PROJECT INFORMATION

Project Title: Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain
Acronym: SYNER-G
Project N°: 244061
Call N°: FP7-ENV-2009-1
Project start: 01 November 2009
Duration: 36 months

DELIVERABLE INFORMATION

Deliverable Title: D6.2 Application and validation study to the city of Vienna (Austria)
Date of issue: February 2013
Work Package: WP6 – Validation studies
Deliverable/Task Leader: VCE – Vienna Consulting Engineers

REVISION: FINAL

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Abstract

The test case in Vienna shows some very interesting results. The methods that have been produced in the project have been tested in a very small area of a big city. This brings some major difficulties for both the software package as well as for the data collection. In general, the theoretical background that has been produced in the various work packages of the project was brought into practise successfully. The interdependencies of systems and their interactions within the system have been shown in the OOFIMS case of the Test Study. The EQvis case shows that the software packages have to be user friendly and easy to handle. The visualisation of the results plays a major role when dealing with stakeholders and officials. EQvis has brought together all these components in one software solution which is easy to handle.

Keywords: Validation, Case Study, Vienna, Application
Acknowledgments

The research leading to these results has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] under grant agreement n° 244061.
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1 Introduction

This report describes the relevant systems of the city of Vienna that has been treated within the Syner-G project. First, a general description of the city is given; chapter 2 focuses on SYNER-G relevant systems and the following chapters presents the implementation into OOFIMS and the obtained results.

1.1 THE CITY OF VIENNA

The city of Vienna is located in the North-Eastern part of Austria. It is the capitol of Austria with a population of about 1.697,982 people. Austria is divided in 9 provinces, while Vienna has a special status and counts also as a province even when it is a city. Vienna has a total area of about 414.89 km² and is crossed by the river Danube.

![Fig. 1.1 Location of Vienna in Austria](image)

It is the 10th largest city in the Europe Union by population. In 2001, the city centre was designated a UNESCO World Heritage Site and in 2005 an Economist Intelligence Unit study of 127 world cities ranked it first equal with Vancouver for the quality of life.

The area of the city is divided in 23 districts. The whole area of the city can be roughly divided in the following categories:

- Force Area with buildings on it (12 %)
- Transportation (13 %)
- Gardens and Parks (28 %)
- Water (5 %)
- Weinbau (2%)
- Forests (18 %)
- Agricultural use (15 %)
The city has a very proud history. Settlements along the Danube near what is now the City of Vienna can be traced back to the 5th century B.C. These were of Celtic origin - as is the name Wien, derived from the Celtic "Vedunia" meaning "river in the woods". The Romans established the garrison camp Vindobona in the 1st century AD. Remainders of the Roman camp can be seen at Hoher Markt and at the underground station Stephansplatz. Vienna began its rise in importance in the Middle Ages when it was made the residence of the Babenbergs and the city walls were raised in 1200. Vienna would become the capital of the Habsburg Empire and remain so for almost seven centuries. Today its imperial past is still visible in monumental structures such as the Imperial Palace (Hofburg), the Schönbrunn Palace, the buildings along Ringstrasse, and many other sites throughout the city.

1.1.1 Historical buildings in Vienna - Gründerzeithäuser

The historical development of the city of Vienna is mostly responsible for the dominance of residential buildings in the inner districts that have been built at the beginning of the last century. These represent about one third of all existing residential buildings (32,000 buildings) and were predominantly built between the years 1850 to 1918 (in the so-called “Gründerzeit”). The estimation and evaluation of structural safety with respect to earthquake loads in these buildings is particularly difficult because in general the material properties are strongly inhomogeneous and the dynamic behaviour is unknown.

Due to the high demand for housing in the city centre, especially in recent decades, unused attic space was being adapted from already existing buildings. Because of existing legislation these adaptions have to be proved with respect to seismic codes.

The historical building development in Vienna is mostly driven by the enormous population growth in the last decades. The population in Vienna in 1840 was about 440,000 and 60 years later it was 1,643,000. In 1918 the population in Vienna had a maximum of about 2,238,545 people. This phase, which was dominated by the urban growth, is called “Gründerzeit”.

This phase can be subdivided in 3 parts:
Frühgründerzeit (1840-1870)
Hochgründerzeit (1870-1890)
Spätgründerzeit (1890-1918)

The enormous population growth during the Gründerzeit can be explained by the fast growing immigration and the excess of birth. Especially during the industrial revolution there were many companies that built their business in the outskirts of the city so that the urban structure of the inner city did not change.

During the Gründerzeit, the construction activities have to be divided in public, private and communal activities.

Public construction activities: the public construction activities were dominated by the expansion of the railroad network. The development of the city structure was determined by the new railroads and railroad stations. The Ringstraße in the inner city was built so that the inner city and the outskirts got connected. Additionally the Danube had been regulated so that the left side of the Danube got settled.

Private construction activities: the design Vienna got influenced most by the building regulation. In 1859 a building code got published that regulated the building height to a maximum of 22.1 meters. Additionally the width of street had to have a minimum of 13.6 meters. Due to a tax reform regarding the construction of new houses, the building activity was raised. Another influence was the constantly increasing land price. Instead of building new houses there was a trend of adding new storeys to existing buildings.

Communal construction activities: the communal construction activities were influenced through the construction of company housing for workers that work in companies belonging to the city. During the Gründerzeit approximately 450,000 housing units were built. These units were very small and especially in the area of the outskirts of the city their percentage was about 85%.

1.1.2 Geology

The city of Vienna is placed east of the Alps, at the west end of the tertiary Wiener Beckens. Three main basics can be identified:

- Brash and sand from the river Danube
- Loose rock – tertiary loose rock from the Vienna basin
- Solid rock from the flysch zone and the limestone alps

There is a system of north-south aligned faults and cracks that goes through the city of Vienna.

The Vienna basin is a tectonic pull-apart basin of about 200 km length and 60 km width. It sunk in the Alpine-Carpathian body. The basin developed on a northeast-trending sinistral fault system and became a part of the Parathetys. The tectonic units of the Alps continue in the pelvic surfaces. They form the basis for the syntectonic tertiary basin fill. This fill consists of several hundred to a thousand meters deposits in marine, brackish, limnic and fluvial facies. The total thickness of tertiary deposits in the Vienna Basin reaches over 5,000 meters along the tectonic fault zone.
The sandy, tertiary strata of the uppermost 50 to 100 meters are ground water – saturated. Morphologically, the flysch zone and the Limestone Alps, form the hills of the Wienerwald in the western part of the city.

The flysch zone consists lithologically (gesteinsinhaltlich) mainly of sandstones and marl.

1.1.3 Seismicity

The majority of seismic risk in Austria is associated with the Vienna Transform fault zone, which runs through the eastern part of Austria beneath the city of Vienna and surrounding areas.

Fig. 1.4 Earthquake zones in Austria (2002) shows the earthquake hazard situation in Austria.
Introduction

Seismic activity varies across the country. An event in 1348 with an estimated magnitude of 6.7 destroyed a large part of Villach. In 1590 an earthquake with a magnitude close to 6 near Neulengbach damaged houses in Vienna. There are several documents that report about the collapse of the towers of Michaelerkirche and Schottenkirche. There is also documentation about 9 deaths because of the partial collapse of a tavern. More recently, an event in 1927 with an estimated magnitude of 5.2 caused severe damage to buildings in Schwadorf, to the southeast of Vienna.

The Ebreichsdorf - Earthquake

The Vienna Basin together with the Inn valley (Tyrol) and the Mur- Mürz valley (Styria) is one of the main seismic active areas in Austria. During the 20th century 345 earthquakes in the
Vienna Basin and adjacent areas in Styria could be felt, 17 earthquakes caused building damage. The latest event causing considerable damage happened on July 11 2000 at 04:49:49 Central European Summer Time (CEST). The epicenter was located near Ebreichsdorf, Lower Austria. The epicenter intensity was assessed as 6 on the intensity scale “EMS- 98”, the magnitude was 4,8 on the Richter scale. The ground shaking was felt strongly in most areas of eastern Austria and also in Vienna.

From the geological point of view the Vienna Basin constitutes a pull-apart basin at the eastern end of the Mur-Mürztal-fault (Gutdeutsch and Aric, 1987). Beginning at the Semmering the fault splits into a number of faults, of which the most western fault has been coined “Thermenlinie” by Suess (1873). The Ebreichsdorf earthquake occurred on a deep fault beneath the Vienna Basin situated in the middle of the basin, which connects the well-known seismic focuses of Schwadorf, Wiener Neustadt and Seebenstein/Pitten. Fig. 1.6 shows the tectonic setting including the seismicity of the Vienna Basin.

