It can be seen that in Beirut, more than 24% of the population lives in housing more than 50 years old, and 52% in housing between 24 and 49 years old. The age of the buildings, coupled with the lack of seismic code guidelines, poor urban planning, proximity of buildings to

each other which the possibility of pounding, and the steep slopes in many regions within the country leads to the conclusion that the housing sector is highly vulnerable in Lebanon.

Table 34 *Distribution family ratios by the age of housing and provinces in 1997*

Age of housing in years	Beirut	Beirut Suburbs	Mount Lebanon	North	South	Nabatiyeh	Beqaa	National Average
Less than 5	1.9	9	8	5.1	7.7	6.7	9	7.1
5-9	2.4	7.2	8.9	7.9	12.7	10.1	10.3	8.3
10-24	18.4	28.2	34	35.2	37.6	37.7	38.3	32.4
25-49	52.3	48.2	33	34.3	30.3	30.5	29.6	37.9
More than 50	24.8	7.2	15.8	17.1	11.6	15	12.8	14.1

- **Type of housing**, where houses made of reinforced concrete and steel are expected to perform better during disasters. It should be recognized however that this is an over-simplification as the eventual performance of any housing unit will depend on the proximity of its natural frequency to that of the ground beneath it and to the proximity to both of those to the dominant frequencies within the earthquake motion. The response will also depend on the type of the foundation and the likelihood of landslides and/or liquefaction triggered by the earthquake. While this line of analysis should be pursued in the future, by first collating additional data regarding the distribution of buildings with respect to Caza, material type, date of construction and type of design.

- **Building codes** The challenge in Lebanon is not limited to the lack of any seismic code prior to 2005 but also to the fact that general building codes may not be strictly enforced due to weak enforcement procedures.

- **Non-permanent, non-engineered structures**, where large number of the residents in the country live in non-permanent structures or structures which have been built in illegal settlements in violation to construction codes and planning regulations. This implies that these constructions are usually completed very rapidly to avoid blockage by the authorities, with no or little guidance and supervision, and often on unsuitable land. These construction practices in turn increase the vulnerability of these structures. While this practice has been ongoing for a long time beginning with Palestinian camps and informal settlements, it has continued with rural immigration to main urban employment centres (Beirut and Tripoli), followed by displacement and illegal settlement in public land during the civil war, and finally more recently it continues in some regions near Tyre, Tripoli and Beirut Southern Suburbs amongst others.

- **Population living in proximity to hazardous industries**, which can be subdivided into two main categories. The first category is that part of the population which has illegally settled in areas that contain specific hazardous industries such as those dwellers near karantina, Zouk plant, Beddawi refinery, and the Metn industrial cities amongst others. It also include those residents who live in residential areas where industrial "entrepreneurs" have setup shop in the midst of residential areas (sometimes even taking a flat within a building) with no regard to public safety and societal concerns.

- **Ownership and Age of Building**, which combine together to form an acute form of vulnerability. This is particularly true for the case of old buildings whose owners have rented out according to old contract which does not provide sufficient amount of revenue to justify (from a mere-owner financial perspective) a rehabilitation of the building. This requires incentives offered by the state for

the owner(s) of such buildings and/or for the tenants. It must be recognized that this situation is extremely dire, where buildings might collapse without the presence of earthquake loads, as evidenced by the recent collapse of one such building in Achrafieh in 2012, which led to the deaths of more than 25 people divided amongst Lebanese and foreign nationals.

Based on the above discussion, it is clear that the areas requiring a priority action are (simultaneously and not in any order): 1. Buildings more than 50 years old, 2. Buildings in illegal settlements (which sometimes rise to be three or four floors) and settlements in the vicinity of hazardous industries (either because the residential settlement encroached on the industrial area or vice-versa).

3.4.6 Education Sector

The factors which influence the vulnerability of the schools (and those within them) to earthquake hazards in Lebanon include the following main parameters:

Year of construction of school building(s), where some of the schools are very old with deteriorating building strength. These schools are particularly vulnerable to damage during earthquakes, particularly if they are located on soft soils and/or soils that may be subject to liquefaction. Table xx shows the age of the schools in Lebanon.

The method of construction of the school, which includes the type of material, type of foundation, connections, and level of ductility in design and in construction.

The original purpose of the school building(s), with many schools not being originally built to serve as schools which creates a variety of challenges. In some cases it is extremely difficult to plan prompt evacuation of students because of the way the school has been designed. In other instances, the school still shares some of its premises

with shops, residential apartments and work-places containing hazardous materials. Finally, in all these cases the school was not designed or constricted taking into account that it will be hosting a large number of vulnerable children and as such afforded a higher degree of protection.

Ownership of the school, where in some cases the school is owned by individuals, companies, heirs to individual estates, religious authorities etc. This in turn complicates the rehabilitation and strengthening works in the school, especially for public schools. In such instances, the state considers itself not responsible for the rehabilitation of the school and the private owners are not forced to meet seismic criteria before renting their premises out to act as schools. This is also true in the case of "semi-private" schools and private schools.

The Number of students in each school, where in some instances this number exceeds 1000. If combined with the factors contributing to vulnerability such as age, location and year of design

The Gender of students, which is important for several reasons. It is essential to ensure that both girls and boys are being afforded the same degree of protection and preparedness and in order to do that it is important to identify any generic differences in the current situation. It is also important since preparedness and emergency response and recovery plans must be afforded a large degree of

Age group of students, where with younger age groups the issue of emergency preparedness and response becomes more challenging and requires additional targeted and tailor-made training and preparedness.

Location, in terms of proximity to faults and in terms of proximity to main roads.

These issues, amongst others, were discussed in a summary report on the prioritization of the vulnerability of schools carried out on behalf of UNICEF and SAVE THE CHILDREN, with the Ministry of Education and Higher Education as the main public sector beneficiary [17]. The main recommendation for the education sector includes the following:

- The development of a national earthquake school safety program, which would include the following main elements:
    - A national program developed with the Ministry of Education and Higher Education, for the seismic safety of schools outlining requirements in all related fields over the midterm (ten to fifteen years).
    - Risk management programs in schools.
    - Emergency response plans in schools.

Pilot activities of the above have already started with various deliverables currently under review.

3.4.7 Energy Sector

The energy sector in Lebanon is comprised of the following main components:

- **Tank farms and tank farm terminals along the coast** which, due to unchecked urban expansion, are now in some cases in the middle of unchecked urban sprawl in contrast to when they were designed when the area was considered relatively remote. In most cases these have not been designed to resist earthquakes. The degree of vulnerability of these tank farms to earthquakes is relatively high. This also applies to tank farms servicing some of the main critical infrastructure in the country, including the Rafiq Hariri Beirut International Airport. These tanks farms have also not been designed to resist the elevated

temperatures arising from fires which may break out as a result of earthquakes or the high strain rate loading which may occur as a result of explosions which in turn may also occur as a result of an earthquake, prior, after or instead of a fire.

- **Main electric generation installations**, including the Zouk electric generation plant, which again has not been designed to resist any earthquakes. Furthermore this plant has also not been designed to resist the fires and/or explosions that may occur in the aftermath of an earthquake. This applies to the building itself as well as o the large equipment and the small piping systems. Finally, this plant, originally built in a remote area is now surrounded by unchecked urban expansion. The above implies that these plants and the surrounding area are highly vulnerable to earthquakes.

- **Petrol stations** scattered throughout the country including in residential neighbourhoods, and in some case even in close proximity to schools. These also have an underground storage facility where the oil is stored. It is extremely important to assess the vulnerability of these stations to earthquake damage.

All the above issues are considered a priority which must be promptly addressed.

3.4.8 Public Buildings Sector

Within the context of this report, the public sector encompasses the buildings hosting the first responders in the emergency response services, including the civil defence. These were treated separately in the report on the resilience of the national critical infrastructure, but may be treated as part of the public sector for the purposes of this report.

The vulnerability of the public sector buildings share some of vulnerability factors with housing and other with schools, and as such most of the points referred to for the above two sectors are applicable to the public buildings sector. In addition, the discussion below summarises some of the specificities within the main factors affecting vulnerability in the public building sector:

Age of building, where it is expected that everything built prior to 2005 was not built according to seismic design standards. For example, it has been established through discussion with various personnel that all the civil defence buildings, hosting the civil defence which is meant to play a significant role in the aftermath of an earthquake, has themselves not been designed to resist earthquakes!

Type of design, which includes material, construction practices, level of ductility, connection types, and the use of any seismic design considerations.

Purpose of Building, where some buildings which serve critical functions for the executive, legislative, judiciary, or law enforcement powers must be afforded a higher degree of protection corresponding to the role that these authorities must play during and in the immediate aftermath of a devastating earthquake. However, this first necessitates a discussion with all relevant stakeholders in the country on the level of acceptable and intolerable risk, corresponding to various hazardous events and their possible effects on residential houses, assets, the environment and critical infrastructure including come of the more critical public buildings.

In this sector, the protection of the buildings housing the primary response agencies including the fire brigade, the civil defence, the red cross and the Lebanese Army (which over the years for a variety of reasons increasingly plays a "civilian" role) must be considered a priority. Within this group, it is envisaged that the civil defence and the

fire brigade buildings are more vulnerable than the buildings corresponding to the remaining two types of responder agencies.

3.4.9 National Icons Sector

The national icons, some of which were identified in Section 3.3.10 above, are all considered vulnerable to earthquake risk. Some of the main factors affecting their vulnerability include:

- **Age**, where some of these structures have been standing erect for thousands of years, and as such are continuously being subject to an erosion process due to exposure to the elements of nature.
- **Previous damage**, which may be an indication of several phenomenon. If it is a recent occurrence, this may imply that it corresponds to a reduction in strength to a level where damage is becoming apparent. If it corresponds to a much earlier event then it implies the occurrence of a rare event in the distant past which might recur in the near future.

The priorities in this field must be the Byblos site, the Baalbek, Tyre, Sidon, Beit el Dine and the Jeita grotto. While preliminary work is underway for the protection of some of these sites, the integrity of the remaining sites must be promptly assessed and identified vulnerabilities addressed. Furthermore, as in other critical national infrastructure sectors, there is a need to agree on the level of tolerable risk and the corresponding probability of occurrence of the event under consideration. Figure 15 shows the reinforcement of the structural stability of the northern medieval tower of Byblos ancient port [18]. Notwithstanding the importance of the above works, and other strengthening works within the same project, it should be recognized that these are being carried out to protect against the hazards of continuous temperature gradient effects underwater, and meteorological hazards. There is a need to also assess the structural

integrity of the site against earthquake hazards. This is particularly important for two reasons: 1. It may be more cost-effective to carry out the protection of the site by adopting a holistic approach which accounts for the threat of all hazards at once, 2. In some extreme cases some strengthening works against meteorological hazards (being carried out based on static design considerations) may alter the dynamic characteristics of some of the elements on the site thereby shifting them to a natural frequency range more susceptible to earthquake damage. Therefore it is also necessary to adopt a holistic approach from a safety perspective.

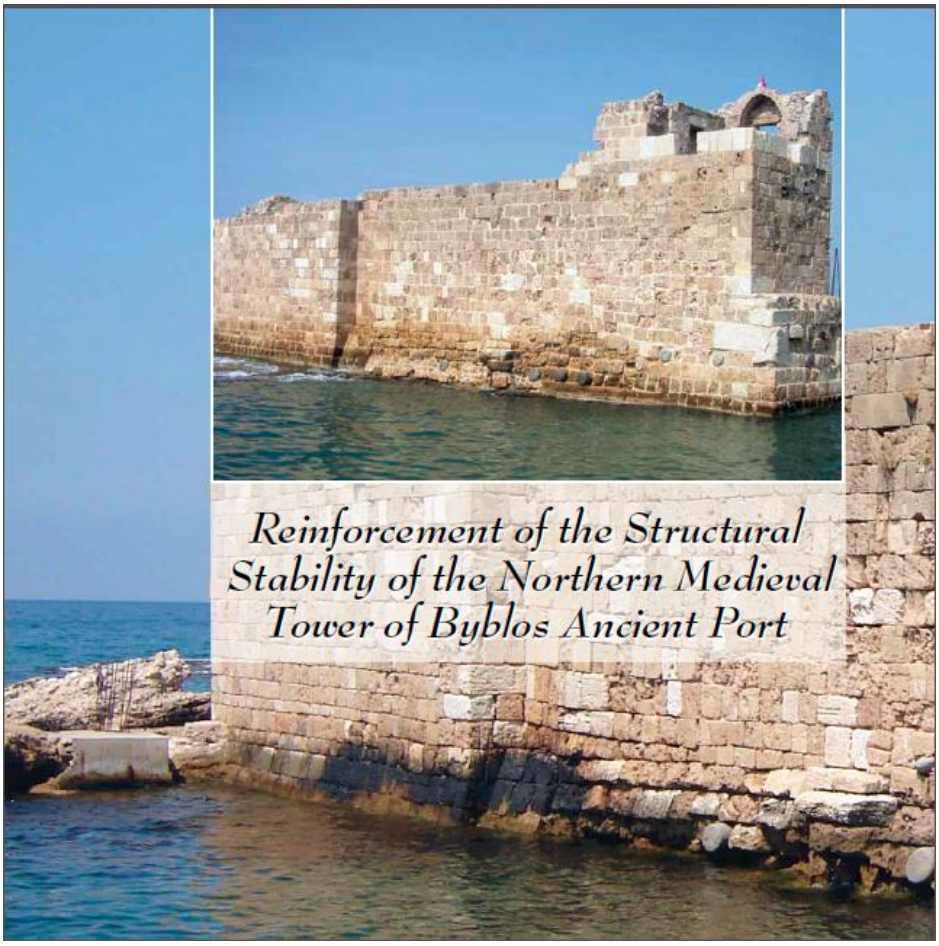

Figure 15 *Reinforcement of the Structural Stability of the Northern Medieval Tower of Byblos Ancient Port against meteorological hazards*

Figure 16 shows some of the repair works to some elements within the Baalbek site against rain water damage [19]. Notwithstanding the

importance of these works, as mentioned above for the case of the Byblos site, it is important to carry out an assessment of earthquake hazards and associated vulnerabilities and risks. This is particularly important since any strengthening work for other hazards carried out using a static strength perspective may actually lead to a shift in the dynamic properties of some elements on the site which in turn might make them more vulnerable to some of the more dominant frequencies of earthquake motion. It is equally important that the level of earthquake risk, for which the site should be protected, is determined using a participatory approach with all relevant stakeholders. For example, Baalbek was inscribed on the UNESCO World Heritage List in 1984 under criteria I and iv which constitutes a "universal testament to Baalbek's universal value, which means that it belongs to all humanity and to future generations" [19]. However, such a site must be protected against an extreme rare earthquake corresponding to a low annual probability of occurrence. Unfortunately, the above study, when identifying the probability of an earthquake to be considered in their future assessments refer to "an earthquake that may happen once every hundred and fifty years in the Baalbek region". Such a "low" severity event is not adequate for the protection of the site against more severe earthquakes which has clearly rocked the site over the past thousands of years, and as such is inadequate and in need of prompt revision.

