Relation between BMI and Exit Time of a Building in an Emergency Situation: Earthquake

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Abstract—**This paper states a research on what is the relation established between the Body Mass Index (BMI) and the exit time of people inside of the building when an earthquake takes place. To accomplish this goal in this article is presented a case of study in where is develop a simulation that uses as physical infrastructure a graph representation of a university building in Ecuador. The sensor nodes and the evacuation routes are also represented in this simulation. On the other hand, the study is developed using metrics as the earthquake magnitude, the body mass index, nature of soil, footwear and clothing, all of this variation combined between them allow to determine the relation of BMI and exit time in an emergency situation.**

As a result of this work solid conclusions are obtained, displaying the statements as the BMI is related to the exit time independently of the speed of the people, the clothing that one person is using at the moment of an emergency affect the time that they need to evacuate and it is increased with the type of shoes when walking. Another important topic that influence at the exit time is the type of soil, because it generates a considerable reduction of the speed of the person to go to an exit door. Finally, all of the experiments and the result of that are introduced in the body of this document and additional information in the appendix section.

Index Terms—**BMI, earthquake, building, exit time, emergency situations, escape routes.**

I. Introduction

AT the present time, earthquakes have occurred throughout the world, especially in those countries that integrate the Pacific Ring of Fire, which causes a series of meteorological events due to intense seismic and volcanic activity. Among the countries that include the ring of fire are: Chile, Argentina, Bolivia, Peru, Ecuador, Colombia, Panama, Costa Rica, Nicaragua, El Salvador, Honduras, Guatemala, Mexico, United States, Canada, and down the coasts Indonesia, Malaysia, East Timor, Brunei, Singapore, New Guinea, Solomon Islands, Tonga, Samoa, Tuvalu and New Zealand [1]. Volcanoes are not uniformly distributed on the planet, but are where the geological activity is greater. For this reason, the Pacific Ring of Fire concentrates 75% of the world's active volcanoes, which means that up to 90% of earthquakes occur. There are also numerous islands and archipelagos, as well as volcanoes located above the subducting plates; for example: the Arch of the Aleutian Islands and the Kuril Islands [2]. The volcanoes and earthquakes of the ring of fire awaken fascination and fear in the people living in these countries, since they bring with them beauty but at the same time serious natural disasters.

Due to the urban habitat of Latin America, a natural disaster such as: forest fire, the eruption of volcanoes and earthquake, can become a catastrophe both in the loss of material goods as that of living beings. The geographical situation, climatic, geological and Geo-technical conditions of Latin America are affected by a number of natural phenomena, damaging both the population, the environment and the socioeconomic development of these countries. Historically, these climatological events are not new, but the population growth in rural and urban areas are [3]. In these regions, natural phenomena such as floods, cyclones, etc., occur during foreseeable periods, especially during the rainy season. The instability of the soil and particularly in the urban areas where the poorer populations settled, combined with the lack of urban planning, increases the vulnerability of the countries of Latin America. Urban environmental risks result from the combination of several factors linked to threats of natural and/or anthropogenic phenomena multiplied by the level of socioeconomic vulnerability of the affected societies [4]. The municipalities or autonomous governments of these countries have been willing to take action in order to protect the peoples of these communities [5]. Based on this, a prototype of a reactive evacuation system is being developed at the Escuela Superior Politécnica del Litoral (ESPOL), which allows people in the different buildings on the campus to be evacuated to the nearest exits [6]. This article focuses mainly on knowing the impact of the BMI in the time it takes a person to leave a building when they are in the presence of an earthquake, through the results of a simulation exposed to different scenarios, such as: Different magnitudes of an earthquake, Types of soils (wood, concrete, ceramics and marble) and clothing of men/women, using the Dijkstra Algorithm to calculate optimum escape routes of a building of three floors with reference to the Main Building of the ESPOL.

This paper is divided into six sections:

Section I is the introduction of this research, by showing the current situation in places where this type of study is necessary and presenting the motivation for developing new strategies in order to reduce the number of victims in natural disasters as earthquake and others.

Section II represents the problems that involve the natural disasters in Latin America, which is where the case of study is developed. Moreover, the type most common natural disasters that affect these zone is described, the prevention strategies used to reduce the number of victims of this event, and finally, how the technology has been developed in order to be applied in this type of application.

The section III is focused in present the variables involved

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in the problematic of safeguarding people in case of an earthquake. The main parameters needed to evaluate the impact of earthquakes. The seismic waves, earthquake magnitude and seismic intensity are also presented for being introduced as parameters in the case of study.