Fig. 1.6 Structural setting and seismicity of the Vienna Basin
2 Systems of Vienna relevant to Syner–G

2.1 BUILDINGS

There is a total amount of 168,167 buildings in Vienna, where about 139,557 (87 %) buildings are classified as residential buildings (Fig. 2.1).

The municipal department for buildings in Vienna is called Building and Facility management. This department provides detailed information of all the buildings in Vienna.

Fig. 2.1 Image of the number of buildings in Vienna divided in residential and non – residential buildings

2.1.1 Non-residential buildings

In Vienna there are about 28,610 buildings classified as non – residential. The classification of these buildings is divided in hotels, office buildings, buildings for retail industry, traffic and communication, factories and storage buildings, cultural buildings and buildings for education and others.

Fig. 2.2 shows the usage of non – residential buildings in Vienna.
2.1.2 Residential buildings

Currently there are 1.697.982 people living in 23 districts in Vienna that sums up to 4.05 people per km².

From all the residential buildings there are 82.273 (59 %) buildings with 1 or 2 flats, 23.353 (17 %) buildings with 3 – 10 flats and 33.413 (24 %) buildings with more than 11 flats in Vienna (Fig. 2.3).

2.1.3 Schools

Currently there are 380 public schools in Vienna. There is a municipal department called Vienna schools. The objectives of this department are the construction, maintenance, modernization and administration of all the public schools in Vienna.

185.020 people are attending the 380 schools in Vienna.
2.1.4 Fire stations

In Vienna there are 27 fire stations located all over the 23 districts. The fire protection is divided in 9 sections all over the town. This unit has an average of more than 36,000 operations a year.

The responsible department is the Fire department and disaster relief.

2.1.5 Health Care Facilities

There are currently 12 hospitals in Vienna. The assistance for all these hospitals rests with the KAV – Vienna Hospital Association. It has detailed information about hospitals and for example number of patients per hospital.

The Ambulance and patient transport service is responsible for the transportation and organization in case of an emergency. There are 12 rescue centers allocated in the city of Vienna. These centers are located in a way that the rescue teams can generally arrive at most 12 minutes after an emergency call.

2.1.6 Children Facilities

The city of Vienna offers a big variety of childcare facilities. The Vienna Children’s Day Care Centre is the responsible authority in Vienna. In 2008, 71,521 children attended the different facilities like day nurseries, kindergartens, after-school care clubs and mixed-age facilities.

2.2 LIFELINES

Lifelines are vital for the community life. In a certain degree the development and the growth of a society is reflected in the quality and the efficiency of its lifeline system. Modern societies are totally dependent on a complex network of infrastructures, which supply energy, fresh water, provide transportation and communication services, manage urban waste disposals. Infrastructure systems together comprise the fabric by which society and its built environment is threaded together. They are the basic installations and facilities on which the continuance and growth of a community depended.

The operation of lifeline systems during and after a destructive earthquake is of vital importance for society as they contribute to the rescue operations, the emergency and recovery actions.

2.2.1 Transportation

**Road Network**

The road network is very essential for quality living in a city. In case of a disaster it is the most essential network with respect to emergency efforts.

The Vienna road network currently consists of about 6772 roads with about 2800 km length. 51 km out of them are highways; 216 km are main roads and the rest fall under the category of municipal roads.
The Municipal Department for the road network is called *road management and construction*. The department objectives are the development, the construction, the maintenance and the general administration of public traffic areas, as well as the construction and maintenance of traffic signs, road marks, etc.

![Fig. 2.4 Main highways around the city of Vienna](image)

The road management and construction department has detailed digital information of road maps for Vienna. Additionally it has a database that has all information about wires, cables, canals, etc. that are underground. This means that all the space that is used underground is digitally stored in this database, even when above ground changes happened. This database is regularly updated in cooperation with the Surveyors central department of the city.

**Bridges**

Bridges are the most vulnerable components of roadway systems. Their damage is greatly disruptive due to the lack of redundancy, the lengthy repair time or the rerouting difficulties. The disruption to the highway network can strongly affect the emergency efforts immediately after the earthquake or the rebuild and other business activities in the following period.

Currently there are 10 bridges in Vienna that connect the left and right side of the Danube, 7 bridges over the Neue Donau and 35 bridges over the Donaukanal. The total length of all the bridges is 54 km.

The municipal department for bridges in Vienna is called *Bridge Construction and Foundation Engineering*. The department objectives are the maintenance, security and construction of bridges in Vienna.

The Bridge Construction and Foundation Engineering has very detailed information about all those bridges. Fig. 2.5 shows an example of the database of the different bridges in Vienna.
Systems of Vienna relevant to Syner–G

Fig. 2.5 Example of the database for information about the different bridges in Vienna

Railroad Network

The whole public transport sector in Vienna covers about 934 km. All together there are 117 lines - 5 underground lines, 28 tramways and 83 buses - in the city of Vienna. The underground lines cover a distance of about 69 km while the tramways cover 227 km. In addition to that there is the Schnellbahn. It is a railroad directly in the city and has 15 lines and 56 stations. Additionally, there are 3 main railway stations that cover the long distance traffic.

The organisation and assistance of the railroad network rests with the Wiener Linien and the ÖBB (Österreichische Bundesbahnen).

Fig. 2.6 Public transport system in Vienna
While the underground lines and the tramways fall under the responsibility of the Wiener Linien, the Schnellbahn and the railway belong to the ÖBB. In total about 803,64 million passengers are being transported in a year.

2.2.2 Water and waste water system

The water supply system
The water system in Vienna can principally be divided in two main water lines. These are the first and second Hochquellenleitung. The capacity of the first conduit is 220,000 m$^3$/day and 217,000 m$^3$/day for the second conduit. Additionally there are two water works which have a capacity of about 142,000 m$^3$/day. This results in a maximum capacity of about 589,000 m$^3$/day. The average daily consumption is 390,000 m$^3$/day.

The responsible authority of the whole water system in Vienna is the municipal department Vienna Waterworks. It has detailed information of the water supply in Vienna.

Additionally the system of fire-hydrants plays a major role in the water supply system in a city.

The waste water system
The waste water system in Vienna is roughly 2,300 km long and takes all sewage in Vienna to one main sewage treatment plant. The whole net of housing canals is 6,300 km long and transports 220,000,000 m$^3$ sewage per year. The average pipe cross-sections are in the range from 0.7/1.05 m to 5/4.2 m.

The maintenance, clearance and control rest with the municipal department Vienna Waste Water Management.

2.2.3 Electric power system
Loss of power or communication can severely impact the emergency response, especially when the disruptions concern critical facilities, such as hospitals, command centres, police stations etc. Loss of power may have severe indirect effects due to the synergies between the lifelines and the dependence of all networks on the power supply system.

The most important energy distributor for electricity and gas in Vienna is Wien Energie GmbH, but in principle the energy market is liberalised. Wien Energie, which belongs to the Wiener Stadtwerke Holding AG, operates several power plants (water, thermal) around Vienna.

In the city of Vienna there are 117 facilities that produce 6647 GWh electricity per year. There are 4 big facilities: Conventional thermal power plants Simmering (903 MW power, 2539 GWh), Donaustadt (545 MW, 2260 GWh) and Leopoldau (145 MW, 597 GWh) and one big hydroelectric power plant in Freudenau (172 MW, 1037 GWh).

The power lines in Vienna cover a distance of about 22,000 km, with 46 transformer substations.
2.2.4 Gas system

The most important energy distributor for gas is Wien Energie GmbH. The whole gas system of Vienna is more than 3,400 km long. There are 123,000 house service connections and the conducted amount of gas is 1.7 Mrd. Nm³.

The proper department for the electricity and gas system in Vienna is the municipal department Inspection of Business Establishments, Electrical and Gas Equipment, Fire Prevention and Official Authorisation of Events.
3 Disaster Control in Austria

The disaster management in Austria (and in Vienna) is generally composed of two components:

- There is a public system which includes the prevention, combat and management of disasters. It includes the creation of disaster management plans and alert systems, as well as professional and volunteer organizations.
- Self-Protection: these are all the measures that everyone can take by themselves. These include for example the construction of shelters or taking first aid courses.

In Austria there is a federal Crisis and disaster management installed in the nationwide level. Since 2003 it is part of the federal ministry of the interior and this ministry’s objectives are the coordination and management of the bureau as well as international emergency aid.

The operational part of this bureau is the Bundeswarnzentrale, it represent the information platform. It has direct contact to all relevant organisations in Austria and is the contact for other nations. Additionally it is the central contact point for the warning and alarm system nationwide.

Fig. 3.1 General presentation of the disaster management in Austria
In case of a disaster, there are well established plans how to react to it. Every municipality, district and province in Austria has to have clear terms how to react in case of emergency. If a catastrophic event occurs the alarm chain is defined for every municipality, district, province and even up to the federal level.

Vienna also has such disaster management plans.