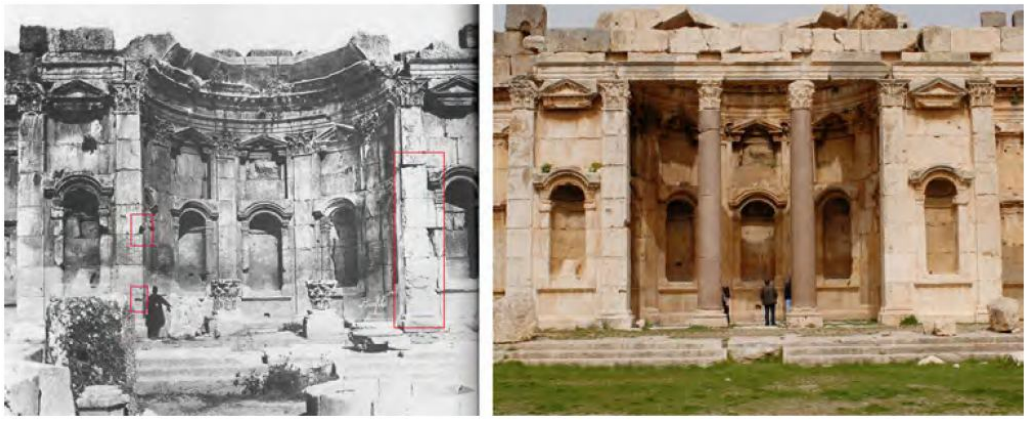

Figure 16 *Reinforcement of the Structural Stability of the Northern Medieval Tower of Byblos Ancient Port against meteorological hazards*

3.4.10 Tourism Sector

Hotels and restaurants are scattered across Lebanon. The factors affecting vulnerability are in many ways similar to those affecting housing, public sector buildings, schools and hospitals. In addition, the main specificities related to the tourism sector within the above vulnerability factors are discussed below:

- **Age of hotel**, where many of the hotels, restaurants and nightclubs in Lebanon has been built prior to the Lebanese civil war in 1975 and rehabilitated just after its end in the 1990s. This implies that, in most cases, such rehabilitation was carried out from a static strength point of view. Furthermore, several of these restaurants are in old buildings in residential areas and as such are not designed to resist earthquakes.

- **Asymmetry in shape and height of floors**, dominating the design of hotels worldwide and in Lebanon. Earthquake observations reveal that such discontinuities in strength and stiffness often lead to a concentration of earthquake loading leading to partial collapse in corresponding floors. This can be avoided simply by

designing all such hotels, including said discontinuities, to be earthquake resistant.

- **Number of floors**, which have a direct impact on the need for thoroughly tested emergency response plans particularly in establishments which may be hosting large numbers of people and which contain hazardous inventory that may lead to a fire or explosion in the aftermath of a disaster.

- **Presence of Fire Escapes**, where many restaurants and nightclubs do not have any safety exits or fire escapes. In the case of an earthquake, and in the presence of flammable inventory, large groups of people, loud music and young people under the influence of alcohol, together with the absence of fire escapes, it can easily be concluded that any fire that breaks out in the aftermath of an earthquake may lead to a large number of injuries and fatalities.

- **Location**, where in some cases, particularly for nightclubs, the premises of these entertainment facilities are in dire proximity to locations storing large quantities of hazardous, flammable substances.

The main priorities in this sector is to ensure that the nightclubs and restaurants have fire escapes in case of fire after an explosion (it is assumed that the vast majority if not all hotels do have fire exits). A second priority is to ensure that all hotels /restaurants and nightclubs which can host more than 250 people at any one time have been designed to resist earthquakes or are in the process of rehabilitation to become as such. Last but not least, a third priority is to move touristic facilities away from sites storing large substances of hazardous material.

3.4.11 Telecommunications Sector

The telecommunications sector consists of three main components, the buildings hosting the premises of the various public sector and private sector stakeholders, the transmission lines and the transmission towers. The buildings share the same vulnerability factors with the buildings of the various sectors referred to in earlier sections, especially those buildings hosting critical national infrastructure. Two main issues should be reiterated in this regard: 1. The importance of deciding on a return period event for which the sector must be able to withstand the damages without failure or interruption of services, with plans for a quick recovery in case of interruption; and 2. The age some of these buildings, which are old and have not been built to resist earthquakes.

The telecommunication sector is perhaps one of the first sectors engaged in the development of recovery plans. Alas, like the banking sector, it is focusing its recovery on data recovery without sufficient effort being directed at ensuring that the buildings hosting the redundant equipment to help and ensure recovery will remain resistant to earthquakes.

The following points can be made regarding the two remaining components of the telecommunication sector (transmission towers and transmission lines):

- **Connections** The tower structures are lattice type structures with a large degree of redundancy. However the connections, whether at the main buildings or at the towers play an important role in determining the continuity of the services and the minimization of the damage, as evidenced by recent observed damage during the Haiti earthquake [20]. **Error! Reference source not found.** shows a damaged cable tray from the cellular tower to the data centre. The cable tray separated from its attachments to the building, probably due to the significant differential inter-storey displacements of the heavily damaged

low-rise building, as shown in **Error! Reference source not found.** [20].

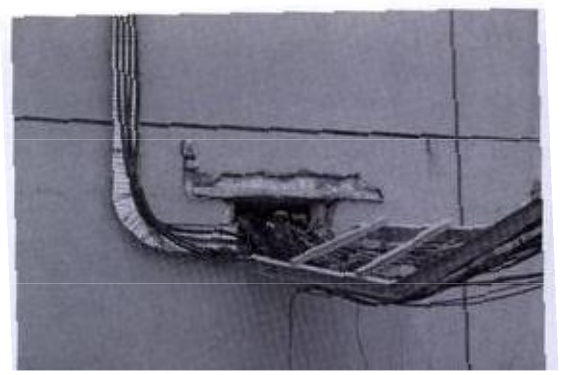

Figure 17 *Damaged Cable Tray from Tower to Data centre*

Figure 18 *Failure of Beam-Column Joint Close to Cable Tray Attachment to Building*

- **Alignment Issues** for microwave antennas. These antennas either link with major nodes of the cellular network or serve as an end-point link to local cell site. Microwave links at these frequencies are highly directional, requiring highly specialised instruments and technicians to achieve the precise alignment required for reliable data links. [20]. Figure 19 shows the trussed tower supporting the microwave antenna both of which were undamaged and as such there was no realignment necessary [20].

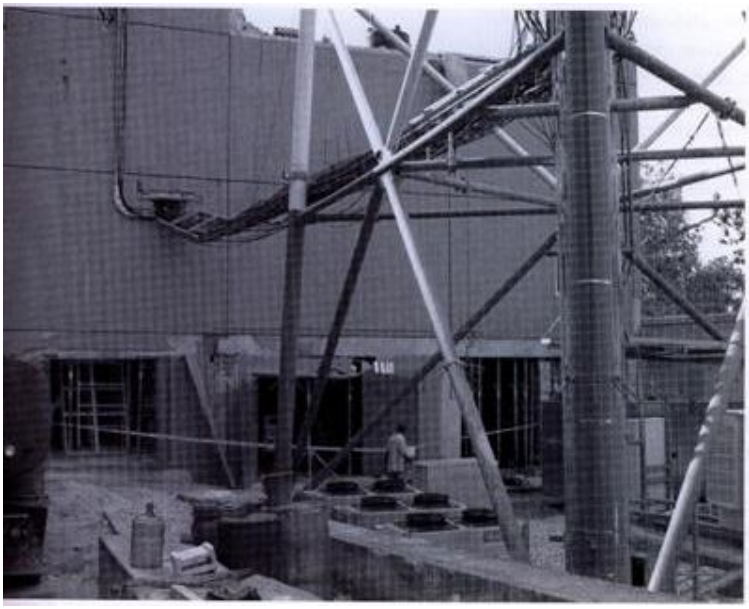

Figure 19 *Damaged Cable Tray from Tower to data Center at Haiti Cellular Phone Company*

- **Uninterrupted power supply systems** whose failure can cause damage to the service and eventual interruption. These must be designed in such a way to be able to withstand any differential movements due to the differential movement of the supports. Figure 20 shows an unanchored UPS system during the Haiti Earthquake at the Cell phone companies. The system consisted of multiple free standing cabinets located at grade level with top entry and exit electrical conduits. The cabinets were not fastened together so they moved independently of one another [20].

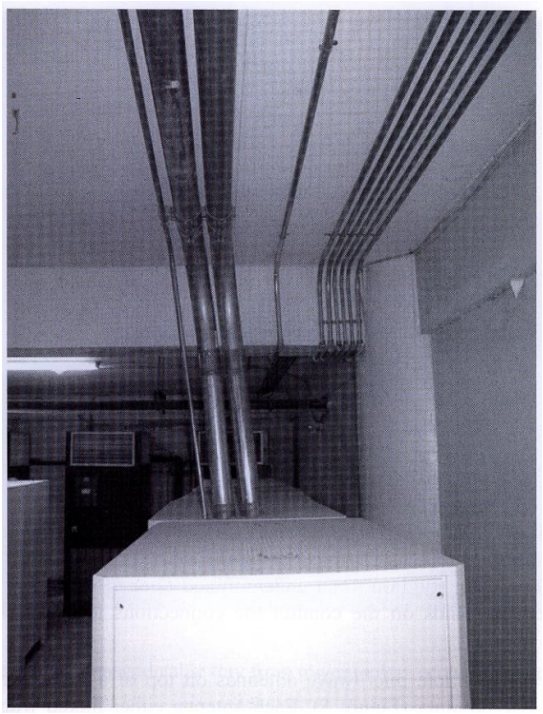

Figure 20 *Unanchored Uninterrupted Power Supply System at Haiti Cell Phone Company*

The main priorities in this sector are to ensure that that any equipment used for the recovery plan are housed in buildings that are built to resist earthquakes. Furthermore, the level of earthquakes that these buildings must resist must be determined based on a participatory approach with all concerned stakeholders to determine the level of acceptable and intolerable risks. Finally it is equally important to ensure that the connections, including cable trays and connections of the UPS are designed in such a way to ensure ductility and resilience to differential movements.

3.4.12 Water and Waste Water Sector

The water sector consists of water storage tanks, water pipelines, wastewater pipelines, wastewater treatment plans and existing and proposed dams. The following factors contribute to the vulnerability of the various elements constituting the water and wastewater sector:

- **Year of design**, where most components designed before the end of the civil war are not expected to have any earthquake design considerations.
- **Vertical Excitation**, which has a particular importance for water retaining structure as the hydrodynamic pressure due to gravity is transferred to an additional load which may cause lateral instability.
- **Fluid Structure interaction**, which has particular importance for water storage tanks and dams. In the storage tank case sloshing pressure may lead to overboard and spilling and even contribute to overturning. Convective and impulsive hydrodynamic pressure at the bottom and mid height of the tank may lead to elephant-foot and diamond shape buckling. In the case of dams the additional hydrodynamic pressures caused by earthquake motion may also lead to lateral instability of its different kinds depending on the type of dam under consideration.
- **Non-synchronous motion,** which is particularly important for long structures such as dams.

The main priority for this sector is to ascertain the earthquake design period for the case of dams based on a participatory stakeholder approach which accounts for acceptable and intolerable levels of risk. A second priority is to ensure that vertical acceleration and fluid structure interactions effects as well as non-synchronous motion are being accounted for in a consistent manner not dependent on the knowledge and experience of the designer. Instead it should be reflected in the design specification put down by the respective authority. For the case of water and any wastewater storage tanks, there is a need to ensure that these are designed to resist earthquake motion and rehabilitate any vulnerable items using simplified methods and procedures.

3.4.13 Financial Sector

The financial sector consists of four main components, the buildings hosting the main headquarters and branches of the various banks, including the Central Bank of Lebanon, the equipment needed for dispensing cash to the public, equipment needed for data storage and recovery, and the various cables and connections in-between these systems. The buildings share the same vulnerability factors with the buildings of within the various sectors referred to in earlier sections, especially those buildings hosting critical national infrastructure. Two main issues should be reiterated in this regard: 1. The importance of deciding on a return period event for which the sector must be able to withstand the damages without failure or interruption of services, with plans for a quick recovery in case of interruption; 2. That some of these buildings are old and have not been built to resist earthquakes; and 3. The importance of building ownership as many bank branches occupy a floor or two in commercial or residential buildings and as such the responsibility of the rehabilitation of the building to become seismically resistant may not be easily attainable.

The financial sector is perhaps one of the first sectors engaged in the development of recovery plans. As for the telecommunications sector, there is a need to ensure that emphasis is not directed solely at data recovery without sufficient effort being directed at ensuring that the buildings hosting the redundant equipment to help and ensure recovery will remain resistant to earthquakes.

The following points can be made regarding the three remaining components of the financial sector:

Uninterrupted power supply, which must be resilient to ensure that the recovery process is not hampered.

Fires and explosions, which may occur in the aftermath of the earthquake, must be accounted for, particularly in any building and equipment important for the recovery process.

Differential displacement, which the equipment might experience as a result of the differential displacement within the building, must be accounted for.

Based on the above, the main priorities in the banking sector are to ensure that the recovery centres and equipments are located in buildings that can resist earthquakes. A second priority is to ensure that the recovery and redundancy centres have uninterrupted power supplies that can resist the secondary effects of earthquakes including differential displacement in both the horizontal and vertical directions and inter-storey drift.

3.4.14 Agriculture and Fisheries Sector

The agriculture and fisheries sector is not particularly vulnerable to earthquakes but to other hazards such as tsunamis, floods and forest fires which will considered in later sections of this report. The only situation where the vulnerability of agriculture sector due to earthquakes may arise is in case of dam bursting or failure due to earthquake loads. However, dam safety is addressed in the water and wastewater sector.

3.5 Regional Vulnerability and Risk Assessment

3.5.1 Introduction

In the previous section sectoral vulnerability was assessed by identifying factors affecting vulnerabilities in order to determine priorities for action to reduce these vulnerabilities within the various sectors. Notwithstanding the importance of the above, it is equally important to determine the different factors contributing to regional vulnerability in order to determine priorities for reducing these vulnerabilities in the

various regions. To this end, it is first important to give a precise definition of vulnerability in order to determine what it is that needs to be measured. In the context of this study, the measured regional vulnerability must reflect the following:

- The level of potential damage that may occur to people, assets and livelihoods and the environment corresponding to different hazards.
- The susceptibility and predisposition of people, assets, livelihoods and the environment to undergo injury, death or damage.
- The options available to individuals, communities and societies to undertake prevention / mitigation measures in order to protect themselves against various hazards or to respond and recover from the consequences of a hazardous event without relying on external help (depending on the level of the risk profile under consideration and whether it is carried out at the individual / household, community or national levels).
- The specificities associated with the different hazards.
- The interaction between social, economic, physical, natural and institutional factors that give rise to vulnerability.

