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TOWARDS INTEGRATED SEISMIC RISK ASSESSMENT IN PALESTINE – APPLICATION TO THE CITY OF NABLUS

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Abstract. *Using large-scale seismic risk assessment studies for reduction of potential losses is becoming an evermore popular trend around the globe. Accordingly, a number of different models and techniques for the characterization of the different risk variables have proliferated in the recent years. Furthermore, the quality, or accuracy, of risk estimates will be certainly higher when a truly integrative model is employed, characterizing hazard, (physical and social) vulnerability and exposure in the most complete as possible manner. Regions with a large percentage of non-seismically designed buildings are particularly vulnerable to seismic events and are those that can benefit the most from risk assessment studies for decision making. As such, the main purpose of this study is to propose a framework for integrated seismic risk assessment in Palestine, where earthquake induced risk awareness is still at an early stage. A methodology to combine an existing state-of-the-art hazard model with new vulnerability and exposure models, specifically built upon local field surveys and national data collection, is proposed. The outcome of the study will enable the identification of the regions that are more vulnerable to earthquakes and future rapid loss assessment at regional scale.*

1 INTRODUCTION

The seismic activity in Palestine is not negligible and is largely affected and controlled by geodynamic processes acting along the Dead Sea Transform (DST). The DST is a north-south striking left-lateral shear zone extending from the incipient oceanic ridge (Red Sea) in the south to the Taurus plate collision in the north (Turkey). About 105-110 km of left-lateral displacement between the African and Arabian tectonic plates took place along this fault system during the last 15 million years. Historically, estimated events reached up to IX in the Modified Mercalli Scale in the Dead Sea region. In the same area, the determinable magnitudes of the recorded earthquakes range between 1.0 and 7.0 on the local magnitude Richter scale.

Together with observed seismicity, the Palestinian region faces important issues related to structural and societal factors. First, a high vulnerability, as a direct result of a high percentage of weak buildings not complying with seismic design requirements, thus with high potential for damage and losses. Secondly, measures of seismic risk mitigation are not enforced with national and public policies, which results in an absence of effective control of design and construction practice. The two aforementioned elements are exacerbated by the weakness in the general institutional capacity in disaster management, by insufficient professional capabilities of both engineers and decision makers and by a lack of awareness of citizens on seismic risk matters.

In the light of such facts, strategic directions were devised for the implementation of seismic disaster risk reduction. Recently, the population of Palestine has become more aware of the concept of seismic risk, significantly due to the results of the FP7-SASPARM (Support Action for Strengthening Palestinian-administrated Areas capabilities for Seismic Risk Mitigation) project, held during 2013 and 2014. SASPARM activities were focus on the strengthening of the research capabilities of An-Najah National University through the development of a comprehensive database of existing research data, the promotion of training for scientists and students in the field of seismic risk with the collaboration of European partners – EUCENTRE (European Centre for Training and Research in Earthquake Engineering) and IUSS (Institute for Advanced Study). Subsequently, new activities proposed within the DG-ECHO SASPARM 2.0 (2015-2016) project are further raising such awareness and strengthening their capabilities to cope with seismic risk. Engagement in training courses and workshops takes place not only at the local community level but also even Palestinian stakeholders, governmental (GO) and non-governmental (NGO) institutions, students and practitioners are effectively involved. One of the major goals of the SASPARM 2.0 initiative is the development of an integrated seismic risk model for Palestine, based on a state-of-the-art hazard model and in-field collected vulnerability and exposure data. The city of Nablus, the first Palestinian city to join the UNISDR’s Making city resilient campaign, constitutes the case study area for the implementation and calibration of the model. In this paper, the framework for the achievement of the integrated model for the challenging Palestinian region is described, together with the main assumptions and assessment of options for the different risk components.

2 CONTEXT – THE SASPARM 2.0 PROJECT

The activities of SASPARM 2.0 (Support Action for Strengthening Palestine capabilities for seismic Risk Mitigation) are organised into eight main operative tasks, comprising the collection of vulnerability data and implementation of vulnerability models; training for targeted groups; development of self-assessment tools to understand potential unsafe situations and the related mitigation measures (retrofitting and insurance coverage). The project is managed by the same consortium of SASPARM and is creating a Web-Based Platform (WBP) for seismic risk mitigation, which integrates a database of vulnerability data on buildings, collected on field.