To guarantee the efficient execution of the necessary measures, a well-established schedule is developed that accurately determines the order in which to mobilize the forces:

- Information about the catastrophic event to the information center of the fire department
- Reporting to the city hall station
- Initiation of a disaster control center through the city hall station
- Informing the head of the Executive Group Organisation, Safety and Security – Group “Disaster Management and immediate measures”
- Calling of the responsible persons of the Executive Group Organization, Safety and Security – Group “Disaster Management and immediate measures” and set up of the disaster management center
- Informing the mayor
- The mayor orders the draft of the political disaster management
- The information center of the fire brigade calls the head of the Einsatzleitstelle
- Informing the Chief executive director, all member of the disaster management and the press.

The general management in case of an emergency rests with the mayor or a chosen member of the city senate.
The warning and alarm system is Vienna currently consists of:

- 180 electronic and pneumatic sirens, which are mostly placed on roofs of public buildings;
- a central computer station, which is connected to all sirens through 4 relay stations. This computer station controls the whole system 24 hours a day and is located at the disaster management center at the Wiener Rathaus. There is also a back-up system located at the central fire brigade in the first district of Vienna.

The activation of the alarm is carried out through coded radio signals and can be divided in single – activation, activation of whole districts or activation of all sirens together. The management of this system rests with the city hall station.

The activation of the system is organised as follows:

- catastrophic event
- initiation of a disaster control center
- decision about activating the alarm system
- informing the public via radio and television
- activation of the alarm system

If there is a catastrophic event it is most essential that the information and alarm system works as fast as possible. In order to ensure such a system, an alarm- and warning system was installed in Austria.
Currently there are 8,120 fire sirens in Austria, in Vienna there are 176 so called civil protection sirens, which cover the whole country of Austria. The activation of these sirens can be carried out at the federal level as well as in the municipal, district or province level. The information about the event/disaster has to be provided through radio and television additionally.

The nationwide activation for all sirens in the country rests with the Bundeswarnzentrale at the disaster coordination centre/ federal ministry of the interior, the activation with respect to provinces rests with the various provincial warning centres.
4 The case study in Vienna

In the framework of the SYNER-G project two case studies have been performed: one in the city of Thessaloniki which has a high potential of seismicity, the other in Vienna which has a moderate seismicity potential.

The region of interest in the city selected is the Brigittenau district.

Brigittenau is the 20th district of Vienna. It is located north of the central district, north of Leopoldstadt on the same island area between the Danube and the Danube Canal. Brigittenau is a heavily populated urban area with many residential buildings. The district’s name comes from the Brigitta Chapel, built between 1645 and 1651. It consists of a good tract of land secured by the regulation of the Danube 1870-75 and many of the major streets are named after members of the Danube Regulation Commission. Therefore it does not contain any distinctive historical areas. Brigittenau was separated from the 2nd district in 1900. Fig. 4.1 shows the whole city of Vienna and the area that will be covered in the Syner-G case study.

Over 40 % of the Brigittenau land area is in traffic zones. The green area share amounts to only about 10 %. The traffic load is very high because the most important connection Saxons leads over the Danube through the district. Moreover 86 % of all employed of Brigittenau do not have jobs in the district.
The developed area of Brigittenau comprises 38.7% (Vienna city-wide 33.32%) of the district area. The proportion of housing in the developed area amounts to 64.2%, plus 21.2% for operations, and 10.7% dedicated for facilities in the cultural, religious, sports or the public sector. Green space in Brigittenau takes in only 7.9%, for which Brigittenau lies in the lower third of the Vienna municipal districts. About 66% of green space is in parks, 22.3% in sport and leisure areas, with the remainder in small gardens and meadows. Due to the large shares of the area for the Danube Canal and Danube, waters take 20.9% of the total district territory. This is the second highest value of a district. The proportion of traffic area in the district, with 32.9%, is the fourth highest value in Vienna.

The reasons for the choice of this particular area can be summarized as follows:

- The district consists of various types of buildings, with building practices that start from 1848 up until recently.
- The topic of transportation is covered even in this relatively small area as there are railroads/railway stations, underground and tramway lines as well as bus lines, numerous very frequently used bridges across the Danube.
- There are numerous essential facilities like fire stations, police stations, schools, ambulance stations, an important hospital, the Millennium Tower (one of the tallest buildings in Vienna), etc.
- There is a huge amount of data available for the whole district (lifelines, essential facilities, etc.).

All the information about the area like buildings, transportation, bridges, etc. is gathered in various databases and every item on this GIS–map is linked to the database.

### 4.1 BUILDINGS

Buildings are masonry constructions built in the period of 19th and 20th century and belong to residential and commercial group of buildings due to its usage purpose. Most of them have distinctive facade elements, sculptures and statues. Some of them are built with balconies.

Within the SYNER-G project the classification and description of buildings in 20th district have been done due to their construction year, building usage, construction practise, etc. Fig. 4.2 shows a rough classification of the construction year for these various buildings. A more detailed classification can be seen in Fig. 4.3.

Next, these buildings have to be classified in terms of building usage (Fig. 4.4). The categories were chosen to be:

- Residential
- Student – Residence
- Operational
- Shop
- Public Building
- Infrastructure – Maintenance
- Church
The case study in Vienna

- Hospital
- Infrastructure – Transportation
- Other.

Fig. 4.2 Rough classification of the building stock in terms of construction year.

Fig. 4.3 Detailed classification of the building stock.
The assessment was conducted as described in A: buildings data collection form. All the information about the buildings is summarized in a database. Every building has a number in this database and the most essential details about the buildings like construction year, number of floors, the existence of lofts/cellars and the usage.

Additionally the database features a fotolink to every building Fig. 4.5 shows an example of this database.
4.1.1 Essential facilities: fire station

The nearest fire station in 20th district is located in the Brigittaplatz 11-13. The fire station Brigittenau was built in 1929 in a municipality house of Vienna. On the ground floor and on the first floor of the building are the crew quarters. The three-storey drill tower in the small farm is integrated into the building. A fire engine is available as an emergency vehicle. Six people in the group provide station Brigittenau to its service.

4.1.2 Essential facilities: hospital

Lorenz Böhler Emergency Hospital is one of the Emergency Hospitals in Vienna, located in Donaueschingenstrasse in the 20th District, Brigittenau. It was the first accident hospital in Vienna.

The first beginnings of Traumatology in Vienna were both at the I. Surgical Clinic under Anton Eiselberg and the Second Department of Surgery of the General Hospital under Julius Hochenegger, who established their first hospital trauma departments.

At the urging of Lorenz Böhler, the General Accident Insurance AUVA put two floors available in one of their office buildings in the Webergasse 2-6, 20th District of Vienna. These have been converted into an Emergency Hospital. The work was begun in 1923 and the opening was in year 1925. Lorenz Böhler was appointed as medical director. In this role he worked until 1963 and made the Emergency Hospital to a global model of Trauma Hospitals.

The hospital with 52 beds originally was developed by 1934 to hospital with 120 beds and several surgical. In 1945, the Emergency Hospital was heavily damaged by bombing, but the operation could be maintained.

A year after the resignation of Lorenz Böhler 1964, the General Accident Insurance Fund decided to build the new construction of the hospital in Donaueschingen street. Construction began in January 1967. On 9 November 1972 it was the commissioning of the Lorenz Böhler Trauma Hospital.

Medicinal Equipment

The Vienna Emergency Hospital Lorenz Böhler has in trauma surgery four stations with more than 118 beds. The Department of Anaesthesiology and Intensive Care Medicine on an Intensive Care Unit have 10 beds.

Hospital has the following contents:

- Medical-surgical laboratory
- Emergency room with built-in computer tomography and roentgen for severely injured
- 6 operating rooms
- roentgen: PACS appliances: computer tomography, magnetic resonance imaging, fluoroscopy
- colour-coded Doppler ultrasound, ultrasound machine
- physiotherapy with inpatient and outpatient care: individual and group exercises, electrotherapy, laser therapy, ultrasonic therapy, lymphatic drainage, cybex, lido
ergo therapy
- helicopter landing site.

Legal duties:
- Prevention of occupational accidents and diseases
- Occupational medical care
- First aid for occupational accidents
- Post traumatic treatment
- Rehabilitation
- Compensation
- Research.

4.1.3 Other essential facilities

Additionally the Millennium tower is being considered as an essential facility because it’s one of the highest buildings in Vienna with many flats and many people living or working there.

4.2 ROAD NETWORK

4.2.1 Bridges

On the west and east side of the area there are many crucial bridges across the Danube. These bridges represent the most important bridges in terms of capacities for the city of Vienna. The bridges in this area are summarized in a database, where their most important features are summarized, together with a picture. Fig. 4.6 shows an example of this database.
The next step in identifying the relevant data is to collect data for the transportation in this part. As stated above, one of the reasons to choose this particular area was that there is plenty of data for the transportation system in Vienna.