3.5.2 Challenges in the Assessment of Regional Vulnerability

In determining the values of the different factors contributing to vulnerability, extensive use was made of the following studies:

- National Physical Master Plan for Lebanese Territories [3]
- Socio-Economic Status in Lebanon [5]
- Household Survey 2004 [21]
- Household Survey 2007 [6]

- Atlas of Lebanon [11]
- Central Administration of Statistics [10]
- Health Beyond Politics [9]
- Poverty, Growth and Income Distribution in Lebanon [22]
- Lebanon Urban Profile [7]

Notwithstanding the importance of the above studies and the data they present on the social, economic, and environmental indicators within Lebanon, the following issues must be recognized:

- The required data is not readily present at the Caza level, where in many cases the study does not go beyond the governorate level. In other cases, cazas are lumped together based on several rational considerations.
- Contradictions within the data persist with some cases more blatant than others, mainly due to the paucity of clear mandates for data generation, collation and dissemination within the various public bodies.
- The above studies were carried out to assess various aspects of socio economic conditions and distribution within Lebanon. Inevitably, this implies that some of the requested data for carrying out an extensive vulnerability assessment form a DRR perspective is not readily available.

Notwithstanding the above challenges, the collated data was successfully used to draw a picture of the distribution of various factors that contribute to disaster vulnerability. In this context, three main points should be recognized:

- The results may be used to track progress with time and the effect of various DRM initiatives on reducing disaster risk within

the country. To this end, the data must be regularly updated as new DRR initiatives unfold and as new development projects and investment activities are carried out.

- The results may be used to qualitatively study the variation of vulnerability within the regions and cazas.
- The results, in their current form, should not be used as absolute numbers. Instead they are qualitative providing indications on vulnerability as outlined in the two points above.

3.5.3 Main categories of Factors Contributing to Vulnerability

Factors contributing to vulnerability are divided into five main categories:

- Physical
- Social
- Economic
- Natural
- Institutional

As will be seen in the next sub-sections, each one of the above categories contains sub-factors each of which is determined based on a series of parameters.

3.5.4 Physical Factors Contributing to Vulnerability

The main physical factors affecting vulnerability are the following:

1. Electricity.
2. Water.
3. Sanitation and Solid Waste Disposal.
4. Accessibility of Roads.
5. Housing and Landuse.

In the remainder of this section on vulnerability, a numbering scheme is used to show the level of vulnerability; 0-1 being critical, 1-2 very high vulnerability, 2-3 high vulnerability, 3-4 average vulnerability, 4-5 acceptable vulnerability (i.e. resilient).

Table 35 below summarises the above factors for the Different Cazas. Notes 1 to 6 within the table present the parameters used for determining the vulnerability, or resilience, of each of the five physical factors. These parameters were weighted and summed to arrive at a vulnerability number for the factor under consideration. The factors were also weighted and summed in order to arrive at a number for physical vulnerability.

Table 35 *Distribution of Physical Factors Affecting Vulnerabilities with Caza*

Mohafaza/Caza	Electricity	Water	Sanitation / Solid Waste	Roads Accessibility	Housing / Land-Use	Physical Factors Contribution to Vulnerability
Beirut	3.25	4.03	3.63	3.00	2.07	2.63
Dahiyeh	2.71	3.66	3.23	3.00	2.30	2.64
Baabda	3.10	3.78	2.84	3.00	2.58	2.82
Metn	3.20	4.08	3.28	3.00	2.53	2.87
Kesserouan	3.20	4.01	3.21	3.00	2.58	2.89
Jbeil	3.14	4.01	3.21	3.00	2.58	2.88
Alley	2.74	3.50	2.65	2.50	2.68	2.74
Chouf	2.74	3.50	2.65	2.50	2.68	2.74
Mount-Lebanon	2.98	3.79	2.97	2.86	2.60	2.82
Tripoli	3.00	2.88	2.85	3.00	2.00	2.24
Koura	3.08	3.06	3.04	3.00	2.83	2.92
Zghorta	3.08	3.06	3.04	3.00	2.88	2.95
Batroun	3.08	3.06	3.04	3.00	2.88	2.95
Aakkar	2.56	2.00	1.96	2.00	2.83	2.55

Mohafaza/Caza	Electricity	Water	Sanitation / Solid Waste	Roads Accessibility	Housing / Land-Use	Physical Factors Contribution to Vulnerability
Bcharreh	3.08	3.06	3.04	3.00	2.88	2.95
Miyeh-Dennieh	2.56	2.00	1.96	2.00	2.83	2.55
Administrative North Lebanon and Akkar	2.92	2.73	2.70	2.71	2.85	2.81
Zahle	2.80	3.56	2.90	3.00	2.84	2.93
West Bekaa	2.50	3.29	2.53	2.50	2.74	2.73
Baalbek	2.40	2.96	2.21	2.00	2.74	2.60
Hermel	2.40	2.96	2.21	2.00	2.74	2.60
Rachaya	2.50	3.29	2.53	2.50	2.74	2.73
Bekaa	2.52	3.21	2.48	2.40	2.76	2.72
Saida	2.85	3.71	2.49	3.00	2.57	2.75
Tyre	2.76	3.60	2.31	3.00	2.52	2.68
Jezzine	2.85	3.71	2.49	3.00	2.77	2.87
South Lebanon	2.82	3.68	2.43	3.00	2.62	2.77
Nabatiyeh	2.66	3.54	2.30	2.50	2.64	2.68
Bent Jbeil	2.56	3.08	1.84	2.00	2.64	2.53
Marjaayoun	2.70	3.25	2.01	2.70	2.64	2.65
Hasbaya	2.79	3.38	2.20	2.70	2.64	2.69
Administrative Nabatiyeh	2.68	3.31	2.09	2.48	2.64	2.64

NOTES

1. When measuring the five physical factors affecting vulnerability, an attempt is made to measure both resilience and vulnerability.
2. Electricity's contribution to vulnerability is a combination of several parameters including network access, availability and supply, together with the availability of redundant capacity / resources (which is an important measure for ensuring resilience). The same approach is used for measuring Water's contribution to vulnerability.
3. Sanitations' contribution to vulnerability includes sub-factors such as access, waste collection and treatment, and recycling.
4. Very little data exist on the conditions of the roads (% paved, accessibility during normal and hazardous conditions, and availability of functioning drains) segregated at the Caza level.
5. Housing / landuse contributes significantly to vulnerability and includes codes, presence of non-engineered structures, and proximity to hazardous sites.

The following comments can be made regarding physical factors affecting vulnerability to earthquake hazards:

- In some cases, insufficient data is available at the Caza level, and several cazas are lumped together, such as the case of Alay and Chouf, and in some instances Jbeil and Keserwane. For example the age of the housing, especially that over 50 years old, was given the maximum weight in shaping house/landuse factors affecting vulnerability. However, the data is available at the governorate level, and does not represent the variation available between the cazas of, for example, Tripoli, Batroun Minieh-Dinieh, etc. Clearly there is a need to delineate the data at Caza and even municipality level to further comprehend the variation of vulnerability within cities. This is particularly important since vulnerability does vary significantly within the same city and municipality in adjacent neighbourhoods, as shown in Figure 21 [7].

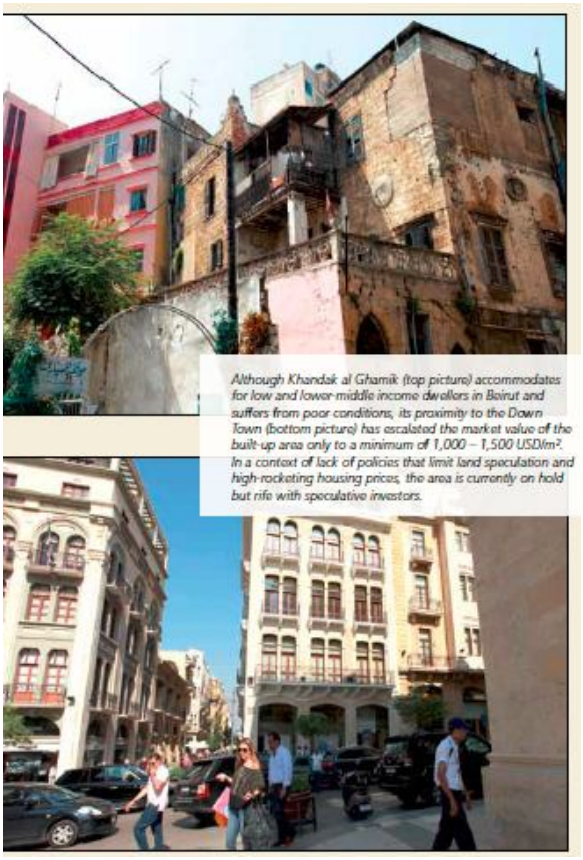

Figure 21 *Adjacent Areas of Khandaq Al Ghamiq and Downtown Beirut*

- Often focus is placed only on the physical factors affecting vulnerability, with special emphasis on the accuracy of codes. This alone does not explain how certain vulnerabilities are shaped. For example, the vulnerability of old buildings that are in a dire situation and structurally sound can only be explained and understood by looking at house ownership issues.
- Similarly, the case of housing in close proximity to hazardous sites and inventories; and the case of factories in residential areas, can only be understood by looking at landuse issues.
- In a similar manner, the factors shaping the risk of those inhabiting in non-engineered structures, can only be understood by adopting a holistic approach of examining the social, economic, physical and other factors contributing to this situation.
- The possibility of fires breaking out in the wake of an earthquake increase with increasing likelihood of a spark source. Electricity parameters affecting vulnerability captures this by accounting for the socio-economic condition of the area which in turn indicates the likelihood of hooking to public electricity lines as in Nebaa shown in **Error! Reference source not found.** [7]. This is a widespread practice in residential neighbourhoods, where petrol stations are sometimes located.

Figure 22 *Hooking on to Public and Private Electricity Lines, Nebaa*

3.5.5 Social Factors Contributing to Vulnerability

The main social factors affecting vulnerability are the following:

1. Population.
2. Health.
3. Education and Awareness.
4. Social Capital.
5. Community Preparedness.

Table 36 below summarises the above factors for the Different Cazas.

Notes 1 to 6 within the table present the parameters used for determining the vulnerability, or resilience, of each of the five social factors. These parameters were weighted and summed to arrive at a vulnerability number for the factor under consideration. The factors were also weighted and summed in order to arrive at a number for social vulnerability.

Table 36 *Distribution of Social Factors Affecting Vulnerabilities with Caza*

Mohafaza/Caza	Population	Health	Education / Awareness	Social Capital	Community Preparedness	Social Factors Vulnerability Contribution

Mohafaza/Caza	Population	Health	Education / Awareness	Social Capital	Community Preparedness	Social Factors Vulnerability Contribution
Beirut	2.96	4.33	3.70	3.00	3.00	3.40
Dahiyeh	2.92	3.35	3.21	3.00	3.00	3.10
Baabda	3.14	3.53	3.21	3.00	3.00	3.18
Metn	2.97	3.88	3.60	3.00	3.00	3.29
Kesserouan	3.14	3.35	3.60	3.00	3.00	3.22
Jbeil	3.14	3.35	3.60	3.00	3.00	3.22
Alley	3.34	3.20	2.92	2.50	2.50	2.89
Chouf	3.34	3.20	2.92	2.50	2.50	2.89
Mount-Lebanon	3.19	3.20	2.92	2.50	2.50	2.89
Tripoli	2.88	3.42	3.31	2.86	2.86	3.13
Koura	2.88	2.90	2.93	3.00	3.00	2.94
Zghorta	3.06	2.83	3.14	3.00	3.00	2.97
Batroun	3.06	2.83	3.14	3.00	3.00	3.00
Aakkar	2.76	2.83	3.14	3.00	3.00	3.00
Bcharreh	3.06	2.35	2.18	2.00	2.00	2.26
Miyeh-Dennieh	2.76	2.83	3.14	3.00	3.00	3.00
Administrative North Lebanon and Akkar	2.92	2.35	2.18	2.00	2.00	2.26
Zahle	3.25	2.70	2.83	2.71	2.71	2.78
West Bekaa	2.93	3.49	3.35	3.00	3.00	3.22
Baalbek	2.78	2.92	2.82	2.50	2.50	2.73
Hermel	2.78	2.18	2.63	2.00	2.00	2.32
Rachaya	2.93	2.18	2.63	2.00	2.00	2.32
Bekaa	2.93	2.92	2.82	2.50	2.50	2.73
Saida	2.93	2.74	2.85	2.40	2.40	2.66
Tyre	2.93	2.65	3.35	3.00	3.00	2.99

Mohafaza/Caza	Population	Health	Education / Awareness	Social Capital	Community Preparedness	Social Factors Vulnerability Contribution
Jezzine	3.28	3.11	2.79	3.00	3.00	2.97
South Lebanon	3.05	2.80	3.16	3.00	3.00	3.00
Nabatiyeh	2.92	3.41	2.89	2.50	2.50	2.84
Bent Jbeil	2.77	2.25	2.00	2.00	2.00	2.20
Marjaayoun	2.98	2.46	2.21	2.70	2.70	2.61
Hasbaya	2.98	2.46	2.21	2.70	2.70	2.61
Administrative Nabatiyeh	2.92	2.64	2.33	2.48	2.48	2.57

NOTES

1. When measuring the five social factors affecting vulnerability, an attempt is made to measure both resilience and vulnerability.
2. Population's contribution to vulnerability measures as a combination of several parameters including rate and density, percentage below 14 years and above 65 years, and percentage of population living in informal settlements.
3. Health's contribution to vulnerability includes percentage of population with diseases, access to health facilities, preparedness for and functionality during and after a hazardous event.
4. Education's contribution to vulnerability includes sub-factors such as access, preparedness for and functionality during and after a hazardous event, literacy rates, awareness campaigns and programs, drills preparation and frequency and access to internet.
5. Social capital contribution to vulnerability includes participation in community activities and in the DRR decision making process and the ability to organize debate and reach consensus through compromise.
6. Community preparedness includes preparedness in terms of material and logistics, participation in relief work, strength of NGOs and CSOs and evacuation drills.

The following comments can be made regarding the social factors affecting vulnerability to earthquake hazards:

- Very high rates of population densities, often in poor neighbourhood with small alleyways, leads to high vulnerability in terms of possible number of deaths and injuries as well as difficulties posed to rescue agencies.
- Having an active NGO and CSO sector in Lebanon increases resilience, provided there is sufficient participation in community activities.
- The various factors that contribute to vulnerability interact together and should not be seen as standalone factors. For

example, Tripoli city constitute 80% of the total urban population in the Caza (population being a social factor contributing to vulnerability). The old city houses old buildings, and small alleyways (housing a physical factor) and houses the poor (economic factor) 80% of which are tenants in the old city and have been living there for at least 30 years (house ownership identified as a physical factor). Once again, this shows the need to adopt a holistic approach to first understand the factors shaping vulnerability in the various Lebanese cities in order to then be able to propose solutions based on the actual conditions, as shown in Figure 23 [7].