The section IV states, all the environment used to deploy the study, starting from the physical infrastructure used for the analysis, which includes the type of sensors to monitor the building, the escape routes defined in this setup, using a graph representation of the building.

In section V is where the simulation is conducted and tested with all the variables needed to determine the relationship between BMI by the exit time, this includes the earthquake magnitude, the body mass index, nature of soil, footwear and clothing. Finally, with the simulation and tests conducted with these variables, in section VI presents the results and discussions derived from this work, and also generate the tables and curves presented in the appendix section. The results of all of the work developed in the previous section, are presented in section VII generating the conclusions and future works.

II. Natural Risks in the Urban of Latin America

The countries of Chile, Peru, Ecuador and Colombia due to their geographical situation present a greater problem in the coastal zone; these are located at the intersection between the Nazca plate and the South American plate [7], making them more vulnerable to natural disasters. Governments facing these crises must act immediately, as indicated by Jrome Chandes, with a report on the logistical coordination that must exist in human management in the face of disasters; Giuseppe Damiano, with a proposal of rescue intervention during the earthquakes; Joaqun Aguilar, different cases of emergencies in the city of La Paz (Argentina); Robert D 'Ercole, Urban Vulnerabilities and Crisis Management in Quito [8], and Jos Sato, with a scenario, design on the impact of a major earthquake in Lima [9].

The sustainable development of a society poses major challenges at the regional, national and local levels, because the timing of a catastrophe or how much damage it causes in the communities is not known exactly [10].

A. Natural Disasters

Natural phenomena such as earthquakes, floods, landslides, mud-flow, avalanches, hurricanes, cyclones, tornadoes, tsunamis, volcanic eruptions, droughts, fires, erosion and deposition of soils, among others, are the natural phenomena which most affect the countries of Latin America. However, this is predictable for several reasons [4]:

- The countries of Latin America are located between the two tropics (Cancer and Capricorn) and its coasts are bathed by the Atlantic and Pacific Oceans, attracting their lands the humidity of both.
- In tropical regions, solar radiation is almost perpendicular to the earth's surface, so air tends to rise by decreasing its density as it expands with increasing temperature. On the other hand, the intense solar radiation generates in the hot oceanic waters a high evaporation.

According to Maskrey <<*A natural disaster is the coincidence between a dangerous natural phenomenon and certain vulnerable conditions*>>, a daily threat in several countries [10].

B. Prevention

It is common to speak of the increase in disasters, especially in the areas occupied by marginalized population groups, as well as the weakness of relevant organizations to respond to the growing demand for needs [11]. However, some countries have taken up disaster risk management, a clear example of which is Ecuador since 2008, when the national government assumed responsibility for the humanitarian response in the recovery and reconstruction process with a risk reduction approach. Mara del Pilar Cornejo de Grunauer (Secretariat for Risk Management), presented a report based on the five priorities of the Hyogo Framework for Action (2005-2015):

- Ensure that disaster risk reduction is a national and local priority, with a strong institutional basis for its implementation.
- Identify, evaluate and closely monitor disaster risk and improve early warning.
- Use knowledge, innovation and education create a culture of security and resilience at all levels.
- Reducing underlying risk factors
- Strengthening disaster preparedness for effective response

Using these aspects to improve, Ecuador step from being a recipient of humanitarian aid to donor, i.e.; Offers assistance to different countries that have suffered some eventuality. The Ecuadorian Ministry of Defense states: <<*We protect these citizens from floods, mudslides, fires and the effects of volcanic activity. We contribute to the regional integration and to the reconstruction of the brother countries like Cuba and Haiti through the engineers of the army*>> [12].

C. Population Train

Disasters are impossible to prevent, but given their negative impact can be reduced or avoided by some actions, such as; Installation of early warning systems and evacuation plans. But, it is useless if people are not properly aware to act effectively in an emergency, e.g.; Teaching children in schools react to earthquakes, train adults through advertising posters and conduct drills that clearly indicate what to do at the moment [13]. Technology has become an essential part of everyday life, then; Why not use it for disaster training?, says Ivan Marcelo and Jose Valencia [14], with the development of interactive application for digital television in order to guide the population in natural disasters.