Fig. 4.7 shows the area with its various transportation networks: all essential public transportation systems available in Vienna reach Brigittenau district.
Fig. 4.7 Overview of the transportation networks in the considered area of interest
5 Deterministic Analysis: Vienna Input Data for EQvis

5.1 THE BUILDING IDENTIFICATION PROCEDURE

The BIP procedure has been formulated to identify and inventory buildings that will be considered in the Syner-G project. The BIP procedure can be implemented relatively quickly and inexpensively to develop a list of potentially hazardous buildings without the high cost of a detailed seismic analysis of individual buildings. The inspection, data collection, and decision-making process typically will occur at the building site, taking an average of 15 to 30 minutes per building (30 minutes to one hour if access to the interior is available). The main purpose of this procedure is to identify and categorize buildings in a relatively big area. The output of this procedure is a fact sheet for every building which contains all the essential information with respect to earthquakes and the overall condition of the building. The Data Collection Form includes space for documenting building identification information, including its use and size, a photograph of the building, and documentation of pertinent data related to seismic performance.

Buildings may be reviewed from the sidewalk without the benefit of building entry, structural drawings, or structural calculations. Reliability and confidence in building attribute determination are increased, however, if the structural framing system can be verified during interior inspection, or on the basis of a review of construction documents. The BIP procedure is intended to be applicable nationwide, for all conventional building types. Bridges, large towers, and other non-building structure types, however, are not covered by the procedure.

5.1.1 Completing the Building Identification Protocol

The purpose of the chapter is to give instructions how to complete the Building Identification Protocol.

The Building Identification Protocol is completed for each building screened through execution of the following steps:

a) Verifying and updating the building identification information;

b) Walking around the building to identify its size and shape and looking for signs that identify the Construction year

c) Determining and documenting occupancy;

d) Determining the construction type;

e) Identifying the number of persons living/working in the building

f) Characterizing the building through the ground plan and determining the distance to traffic area.

g) Characterizing the building elevation; Using the laser telemeter to define building height; identifying soft stories or added attic space
h) Identifying façade elements inclusively number of windows and doors
i) Determining non-structural members
j) Determining the overall condition of the building
k) Noting any irregularities/anomalies
l) Taking pictures with the digital camera

All these steps have to be done carefully. Each step is now explained in detail.

a) Verifying and updating building identification information

This is the first step in the whole procedure. When you arrive at the site you first have to check if this is the building you want to examine. If this is the case start filling the first field in the protocol. Start with date, name and time and work your way down.

<table>
<thead>
<tr>
<th>Protocol for building identification procedure</th>
<th>Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>No.</td>
</tr>
<tr>
<td>Time:</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Address:</th>
<th>Street / No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLZ</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5.1 Verifying and updating the building identification information

b) Walking around the building to identify its size and shape, and looking for sign that identify the Construction year

At first the building should be looked at to identify its size and shape and to get a first impression of the building. The construction year of a building can be determined if there is a sign at the facade of the building. If there is not such a sign, and the construction year cannot be determined the field Construction Year should be empty. It is much better to analyse this building later if needed, than to have a wrong construction year.

c) Determining and documenting occupancy

This is a pretty important field. It describes the general usage of the building, like apartment building, school, kindergarten, hospital, office building, etc. If the building usage is not limited to one category the percentage of the usage categories have to be identified. Example: Apartments (70 %), Offices (30 %)

d) Determining the construction type

The construction type can be hard to identify in the field and without appropriate additional knowledge. What can be determined easier is the construction material. It is often very helpful if one knows the year of construction, because in certain periods, construction materials were very similar. It can also be helpful to have a look into the building, if possible. Often the interior walls can give clues what building type is present. Sometimes it also helps to get into the basement, because the walls are not always covered in basements.
e) Identifying the number of persons living/working in the building

This is a very important step in the whole procedure. In order to find the possible persons, which can be in danger during an earthquake, one has to know how many people are living/working in a building. The number of dwelling units can easily be determined in the entrance area of a building by looking at the number of door bells or the number of mail boxes. All dwelling units, even not used ones, should be counted. The next field addresses the number of people living or working in areas not depicted as dwelling units like shops at the basements, cafes, etc. The number can only be approximated, but this number should depict the maximum number of persons that can stay/work in the building. An Example: There is a building with a café in the basement. This café has 3 employees working there and about 10 tables, where 3 persons can sit. Even when at the time of the screening process the café was empty the number to be filled has to be 33. (3 workers + max. 30 guests).

f) Characterizing the building through the ground plan and determining the distance to traffic area

The characterization of the building through the ground plan can mostly be made with a plan of the city. There are three questions to be answered: Is the building a Corner Building? Are there any adjacent buildings? Does the building have a rectangular ground plan?
Fig. 5.3 Plan views of various building configurations showing plan irregularities; arrows indicate possible area of damage (FEMA – report, RVS)

The distance to traffic area means the lowest distance between building and street. Parking areas and sidewalks do not count as traffic areas and should not be considered. The purpose of this distance is to know whether street can be blocked by building debris or not.

<table>
<thead>
<tr>
<th>Persons/Dwelling Units</th>
<th>Number of Dwelling Units</th>
<th>Number of Persons Working</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corner Building</td>
<td>05</td>
<td>06</td>
</tr>
<tr>
<td>Adjacent Buildings</td>
<td>07</td>
<td>08</td>
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<tr>
<td>Rectangular Ground Plan</td>
<td>09</td>
<td></td>
</tr>
<tr>
<td>Distance to Traffic Area</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

Fig. 5.4 Steps e and f
g) Characterizing the building elevation; Using the laser telemeter to define building height; identifying soft stories or added attic space

The easiest fact to determine is the number of floors. This number represents all floors, including the ground floor. Attention has to be paid to additional attic space. Attic space should only be counted if the housing area is more than 50% of the ground floor area. An important field is the building height. Building height is defined as the height from the top edge of the sidewalk to the beginning of the cornice. It has been proven to be the easiest way, if one can measure the distance with a laser – telemeter. If the building height is being approximated this has to be noted. If the building height cannot be measured directly one can also use the measuring tape, put it to the wall of the building and take a photo. The building height can then be determined afterwards. The same procedure can also be done with balconies, etc. If there are shops or cafes at the ground floor, this has to be noted here. Most of the time, if there is a shop at the ground floor this floor represents a soft story. A soft story is a floor (does not have to be the ground floor) where most of the interior walls are missing due to the space needed. Additional attic space can often be determined by looking at the windows at the attic or due to the existence of balconies.

![Soft story at the ground floor and Additional attic space](image)

**Fig. 5.5 Identifying soft stories and additional attic spaces**

h) Identifying façade elements inclusively number of windows and doors

The first priority is to determine the number of windows and doors at the facade facing the street. If it is possible to determine the numbers also for the sides facing the courtyard, do so. Identifying the façade elements means to determine how detailed the façade design is. Examples are given in the Figs below.

![Façade elements examples](image)
<table>
<thead>
<tr>
<th>not detailed</th>
<th>simple</th>
<th>detailed</th>
</tr>
</thead>
</table>

![Very detailed image](image-url)

**Fig. 5.6 Identifying facade elements**

1. Determining non-structural members

The first thing to determine is the number of chimneys. This can be tricky, because it is possible that one cannot see the chimney from the ground. If it is not possible to count the chimneys leave this field open.

![Building with 7 chimneys](image-url)

**Fig. 5.7 Example for a building with 7 chimneys**

The second thing is to determine all those façade elements that can fall off the building and on the street. This includes sculptures, balconies, statues, etc. It is important to count all potentially hazardous elements at the façade, so even shop signs have to be considered here.
j) Determining the overall condition of the building

This part focuses on the overall condition of the building. The main attributes are the presence of water damages, damages to the roof and cracks in the walls. This mainly means the cracks in the walls. It should, if possible, be distinguished between cracks on the facade (they should not be counted) and cracks in the walls. If the crack is going diagonal it should be counted anyways.

Humidity and Efflorescence can often be seen at the different colors at the facade.
Damages at the roof can often be determined if one can see humidity at the facade. If it is possible to get into the building, one should make photos and document it well. Damages at the roof can be very dangerous if not properly treated.

k) Noting any irregularities/anomalies

If there is anything out of the ordinary that is not explicitly in the checklist this is the place to write it down. If anything is written down here, it should always be documented with a photo if possible.

Fig. 5.11 Irregularities/anomalies and soft story

l) Taking pictures with the digital camera

A software program can modify pictures and combine them. The software is designed to reconstruct a coherent building out of your photographs. Note that since it is an automatic process, it can always lead to unexpected results. In order to avoid these degenerated cases, please take your photos with care and follow this guidelines. For each new reconstruction project you should focus on only one building, or even only one facade.
Having chosen your facade, plan the track, how could you walk and take the photos. You should move in approximately a half-circle around the façade. Note, that coherent paths, with distance of about 1-3 steps between the shots deliver best results.