Figure 23 *Part of the Old city of Tripoli, showing interaction of economic, social and physical factors affecting vulnerability*

3.5.6 Economic Factors Contributing to Vulnerability

The main economic factors affecting vulnerability are the following:

1. Income.
2. Employment.

3. Household Assets.
4. Finance and Savings.
5. Budget and Subsidy.

Table 37 below summarises the above factors for the Different Cazas.

Notes 1 to 6 within the table present the parameters used for determining the vulnerability, or resilience, of each of the five economic factors. These parameters were weighted and summed to arrive at a vulnerability number for the factor under consideration. The factors were also weighted and summed in order to arrive at a number for economic vulnerability.

Table 37 *Distribution of Economic Factors Affecting Vulnerabilities with Caza*

Mohafaza/Caza	Income	Employment	Household Assets	Finance / Savings	Budget / Subsidy	Economic Factors Contribution to Vulnerability
Beirut	4.0	3.1	3.3	3.3	3.0	3.3
Dahiyeh	3.3	3.0	3.0	3.0	3.0	3.1
Baabda	3.5	2.2	3.2	3.2	3.0	3.0
Metn	4.1	3.1	3.7	3.7	3.0	3.5
Kesserouan	4.0	3.1	3.7	3.7	3.0	3.5
Jbeil	4.0	3.1	3.7	3.7	3.0	3.5
Alley	3.2	2.1	2.7	2.7	2.5	2.6
Chouf	3.2	2.1	2.7	2.7	2.5	2.6
Mount-Lebanon	3.6	2.7	3.2	3.2	2.9	3.1
Tripoli	2.0	2.0	1.8	1.8	3.0	2.1
Koura	3.2	2.1	2.7	2.7	3.0	2.7
Zghorta	3.2	2.1	2.7	2.7	3.0	2.7
Batroun	3.2	2.1	2.7	2.7	3.0	2.7

Mohafaza/Caza	Income	Employment	Household Assets	Finance / Savings	Budget / Subsidy	Economic Factors Contribution to Vulnerability
Aakkar	1.4	1.8	1.2	1.2	2.0	1.5
Bcharreh	3.2	2.1	2.7	2.7	3.0	2.7
Miyeh-Dennieh	1.4	1.0	1.2	1.2	2.0	1.4
Administrative North Lebanon and Akkar	2.5	1.9	2.1	2.1	2.7	2.3
Zahle	3.5	2.2	3.0	3.0	3.0	2.9
West Bekaa	2.8	1.2	2.2	2.2	2.5	2.2
Baalbek	2.6	1.2	1.8	1.8	2.0	1.8
Hermel	2.6	1.2	1.8	1.8	2.0	1.8
Rachaya	2.8	1.2	2.2	2.2	2.5	2.2
Bekaa	2.9	1.4	2.2	2.2	2.4	2.2
Saida	2.2	1.9	1.7	1.7	3.0	2.1
Tyre	2.6	1.2	2.1	2.1	3.0	2.2
Jezzine	2.2	1.1	1.7	1.7	3.0	1.9
South Lebanon	2.3	1.4	1.8	1.8	3.0	2.1
Nabatiyeh	3.2	2.0	2.0	2.0	2.5	2.3
Bent Jbeil	2.5	1.9	1.4	1.4	2.0	1.8
Marjaayoun	2.5	1.9	1.4	1.4	2.7	2.0
Hasbaya	2.3	1.9	1.4	1.4	2.7	1.9
Administrative Nabatiyeh	2.6	1.9	1.5	1.5	2.5	2.0

NOTES

1. When measuring the five economic factors affecting vulnerability, an attempt is made to measure both resilience and vulnerability.
2. Income's contribution to vulnerability measures as a combination of several parameters including percent below poverty rate, income sources, dependency ratio and informal sector contribution.
3. Employment's contribution to vulnerability includes percentage of population unemployed 9includingf women and children), and informal sector unemployment.
4. Household's assets include radio, television, computer, telephone, mobile landline and internet access.
5. Finance and savings contribution to vulnerability includes availability of credit for DRR, accessibility of credit facility by urban poor, insurance and the existence of disaster risk financing instruments.

Mohafaza/Caza	Income	Employment	Household Assets	Finance / Savings	Budget / Subsidy	Economic Factors Contribution to Vulnerability
6. Budget and subsidy includes annual budget for DRR, availability of subsidies for strengthening houses, and alternative livelihoods.						

The following comments can be made regarding economic factors affecting vulnerability to earthquake hazards:

- As seen in the previous section, the various factors interact together to shape vulnerability to earthquake hazards. For example, urban areas, unchecked urban areas many near hazardous facilities have residents living in non-permanent / non-engineered structures, which are vulnerable to seismic motion (physical factors contributing to vulnerability). They also have a high concentration of people under 14 and above 65 (social vulnerability) and residents in these areas are poor, with no access of any credit facilities to DRR and no insurance (economic factors affecting vulnerability.
- Household assets which includes radio and TV has a direct impact on the ability to receive with and interact with early warning messages, but which can only be effective if coupled with a sufficient level of awareness (social factors contributing to vulnerability) an regular drills (institutional factors to be discussed in future sections).

3.5.7 Natural and Environmental Factors Contributing to Vulnerability

The main natural and environmental factors affecting vulnerability are the following:

1. Ecosystem Services.
2. Landuse in natural terms.
3. Environmental Policies and food security.

Table 38 below summarises the above factors for the Different Cazas.

Notes 1 to 5 within the table present the parameters used for determining the vulnerability, or resilience, of each of the natural / environmental factors. These parameters were weighted and summed to arrive at a vulnerability number for the factor under consideration. The factors were also weighted and summed in order to arrive at a number for natural / environmental vulnerability.

Table 38 *Distribution of Natural and Environmental Factors Affecting Vulnerabilities with Caza*

Mohafaza/Caza	Ecosystem Services	Natural Landuse	Environment Policies / Food Security	Natural / Environmental Factors Contribution to Vulnerability
Beirut	1.50	1.50	3.50	2.10
Dahiyeh	1.50	1.50	2.90	1.92
Baabda	2.00	2.00	3.18	2.35
Metn	2.00	2.00	3.64	2.49
Kesserouan	3.00	3.00	3.76	3.23
Jbeil	4.00	4.00	3.96	3.99
Alley	4.00	4.00	3.36	3.81
Chouf	4.00	4.00	3.36	3.81
Mount-Lebanon	2.93	2.93	3.45	3.09
Tripoli	1.50	1.50	1.98	1.99
Koura	2.00	2.00	2.96	2.29
Zghorta	3.00	3.00	3.16	3.05
Batroun	3.00	3.00	3.16	3.05
Aakkar	3.00	3.00	1.74	2.62

Mohafaza/Caza	Ecosystem Services	Natural Landuse	Environment Policies / Food Security	Natural / Environmental Factors Contribution to Vulnerability
Bcharreh	3.00	3.00	3.16	3.05
Miyeh-Dennieh	3.00	3.00	1.74	2.62
Administrative North Lebanon and Akkar	2.71	2.71	2.56	2.67
Zahle	3.00	3.00	3.36	3.11
West Bekaa	3.00	3.00	2.86	2.96
Baalbek	3.00	3.00	2.66	2.90
Hermel	3.00	3.00	2.66	2.90
Rachaya	3.00	3.00	2.86	2.96
Bekaa	3.00	3.00	2.88	2.96
Saida	2.00	2.00	2.14	2.04
Tyre	2.00	2.00	2.50	2.15
Jezzine	3.00	3.00	2.34	2.80
South Lebanon	2.33	2.33	2.33	2.33
Nabatiyeh	2.50	2.50	3.04	2.66
Bent Jbeil	3.00	3.00	2.62	2.89
Marjaayoun	3.00	3.00	2.62	2.89
Hasbaya	3.00	3.00	2.46	2.84
Administrative Nabatiyeh	2.88	2.88	2.69	2.82

Notes

1. When measuring the five parameters affecting natural vulnerability, an attempt is made to measure both resilience and vulnerability.
2. Ecosystem services include the quality of soil, air and water.
3. Landuse in natural terms includes settlement in hazard prone areas, available green space and loss of urban green space in the last 50 years.
4. Environmental [policies includes sub factors such as existence and compliance with environmental policies, waste management systems, and strategies for air pollution reduction.
5. While natural and environmental factors contributing to vulnerability remain the same, their weight will vary according to the hazard under consideration.

Landuse degradation, including the loss of green cover in urban areas can have a detrimental effect on the likelihood of collapse of buildings due to landslides triggered by earthquakes. Economic conditions and lack of enforcement of landuse planning imply that poor communities often build on unstable land susceptible to earthquake triggered landslides. This probability is further increased by the loss of green cover in urban areas, thereby showing, yet again, how physical, social, economic and environmental factors interact to concentrate vulnerability to disasters.

3.5.8 Institutional Factors Contributing to Vulnerability

The main institutional factors affecting vulnerability are the following:

1. DRR Mainstreaming.
2. Disaster Management Framework.
3. Disaster Response Effectiveness.
4. Collaboration.
5. Good Governance.

Table 39 below summarises the above factors for the Different Cazas.

Notes 1 to 6 within the table present the parameters used for determining the vulnerability, or resilience, of each of the five institutional factors. These parameters were weighted and summed to arrive at a vulnerability number for the factor under consideration. The factors were also weighted and summed in order to arrive at a number for institutional vulnerability.

Table 39 *Distribution of Institutional Factors Affecting Vulnerabilities with Caza*

Mohafaza/Caza	DRR Mainstreaming	Disaster Management Framework	Emergency Response	Collaboration	Good Governance	Institutional Factors Contribution to Vulnerability

Mohafaza/Caza	DRR Mainstreaming	Disaster Management Framework	Emergency Response	Collaboration	Good Governance	Institutional Factors Contribution to Vulnerability
Beirut	2.40	3.30	3.00	3.00	2.00	2.74
Dahiyeh	2.40	3.00	3.00	3.00	2.00	2.68
Baabda	2.40	3.20	2.00	2.00	2.00	2.32
Metn	2.40	3.70	3.00	3.00	2.00	2.82
Kesserouan	2.40	3.70	3.00	3.00	2.00	2.82
Jbeil	2.40	3.70	3.00	3.00	2.00	2.82
Alley	2.40	2.70	2.00	2.00	2.00	2.22
Chouf	2.40	2.70	2.00	2.00	2.00	2.22
Mount-Lebanon	2.40	3.28	2.50	2.50	2.00	2.54
Tripoli	2.05	1.80	2.0	2.0	2.0	1.97
Koura	2.05	2.65	2.00	2.00	2.00	2.14
Zghorta	2.05	2.65	2.00	2.00	2.00	2.14
Batroun	2.05	2.65	2.00	2.00	2.00	2.14
Aakkar	1.38	1.15	2.00	2.00	2.00	1.71
Bcharreh	2.40	2.65	2.00	2.00	2.00	2.21
Miyeh-Dennieh	1.38	1.15	1.00	1.00	2.00	1.31
Administrative North Lebanon and Akkar	1.91	2.10	1.86	1.86	2.00	1.94
Zahle	2.40	3.00	2.00	2.00	2.00	2.28
West Bekaa	2.40	2.15	1.00	1.00	2.00	1.71
Baalbek	2.40	1.75	1.00	1.00	2.00	1.63
Hermel	2.40	1.75	1.00	1.00	2.00	1.63
Rachaya	2.40	2.15	1.00	1.00	2.00	1.71
Bekaa	2.40	2.16	1.20	1.20	2.00	1.79
Saida	2.40	1.65	2.00	2.00	1.65	1.94

Mohafaza/Caza	DRR Mainstreaming	Disaster Management Framework	Emergency Response	Collaboration	Good Governance	Institutional Factors Contribution to Vulnerability
Tyre	2.40	2.10	1.00	1.00	2.10	1.72
Jezzine	2.40	1.65	1.00	1.00	1.65	1.54
South Lebanon	2.40	1.80	1.33	1.33	1.80	1.73
Nabatiyeh	2.40	1.95	2.00	2.00	1.95	2.06
Bent Jbeil	2.40	1.35	2.00	2.00	1.35	1.82
Marjaayoun	2.40	1.35	2.00	2.00	1.35	1.82
Hasbaya	2.40	1.35	2.00	2.00	1.35	1.82
Administrative Nabatiyeh	2.40	1.50	2.00	2.00	1.50	1.88

1. NOTES
2. When measuring the five institutional parameters affecting vulnerability, an attempt is made to measure both resilience and vulnerability.
3. Mainstreaming DRR includes the incorporation of DRR in landuse plans, housing policies, school curricula, transport policies and environmental protection plans.
4. Effectiveness of response management framework includes training of emergency workers, disaster training programs, and lessons learnt incorporation into plans.
5. Collaboration includes setups for collaboration with neighbouring regions, national authorities, NGOs and the private sector, and the degree of dependency on this collaboration.
6. Good governance includes implementation of DRR plans, accountability and transparency of government, building code implementation, effectiveness of early warning systems and frequency of disaster drills.

The following comments can be made regarding physical factors affecting vulnerability to earthquake hazards:

- Collaboration with NGOs and civil society organization, abundantly present within Lebanon, constitutes an improvement in the level of resilience, albeit these NGOs are only now starting to work in DRR and without always having adequate training for their staff on developing community DRR initiatives and supervising their implementation.

- Risk governance, is dominated by the very limited progress in the implementation of DRR plans and building codes; and lack of accountability frameworks for disaster risk.
- Mainstreaming DRR into planning also contributes significantly to vulnerability as this is yet to take place.
- It is envisaged that as regional and Caza-based plans for response are put in place, with regular drills, the level of resilience will increase. This should take place once the law for the disaster risk management unit passes the parliament and the unit becomes functioning.
- The issue of accountability is directly linked to the existence of clear mandates for DRR, in the various sectors, which is not the case in Lebanon. For example, it is clear that ensuring the safety of schools is the responsibility of the Ministry of Education and Higher Education (MEHE) which if needed can expect help from UN agencies mandated with working with children such as UNICEF and other international NGOs that work with children such as Save the Children. On the other hand, the general operational safety (not specifically against hazards) of preschools and nurseries is considered the responsibility of the Ministry of Public Health (MoPH) which issues licensing certificates for nurseries to operate within the country. MoPH cooperates with the WHO for carrying out initiatives related to the seismic safety of hospitals. However, MoPH does not have the capacity to embark on a program for the seismic safety of nurseries. Furthermore, it is not clear whether this is its responsibility. This ambiguity in mandates is indeed reflected in the fact that while there are currently programs for school safety within MEHE, aided by UNICEF and Save the Children, and programs for hospital safety within MoPH aided by WHO, there are currently no national programs for ensuring the seismic safety of nurseries.