D. Technology for the Benefit of the Community

In the 1990s, the United Nations sponsored the International Decade for Natural Disaster Reduction (IDNDR) to reduce losses caused by natural disasters [15], [16]. Since then, it studies have been carried out to safeguard lives with the help of technology. These include: Chen-Yuan Chen et al. [17], which describes natural disaster prevention programs using virtual reality for the purpose of obtaining an understanding of the use of information system and acceptable behaviors, mainly the acceptance of users of virtual reality, as well as provide a reference for future disaster prevention programs, or by LI Jing-qi, XIA Ji, which propose the creation of disaster prevention parks and emergency shelters. Like these, there are many different proposals that have a single and strong purpose *Save and Protect Lives* [18].

III. Earthquakes

An earthquake is a sudden movement or vibration caused by the sudden relaxation of energy, accumulated by deformation of the lithosphere, which propagates in the form of seismic waves. These are presented instantly causing serious damage, depending on their intensity, this makes it one of the most damaging and destructive natural disasters on the planet. These causes several damages directly to the people, for example: death, injuries, destruction of homes, loss of family members and in turn bring with them other natural phenomena that are unleashed by the action of an earthquake, e.g.: landslides, Floods, tsunamis, epidemics, etc. [19].

Earthquakes Tectonic: They occur due to the sudden and violent rupture of the rocks due to the deformation that has accumulated in the medium. These usually occur where the concentration of force by the tectonic plates results in readjustments on the surface of the Earth. In an earthquake are distinguished:

- *Hypocenter*: Deep inner zone where the earthquake occurs.
- *Epicenter*: Area where there is the highest intensity of seismic waves.

A. Seismic Waves

Seismic waves are produced by the release of mechanical energy in the process of rupture in the seismic source and are the ones that transport seismic energy from the focus to the place. There are *Internal*: They travel in all directions from the seismic focus, and *Superficial*: They are generated by the composition of the surface layers and propagate fundamentally in the most superficial areas of the Earth [19].

1) P Wave: They are longitudinal internal waves similar to sound waves, which produces movements of the particles in the same direction of propagation of the wave and what causes the rock to compress and dilate to its path (First waves to arrive due to its speed of propagation). (Figure 1)

2) S Wave: They are transverse internal waves, that make lateral vibrate the rock producing sharp effects (They arrive second and are waves of greater energy). (Figure 1)

3) Surface Waves: They are waves that propagate on the earth's surface, carry a lot of energy and can cause serious damage. There are two types: Wave Love and Rayleigh. (Figure 1)

B. Earthquake Magnitude

The size of earthquakes is measured with magnitude, which is an instrumental measure based on the magnitude of the seismic wave amplitude recorded by a seismograph.

Local Magnitude $(\mathbf{M}_l)$ This scale was defined by Richter (1935)[20] for earthquakes in California from the amplitude measurements of a Wood-Anderson (W-A), (Period To = 0.8, maximum amplification = 2800 and damping ratio Y = 0.8), as [19], [21], [22]:

$$\mathbf{M}_L = Log\mathbf{A}_L(\mathbf{D}) + \mathbf{F}_L(\mathbf{D})$$

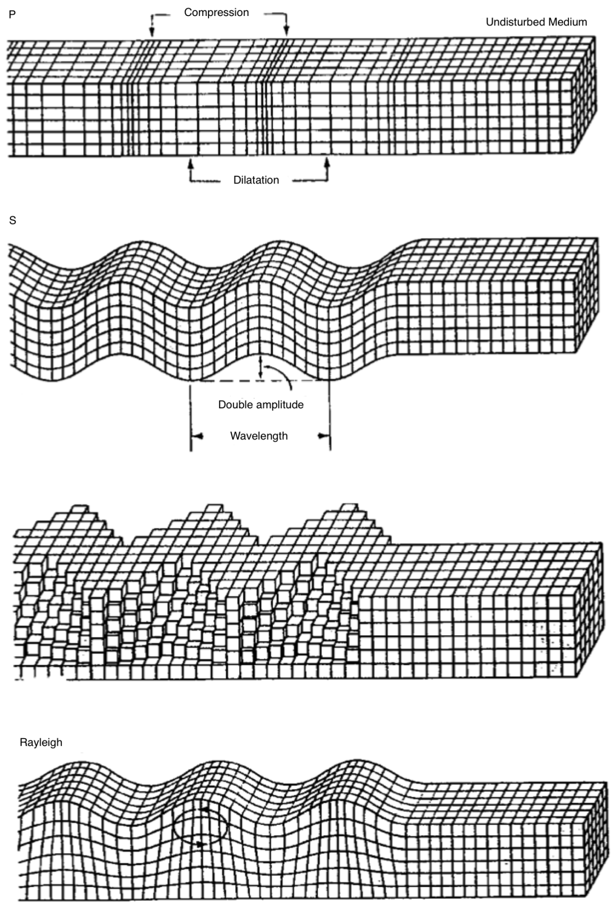

Fig. 1. Schematic Representation of Soil Movement for Different Types of Seismic Waves [19]