In order to obtain a coherent point-cloud of your object, you should try to keep as much as possible of the object (facade) in each photograph.
It might not always be possible to move to good locations: e.g., due to obstacles in front of you or due to other buildings, cars or other objects in the near. In such cases try to move around them, even if you have to interrupt your path, but again try to keep as much as possible of the facade in each picture. Do not supply ambiguous content. Note, that the algorithm matches the photos by their visible properties. Do not deliver images which you couldn't distinguish by yourself. For example, if you want to reconstruct highly repetitive facade, like shown i.e. Fig 4, try not to supply images like shown in Fig 5. It will confuse the software and produce mismatches. In general it is better to supply fewer images with good quality, than too many poor photos.
Fig. 5.15 Facade with highly repetitive content. If you make close-up photographs from two ends of such building, they will be ambiguous, even for you! Try to avoid such input.

Fig. 5.16 Who can distinguish which side of the building it is?

5.1.2 Building Identification Process – an example

This section provides an example for the building identification process. The following example describes a part of the process for the city of Vienna. The first thing to do is
choosing an area of interest and collecting all information about the area that does not need field work: street plans, building plans, geology maps, etc. Once this information has been gathered the route of the screeners can be identified. If the buildings to be identified are selected, the screeners can begin to investigate the area. It has been shown that the best way to begin the process is to have a very detailed route and detailed plans for the field observations. The last step is transferring the information on the BIP Data Protocols into the relational electronic Building BIP Database. This requires that all photos are numbered (for reference purposes), and that additional fields (and tables) be added to the database for those attributes not originally included in the database. After arriving at the site the screeners observe the building as a whole and begin the process of gathering the information in the building identification protocol, starting with name, date, time, protocol number and the street address. The next step is to take photos of the building. This step can also be performed at the end of the screening process, after filling all the fields of the protocol. After determining the building usage, the construction year and the construction type are being determined. These two fields can also be left empty, in case that the construction year or type cannot be determined for sure. The next big block of fields is pretty easy to determine, number of persons/dwelling units, ground plan, elevation and façade. Non-structural members cannot always be determined properly like number of chimneys. The procedure is the same as for the construction year, if the number cannot be determined for sure, the field should be left empty. After determining the overall condition of the building there is a big field for irregularities. In each example there is an oriel starting at the first floor. This is written in this field and a photo is taken.
### Deterministic Analysis: Vienna Input Data for EQvis

**Fig. 5.17 Building Identification protocol**

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<td>Soil Story: X 14</td>
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<tr>
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<td>&gt; 6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detailed Facade Elements</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 3</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>&gt; 6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sculptures/Statues</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 3</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>&gt; 6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>21 Cracks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>22 Humidity/Efflorescence</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>23 Damage on the Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anomalies/Inequalities</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>from the first floor up there is an oriel</td>
</tr>
</tbody>
</table>
Fig. 5.18 Building photos taken of a single building with two street views
5.2 INPUT DATA IN EQVIS

5.2.1 Building Data

The protocols of the last chapter had to be ingested into the software platform. First, the data was put into shapefiles, which were created prior to the survey. Each building point gets an attribute table where the data of the survey is stored. The next step is to ingest the data in the platform. The following Figures show the data in the platform which then serves as the basis for all analyses performed within the project.

![Fig. 5.19 Buildings in the test area together with a small example of the attribute table](image)
5.2.2 Railway Data

Fig. 5.20 Railway tunnels in the test area

Fig. 5.21 Railway bridges in the test area
5.2.3 Road Network Data

Fig. 5.22 Road bridges in the test area

Fig. 5.23 The road network in the test area
6 Deterministic Analysis: Vienna EQvis Outputs

6.1 HAZARD INPUT

EQvis produces the hazard in a deterministic way. For the case study in Vienna two different earthquakes are considered. A historical earthquake from 1590 located in Neulengbach with a magnitude of 6 and a "method testing" earthquake with a magnitude of 7. Table 6.1 gives the characteristics of the earthquakes produced for the simulations. In Figure 6.1 and figure 6.2 one can see a screenshot of the PGA distribution around the test area.

The soiltypes are also considered. The soilmap of the test area is shown in Figure 6.3.

<table>
<thead>
<tr>
<th></th>
<th>Neulengbach</th>
<th>method testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>magnitude</td>
<td>6,00</td>
<td>7,00</td>
</tr>
<tr>
<td>longitude</td>
<td>15,909722</td>
<td>16,543582</td>
</tr>
<tr>
<td>latitude</td>
<td>48,200278</td>
<td>48,0366424</td>
</tr>
</tbody>
</table>

Fig. 6.1 PGA distribution for the “method testing” earthquake in EQvis
6.2 RESULTS

As mentioned in the previous sections two earthquakes have been created and analyses have been performed with the results. The two earthquakes are a little bit different, since the Neulengbach earthquake is much further away from the test area with a lower magnitude than the “method testing” one.
Since the PGA values in the test area are different, consequently also the damages to the various structures and systems are different. It was decided to display the damages in two different ways for the two earthquakes. The damages caused by the Neulengbach earthquake will be shown as the probability of reaching the damages state “slight”, which is the first damage state in the fragility curves used.

In the case of the “method testing” earthquake a two different formulas for deriving a “mean damage” will be used. The formula for calculating the mean damage is

\[ \text{meandamage} = g_i * I + g_m * m + g_h * h + g_c * c \]

where I is the probability of reaching the damage state “slight”, m is the probability of reaching the damage state “Moderate”, h is the probability of reaching the damage state “Heavy” and c is the probability of reaching the damage state “Complete”. The factors before the probabilities are called “damage ratios” and can be specified by the user when ingested.

The damage ratios used in this test case are written in the following table.

<table>
<thead>
<tr>
<th></th>
<th>Insignificant</th>
<th>Moderate</th>
<th>Heavy</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>buildings</td>
<td>0,005</td>
<td>0,155</td>
<td>0,55</td>
<td>0,9</td>
</tr>
<tr>
<td>roadway</td>
<td>0,005</td>
<td>0,08</td>
<td>0,25</td>
<td>1</td>
</tr>
<tr>
<td>railway</td>
<td>0,005</td>
<td>0,08</td>
<td>0,25</td>
<td>1</td>
</tr>
<tr>
<td>road tunnel</td>
<td>0,005</td>
<td>0,08</td>
<td>0,25</td>
<td>1</td>
</tr>
<tr>
<td>railway tunnel</td>
<td>0,005</td>
<td>0,08</td>
<td>0,25</td>
<td>1</td>
</tr>
</tbody>
</table>

6.2.1 Results for the “method testing” earthquake

The first and most important result is the damage to the building stock where the results are obtained building by building. The user can quickly look at the results for each building and filter them. Each building has a very detailed description of the contents as described in the previous chapters.
The distribution of damage to the buildings shows that the building stock is very homogenous. There are very few building collapses, some heavily damaged buildings but the majority of the building stock remains in good condition.
The damage to the railway tunnels is very low compared to the building damage. There is only one tunnel with a mean damage of 0.05 which is very low. It was expected that an earthquake of this magnitude and distance will not produce major damages to tunnels in general.

![Railway bridge damage for the “method testing” earthquake](image)

**Fig. 6.6 Railway bridge damage for the “method testing” earthquake**

The maximum mean damage to railway bridges is 0.11 which is not that small anymore. As expected the bridges closer to the epicentre as well the bridges with bad soil conditions have the highest values.
The damage to road bridges is similar to the damages to the railway bridges. As before the more southeast the more mean damage there is.
Fig. 6.8 Road damage for the “method testing” earthquake

The damage to the road network is quite large. The maximum mean damage is around 0.12.
6.2.2 Results for the “Neulengbach” earthquake

This case is very interesting since this earthquake has really happened in 1590. There are very few articles and data for the consequences of this earthquake, but it there were reported some major damage to some buildings in Vienna. The simulation also shows some potential of failure of some buildings. The maximum mean damage is around 0,14 with moderate damage probabilities up to 0,34.
Fig. 6.10 Railway tunnel damage for the “Neulengbach” earthquake

Fig. 6.11 Railway bridge damage for the “Neulengbach” earthquake
The damages to roads, road bridges, railway bridges and tunnels are very low. All the figures show the probability of reaching the damage state “slight” and the maximum value is 0.18. There were no reports of damages to these systems in the archive of the earthquake, so it is not expected that there was damage back in 1590.
7 Probabilistic Analysis: Vienna Input Data for OOFIMS

7.1 ANALYSIS

OOFIMS module allows to perform probabilistic analysis; Montecarlo method has been chosen, selecting a minimum value for the covariance of 0.02. 10000 runs have been performed.