The awareness of the community is a fundamental step in the resilience process, since the citizens have to monitor their individual properties and be able to understand, with and, when feasible, without the advice of an expert, if their house can withstand an earthquake or if retrofit is required, applying seismic standards. On the other hand, practitioners as well as governmental (GO) and non-governmental (NGO) stakeholders have to be made aware of the importance of the right application and implementation of the new Seismic Building Code. The outcomes and tools released during SASPARM 2.0 will put together all the available information on the different risk components for a better management and mitigation of seismic risk in Palestine. An overview of the framework defined for the development of an integrated risk model for Palestine, together with the description of choices and assumptions for the main risk components is given in the following sections.

3 SEISMIC HAZARD

The Eastern Mediterranean region, due to its geological structure that is characterized by the junction of major tectonic plates (African, Arabian and Eurasian) results in very high tectonic activity. Over the time, the region has indeed frequently witnessed natural hazard phenomena, resulting in great losses of life and property. Field studies and investigations indicate that large portions of the land surface, population and infrastructure of the region have been subjected to earthquakes in the past or will be subjected to earthquakes in the future [1].

Seismicity information including historic and prehistoric data indicates that major destructive earthquakes have occurred in the Jordan – Dead Sea region (Fig.1). The most recent earthquake (M_L 5.2) took place on February 11th, 2004 [2].

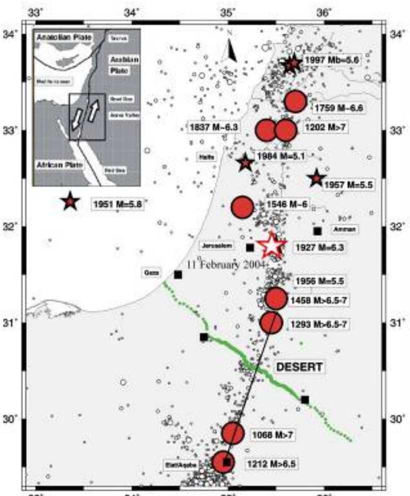


Figure 1. Seismic Activity in the Dead Sea Transform Region for the period 1000 - 2007.

Currently, in Palestine the in-use seismic hazard map dates back to 1997 [3]. It is defined in terms of peak ground acceleration, which is assessed for 10% of exceedance in 50 years for generic rock (Fig.2). Based on such hazard map, Palestine has been divided in four seismic zones: 1, 2A, 2B and 3. Adopting the American Uniform Building Code (UBC97), a seismic zone factor (Z) has been associated to each of them (Fig.3).

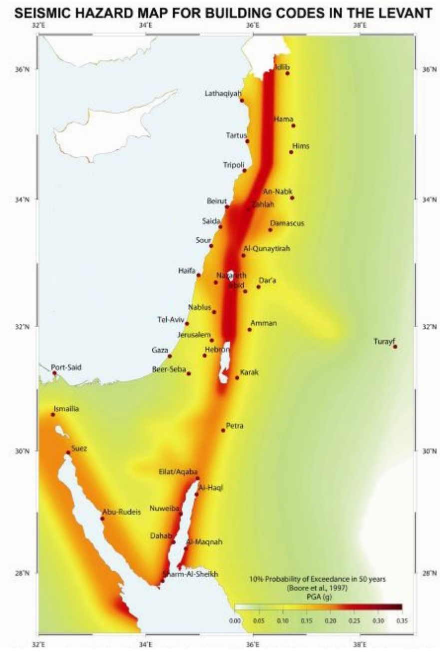


Figure 2. Hazard Map with 10% probability of exceedance in 50 years [2]