Where $\mathbf{A}_L(\mathbf{D})$ is the maximum amplitude of the horizontal register on a seismograph (W-A) located at a distance $\mathbf{D}$ from the epicenter and the calibration function $\mathbf{F}_L(\mathbf{D})$ is:

$$\mathbf{F}_L(\mathbf{D}) = -Log\mathbf{A}_o(\mathbf{D}/\mathbf{M}_L = 0)$$

Where $\mathbf{A}_o$ is the maximum amplitude, in millimeters, for an earthquake of zero magnitude recorded at distance $\mathbf{D}$, as shown in Table I:

TABLE I
Calibration Function of Magnitude

$\mathbf{D}$	$\mathbf{F}_L(\mathbf{D})$	$\mathbf{D}$	$\mathbf{F}_L(\mathbf{D})$	$\mathbf{D}$	$\mathbf{F}_L(\mathbf{D})$	$\mathbf{D}$	$\mathbf{F}_L(\mathbf{D})$
0	1.4	90	3.0	260	3.8	440	4.6
10	1.5	100	3.0	280	3.9	460	4.6
20	1.5	120	3.1	300	4.0	480	4.7
30	2.1	140	3.2	320	4.1	500	4.7
40	2.4	160	3.3	340	4.2	520	4.8
50	2.6	180	3.4	360	4.3	540	4.8
60	2.8	200	3.5	380	4.4	560	4.9
70	2.8	220	3.6	400	4.5	580	4.9
80	2.9	240	3.7	420	4.5	600	4.9

C. Seismic Intensity

Seismic intensity (I) is a measure based on the effects of terrain, structural damage and the way the earthquake is felt by people [19], [23].

IV. Incidence and Evaluation Factors

Evacuation routes represent an exit from the building for each user, but each person experiences a different sensation in an earthquake. To do this, the factors affecting users and the evaluation metrics that will be taken into account are detailed below.

A. Earthquake Magnitude

To simulate and plot quake/AE data using a heterogeneous Poisson process of thinning method, based on the Local Magnitude (Richter). To do this, the earthquake simulation of Andres Bell et al. [24] is used, in which the values of: *Failure Time: 1000, Power-law exponent: 0.9, Power-law amplitude: 50 and Minimum catalog magnitude: 3.5*, must be set to obtain values of magnitude in a time interval Δt, as shown in Figure 2:

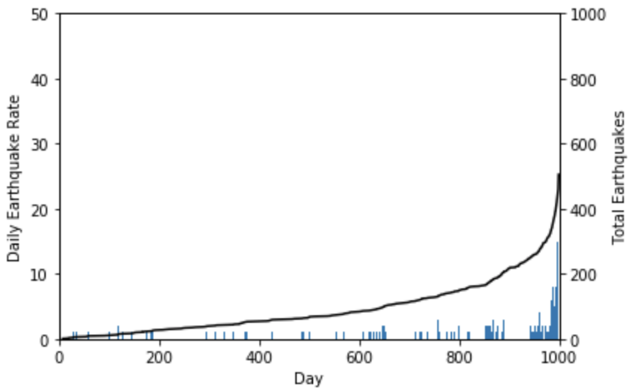

Fig. 2. Total earthquakes produced in the days and Daily Earthquake Rate

In Figure 3, it is important to note that the minimum magnitude of an earthquake is 3.5 (Richter); Although it is a value almost imperceptible to humans (depending on what is performing at the time of the incident). In addition, for all magnitudes it is assumed that the earthquake occurs 10.0 km deep below the earth's surface.

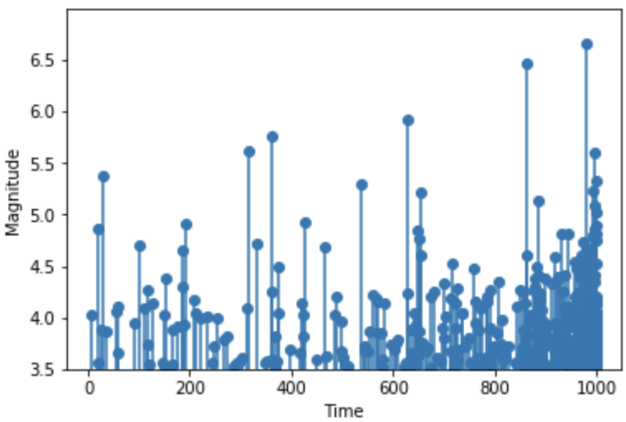

Fig. 3. Different magnitudes of earthquakes in the simulation

B. Body Mass Index

Body mass index (BMI) is the recommended parameter by the World Health Organization (WHO) to assess the nutritional status of subjects aged less than 20 years. However, during puberty the correlation between BMI and fat mass decreases notably [25].