3.5.9 Regional Vulnerability to Earthquake Hazards

Table 40 below summarises the vulnerability factors for the Different Cazas, together with the overall regional vulnerability.

The factors affecting the vulnerability of each Caza to disaster are weighted and summed to arrive at an overall value of vulnerability for each Caza. A colour coding scheme is used as follows:

- Green (corresponding to a score between 4 and 5: vulnerability level is low and acceptable, no further reduction in vulnerability is necessary. However, it remains necessary to monitor the different factors contributing to vulnerability.
- Yellow (corresponding to a score between 3 and 4): vulnerability if moderate and needs reduction and monitoring.
- Orange (corresponding to a score between 2 and 3): vulnerability is high and needs prompt reduction and monitoring.
- Pale red (corresponding to a score between 1 and 2): vulnerability is very high and needs immediate reduction and monitoring.
- Dark red (corresponding to a score between 0 and 1): vulnerability is critical and needs reduction and monitoring.

Table 40 *Distribution of Factors affecting Vulnerabilities with Caza*

Mohafaza/Caza	Physical Factors	Social Factors	Economic Factors	Natural / Environmental Factors	Institutional Factors	Vulnerability
Beirut						
Dahiyeh						
Baabda						
Metn						
Kesserouan						

Mohafaza/Caza	Physical Factors	Social Factors	Economic Factors	Natural / Environmental Factors	Institutional Factors	Vulnerability
Jbeil						
Alley						
Chouf						
Tripoli						
Koura						
Zghorta						
Batroun						
Aakkar						
Bcharreh						
Miyeh-Dennieh						
Zahle						
West Bekaa						
Baalbek						
Hermel						
Rachaya						
Saida						
Tyre						
Jezzine						
Nabatiyeh						
Bent Jbeil						
Marjaayoun						
Hasbaya						

If we combine the above vulnerability distribution with exposure distribution for earthquake hazard throughout Lebanon, we may arrive at the following conclusions:

- The five main cities of Lebanon (**Beirut, Tripoli, Sidon, Tyre and Zahle**) all of which have a high degree of vulnerability) are also subjected to a high exposure to earthquake hazard arising from the concentration of economic activities and human settlements in these areas (some of which using non-engineered structures). **This makes the risk corresponding to seismic hazard in these cities very high**.

- Within these four cities where the seismic risk is high, there is a large degree of variation between the different municipalities and cadastres comprising the Caza and sometimes inside specific cadastres / cazas.

- Reducing Institutional factors contributing to vulnerability would significantly reduce vulnerability to earthquakes hazards throughout Lebanon.

- Reducing economic factors contributing to vulnerability would significantly reduce vulnerability to earthquakes hazards throughout Lebanon.

Based on the above, the following recommendations are made regarding the prioritization of *regional* interventions for disaster risk reduction:

- The five main cities of Beirut, Tripoli, Sidon, Tyre and Zahle.

- The Cazas witnessing a large concentration of industrial activities using hazardous material (e.g. Metn).

- Reducing institutional factors affecting vulnerability may e achieved by a variety of measures including incorporating DRR into housing policies, environmental plans, transport policies, investment plans, and landuse policies.

- Reducing economic factors affecting vulnerability may be achieved by a variety of measures including provision of credit facilities for the urban poor for DRR, incentives for employment within a "DRR sector", and the development of disaster risk financing instruments.
- A full set of proposed recommendations for discussion will be outlined in the strategy document for DRR [23].

4 Tsunami Hazard and Corresponding Exposure, Vulnerability and Risk Assessment

4.1 Introduction

This chapter addresses tsunami hazards, and the remaining chapters address flooding and forest fire hazards, follow the same methodology adopted for assessing vulnerabilities and risks due to earthquake hazards.

For the sake of succinctness, the main specificities of exposure, vulnerability and risk corresponding to tsunami hazards will be highlighted and discussed in this chapter, rather than reproduce the whole set of tables and figures discussed in the previous chapter.

4.2 Data needed for the Generation of Tsunami Hazard Maps

Lebanon does not yet have a hazard prone area map or a hazard intensity map corresponding to the tsunami hazard. This is mainly due to the challenges involved in the generation of the required base data (including data on bathymetry as well as the paucity of clarity on the mandates of the various public body institutions regarding the generation of such maps. In addition, the skills needed for the generation of these maps are still lacking within the public sector agencies).

Lebanon however is prone to tsunami hazards and its cities has in the past, like most cities along the eastern coast of the Mediterranean Sea, been subjected to devastating Tsunamis. This is particularly true since the Lebanese coast consists of very few offshore coral islands and very few coastal areas remain covered with unspoiled forests and/or vegetation.

The primary data required for a comprehensive tsunami hazard intensity map generation include topographic and bathymetric data related to Lebanon coastal cities as well as fault place parameters

corresponding to worst-case (or other events corresponding to pre-agreed return periods) seismic events for the respective subduction segments. Table 41 summarises the data requirements, possible resources and the availability of such data for future assessments.

Table 41 *List of Data Requirement and Availability for the Tsunami Hazard Assessment*

Type of Data	Source	Mandate	Availability
Bathymetric Data • **Mediterranean Sea Basin** • **Seaboard off Lebanon** • **Local bathymetry for some near-shore locations**		Not clear. Lebanese Army, Centre for remote sensing and Geophysical research centre are stakeholders.	Not available
Elevation data of Coastal zone of Lebanon • **LIDAR** • **Land based surveys**	Lebanese Army, Centre for remote sensing	Lebanese Army, Centre for remote sensing	
Miscellaneous base data • **Administrative boundaries** • **Landuse, drainage network, road network, etc**	Centre for remote sensing, CDR	Centre for remote sensing, CDR	
Seismic data • **Fault parameters for maximum credible events**		Geophysical Research Centre	Not available
Data on previous Tsunamis for possible model validation • **Tsunami heights** • **Extent of inundation**		Geophysical research Centre	Not available

4.3 Specificities in Exposure to Tsunamis

Notwithstanding the lack of tsunami hazard intensity maps, it is possible to make the following observations regarding exposure to tsunami hazards:

- Four of the five largest Lebanese cities (namely Beirut, Tripoli, Sidon and Tyre) are along the coast, and several of which have been destroyed in past tsunamis or combined tsunamis and earthquakes.
- These four cities also have a concentration of illegal settlements and gatherings, refugee camps and settlements next to hazardous industries/activities.
- In addition to these four cities, there are smaller towns scattered along the coast to the north and the South of Beirut with high degrees of exposure.
- Several hazardous industries are located along the coast including the Zouk electric generation plant, the Beddawi refineries, and the oil storage depots north of Beirut along the Dawra motorway amongst others.

Based on the above, it is vital to determine the following in order to improve the quality of the assessment on the tsunami hazard:

- The bathymetry in the proximity to the four main cities, as well as the smaller towns and the locations of the hazardous sites should be promptly determined to assess which of these cities / sites are subjected to the highest degree of exposure.

4.4 Specificities in Sectoral Exposure and Vulnerability to Tsunamis

4.4.1 Introduction

The main mitigating defence against tsunamis, which is only feasible for special locations, is the erection of high tsunami walls to prevent the tsunami from drowning certain sites.

Another important *preparedness* measure to tsunamis, which presupposes the existence of early warning system for tsunami threats coupled with effective drills on behaviour, is to evacuate citizens away from the low-lying locations in case of a tsunami threat.

This section addresses the above two possible mitigating effects for the various sectors considered in this study.

4.4.2 Housing Sector

Four of the five main cities of Lebanon lie on the coast, where more than 65% of the Lebanese inhabitants live (in excess of 2.7 million people). As such there is a need to develop evacuation plans for citizens in case of tsunami threats, while taking into account the capacities and weaknesses of the current road network.

4.4.3 Education Sector

According to the Educational Statistical Bulletin, 1,372,132 people, or 34.35% of the population, were involved in education in the year 2010-2011. Of these 1,241,934 were students, enrolled in either public or private education from kindergarten up until and including university, including vocational education and training. The total number of staff (teachers and administrators) was 130,198. The above fact shows the importance of safeguarding schools against tsunamis by having effective evacuation plans and regular drills, linked to a national early warning system. While schools and educational establishments are working on evacuation plans, these will not be fully effective if not coupled with a functioning and trained upon national early warning

system against tsunamis. Such a system is yet to be developed. The large number of families and individuals involved in the education system within Lebanon also stresses the effectiveness of schools as a vehicle for the delivery of awareness and safety messages.

4.4.4 Health Sector

The fact that four of the five main cities in Lebanon lying along the coast, including the capital Beirut, inevitably implies a concentration of hospitals in these cities even if not directly at the coast. Again, there is a need to determine expected wave eight and expected inland inundation to determine the degree of vulnerability and draw evacuation plans accordingly.

4.4.5 Energy Sector

A number of important energy producing installations are located on the coast, including the Zouk electric generation plant, the Beddawi refinery and the Zahrani refinery.

There is a need to develop emergency shutdown systems for these installations linked to the national early warning system once it is produced. Furthermore, a number of oil storage facilities (tank farms) also lie on the coast. It is expected that these would collapse and spill their content leading to excessive pollution in case of a tsunami.

4.4.6 Industrial Sector

Figure 13 and Figure 14 show the distribution of industrial facilities in Lebanon where it can be seen that the vast majority are along the coast in Beirut, to the North between Beirut and Tripoli, and in Tripoli. These industrial installations, often contain hazardous materials which may explode and/or break out in a fire if not shutdown properly. This is particularly important in areas where human settlements have extended to their proximity, which in turn will lead, in addition to possible environmental pollution to large numbers of fatalities and

injuries. Therefore, these installations must be equipped with safety shutdown systems and procedures which must in turn be linked to the national early warning system once it becomes operational. Furthermore, these installations must have evacuation which are linked to the national emergency early warning system and which must take into account the capacities and weaknesses of the existing road network in their vicinity.

4.4.7 Tourism Sector

The touristic infrastructure, as represented by hotels and restaurants, is also concentrated to a large degree along the coast, as shown in Figure 5, Figure 6 and Figure 7.

There is a need to develop emergency evacuation plans for the large touristic establishments and to link these with the national emergency warning systems, once they are established, while taking into account capacities and weakness in the current road network.

4.4.8 Agriculture Sector

The agriculture sector, is vulnerable to tsunamis, as shown in Figure 24 which shows that to the south (between Saida and Tyre) and to the North (Around Tripoli, Akkar and Minieh - Dinieh), there are significant agriculture activities along the coast. The degree of vulnerability can only be effectively determined once the expected tsunami waves height and corresponding inland inundation is determined as part of the tsunami hazard intensity assessment.

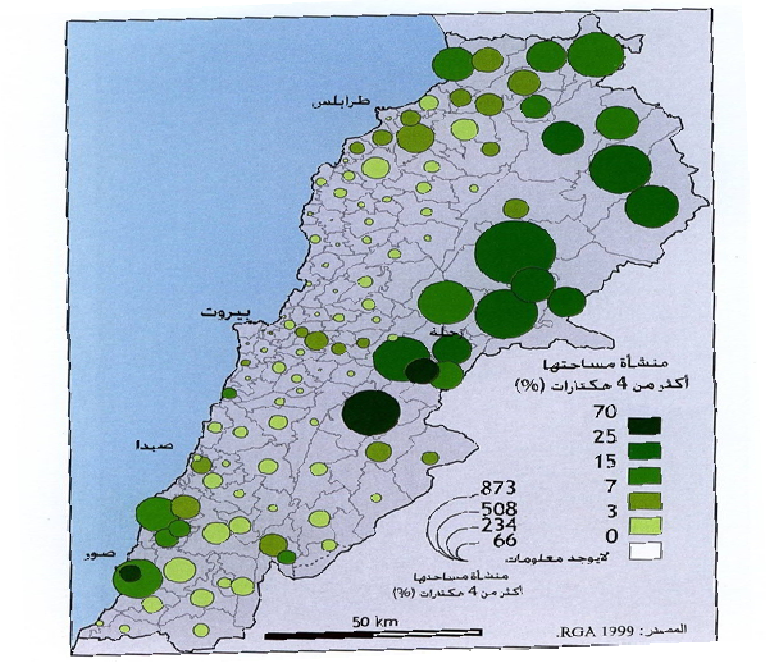

Figure 24 *Large agricultural investments*

4.4.9 Financial, Telecommunication and Public Sector

The financial, telecommunications and public sectors may be lumped together for the tsunami vulnerability assessment, as they have several characteristics in common:

- They are scattered throughout the Lebanese territory, with their main branches in one of the four main cities along the coast, making their data storage and recovery plans vulnerable to tsunami hazards. As such there is a need to develop recovery plans where the redundant recovery centre is located in one of their branches away from the coast, but in premises which has been designed to resist earthquakes.

- Some of the buildings housing these services host a large number of personnel and visitors / customers at any one time and as such there is a need to develop emergency evacuation plans and to link them to the national emergency warning system once it is

developed, while taking into account the weaknesses and capacities of the road network in the vicinity of the location.

4.4.10 Water and Wastewater Sector

An important issue, specific to the water sector, is to ensure that none of the proposed or existing dam sites and dams may e inundated by sea water. Furthermore there is a need to ensure that wells will not be inundated by sea water.

Regarding the wastewater sector, there is a need to ensure that the wastewater treatment plants will not leak and cause pollution as a result of nation by the tsunami.

4.5 Regional Vulnerability to Tsunamis

The factors affecting vulnerability remain divided under physical, social, institutional, natural and economic factors. However, the main change is the weights given to each when determining vulnerability to tsunami hazard. In particular, the following main differences have been identified regarding vulnerability factors corresponding to earthquake and tsunami hazards:

- **Physical Factors affecting vulnerability**: Accessibility of roads, which in turn accounts for variations in the transportation network, percentage of paved roads, and roadside covered drains, amongst others, becomes much more important due to implications on evacuation plans.
- **Social Factors affecting vulnerability**: Awareness and community preparedness have a higher weight as factors contributing to vulnerability to tsunami hazards, since they have a direct impact on effectiveness and promptness of any evacuation schemes.
- **Economic factors affecting vulnerability**: where percentage of population below poverty line, availability of alternative income sources and livelihoods and savings become very important.

- **Institutional Factors affecting vulnerability**: early warning systems, effectiveness of emergency teams and disaster training programs become very important sub-factors contributing to institutional vulnerability.
- **Natural Factors Affecting Vulnerability**: loss of urban green space and available urban green space, as well as settlement in hazard prone areas (all part of the land-use in natural term factor affecting vulnerability) become very important.

Based on the above discussion, the main cazas with high vulnerability to tsunamis are Beirut, Tripoli, Sidon, Tyre, Byblos, Batroun, Jounieh, Minieh-Dinieh. The vulnerability can be refined further when bathymetric data along the coast is determined.