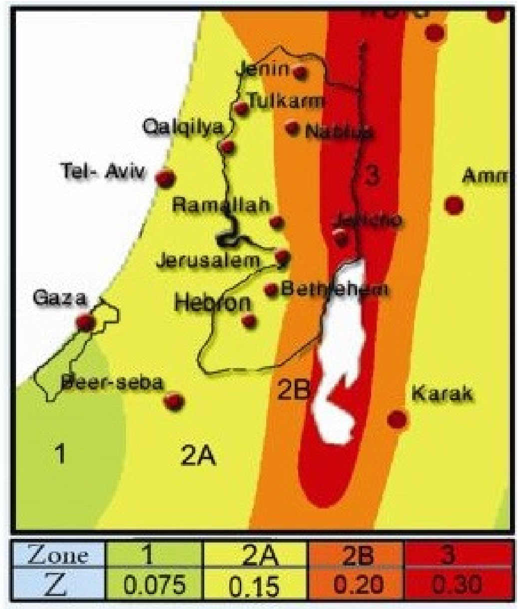


Figure 3. Seismic Zone Factors in Palestine according to Hazard Map and UBC 97.

Additional initiatives have been undertaken to improve such hazard map, aiming to improve the global and regional seismic hazard evaluation in the Eastern Mediterranean region. Specifically, three projects up to the early 2000s are worth mentioning:

i. GSHAP (Global Seismic Hazard Assessment);
ii. SESAME (Seismotectonic and Seismic Hazard Assessment of Mediterranean Basin); and
iii. ESC/WG-SHA (European Seismological Commission Working Group on Seismic Hazard Assessment).

The first regional seismic hazard map developed for the European – Mediterranean region in terms of peak ground acceleration was GSHAP (1992-1999) and was compiled based on the integration of independent hazard results of a number of different test areas and regional and national programs [4]. During the GSHAP project, no attempts were made to harmonize the individual regional or national seismogenic models in the Mediterranean.

For such reason, a further endeavour for the regional hazard assessment in the Mediterranean was carried out within SESAME (1996-2000). By considering a new geometry implementation to avoid the lack of data between different regional sources or gaps at border areas, SESAME succeeded in the final unified seismogenic source model for the Mediterranean region, which consists of 346 sources. Each source was characterized by the corresponding seismicity parameters in terms of minimum and maximum magnitude and earthquake occurrence rates, as illustrated in Fig. 4 [5].

The third project, ESC/WG-SHA, was completed in 2002, and resulted in a unified seismic hazard modelling for Europe and the Mediterranean, integrating the GSHAP Central Northern Europe results with those from SESAME for the Mediterranean (Fig. 5). This comprehensive model for seismic hazard assessment allows, for the first time, the generation of hazard maps, expressing ground motion in different parameters, for different soil conditions and probability levels [6].

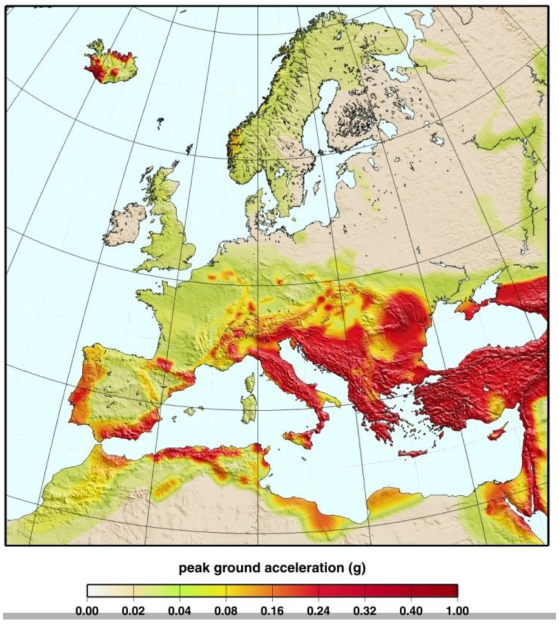


Figure 4. SESAME map with 10% probability of exceedance in 50 years for stiff soil condition [5]