The BMI can not be applied with the same values to children and adolescents due to growth and body development variables, therefore a BMI is obtained with respect to **AGE** and **SEX**, using the equation 1 [26], For the correct interpretation of the BMI, we use the Table II:

$$\text{BMI} = weight/height^2(Kg/m^2) \tag{1}$$

TABLE II
CLASSIFICATION OF BMI ACCORDING TO THE SPANISH SOCIETY FOR THE STUDY OF OBESITY

BMI Male	BMI Women	Interpretation
<20	<20	Under weight
20 - <25	20 - <24	Normal
25 - <30	24 - <29	Obesity Mild
30 - <35	29 - <33	Average Obesity
35 - <40	33 - <37	Severe Obesity
>=40	>=37	Very Severe Obesity

BMI is one of the most important factors in this study, because there is a relationship with the speed at which an individual moves. As indicated by Zoltan Pataky et al. [27] ,in the study of the effects of obesity on functional capacity, given as one of the results Table III, on which we have based ourselves to express the speeds of the individual within the building.

TABLE III
RELATIONSHIP BETWEEN BMI AND THE SPEED OF AN INDIVIDUAL

-	Speed (m/s)	
BMI	Normal Walking	Fast Walking
<20	1.53	2.11
>= 20 <25	1.50	2.03
>= 25 <29	1.43	1.93
>= 30 <35	1.34	1.82
35 <40	1.18	1.73
40	1.15	1.63

C. Nature of the Soil

The human walks differently according to the type of terrain on which he/she moves; Parquet, carpet, cobbled street, asphalt, sand, grass, snow or ice, rising and falling slopes, etc. It has been observed that foot impacts on the ground increase when walking on hard pavements such as asphalt, while softening when the subject walks on natural soils such as wood, grass or sand [28].

The speed with which a user walks depends on the surface, this is because there is a friction force $\mathbf{F} = \mu\mathbf{N}$ that causes some resilience between both surfaces (Floor-Shoes) [29]. For this reason, it has been considered to alternate the user speed between the different nodes that compose the evacuation route of the building, following as a model the study of Aikaterini and Tianjian [30], where they present the frequency and speed of the people when walking, resulting in the Table IV.

TABLE IV
DIFFERENT SPEEDS OF A PERSON WHILE WALKING ON A DIFFERENT SURFACE

-		Speed (m/s)	
Node	**Type of Soil**	***Men***	***Women***
ns	wood	1.37	1.30
no, np	ceramics	1.45	1.37
nlb	marble	1.43	1.32
ne	concrete	1.48	1.40

D. Footwear

The population usually uses footwear to protect the foot against wounds, bumps, dampness and cold. In special circumstances (industrial, sporting), these footwear must have particular characteristics and be designed in such a way as to facilitate the carrying out of an activity.

The characteristics of the footwear that most influence the march are the heel (height and width), the capacity of cushioning, the weight of the footwear, material, control of movements, size, etc. These characteristics can modify the intensity of the plantar pressures and their distribution, they can influence the posture and stability of the subject, in the march, and can even cause pain and diverse injuries [28].

Heel: Women are the ones that present the most alterations and pathologies associated with the fact of using footwear, mainly by the use of shoes of high heel. This modifies the position of the foot and the rest of the body, which causes an alteration in the posture, modification of the distribution of loads and foot pressures, related to alterations in walking and contact with the ground (Table V and VI) [28].

E. Clothing

The characteristics of clothing can condition the way of walking; The weight of the clothes, the comfort or discomfort of the same, that is pleasant and allows or not to carry out the movements properly. For example, a very heavy coat makes the subject walk a little stooped, or a very narrow skirt makes walking small steps (Table VI and VII) [28].