Reducing vulnerability to tsunami hazards may be achieved by adopting the following interventions:

- Development of early warning systems linked to major economic sector activities and cities along the coast.
- Development of evacuation plans and drills in case of tsunami early warning alert.
- Development of emergency shutdown systems for major installations in case of early warning alert.
- Protection of major energy and industrial installations along the coast. However, this first requires detailed knowledge of the expected tsunami height and corresponding inland inundation.

Risk Corresponding to Tsunami Hazards

The high concentration of exposure of economic activities and human settlements in and around Beirut and Tripoli implies that these two cities have a very high risk corresponding to Tsunami hazards.

4.6 Discussion on combined Earthquake and Tsunami Hazard

The possibility of an earthquake and a tsunami occurring consecutively must be taken into account. In such a case, the vulnerability of Beirut and Tripoli is considered critical, while that of Sidon and Tyre is High.

The risk corresponding to the combined earthquake and tsunami hazard is **critical** for Beirut and Tripoli and **very high** for Tyre and Sidon.

5 Flooding Hazard and Corresponding Exposure, Vulnerability and Risk Assessment

5.1 Introduction

For the sake of succinctness, the main specificities of exposure, vulnerability and risk corresponding to flooding hazards will be highlighted and discussed in this chapter, rather than reproduce the whole set of tables and figures discussed in the previous chapter.

5.2 Flood Hazard Maps

Flood hazard maps in Lebanon are restricted to hazard prone area maps as reported earlier in the country situation analysis report on risk assessment [2]. Figure 25 shows the flood hazard prone area map produced by the council for development and reconstruction [3], as part of general principles for developing master plans for landuse purposes, where it can be seen that flood hazard is referred to as flood risk. It can also be seen that Lebanon is divided into flooding zones and urbanized areas.

These areas correspond well with areas reported to be at flood risk by several resident generations [3], including

- Central Bekaa.
- Plains of Aasi, Wadi Khaled, Akkar and Koura.
- Coastal plains of sour Qasmiyeh, saida and Damour.
- Coastal zone of Chekka Batroun and Khaldeh.

These areas should be compared to the geographical distribution of damages arising from the flood hazard [13]. However that study, due to the type and source of data as well limited time, did not separate winter storm damages between that due to excessive rain and wind and other due to flooding. This should be considered as one of the jobs to be carried out in future iterations on the analysis of disaster losses.

Figure 25 *Flood Hazard Prone Area Map*

Notwithstanding the importance of the above map, in the fact that it identifies areas prone to flooding, there is a need to develop flood intensity hazard maps which correspond to a particular return period.

5.3 Specificities in Exposure to Flooding Hazards

Notwithstanding the lack of flooding hazard intensity maps, it is possible to make the following observations regarding exposure to flooding hazards:

- Beirut is not significantly affected by the flooding hazard. However, as urban expansion continues and as climate change patterns continue to unfold this situation may change. Hence there is a need for constant monitoring.

- The coastal plains of Sidon and Tyre, which have illegal settlements and populations, are exposed to the risk of flooding.
- Tripoli has been subjected in the past to flooding from the Abou Ali River, in 1955, which led to the deaths of more than 100 citizens [13] and the construction of a flood wall along both sides of the river bed to avoid the impact of further floods. Notwithstanding the mitigating measure described above, Tripoli is still considered exposed to flooding hazards.
- Zahle is exposed to the flooding hazard.
- Some of the poorest regions in Lebanon, which rely on agriculture which is considered among the vulnerable livelihoods (e.g. Akkar, Baalbek and Hermel), are also exposed to the flooding hazard.

5.4 Specificities in Sectoral Exposure and Vulnerability to Flooding

5.4.1 Introduction

This section addresses sectoral specificities of exposure and vulnerability to flooding. In particular, the housing, education, health, energy and agriculture sectors are discussed.

5.4.2 Housing Sector

Housing in some regions within Akkar, Baalbek and Hermel is located within the flooding plain.

5.4.3 Education Sector

The education sector, in the form of schools exposed to flooding hazard, should develop evacuation plans in case of flooding to be linked with national early warning systems to be put in place.

5.4.4 Agriculture Sector

The agriculture sector is vulnerable to flooding hazard, as shown by comparing Figure 24 and Figure 25 which show a large degree of correlation between the large agriculture investments and areas prone to flooding.

This is particularly important since more than 80000 inhabitants work in agriculture [6], and tend to be among the poorest. The degree of vulnerability can only be effectively determined once the expected flood hazard intensity maps are determined. Other statistics show that 194,000 workers in the agriculture sector, only 33% of which work full time, with percentages of full time workers shown in Figure 11 [8]. In Figure 11, the dark green shows cazas with the lowest percentage of alternative e sources of income, while the lighter colour show cazas with the highest percentage of alternative sources of income, and the cazas shown in white (Beirut) correspond to lack of data.

Zahle, which has the highest number of workers working full time in the agriculture sector. This is followed by Sidon, western Bekaa, Rachaya, Baalbek, Hermel, Akkar, Minieh-Dinieh, Bchare and Tripoli.

Reduction of vulnerability within the agriculture sector includes the selection of diversified crops, and corresponding diversified sources of livelihood. In addition, it also includes the development of flood hazard intensity maps, and linkages to early warning systems which are yet to be developed.

5.5 Regional Vulnerability to Flooding

The factors affecting vulnerability remain divided under physical, social, institutional, natural and economic factors. However, the main change is the weights given to each when determining vulnerability to flooding hazard.

- **Physical Factors affecting vulnerability**: Accessibility of roads, which in turn accounts for variations in the transportation network, percentage of paved roads, and roadside covered drains, amongst others, becomes much more important due to implications on evacuation plans.
- **Social Factors affecting vulnerability**: Awareness and community preparedness have a higher weight as factors contributing to vulnerability to flooding hazards, since they have a direct impact on effectiveness and promptness of any evacuation schemes.
- **Economic factors affecting vulnerability**: where percentage of population below poverty line, availability of alternative income sources and livelihoods and savings become very important in order to reduce vulnerability to flooding hazards, particularly amongst those working in the agriculture sector.
- **Institutional Factors affecting vulnerability**: early warning systems, effectiveness of emergency teams and disaster training programs become very important sub-factors contributing to institutional vulnerability.
- **Natural Factors Affecting Vulnerability**: loss of urban green space and available urban green space, as well as settlement in hazard prone areas (all part of the land-use in natural term factor affecting vulnerability) become very important.

Based on the above discussion, the main cazas with high vulnerability to flooding are Akkar, Minieh, Dinieh, Bchare, Zahle, Sidon, Western Bekaa, Baalbek and Hermel, which have a relatively high exposure of agricultural activities as well as a low percentage of people having alternative sources of income (in addition to agriculture).

Reducing vulnerability to flooding hazards may be achieved by adopting the following interventions:

- Development of early warning systems linked to agriculture sector activities.

- Development of evacuation plans and drills in case of flooding warning alert.
- Development of emergency shutdown systems for major installations in case of early warning alert.
- Development of alternative, secondary, sources of income in areas relying solely on agriculture.

Risk Corresponding to Flooding Hazards

The high concentration of exposure of the agriculture sector, and in some cases human settlements working in this sector, implies that the sectors with a high degree of risk to flooding are Zahle, Akkar, Baalbek, Koura, Hermel, Sidon and Tyre.

6 Forest Fire Hazard and Corresponding Exposure, Vulnerability and Risk Assessment

6.1 Introduction

For the sake of succinctness, the main specificities of exposure, vulnerability and risk corresponding to forest fire hazards will be highlighted and discussed in this chapter, rather than reproduce the whole set of tables and figures discussed in the previous chapter.

6.2 Forest Fire Hazard Maps

Forest Fire hazard maps in Lebanon are restricted to hazard prone area maps as reported earlier in the country situation analysis report on risk assessment [2]. Figure 26 and Figure 27 show the forest fire hazard prone area map produced by AFDC [24] for the years 2005 and 2007 respectively, where it can be seen that forest fire hazard maps are being referred to as risk maps. It can also be seen that Lebanon is divided into six forest fire hazard maps showing no risk, very low risk, low risk, medium risk, high risk and very high risk. These maps have been used in the drafting of the National Strategy for the Management of Forest Fire Risk in Lebanon [25].

The Cazas with the highest risk of forest fires are Alay, Chouf Jezzine, Hasbaya, Marjaayoun, Akkar, Minieh, Zghorta, Bchare, Batroun, Jbeil, Keserwane, Metn, and Baabda. These areas correspond well with the geographical distribution of damages arising from the forest fire hazards [13], shown in for the newspaper dataset, Figure 28 [13] and in for the data set collated by the Lebanese Army on behalf of the High Relief Committee, Figure 29 [14]. However, the cazas of Jezzine, Sour and Bint Jbeil appear more prominent in the damage figures.