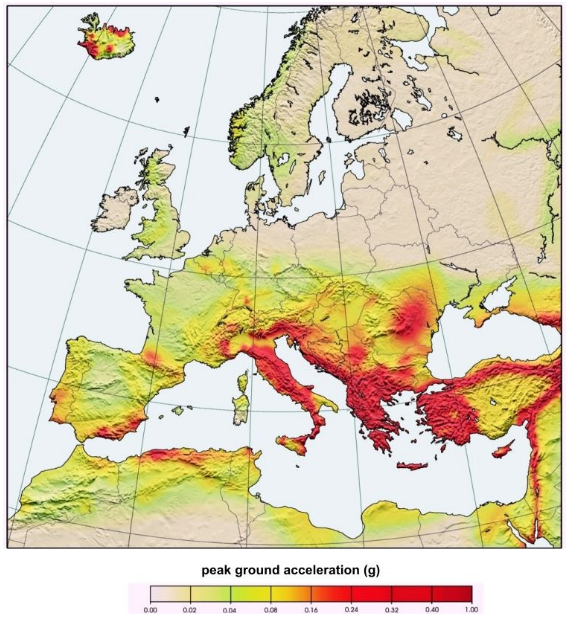


Figure 5. ESC/WG-SHA map with 10% probability of exceedance in 50 years for stiff soil condition [5]

For the development of the integrated risk model of the study herein presented, the use of a further updated hazard model is planned. The updated model is part of the outcomes of the EMME (Earthquake Model of the Middle East Region) project, which aimed at the assessment of seismic hazard, the associated risk in terms of structural damages, casualties and economic losses and also at the evaluation of the effects of relevant mitigation measures in the Middle East region. EMME was carried out between 2010 and 2013 and the final products have just been publicly released [7].

The model for Palestine will thus make use of the most up-to-date hazard data from the EMME initiative. The hazard model will be further employed to selection of real records for fragility analysis (input for Section 4 – Vulnerability), through disaggregation and PSHA calculations (using OpenQuake [8]) for the Nablus municipality.

4 VULNERABILITY

The vulnerability model will foresee two components: physical, calculated for a number of building classes that constitute the taxonomy for Nablus and social, taking into account the feedback provided by the population through specifically developed questionnaires.

4.1 Physical vulnerability

Physical vulnerability is a measure of how prone a building is to damage for a given severity of the ground shaking. The aim of most research works dedicated to this subject is to give a mathematical formulation to vulnerability. The two widely used formulations to describe the vulnerability are: damage probability matrices and fragility curves. The latter describe the conditional probability of exceeding a certain damage limit state in terms of the selected intensity measure of the ground motion. The same probability in discrete terms is a component of a damage probability matrix. In the technical literature, damage probability matrices have been produced when the vulnerability studies are based on observations: data from post-earthquake surveys are treated probabilistically to identify the conditional probability of damage and hence the terms of the damage probability matrices. On the other hand, fragility curves are calculated when the vulnerability studies are mechanics-based, i.e. the seismic behaviour of structures is modelled. The model can be more or less simplified as a function of the level of knowledge of the building stock. The option of quantifying the vulnerability through damage probability matrices is not feasible in Palestine, since databases of damages occurred after past earthquakes are not available. Therefore, sets of fragility curves will be defined for the as built structural typologies identified in Nablus first and then in other Palestinian municipalities.

The case study of Nablus foresees a web database to gather physical vulnerability data on buildings. The definition of a catalogue of building typologies is the first step for large scale vulnerability assessment. Recognition of structural types in Nablus was undertaken by a selected group of practitioners already trained during SASPARM. As it will be described with more detail in [9], the as-built in Nablus can be classified according four main building types: reinforced concrete frame buildings; shear walls buildings; masonry buildings; buildings with soft storey (Fig. 7). Once the building types have been identified the seismic vulnerability of each type is assessed.