TABLE V
FACTORS AFFECTING MOBILITY IN WOMEN

Wear	**Weight (g)**	**Formal wear**		**Informal wear**	
		Light	*Heavy*	*Light*	*Heavy*
Rings (3)	15	x	x	x	x
Belt	50	-	x	-	-
Clock	60	-	-	x	x
Lycra Stockings	5	x	x	-	-
Underwear	50	x	x	x	x
T-shirt	80	-	-	x	-
Long sleeve shirt	110	-	x	-	x
Stockings 3/4	200	-	-	x	x
waistcoat	60	x	x	-	-
dress	100	x	x	-	-
skirt	140	x	x	x	x
short	200	x	x	x	x
jean	550	x	x	x	x
Slippers	300	-	-	x	x
Little boots	400	x	x	-	-
Small heel	4	x	.	-	-
Big heel	6	-	x	-	-

TABLE VI
FACTORS AFFECTING MOBILITY IN MEN

Wear	**Weight (g)**	**Formal wear**		**Informal wear**	
		Light	*Heavy*	*Light*	*Heavy*
Tie	70	-	x	-	-
Wristwatch	100	x	x	x	x
Belt	100	x	x	x	x
Socks	70	x	x	x	x
underpants	100	x	x	x	x
T-Shirt	100	-	-	x	x
Short shirt	120	x	x	x	-
Long shirt	200		x	-	-
Pant	400	x	x	x	x
Jean	700	x	x	x	x
Thick suit of wool	800		x	-	-
Slippers	800	-	-	x	x
Shoes	1200	x	x	-	-

F. Adrenaline Rush

The sudden sensation of excitement of power than often occurs in stressful situations is described as an adrenaline rush, adrenaline (sometimes called epinephrine) being one of the two main hormones released by the medulla of the adrenal gland which covers part of the kidney. In some case, the rush of adrenaline into the system can act as a spur to athletes, often at unexpected moments. The reason is the adrenaline causes profound changes in all parts of the body.

The release of the hormone effectively mobilizes the whole body for either fight or flight: by stimulating the release of glycogen (which server to store carbohydrates in tissues) from the liver, the expansion of blood vessels in the heart, brain and limbs ans the contraction of vessels in the abdomen [31]. Since adrenaline can affect human behavior, and more so in emergencies, where depending on the person can help or hurt you. This behavior has not been evaluated in this study, but has been considered for future work.

V. EXPERIMENTAL SETUP

This work begins with the proposal by Muñoz et al. [32], which describes a wireless sensor network architecture (Temperature, Carbon Dioxide, Carbon Monoxide, Natural Gas and Vertical Liquid) inside a building using several technologies to guide people to the Exits in emergency situations such as fires, floods and earthquakes. This proposal includes a set of sensor nodes that will be responsible for sending the environmental data to a central node (Kafka) and then storing it in a database and can be used by applications of the distress center. Moreover, the distributed communication model proposed by Velásquez et al. [33], for the management of data flowing through the network to the Kafka Cluster, thus having a set of individual cells for each metric (TMP: Temperature, CO2: Carbon Dioxide, CO: Carbon Monoxide), even two special topics to receive system alerts (AL) and one for storage in the database (DB) - MongoDB and Neo4j [34].

On the other hand, as a means of visualization for the external center of administration and relief has been developing a web platform that receives the different events of the whole network using Treejs. In addition, a simulation environment was defined for the verification of the proposals, which uses Akka (communication threads), Kafka (central node) and different DataBase (MongoDB and Neo4j) to store the data of the nodes [33], [35]. However, there are certain external metrics that need to be evaluated, e.g.:

- How fast can people run in these situations?
- Can the effect of danger alter the rationale in what should or should not be done?
- Can psychological or physiological factors prevent a person from leaving a building in emergency situations?
- Can the person's weight interfere with the rapid evacuation?

These are a few questions that are reviewed throughout this study and will be described in depth in the following sections.

A. Polytechnic Community

The Campus Gustavo Galindo covers 690 hectares, of which 40 are urbanized, 40 will be used for future expansion and 600 have been declared a protective forest that ESPOL will reforest as a sign of its concern for nature. This Campus has a modern and functional infrastructure that allows science institutes, faculties and technological programs to fulfill the basic tasks of teaching, research and service delivery, and that the students receive a comprehensive training that includes the practice of any sport. In this study, it is intended to protect the people who work or study in the different buildings of fires and earthquakes.

B. Building Model

The model is based on the ESPOL's Administrative building, which has the following distribution:

- Ground Floor: Administrative Offices and Auditorium
- First Floor: Administrative Offices, Academic Vice-Rectory and General Vice-Rectory
- Second Floor: Administrative and Rectory Offices

Figure 4 shows the physical structure (First Floor) and the exits of the building (Ground Floor) where users should arrive to be safe in an emergency situation.