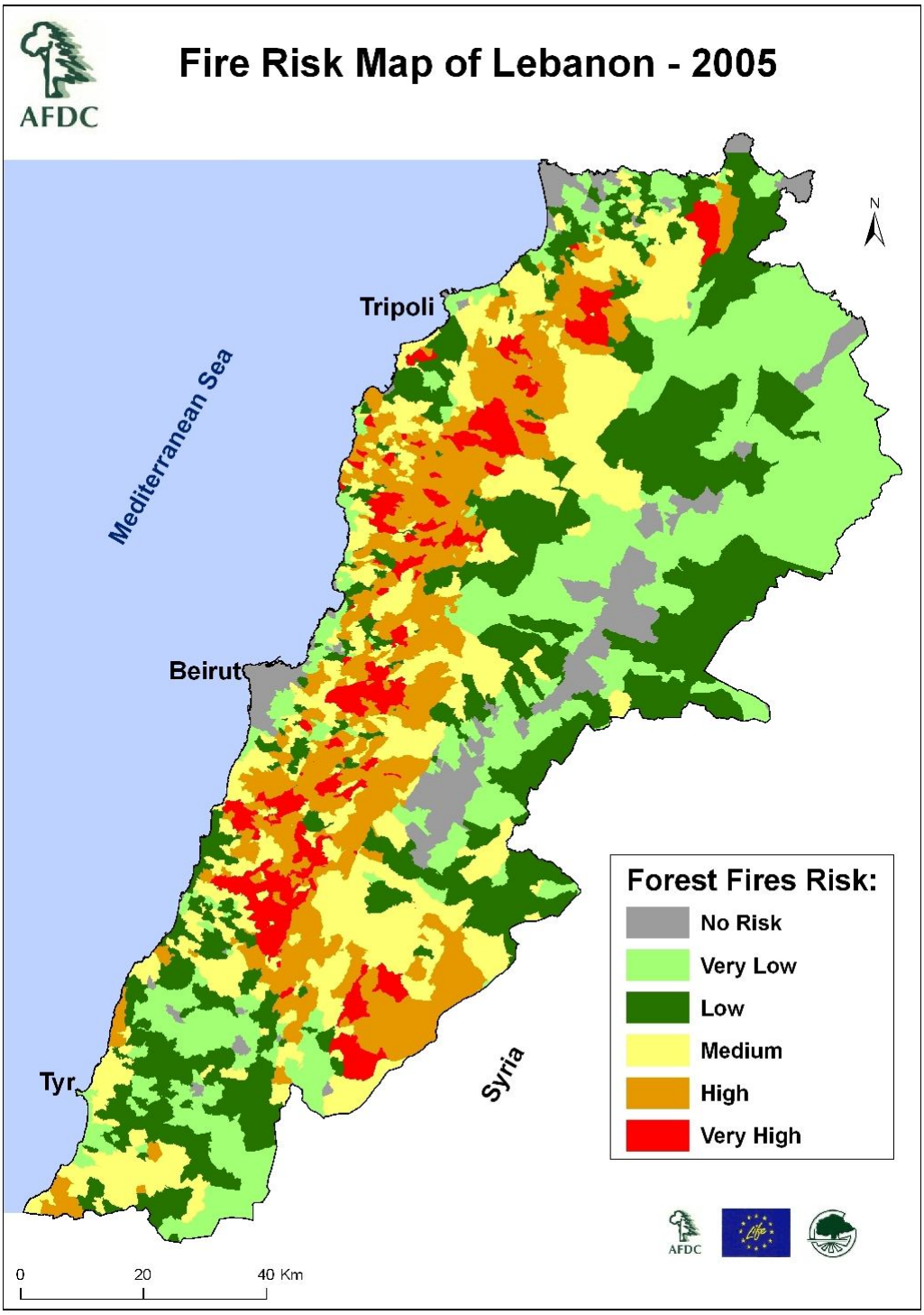

Figure 26 *Forest Fire Hazard Prone Area Map, AFDC, 2005*

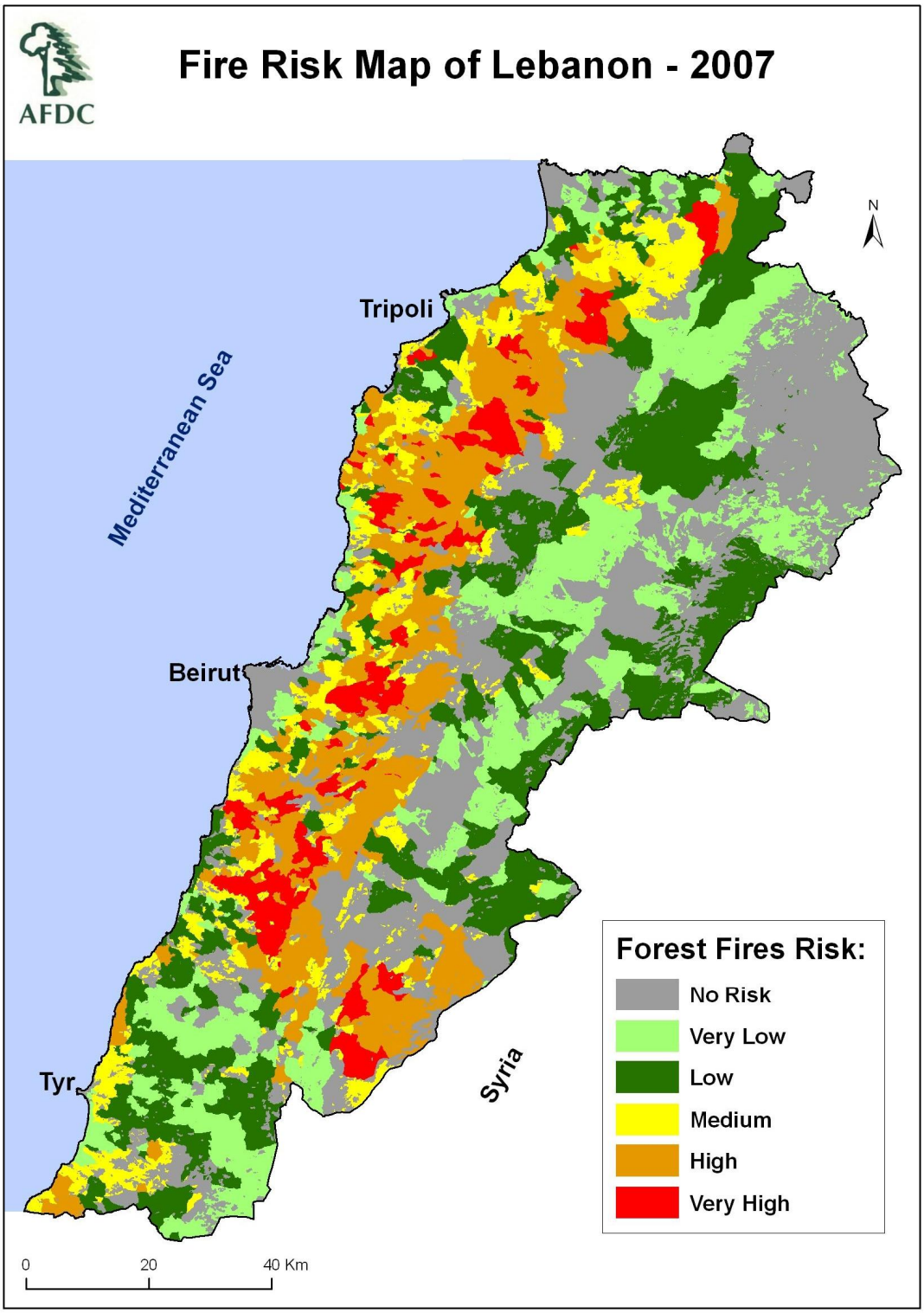

Figure 27 *Forest Fire Hazard Prone Area Map, AFDC, 2005*

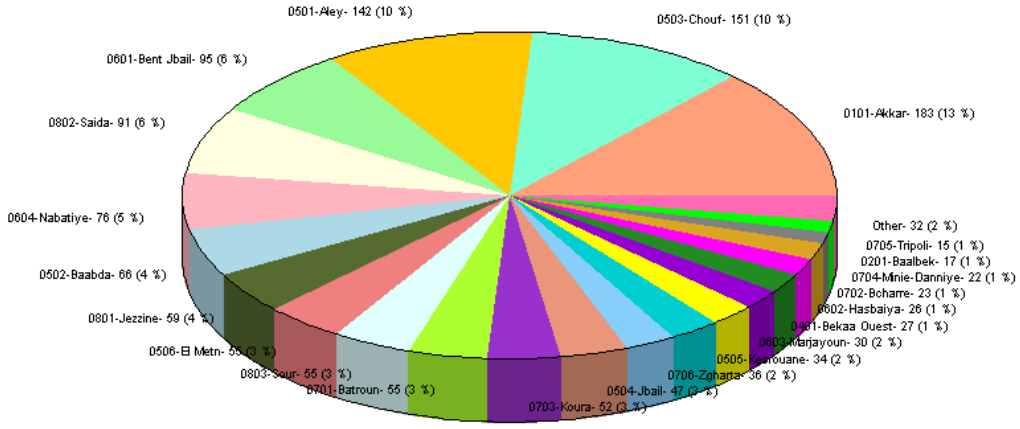

Figure 28 *Distribution of Forest Fire Damages, based on the Newspaper set, 2012*

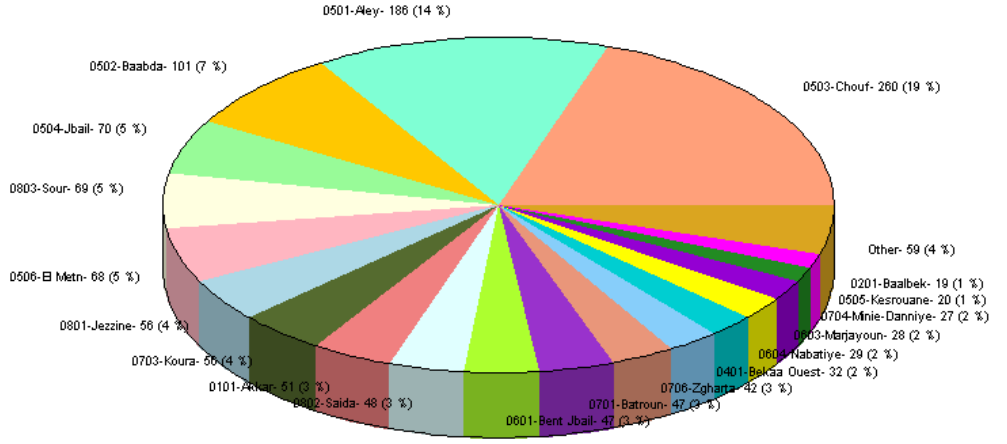

Figure 29 *Distribution of Forest Fire Damages, based on the Damage Collation and Estimation by the Lebanese Army, on Behalf of the High Relief Committee, 2012*

Notwithstanding the importance of the above maps, in the fact that it identifies areas prone to flooding, there is a need to regularly update forest fire hazard maps and correlate them with up-to-date damage patterns.

6.3 Specificities in Exposure to Forest Fire Hazards

It is possible to make the following observations and conclusions regarding exposure to forest fire hazards:

- There is a threat of interaction between forest fire and tsunami hazards. As we have seen in previous figures there is a concentration of forest fires along the western half of Lebanon, in some cases reaching forests / vegetation along the coast. The erosion of such vegetation and tree cover increases the vulnerability to both tsunami and flooding hazards. This is an alarming which is yet to be under control, where it is stated that in the sixties of the last century the forest cover of Lebanon was around 35% to become around 13.5% in 2006 [25] and 12% as reported by a study publish in 2012 [8], whereas if only heavy forest cover is accounted for (i.e. forest cover that covers more than 60% of a particular area) then the current percentage of forest cover drops to 7% [8], as shown in Figure 30.

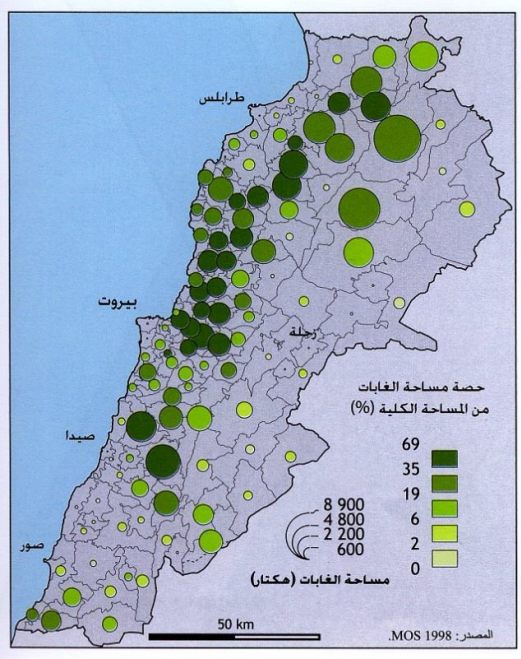

Figure 30 *Forest Percentage of Total Area*

- There seems to be a strong correlation between the strength of fires and proximity to urban areas, as shown in Figure 31 [8], which provide a strong indication that many of these fires are man-made.

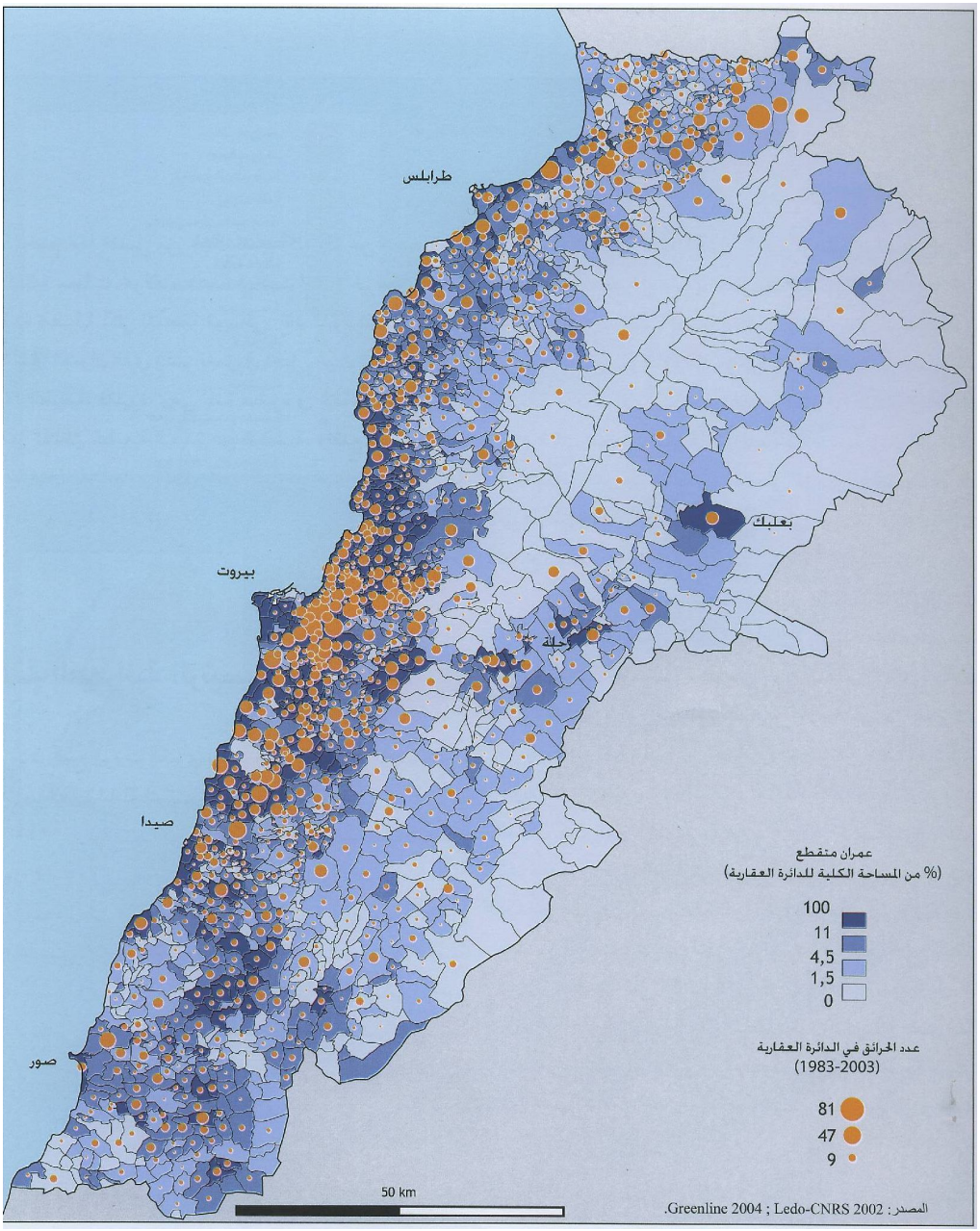

Figure 31 *Forest Fires and the Spread of Urbanism*

- There is a need to develop a model for attaching a monetary value for the loss of forests, which should differentiate between the different types of trees lost and the national specificities. This would allow a more accurate estimate of exposure in monetary terms.

6.4 Specificities in Sectoral Exposure and Vulnerability to Forest Fire

6.4.1 Introduction

This section addresses sectoral specificities of exposure and vulnerability to forest fires. In particular, the agriculture sector is discussed.

6.4.2 Agriculture Sector

As mentioned in the previous chapter on flooding, a large number of workers (in excess of 190,000) rely on agriculture (solely or partially) for their livelihoods. Therefore, it is important to assess to what extent these livelihoods may be vulnerable to forest fires. Furthermore, it is important to examine the proximity of the agriculture crops to the locations of the forest fires. Due to the lack of data, it is not possible to carry out this exercise in any quantitative manner; however, it is possible to qualitatively compare the distribution of agriculture crops as compared to location of the forest fires.

Figure 32 shows the distribution of olive, vines, crop yielding and citrus trees, where it can seen that the vast majority of these are located in the areas identified earlier as being prone to forest fires, particularly along the western and southern plains of Lebanon.

Figure 33 shows the geographical distribution of field and intensive crops, where it can be seen that intensive crops along the coastal cazas are located in areas identified as prone to forest fires.