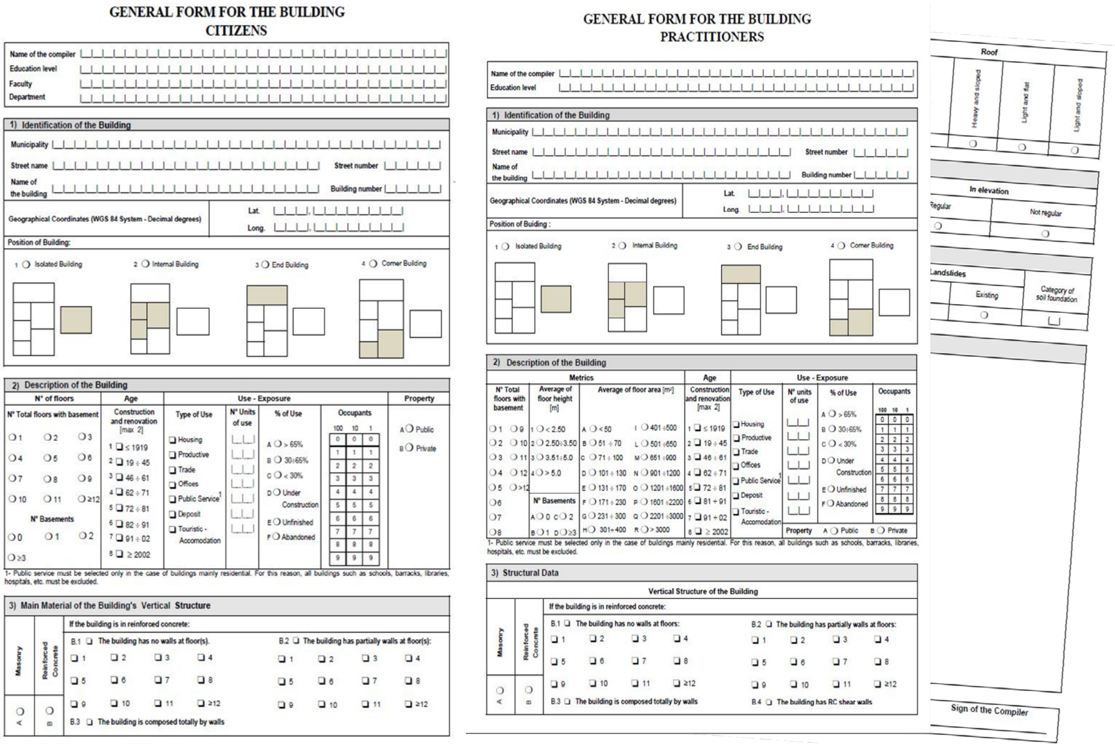
Citizens, practitioners and university students are the main groups involved in the in-situ collection of building data through specially designed forms. The collection forms, one detailed for practitioners and one more simple for citizens, aim to detect the structural characteristics of Palestinian buildings and it is a self-assessment tool to understand how their own buildings are made up of (Fig. 6). The forms allow a quick evaluation as a first cataloguing of the building stock, since they are made of typological and metrical data of the structures. The practitioners' form is composed of six sections, while the citizens' one of four. The sections of the forms are summarised in Table 1.

Section	Practitioners	Citizens
1	Identification of the Building	Identification of the Building
2	Description of the Building	Description of the Building
3	Structural Data	Main material of the Building's Vertical Structure
4	Regularity	Notes
5	Geomorphological Data	
6	Notes	

Table 1. Sections of the collection forms for practitioners and citizens.

Before collecting structural data, training activities were fundamental for the three main local stakeholders – university students, citizens, and practitioners. Both forms were introduced to the students of the An-Najah National University because their support to both the citizens in filling in the forms related to their properties and the practitioners during their field surveys is of fundamental importance. Then, practitioners were trained on the content of the forms and for increasing their knowledge on seismic design and seismic risk prevention. Then, citizens were trained in understanding the type of information required in the form. Practical examples were used for supporting the training. Direct engagement of GO and NGO stakeholders is carried out with the organisation of seminars, workshops, lectures in a collaborative effort between the partners of the Consortium.

Survey data will not just be stored in the on-line georeferenced platform and grouped according to their structural typology, but a specific vulnerability assessment will be performed. Sets of fragility curves will be identified according to their structural types, first in Nablus and, then, in other Palestinian municipalities, hence providing a collection of vulnerability functions that best fit the Palestinian region.



GENERAL FORM FOR THE BUILDING
CITIZENS

Name of the compiler
Education level
Faculty
Department

1) Identification of the Building

Municipality
Street name — Street number
Name of the building — Building number
Geographical Coordinates (WGS 84 System - Decimal degrees) — Lat. — Long.
Position of Building:
1 ○ Isolated Building — 2 ○ Internal Building — 3 ○ End Building — 4 ○ Corner Building