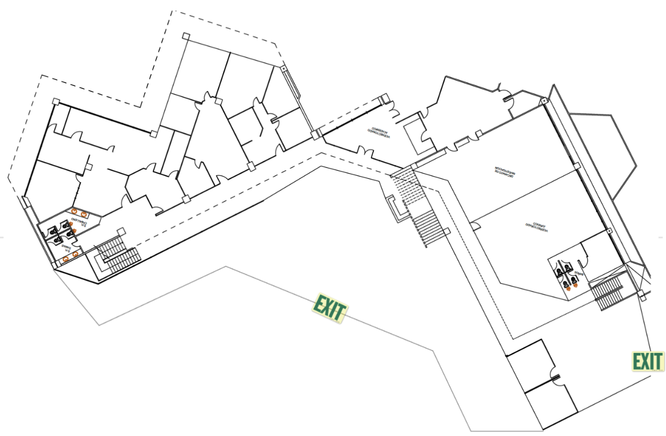

Fig. 4. Schematic of the First Floor of the ESPOL's Administrative Building

C. Escape Routes

This section describes the evacuation routes that users should follow in an emergency situation, depending on where

TABLE VII
DESCRIPTION OF EVACUATION ROUTE NODES

Node	Type	Description
no	Office	Internal administrative offices that do not have a direct access to the corridor
np	Hallway	Administrative offices that have direct access to the hallway or exits of the building.
ns	Stair	These indicate that users are going through a ladder.
ne	Exit	They represent the exits of the building
nob	Lobby	Represents the lobby of the building

' Second Floor, " Ground Floor

they are inside the building. In the Table VII, the meaning of the nodes in Figures 5, 6, 7 is explained in detail:

In Figure 5 (representation of the ground floor), there may be people in the $no(*)'$ and $np(*)'$ of the floor, then walk a distance to the nearest exit $(ne1, ne2, ne3, ne4, ne5, ne6)$ of the building.

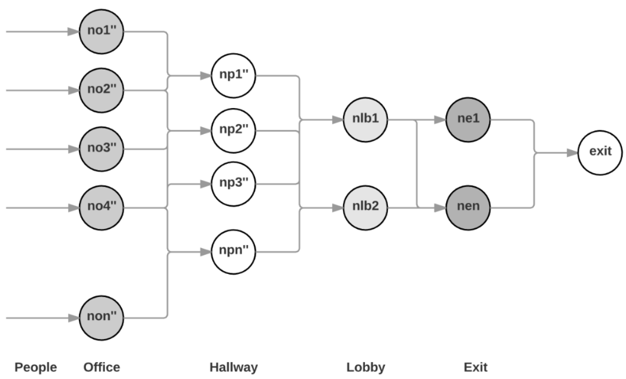

Fig. 5. Evacuation Routes that People should follow If they are on the Ground Floor.

Unlike the ground floor, for people to leave the building there are $(ns1, ns2, ns3)$, generating a longer way that the user must walk, as shown in Figure 6:

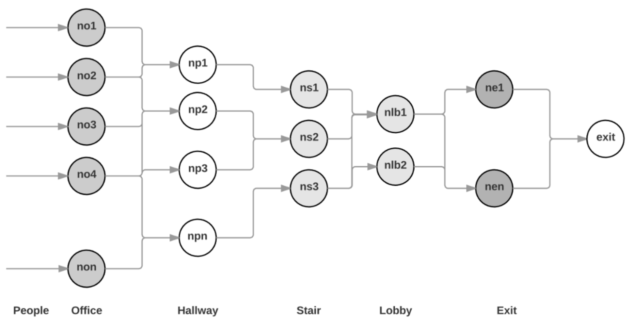

Fig. 6. Evacuation Routes that People should follow If they are on the First Floor.

Being a two-story building, the second one has a structure with the highest concentration of offices in *ZONE C*, in addition, it presents two stairs $ns1'$ and $ns2'$ that are added to the user's road generating a longer route of evacuation, as shown in Figure 7. All the escape routes of the whole building can be appreciated in detail in *APPENDIX A*.

To exit the building we make use of the Dijkstra Algorithm, users must go through any of the established routes, to do so, three adjacency matrices have been defined (one

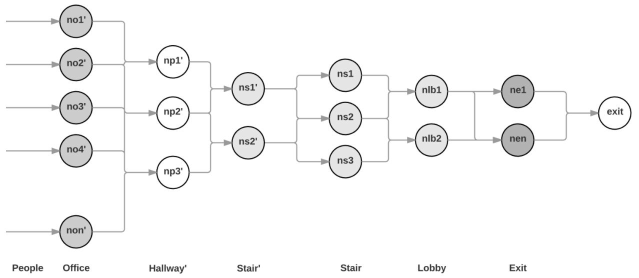

Fig. 7. Evacuation Routes that People should follow If they are on the Second Floor.

for each floor: *Floor 1 [45], Floor 2 [30], Ground [65]*), which indicates the distance between the different nodes.