7.2 SEISMIC HAZARD

Fig. 7.1 Seismic zones that could affect Vienna site

Fig. 7.1 shows the seismic zones that could affect Vienna site. The input is given in the .xls file of Fig. 7.2, providing for each subzone the coordinates of the polygon and the seismic specifics as the fault rake and the fault mechanism.

Akkar & Bommer ground motion prediction equation has been used, choosing the peak ground acceleration as primary Intensity Measure and area fault as source model. Expected values of magnitude can vary in the interval 4.8 - 6.2, according to the historical seismicity of the zone.

Vienna basin does not show susceptibility to landslide nor to liquefaction, therefore have no landslide/liquefaction effects been considered.
7.3 BUILDINGS

7.3.1 Land use plan, subcity districts, building census and building taxonomy

Brigittenau district has been divided into two land use zones, one in the north and one in the south (Fig. 7.4).
Fig. 7.4 Land use plan for Brigittenau district

Three sub-city districts are also considered: for each of them, general information concerning the buildings and their inhabitants (as respectively average building height and employment rate) has also been given as input.

Fig. 7.5 Sub-city districts of Brigittenau
In addition, 11 census tracts have also been identified (Fig. 7.6). While in the deterministic analysis performed with Eqvis, buildings have been input one by one, each one with its own characteristics, in Oofims probabilistic analysis, the buildings have been grouped into zones (census tracts) and for each of those zones, the structural features of the buildings have been statistically classified.

Then, for each typology of buildings, the more appropriate fragility curve has been selected. The final input, (Fig. 7.7 and Fig. 7.8), gives for each census tract the percentage of buildings associated to the fragility curve selected. The complete list of fragility curves (and their parameters) is listed in B: fragility functions - Buildings.
Fig. 7.8 Input file for Oofims: buildings tracts

The methodology to classify the building into census tracts is explained in details in the following subparagraph.

From building to census tracts

As stated in previous chapters, a visual assessment of buildings in the 20th district of Vienna has been conducted according to the form of A: buildings data collection form.

Recorded data provides not only structural information, but also an insight in social and infrastructural roles of buildings, which are important for developing accurate earthquake scenarios. In order to detect and summarize overall trends, data from several buildings is compiled in so called ‘census tracts’. One such tract consists of a variable number of buildings, depending on geographic distribution of buildings in a block. The data is processed in MS Excel with the help of macro programs.

In order to properly summarize properties of a census tract, it has to be decided which characteristics are used and how they are derived from the initial data. How the buildings are summarized to tracts depends on the geographical distribution of buildings. The geographical alignment of census tracts is shown in the one in Fig. 7.6.

Collected data were automatically organized into the census tracts by means of an automatic procedure using macros in MS Excel. Macros are written in Visual Basic, a programming language which provides further automation of processes. By inputting building numbers, the right data are then selected and the census tract characteristics automatically calculated, as listed in...
Table 7.1.
Table 7.1 Census tracts – calculated data

<table>
<thead>
<tr>
<th>Arithmetic average building height</th>
<th>Building height is measured from ground level to roof eaves.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic average traffic distance</td>
<td>Traffic distance of a building is defined as the minimum distance between building wall and road space.</td>
</tr>
<tr>
<td>Arithmetic average number of floors</td>
<td>Floors are counted including the ground floor.</td>
</tr>
<tr>
<td>Sum of business units</td>
<td></td>
</tr>
<tr>
<td>Sum of dwelling units</td>
<td></td>
</tr>
</tbody>
</table>

The first macro reads out and writes data, stored in different MS Excel files to a worksheet of the census tracts file. Therefore all necessary data for the calculation of the aforementioned characteristics is then located in the same file as where the results are calculated and stored. From this point on the file is independent of other files and information is exchanged only internally.

Table 7.2 shows which data is imported. In order to automatically read out information a uniform table layout is advantageous and reduces programing effort.

Table 7.2 Imported data table worksheet

<table>
<thead>
<tr>
<th>Build. Nr.</th>
<th>Build. Height</th>
<th>Floor s</th>
<th>Dwell Units</th>
<th>Traffic Dist.</th>
<th>Masonry</th>
<th>Reinf. Concrete</th>
<th>Steel Skeleton</th>
<th>Comments</th>
<th>Employees</th>
<th>Business Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>6</td>
<td>14</td>
<td>2</td>
<td>X</td>
<td>X</td>
<td>8</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>X</td>
<td></td>
<td>15</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16,5</td>
<td>4</td>
<td>15</td>
<td>5</td>
<td>X</td>
<td></td>
<td>10</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>6</td>
<td>16</td>
<td>5</td>
<td>X</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

The second macro calculates the arithmetic averages and sums for prior chosen buildings. Which buildings are used to calculate the census tracts is determined through a user form. The user form and result section layout is displayed in Fig. 7.9.
Statistical analysis of Brigittenau buildings

From the statistical analysis, it results that 70% of the buildings in the district are masonry buildings, the remaining 30% are reinforced concrete ones.

![Fig. 7.9 User input form and results worksheet](image)

![Fig. 7.10 Masonry and reinforced concrete buildings distribution in Brigittenau districts and sub-districts (pink are the reinforced concrete buildings)](image)
All the sub-districts have a preponderance of masonry buildings; only in the 5th sub-districts the percentage of reinforced concrete buildings is greater than the one of masonry buildings (Fig. 7.10).


### 7.4 ROAD NETWORK

Fig. 7.11 represents the road network in Brigittenau district. Two main roads cut the district in the north-south direction (Jägerstraße and Brigittenauer Lände in the western side, along the Donau Kanal). Wallensteinstraße links the east side (where also a freight harbour is) to the west side of the city through the Friedens bridge over the Donau Kanal.

![Fig. 7.11 Road Network in Brigittenau](image)

Each node of the RN is defined by its longitude & latitude; each side by its starting and ending nodes (Fig. 7.12 and Fig. 7.13).

From a functional point of view, starting and ending nodes on the north-south and east-west directions are defined as external nodes; the nodes where the main roads intersect are CBD-TAZ (Central Business District - Traffic Analysis Zones) type nodes; all the other are simple intersection nodes. All nodes are considered as not-vulnerable (Fig. 7.12).

Road sides (Fig. 7.13) are divided in principal (around 1000 vehicles per hour) and minor (600 vehicles per hour). Principal roads are classified as major arterials; among the minor
roads, we distinguished the primary collectors (those directly linking the major arterials to the smallest roads) and the secondary collectors (the viability of which in case of extensive collapses would not strongly affect the viability of other roads) (Fig. 7.14). The majority of road sides have 2 traffic lanes (roadsegmentA); Brigittenauer Lände has 4 traffic lanes (therefore considered as a roadsegmentB). All the sides are considered as vulnerable.

For each road it is also given its width, the distance with the adjacent buildings, specifying also if there are buildings on both sides or only on one side (Fig. 7.14).

The site characterization is expressed in terms of Vs 30 values (at nodes and sides), site class, and yield acceleration.

Neither tunnel, nor bridge is in the part of the district analysed, therefore only fragility for pavements have been used. In particular, two fragility functions form HAZUS have been used: pavement with 2 lanes and with 4 lanes (NIBS, 2004) (see B: fragility functions - Roads).

<table>
<thead>
<tr>
<th>Road ID</th>
<th>Location</th>
<th>Type</th>
<th>Damage Type</th>
<th>Vulnerable</th>
<th>Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 7.12 Road Network input: nodes
Probabilistic Analysis: Vienna Input Data for OOFIMS

Fig. 7.13  Road Network input: sides

Fig. 7.14  Road Network input: sides
7.5 WATER SUPPLY SYSTEM

Fig. 7.15 represents the Water Supply System (in orange) overlaid to the Road Network (in gray): in most of the cases Water Supply System follows the Road Network (with some exceptions). Three external points (one on the north, one on the west and one on the south-east) represent the constantank nodes that supply the water to the entire district (Fig. 7.16). No vulnerability is assigned to the nodes, while all sides are considered vulnerable.

Sides that deliver the water from the supply-nodes have bigger pipes diameter (1200 mm); the other sides have smaller diameter (600 mm). Only 2 diameter sizes are present (see top line of Fig. 7.16).

All the pipes are in castIron and lay 2 m under the ground level (Fig. 7.17).

Also here, the site characterisation is expressed in terms of Vs 30 values (at nodes and sides), site class, and yield acceleration.