2) Description of the Building

N° of floors — Age — Use - Exposure — Property
N° Total floors with basement: ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10 ○11 ○≥12
N° Basements: ○0 ○1 ○2 ○≥3
Construction and renovation [max 2]: 1 ❑ ≤ 1919; 2 ❑ 19 ÷ 45; 3 ❑ 46 ÷ 61; 4 ❑ 62 ÷ 71; 5 ❑ 72 ÷ 81; 6 ❑ 82 ÷ 91; 7 ❑ 91 ÷ 02; 8 ❑ ≥ 2002
Type of Use: ❑ Housing; ❑ Productive; ❑ Trade; ❑ Offices; ❑ Public Service[1]; ❑ Deposit; ❑ Touristic - Accomodation
N° Units of use
% of Use: A ○ > 65%; B ○ 30÷65%; C ○ < 30%; D ○ Under Construction; E ○ Unfinished; F ○ Abandoned
Occupants: 100 10 1
Property: A ○ Public; B ○ Private

1- Public service must be selected only in the case of buildings mainly residential. For this reason, all buildings such as schools, barracks, libraries, hospitals, etc. must be excluded.

3) Main Material of the Building's Vertical Structure

Masonry — Reinforced Concrete
If the building is in reinforced concrete:
B.1 ❑ The building has no walls at floor(s): ❑1 ❑2 ❑3 ❑4 ❑5 ❑6 ❑7 ❑8 ❑9 ❑10 ❑11 ❑≥12
B.2 ❑ The building has partially walls at floor(s): ❑1 ❑2 ❑3 ❑4 ❑5 ❑6 ❑7 ❑8 ❑9 ❑10 ❑11 ❑≥12
B.3 ❑ The building is composed totally by walls

GENERAL FORM FOR THE BUILDING
PRACTITIONERS

Name of the compiler
Education level

1) Identification of the Building

Municipality
Street name — Street number
Name of the building — Building number
Geographical Coordinates (WGS 84 System - Decimal degrees) — Lat. — Long.
Position of Building:
1 ○ Isolated Building — 2 ○ Internal Building — 3 ○ End Building — 4 ○ Corner Building

2) Description of the Building

Metrics — Age — Use - Exposure
N° Total floors with basement; Average of floor height [m]; Average of floor area [m²]; Construction and renovation [max 2]; Type of Use; N° units of use; % of Use; Occupants
Property A ○ Public B ○ Private

1- Public service must be selected only in the case of buildings mainly residential. For this reason, all buildings such as schools, barracks, libraries, hospitals, etc. must be excluded.

3) Structural Data

Vertical Structure of the Building
If the building is in reinforced concrete:
B.1 ❑ The building has no walls at floors
B.2 ❑ The building has partially walls at floors
B.3 ❑ The building is composed totally by walls
B.4 ❑ The building has RC shear walls

Roof: Heavy and sloped; Light and flat; Light and sloped
In elevation: Regular; Not regular
Landslides: Existing; Category of soil foundation
Sign of the Compiler

Figure 6. Collection Forms.

Nonlinear static analysis [10; 11] will be used for the estimation of the structural demand in the buildings, through a refinement of the SP-BELA (Simplified Pushover – Based Earthquake Loss Assessment) procedure [12; 13]. The method defines the nonlinear behaviour of a random population of buildings through a simplified pushover and displacement-based procedure. The application of the simplified pushover methodology leads to the assessment of a large number of buildings with reasonable computational effort [14; 15], as in the real case study.

Figure 7. RC Building, Building with Soft Storey failure mode, Shear Wall Building and Masonry Building (Clockwise Order).

With the aim of extending the applicability of SP-BELA to the Palestinian context, special attention has to be given to the structural typologies that mainly characterise the building taxonomy, such as frame systems with dominant torsional response and/or vertical/horizontal irregularities [16]. For this reason, SP-BELA procedure will take into consideration suitable correction factors derived from Incremental Dynamic Analysis of a selected groups of different irregular RC building typologies. Finally, the vulnerability curves will be generated comparing the displacement capacity limits identified on the pushover curve and the displacement demand, defined from a response spectrum, for each building in the random population.

4.2 Social vulnerability

Beside the assessment of fragility curves for physical assets, a non-negligible aspect in terms of vulnerability comes from society with its own knowledge, conditions and cultural context. In order to build indicators, able to capture the social characteristics, publically available databases (e.g. national census) are not satisfactory, and a specific tool needs to be defined, as the "Scorecard approach" based on a participatory assessment process [17].