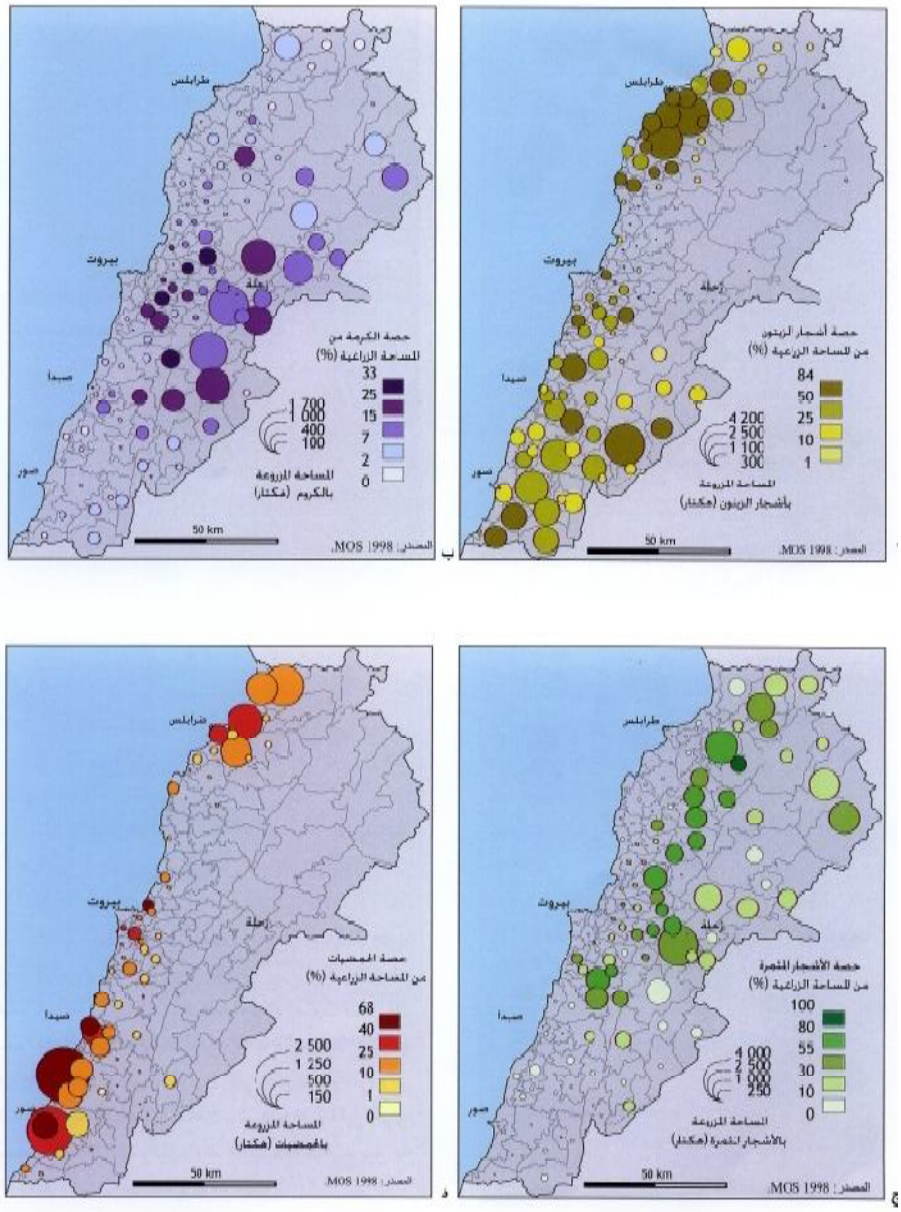

Figure 32 *Geographic Distribution of Crop Yielding Trees*

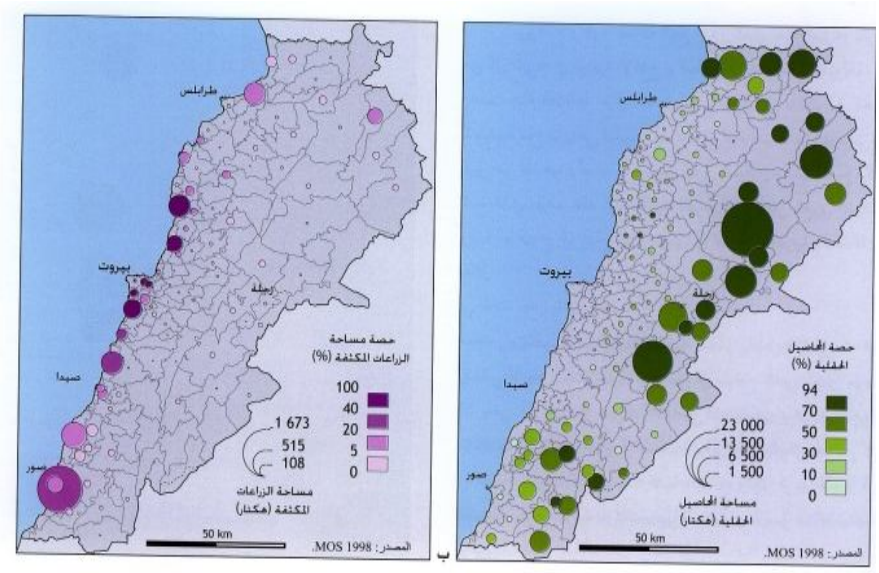

Figure 33 *Geographic Distribution of Intensive and Field Crops*

The percentages of full time workers is shown in Figure 11 [8], where it can be seen that Zahle, which has the highest number of workers working full time in the agriculture sector, has not been identified as prone to forest fires [25]. This is followed by Sidon, western Bekaa, Rachaya, Baalbek, Hermel, Akkar, Minieh-Dinieh, Bchare and Tripoli, which show the second highest category of cazas where workers rely solely on Agriculture. These cazas are prone to forest fires.

Reduction of forest fire vulnerability within the agriculture sector includes the selection of diversified crops, and corresponding diversified sources of livelihood. In addition, it also includes the development of early warning systems, the improvement of the effectiveness of response mechanisms and standardizing the level of response through the country. Work is currently on the last three interventions.

6.5 Regional Vulnerability to Forest Fires

The factors affecting vulnerability remain divided under physical, social, institutional, natural and economic factors. However, the main

change is the weights given to each when determining vulnerability to forest fire hazard.

- **Physical Factors affecting vulnerability**: Accessibility of roads, which in turn accounts for variations in the transportation network, percentage of paved roads, and roadside covered drains, amongst others, becomes much more important due to implications on evacuation plans. In addition access and availability of water becomes important.
- **Social Factors affecting vulnerability**: Awareness and community preparedness have a higher weight as factors contributing to vulnerability to forest fire hazards, since they have a direct impact on effectiveness and promptness of local community schemes. In addition, social capital and community preparedness become very important for determining the vulnerability to forest fires. Indeed, the case of Alley and Chouf who witnessed a large reduction in the amount of forest fires (in terms of hectares burnt) is a testament to the power of the involvement of local communities, where AFDC originally started work in these Cazas.
- **Economic factors affecting vulnerability**: where percentage of population below poverty line, availability of alternative income sources and livelihoods and savings become very important in order to reduce vulnerability to forest fire hazards, particularly amongst those working in the agriculture sector.
- **Institutional Factors affecting vulnerability**: early warning systems, effectiveness of emergency teams and disaster training programs become very important sub-factors contributing to institutional vulnerability.
- **Natural Factors Affecting Vulnerability**: loss of urban green space and available urban green space, as well as settlement in

hazard prone areas (all part of the land-use in natural term factor affecting vulnerability) become very important.

Based on the above discussion, the main cazas with high vulnerability to forest fires hazards are along the western plains of Lebanon, which are already vulnerable due to the loss of forest cover throughout the years.

Reducing vulnerability to forest fire hazards may be achieved by adopting the following interventions:

- Development of early warning systems linked to agriculture sector activities.
- Development of early warning system to alert on possible spread of fires.
- Development of response plans and drills in case of forest fires.
- Development of alternative sources of income.

Risk Corresponding to forest Hazards

The high concentration of exposure of the agriculture sector, and in some cases human settlements working in this sector, implies that the cazas with a high degree of risk to forest fire are along the western plains of Lebanon.

7 Conclusions

7.1 Introduction

This chapter summarises the main conclusions from the study. The conclusions are categorized along the following headlines:

- Methodology
- Exposure, Vulnerability and Risk to Earthquake Hazards.
- Exposure, Vulnerability and Risk to Tsunami Hazards.
- Exposure, Vulnerability and Risk to Tsunami Hazards.
- Exposure, Vulnerability and Risk to Forest Fire Hazards.

A separate report provides recommendations for outlining a National Disaster Risk Reduction Strategy.

7.2 On Methodology

The following salient conclusions can be drawn:

- Vulnerability must correspond to a particular hazard with a particular intensity. However in Lebanon, a national consultative process on the severity (and corresponding return period) of the various hazardous events for which exposure and vulnerability should be assessed and reduced is yet to take place. This fact, coupled with the fact that there is a lack of data at the Caza level for many of the factors affecting vulnerability dictates the adoption of a cost-effective qualitative measure to determine vulnerability.

- There is a need, as part of the national consultative process referred to above, to determine levels of acceptable and unacceptable risk for housing, people, economic activities and critical infrastructure.

- In addition to the physical factor related to the strength of buildings and establishments, different factors interact to shape

the degree and distribution of vulnerability within a country. Therefore in order to capture and understand the salient features of vulnerability an approach is adopted which accounts for social, physical, economic, natural and institutional factors affecting vulnerability. Without adopting such an approach important issues such as the formation and distribution of seismic risk in nurseries, illegal settlements, housing units with tenancy agreements based on old contracts, refugee camps and those in proximity to hazardous installations will not be properly captured and understood.

7.3 Exposure, Vulnerability and Risk to Earthquake Hazards

The following salient conclusions can be drawn:

- Earthquake Hazard is spread throughout Lebanon.
- Exposure to Earthquake is concentrated along five cities of Beirut, Tripoli, Sidon, Tyre and Baalbek
- Vulnerability in these cities is, on average, **very high**, especially if we take into account the age of the buildings, where also none of the buildings built before 2005 are equipped to resist earthquakes.
- Vulnerability in these cities is **critical** in certain areas which have a concentration of Palestinian camps, illegal settlement consisting of non-engineered structures and illegal settlements in close proximity to hazardous installations. It is also critical in housing units with old tenancy agreements.
- The seismic safety (or lack thereof) in nurseries is **critical**, where there is also **cause for great concern** due to a lack of clarity on mandates, accountability and corresponding capacities between the Ministry of Education and Higher Education and the Ministry of Health.

- The Educational Sector vulnerability to earthquake hazards is also **critical**, due to numerous factors contributing to vulnerability including the fact that many of the public schools are old; rented from private owners who are not required to rehabilitate against earthquakes; not purpose built to act as schools which creates difficulties in escape routes; and in some cases lying in proximity to hazardous inventories. Sectoral vulnerability may be reduced by developing and implementing a national school seismic safety program.

- The Industrial Sector Vulnerability to earthquake hazards is also **critical**, due to two main traits characterising industrial installations: 1. In most cases industrial installations are not housed in buildings that can resist earthquakes. Furthermore, their equipment and piping systems are not designed to resist differential displacement at support points, lateral motion, vertical excitation effects or fluid-structure interaction effects during to earthquakes. In some instances they are located in industrial cities where the breakout of a fire or an explosion may spread in between different sites due to very small separation distances between lots. Finally, in some instances residential settlements have, illegally, moved to close proximity of their location. 2. In other cases, it is the industrial installations that have moved, illegally into residential areas by renting parts of apartments or basements to act as factories. Sectoral vulnerability may be reduced by developing and implementing a national industrial seismic safety program according to international standards.

- The Energy Sector vulnerability is also considered **critical** due to two main traits characterising energy installations: 1. In most cases energy installations are not housed in buildings that can resist earthquakes. Furthermore, their large equipment (including

pressure vessels and liquid storage tanks) and piping systems are not designed to resist differential displacement at support points, lateral motion, vertical excitation effects or fluid-structure interaction effects during to earthquakes. In some instances residential settlements have, illegally, moved to close proximity of their location. 2. They are not designed to resist elevated temperature loading as a result of fires, or high strain loading as a result of explosions, both of which may occur in the aftermath of an earthquake. Sectoral vulnerability may be reduced by developing and implementing a national energy seismic safety program according to international standards. Vulnerability may be concentrated in some areas where haphazard hooking to electric lines may provide a source of spark or ignition to the inventory of petrol stations in residential areas.

- The public sector vulnerability is considered **very high** due to the age of the buildings housing some of the public sector ministries and agencies (e.g. of the 300 civil defence buildings none are equipped to resist disasters), the ownership of the building, the original purpose for the building construction, and the lack of risk management programs for these large sites.

- The health sector vulnerability is considered **high**. While some of the modern hospitals have been built against earthquakes, the older hospitals scattered in the main cities have not been built to resist earthquakes. Furthermore, the remote regions of Lebanon rely strongly on medical centres, run by various charities / political parties, none of which are designed to resist earthquakes.

- The telecommunications sector vulnerability is considered **high**. Special care must be taken to ensure that the connections between the cables, data centres and main towers and

antennas will remain intact and will not break during earthquakes.

- The banking sector vulnerability is considered **high**. Special care must be taken to ensure that the ongoing plans to ensure redundancy and prompt recovery cover the actual buildings hosting the backup data storage facilities and not solely the data themselves.
- Vulnerability in all the above sectors may be reduced through the development and implementation of sectoral national seismic safety programs and through the reduction of intuitional factors that contribute to vulnerability.

7.4 Exposure, Vulnerability and Risk to Tsunami Hazards

The following salient conclusions can be drawn:

- In the absence of any tsunami hazard prone area maps or tsunami hazard intensity maps, it is assumed that the whole of the Lebanese coast is subject to Tsunami hazards.
- Exposure to tsunamis is concentrated along many cities and towns along the coast. Four of the five main cities in Lebanon (Beirut, Tripoli, Sidon and tyre where more than 50% of the Lebanese Population reside) have been subjected to Tsunamis in the past and are exposed to future tsunamis. These cities also witness a large concentration of illegal settlements and refugee camps, as well as settlement next to hazardous installations along the coast. According to 1996 statistics more than half the settlements along the coast were constructed in an illegal manner before reaching settlements by the state.
- Most large industrial facilities are along the coast.
- Most touristic activities, manifested by hotels and restaurants, are concentrated along the coast or along coastal cities.

- Several large industrial installations are also located along the coast.
- The vulnerability of these sectors and installations to the tsunami threat is high due to 1. Lack of a national, early warning system for tsunami threats with regular drills; 2. Lack of any mitigating measures (e.g. through tsunami walls) for some of the large installations, 3. Lack of a tsunami hazard map.
- The vulnerability to tsunami hazards may be reduced by 1. Developing tsunami hazard intensity maps showing the expected wave height and inundation distance for the major settlements along the coast; 2. Development of a national early warning system together with evacuation plans taking into account the road network, and where applicable 3. Development of mitigating measures around selected hazardous installations.

7.5 Exposure, Vulnerability and Risk to Flooding Hazards

The following salient conclusions can be drawn:

- Flooding hazard prone areas maps show the flooding hazard concentrated along Central Bekaa, Plains of Aasi, Wadi Khaled, Akkar and Koura, Coastal plains of sour Qasmiyeh, saida and Damour, Coastal zone of Chekka Batroun and Khaldeh.
- The coastal plains of Sidon and Tyre, which have illegal settlements and populations, showing a concentration of 4.1% and 2.6% of total Lebanese population and 3.9% and 2.3% of total private enterprises are exposed to the risk of flooding.
- Tripoli has been subjected in the past to flooding from the Abou Ali River, in 1955. Notwithstanding the mitigating measure in the form of a flood barrier developed post the above flooding, Tripoli is still considered exposed to flooding hazards.

- Some of the poorest regions in Lebanon, which rely on agriculture which is considered among the vulnerable livelihoods (e.g. Akkar, Baalbek and Hermel), are also exposed to the flooding hazard.

- The agriculture sector which has more than 194,000 workers is particularly vulnerable to flooding, especially in regions where the majority rely solely on agriculture for their livelihoods.
- Regions with the highest vulnerability to flooding are defined as those showing an overlap of hazard prone area maps, concentration of agriculture activities, and people reliance on agriculture as a sole source of livelihood. These areas include Zahle, Akkar, Baalbek, Koura, Hermel, Sidon and Tyre.
- It is possible to mitigate against flooding risks by developing early warning systems for both farmers and citizens, and development of alternative sources of income in areas where a vast majority of residents rely solely on agriculture.

7.6 Exposure, Vulnerability and Risk to Forest Fire Hazards

The following salient conclusions can be drawn:

- The Cazas prone to forest fires are Alay, Chouf Jezzine, Hasbaya, Marjaayoun, Akkar, Minieh, Zghorta, Bchare, Batroun, Jbeil, Keserwane, Metn, and Baabda. These areas correspond well with the geographical distribution of damages arising from the forest fire hazards.
- Forest fires and corresponding loss of forest cover, have a direct impact on flooding and tsunami vulnerability.
- Forest fires seem to be concentrated around urban centres.
- The agriculture sector is highly vulnerable to forest fires.
- The cazas with a high degree of vulnerability to forest fires are along the western plains of Lebanon.

- The vulnerability to forest fires may be reduced by a combination of early warning systems and training to improve response time.

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