![Fig. 7.15 Water Supply System overlying to the Road Network](image-url)
### Fig. 7.16 Water Supply System input: nodes

<table>
<thead>
<tr>
<th>Node</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>Name</th>
<th>Diameter</th>
<th>Length</th>
<th>Material</th>
<th>Depth</th>
<th>Vulnerable</th>
<th>Bit럽</th>
<th>Site Class</th>
<th>Depth 3D (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>Node1</td>
<td>200</td>
<td>500</td>
<td>Steel</td>
<td>200</td>
<td>Yes</td>
<td>B</td>
<td>C</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>21</td>
<td>31</td>
<td>Node2</td>
<td>300</td>
<td>600</td>
<td>Plastic</td>
<td>300</td>
<td>Yes</td>
<td>B</td>
<td>C</td>
<td>150</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

### Fig. 7.17 Water Supply System input: sides
7.6 ELECTRIC POWER NETWORK

The Electric Power Network follows the layout of the Water Supply System (Fig. 7.18).
Two generator nodes are identified: one on the west side of the district where the thermal waste treatment plant of Spittelau is; the other one on the east side.
The network lay underground and has a voltage of 230 kV.
Also here, the site characterisation is expressed in terms of Vs 30 values (at nodes and sides) and site class (Fig. 7.20).

Two set of 10000 runs have been performed: the first simulation considers interdependency among electric power network and water supply system, the second instead considers the two systems not dependent one from the other.

Fig. 7.18 Electric Power Network overlying to the Road Network and to the Water Supply System
Probabilistic Analysis: Vienna Input Data for OOFIMS

Fig. 7.19 Electric Power Network input: nodes

Fig. 7.20 Electric Power Network input: sides
8 Probabilistic Analysis: Output from OOFIMS

8.1 AVERAGE RESULTS

In the output of Oofims calculation the case study area is subdivided into cells and calculations are performed for each cell. Cell dimension is approximately 100x100 m (Fig. 8.1).

Fig. 8.1 Output of Oofims calculation: the case study area and cells where calculations are performed

The results reported below refers to the case which interdependency is considered among the water supply system and the electric power network. In particular in what follows we report the data obtained by averaging the results of each run over the total number of runs. This implies that damage level (for buildings, roads, water supply system, and electric power network) spans in the range 0-1, while deaths and injured average (being obtained as sum of affected persons divided by 10000) can have different range.

8.1.1 Buildings

Fig. 8.2 and Fig. 8.3 present respectively the damage distribution and the affected persons in the area of interest. Biggest damage level and death/injured persons are manly concentrated in the south zone of the district where there are almost only masonry buildings.
Fig. 8.2 Average building collapse distribution (left) and building yielding distribution (right)

Fig. 8.3 Average death (left) and injured (right) distribution
Analyzing the mean annual frequency of exceedance and the moving average (Fig. 8.4) one can obtain:

*Mean annual frequency of exceedance – deaths - 500 years return period earthquake:*

\[0.7 \times 10^{-3} \times 35402 \text{ (inhabitants)} = 24 \text{ (deaths)}\]

*Moving average – deaths – 10000 runs:*

\[1.1 \times 10^{-4} \times 35402 \text{ (inhabitants)} = 3.84 \text{ (deaths)}\]

*Fig. 8.4 Mean annual frequency of exceedance and moving average (death persons)*

This means that for an earthquake with 500 years of return period, expected fatalities are 24 while over 10000 runs average dead persons tends to the value of 4.
From Fig. 8.5:

**Mean annual frequency of exceedance – injured persons - 500 years return period earthquake:**

\[ 1.9 \times 10^{-3} \times 35402 \text{ (inhabitants)} = 67.26 \text{ (injured persons)} \]

**Moving average – injured persons – 10000 runs:**

\[ 3 \times 10^{-4} \times 35402 \text{ (inhabitants)} = 10.62 \text{ (injured persons)} \]

---

**Fig. 8.5 Mean annual frequency of exceedance and moving average (injured persons)**

Expected casualties for a 500 years return period earthquake are around 62 and average injured person is around 10 persons.
8.1.2 Roads

Analyzing the roads damage, we get that blocked as well as unusable ones are concentrated in the proximity of collapsed buildings (compare Fig. 8.6 with Fig. 8.2).

![Fig. 8.6 Average blocked roads (left) and unusable ones (right)](image)

8.1.3 Water supply system

Pipes and nodes of the water supply system results to be slightly affected from the earthquake and average level of damage is negligible (Fig. 8.7).
8.1.4 Electric power network

Also the electric power network results to be slightly damaged as shown in Fig. 8.7.
8.2 SELECTED SCENARIO

Among the 10000 runs, a particular scenario has been selected. It presnets a 5,4 magnitude earthquake located in the south-east of Vienna, at a distance of 50 km circa from Brigittenau district (Fig. 8.9). The selected scenario is considered meaningful since it is in the proximity of the tectonic zone of the Austrian region more prone to seismicity.

This scenario produces a pga distribution as in Fig. 8.10. For the sake of simplicity, the values refer to hard rock, realistic ones should account of soil typology in each point of the calculation.

Fig. 8.9 Location of the selected scenario: M = 5,4 earthquake in the south-east of Vienna, about 50 km far from Brigittenau district

Fig. 8.10 Pga on rock for the selected event of M = 5,4
8.2.1 Buildings

Fig. 8.11, Fig. 8.12 and Fig. 8.13 present respectively the distribution of collapsed and yield buildings, death and injured persons and displaced persons in case of good and bad weather conditions.

Deaths distribution is in accordance with the collapsed buildings. Major damaged are registered, as in the averaged results, in the south of the district where mainly masonry buildings are present.

Fig. 8.13 shows the distribution of displaced persons: the main difference among the case of bad weather and good weather is that in the first case it increments the number of displaced persons in the north part of the district where reinforced concrete buildings are mainly present.

Fig. 8.11 Number of buildings collapsed (left) and yield (right) for the selected event of $M = 5.4$
Fig. 8.12 Number of deaths (left) and injured (right) persons for the selected event of $M = 5.4$.

Fig. 8.13 Number of displaced persons in case of bad weather (left) and good weather (right).
8.2.2 Roads

Road damage is presented in Fig. 8.14. It confirms the tendency already identified in the analysis of the average damage with blocked and unusable roads mainly located in the south of the district.

Fig. 8.14 Blocked roads (left) and unusable ones (right) for the selected scenario

8.2.3 Water supply system

Selected scenario does not produce any damage to the water supply system as it could be expected considering that the average damage level obtained before resulted to be negligible.

8.2.4 Electric power network

Finally, Fig. 8.15 presents the damage level that affects the electric power network.
Fig. 8.15 Damage level on the electric power network for the selected scenario

Table 8.1 reports the summary of damage caused by the selected event.

### Table 8.1 Data from the selected event

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Count</th>
<th>Damage Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPN - Broken Transmission Stations</td>
<td>0</td>
<td>BDG - Deaths</td>
<td>4</td>
</tr>
<tr>
<td>EPN - Non-functional demands</td>
<td>10</td>
<td>BDG - Injuries</td>
<td>19</td>
</tr>
<tr>
<td>WSS - Broken pipe</td>
<td>0</td>
<td>BDG - Collapse</td>
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<td>WSS - Non-functional demands</td>
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<td>BDG - Displaced (BW):</td>
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8.3 INTERDEPENDENCY AMONG WATER SUPPLY SYSTEM AND ELECTRIC POWER NETWORK

Fig. 8.16 compares the mean annual frequency of exceedance for the weighted connectivity loss of the water supply system in case interdependency with the electric power network is considered or neglected.

It results that for an earthquake with 500 years of return period, the weighted connectivity loss for the water supply system is around 0.23 when interdependency with the electric power network is considered, while it increments to 0.28 when it is neglected.

Fig. 8.16 Weighted Connectivity Loss for the water supply system with and without interdependency with the electric power network
References

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Initial data was collected through visual assessment of buildings, described in the following document.

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<tr>
<td>22 Humidity/Efflorescence</td>
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<td>23 Damage on the Roof</td>
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## Additional Information to the Protocol

### 00 Checklist
- Equipment: Protocols, digital camera, laser - telemeter, measuring tape

### 01 Photonenumber
In this field, the photonumbers of the memory of the camera have to be noted in order to know which pictures belong to the different buildings.

### 02 Building Usage
This is a pretty important field. It describes the general usage of the building, like apartment building, school, kindergarten, hospital, office building, etc. If the building usage is not limited to one category the percentage of the usage categories have to be identified. Example: Apartments (70%), Offices (30%)

### 03 Construction Year
The construction year of a building can be determined if there is a sign at the facade of the building. If there is not such a sign, and the construction year cannot be determined this field should be empty. It is much better to analyse this building later if needed, than to have a wrong construction year.

### 04 Construction Type
The construction type can be hard to identify in the field and without appropriate additional knowledge. What can be determined easier is the construction material. It is very helpful if one knows the year of construction, because in certain periods construction materials were very similar.

### 05 Dwelling Units
The number of dwelling units can easily be determined in the entrance area of a building by looking at the number of door bells or the number of mail boxes. All dwelling units, even not used ones, should be counted.