In detail, this approach will measure the concept of city resilience to crisis and disasters. As established in the Hyogo Framework for Action (HFA) and more recently in the United Nations campaign for urban disaster reduction [18], the resilience is "the capacity of an individual, community, organization, city and nation to respond, cope and recover from disaster". Further, UN-ISDR established a set of indicators for measuring resiliency and these were implemented in six key areas in the Scorecard (Table 2).

Theme	General Question
Awareness and advocacy	What is the level of awareness and knowledge of earthquake disaster risk?
Social Capacity	What are the capacities of the population to efficiently prepare, respond and recover from a damaging earthquake?
Legal and institutional arrangements	How effective are mechanisms to advocate earthquake risk reduction in your quarter?
Planning, regulation and mainstreaming risk mitigation	What is the perceived level of commitment and mainstreaming of disaster risk reduction through regulatory planning tools?
Emergency preparedness, response and recovery	What is the level of effectiveness and competency of disaster management including mechanisms for response and recovery?
Critical services and public infrastructure resiliency	What is the level of resilience of critical services to disasters?

Table 2. Scorecard themes.

The Scorecard is built with specific questions and answer schemes for each key areas and has been adapted to Nablus background to meet peculiarities. To really measure resiliency, questionnaire will be spread among population and the municipal representatives and an evaluation of potential gaps will be assessed especially for critical areas where further analysis are needed.

5 EXPOSURE

The other relevant factor in the general risk assessment is exposure. The model would like to take into account people, property, systems and other elements present in the case-study area that are thereby subject to potential losses. It is developed to be comprehensive and in agreement with both vulnerability and hazard models, also considering the latest available area to produce up to date estimates.

Data used to build the exposure model can be prepared using two approaches:

i. Using data available to the general public and coming from an official source;
ii. Collecting data directly on the site through the forms already employed for the collection of fragility data. This is a more accurate version but is also strongly dependent on the effective participation of the involved citizens.

A hybrid approach will most likely be employed, in which the exposure model will be initially set up using census and/or national databases data. This version will then be updated and/or validated with real data collected in-situ.

As far as the first approach is concerned, the Palestinian Central Bureau of Statistics [19] has been used to collect databases, statistical data and key indicators (e.g. Housing condition, Population, Price Indices). Some difficulties arise due to the unavailability of some information at the same geographical level. For example, the distribution of the population is available at all levels from Country to Municipality but the number of house units is not. A possible solution to overcome this issue is to disaggregate the number of house units from the national level into the municipality level using the population as proxy. The proposed model takes into account indicators that best describe the exposed asset, such as relative percentages of buildings, floor area, building type and replacement cost. The final aim at this level is to come up with an updated model that could be applied at different levels of resolution.

5.1 Preliminary exposure data

Regarding the types of residential buildings, there are three main typologies: individual houses, apartments (multi-storey buildings) and villas. Respectively, the percentages of distribution of the typologies are 44%, 54% and 2%.

As far as the floor area is concerned, preliminary data for Nablus shows that most of the housing units, around 36%, have an average area of 139.5 m^2, followed by 25% with an average area of 100 m^2 (Fig. 8).

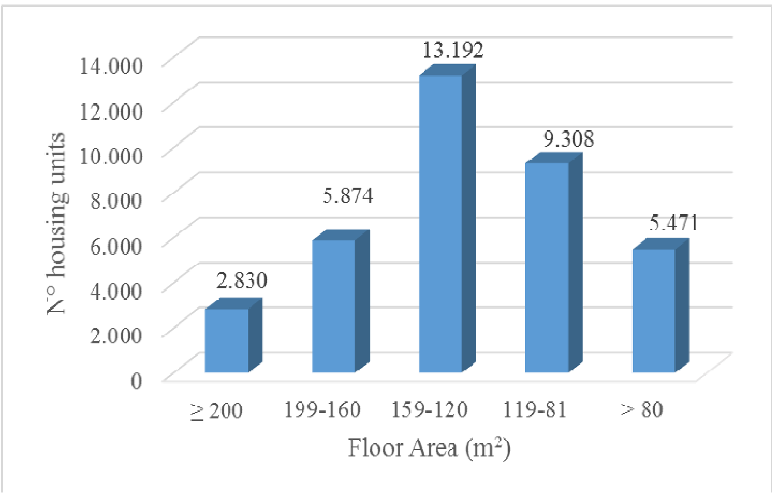


Figure 8. Distribution of housing units by floor area in Nablus.