### 06 Persons
This field addresses the number of people living or working in areas not depicted as dwelling units like shops at the basements, cafes, etc. The number can only be approximated, but this number should depict the maximum number of people that can stay in the building.

### 07-09 Ground Plan

- **Corner Building**

- **Adjacent Buildings**

- **Adjacent Building only on the left side**

- **Rectangular Ground Plan**

- **No Rectangular Ground Plan**
11 Distance to Traffic Area

The distance to traffic area means the lowest distance between building and street. Parking areas and sidewalks do not count as traffic areas and should not be considered. The purpose of this distance is to know whether street can be blocked by building debris or not.

12 Number of floors

This number represents all floors, including the ground floor. Attention has to be paid to additional attic space. Attic space should only be counted if the housing area is more than 50% of the ground floor area.

13 Building Height

Building height is defined as the height from the top edge of the sidewalk to the beginning of the cornice. If the building height is being approximated this has to be noted. If the building height cannot be measured directly one can also use the measuring tape, put it to the wall of the building and take a photo. The building height can then be determined afterwards. The same procedure can also be done with balconies, etc.

14 Shops at the Ground Floor / Soft Story

If there are shops or cafes at the ground floor, this has to be noted here. Most of the time, if there is a shop at the ground floor this floor represents a soft story. A soft story is a floor (does not have to be the ground floor) where most of the interior walls are missing due to the space needed.

![Shop at the Ground Floor](image)

15 Additional Attic Space

This attic space can often be determined by looking at the windows at the attic or due to the existance of balconies.

![Additional Attic Space](image)

16 Number of Windows and Doors

The first priority is to determine the number of windows and doors at the facade facing the street. If it is possible to determine the numbers also for the sides facing the courtyard, do so.
17 Facade design

- none
- simple
- detailed

- very detailed

18 Chimneys

This is the number of chimneys one can see from the outside of the building.

- 7 chimneys

19-20 Non-Structural Members

Non-structural members are all structures that can fall down in the case of an earthquake (sculptures, statues, balconies,...) Shop sign or other signs also fall into this category and have to be counted.
21 Condition /Cracks
This mainly means the cracks in the walls. It should if possible be distinguished between cracks on the facade (they should not be counted) and cracks in the walls. If the crack is going diagonal it should be counted anyways.

22 Condition / Humidity
Humidity and Efflorescence can often be seen at the different colors at the facade.

23 Damage at the Roof
Damages at the roof can often be determined if one can see humidity at the facade. If it is possible to get into the building, one should make photos and document it well. Damages at the roof can be very dangerous if not properly treated.

24 Anomalies/Irregularities
If there is anything out of the ordinary, that is not explicitly in the checklist this is the place to write it down. If anything is written down here, it should always be documented with a photo if possible.
B: fragility functions

BUILDINGS

Borzi et Al 2007-RC - 8 storeys-SeismicallyDesigned (c = 10 %)

Sample Data. Buildings: Random population of buildings is generated using Monte Carlo simulation where random variables are used to describe the geometry and the material properties of the structures.

The uncertainties in the geometric and material properties are accounted for in the methodology.
Sample Data. Buildings: Random population of buildings is generated using Monte Carlo simulation where random variables are used to describe the geometry and the material properties of the structures.

The uncertainties in the geometric and material properties are accounted for in the methodology.

Seismic hazard: 100 recorded accelerograms from different parts of the world.

Structural variability is taken into account by considering the structural input parameters (period T and strength ratio h) as random variables, and ground motion uncertainty is taken into account by selecting a set of records with different characteristics.

Reference fragility curves are generated for different classes of reinforced concrete structures. Furthermore, the sensitivity of the parameters and techniques involved in the generation process are investigated: the effect of post-yield to initial stiffness ratio variability (negligible), sampling technique (negligible), sample size (negligible), limit state variability (significant), degrading hysteretic behavior (significant).

Seismic hazard: 100 recorded accelerograms from different parts of the world.

Structural variability is taken into account by considering the structural input parameters (period $T$ and strength ratio $h$) as random variables, and ground motion uncertainty is taken into account by selecting a set of records with different characteristics.

Reference fragility curves are generated for different classes of reinforced concrete structures. Furthermore, the sensitivity of the parameters and techniques involved in the generation process are investigated: the effect of post-yield to initial stiffness ratio variability (negligible), sampling technique (negligible), sample size (negligible), limit state variability (significant), degrading hysteretic behavior (significant).
Erberik 2008 - RC - mid-rise infilled frame MRIR:


Seismic hazard: 100 recorded accelerograms from different parts of the world.

Structural variability is taken into account by considering the structural input parameters (period T and strength ratio h) as random variables, and ground motion uncertainty is taken into account by selecting a set of records with different characteristics.

Reference fragility curves are generated for different classes of reinforced concrete structures. Furthermore, the sensitivity of the parameters and techniques involved in the generation process are investigated: the effect of post-yield to initial stiffness ratio variability (negligible), sampling technique (negligible), sample size (negligible), limit state variability (significant), degrading hysteretic behavior (significant).
Erberik and Elnashai 2004 – RC Flat Slab - mid-rise infilled frame MRINF:

Sample Data. Buildings: schematic 5-story flat slab structure designed according to the regulations of ACI 318-99

Seismic hazard: 10 spectrum-compatible recorded accelerograms.

The yield strength of steel and the compressive strength of concrete have been chosen as the random variables. In particular, a lognormal distribution is assumed for the yield strength of steel (mean= 475 MPa and cov = 6 %) and a normal distribution is employed for the variability of concrete strength (mean= 28 MPa and cov = 15 %). To treat uncertainty, Latin Hypercube Sampling (LHS) Technique is employed.

The developed curves were compared with those in the literature derived for moment-resisting RC frames. The study concluded that earthquake losses for flat-slab structures are in the same range as for moment-resisting frames for low limit states, and considerably different at high damage levels. This is due to the different structural response characteristics of the two structural forms.
Sample Data. Buildings: earthquake-damaged Greek buildings + a large number of building types are modeled and analyzed. Seismic Hazard: real earthquakes (1978 Thessaloniki earthquake) and 16 accelerograms.

The hybrid approach combines statistical data with appropriately processed results from nonlinear dynamic or static analyses.

Three primary sources of uncertainty are taken into account: uncertainty in the definition of damage state, variability in the capacity curve and uncertainty associated with the seismic demand.
RISK-UE2003 – RC Moment Frame-HR-HC-UTCB Hybrid Approach

![Graph showing fragility functions]

<table>
<thead>
<tr>
<th>Parameters:</th>
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<th>Complete</th>
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RISK-UE2003 – RC Moment Frame - LR-HC-UTCB Hybrid Approach

Parameters:

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Sample Data. Buildings: RC structures in Macedonia constructed with modern practice. Actual seismic design code (1981). Seismic Hazard: An extensive strong motion database from 1979 Montenegro earthquake is used. Some world-wide earthquake records as well as local strong motion data from 1994 Bitola earthquake are also included in the stated set.
Vargas Et Al 2010 – RC - 8storeys

Sample Data. Buildings: family housing, regular in plant, with waffle slabs instead of beams. 8 storeys.

Seismic Hazard: Eurocode 8, Type 1 for soil type D is taken as target spectrum. A series of accelerograms from Spanish database and European database with mean elastic response spectrum compatible with the target spectrum are considered.

The uncertainty of the mechanical properties of the materials and the uncertainty of the seismic demand are taken into account.
Borzi Et Al 2008b-MA Brick - High Percentage Voids – 2 storeys

Sample Data. Random population of buildings is generated using Monte Carlo simulation where random variables are used to describe the geometry and the material properties of the structures.

The uncertainty in the capacity of the buildings and in the displacement demand is taken into account.

The fragility curves have been generated for In-Plane failure mechanism and for Out-of-Plane failure mechanism.

They use an alternative approach to compute the performance point taking into account the definition of the input motion in terms of a power spectral density function and an equivalent stationary time duration $T$. 
RISK-UE2003 - M12-HR-UNIGE Approach

Parameters:

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</table>
Borzi Et Al 2008b – MA Brick-Low Percentage Voids - 4storeys

Sample Data. Random population of buildings is generated using Monte Carlo simulation where random variables are used to describe the geometry and the material properties of the structures.

The uncertainty in the capacity of the buildings and in the displacement demand is taken into account.

The fragility curves have been generated for In-Plane failure mechanism and for Out-of-Plane failure mechanism.
RISK-UE2003- M12-LR-UNIGE Approach

![Graph showing probability of exceedance vs. Sd(T.S) [cm]](image)

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ROADS

Pavement, 2 lanes (NIBS, 2004):

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Pavement, 4 lanes (NIBS, 2004):

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