Finally, with respect to the replacement cost, two methodologies were adopted to obtain the best results accounting for the wide variety in the region in terms of lack of homogeneity due to consecutive changes in the local law and variation in the construction materials and building techniques.

The first procedure takes into account data available on the governmental statistics website. The replacement cost is calculated by knowing the yearly expenditure on new buildings with specific materials (e.g. stone, masonry), adding the number of squares meter licensed in that specific year for that specific class. Table 3 illustrates an example of such data processing for stone buildings.

Year of survey	Construction material of external wall	Licensed area in 1,000 m^2	Expenditure in 1,000$
2014	Stone	2,719.9	249,897.3

Table 3. Example of calculation for replacement cost.

Taking into account the figures presented in Table 3, the final replacement cost comes as 91$/m^2.

On the other hand, the second procedure is based on expert opinion, using feedback from practitioners, engineers, engineering associations, etc. The replacement cost varies according to the building types: 550-600$/m^2 for apartments in multi-storey buildings, 750$/m^2 for individual houses and at least 900$/m^2 in case of villas. When comparing with the data from the official website, a large gap is observed with the reality of construction for the Nablus case study.

6 LEGAL AND REGULATORY FRAMEWORK

Finally, the development of an integrated risk model in Palestine will also enable the elaboration of guidelines and recommendations to promote local risk governance and management. Such task will include and redefine, if needed, the respective inputs of various GO and NGO Institutions by suggesting roles and possible forms of partnership between the three main stakeholders: government, private sector, including the (re)insurance and finance sectors, and the civil society (scientific/academic institutions, civil society organizations, media, the general public). Guidelines focusing on common procedural frameworks for encouraging and, whenever feasible, setting-up new partnerships and a set of methods and tools for cooperation between the different actors or stakeholders will be released at the end of the project. In this way, tailor-made recommendations will be available for the various institutional (policy, legislative and organizational) frameworks and cultures in Palestine. Therefore, the guidelines to be developed will be useful to quantify and assess physical, environmental and social resilience also from the risk governance point of view. In particular, to reach this aim, a questionnaire has been developed on the basis of the Self-Assessment Guiding Tool annexed to the G20/OECD Methodological Framework on Disaster Risk Assessment and Risk Financing (http://www.oecd.org/gov/risk). The questionnaire has been spread among the three main stakeholders in Palestine. The outcomes of the questionnaire will be processed suggesting roles and possible forms of partnership between the three main actors for a better management of seismic risk.

7 CONCLUSIONS

This paper intended to provide a general overview of the construction of a first-hand integrated seismic risk model for the Palestinian territory, using the municipality of Nablus as pilot study. A detailed framework including considerations around the different risk components – hazard, vulnerability and exposure – was presented.

The hazard model is established essentially on the basis of the recent EMME project that covered the entire Middle East region with significant detail and up-to-date tools (OpenQuake). The model will be further exploited to select real records to accurately develop a building fragility model.

The vulnerability model is largely comprehensive, as it includes both physical and social vulnerability components. Furthermore, both are modelled with different levels of detail, using census/database data and in-situ collected information. Indeed, the latter aspect, fulfilled through the use of specifically developed survey forms, constitutes one of the major novelties of this study. Fragility curves for a predefined building taxonomy are built using expedite nonlinear static analyses, adapted to the Palestinian in-built. On the other hand, social vulnerability indices are identified and established based on tailored questionnaires distributed to the general population and stakeholders in Nablus.

Finally, the exposure model builds upon extensive public data collection and feedback from several experts in the field. The entire model relies significantly on the cooperation with local bodies, entities and universities, yielding a double effect: sharing information and increasing awareness.

The general framework is seen as a pilot study, starting from the area of Nablus city, characterized by a difficult political context. Ultimately, the goal is to extend it to other regions in Palestine as well as to neighbour countries that features similar in-built environment. The achievements of risk assessment and loss estimation results in this case study, particularly the ones based on crowdsourcing data, also represent an enrichment for Europe.

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