D. Experimental Data

The experiment was carried out with a dataset containing a sample of 4785 people; 2625 women and 2160 men, with different values of: height, weight and age. Exposing the sample to different scenarios, among them: Different magnitudes of an Earthquake, Mobility of the body according to its dress and an increase of adrenaline (expressed in percentage of speed).

In order to measure the times, the users have been placed in different offices (no) of the three floors, from this point, it calculates the optimal route that must follow to leave the building, taking into consideration that each time he/she walks on a floor the speed will vary according to the BMI.

VI. Results and Discussions

With the information described in previous sections, a simulation with 4 scenarios were proposed: One ideal and three with different magnitudes of earthquake (1: 4.0186480949, 2: 5.7565922936, 3: 6.4711380880). In each of the scenarios the sample of people (BMI) was used, taking into account the mobility (clothing) and the type of soil where the user walks (varying the speed depending on the ground). The simulation generates two times (Normal and Fast) that it takes a user to leave the building, the location or initial point of the user that allows to obtain the route through the graph, distance to the exit and the speed in each one of the types of soil considering the BMI of the individual.

One of the first comparable results in the scenarios is the difference between the times (Normal and Fast). As shown in Figure 8, for each BMI category, the two times present in the ideal scenario (No earthquake affected), what is observed is an almost linear behavior, that is to say, Who is farther away from the exit will present times greater than those that are nearby. On the other hand, in Figure 9, the scenario is presented when it is exposed to a magnitude of 4.0186480949, showing a slight alteration in the times with respect to Figure 8 (Ideal). In experiments with different magnitudes of earthquake, the exit times of the building (Normal, Fast) present a slight variation in each one of the types of soils where people walk, as shown in Figure 10 and 11, where we classify the times taking into consideration the BMI for men and women, noting that when someone goes through a node that has the wooden floor the time to leave that surface is greater in relation to concrete, ceramics and marble. Moreover, an important point in these figures is that as the earthquake increases in magnitude, the times of each surface increase proportionally, for both men and women.

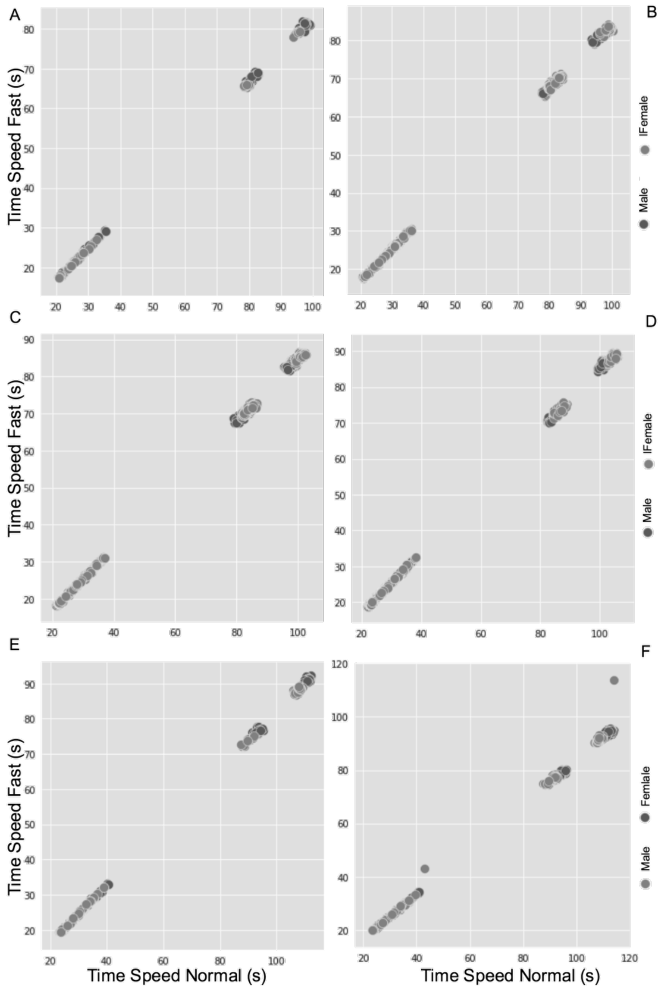

Fig. 8. Times of the users (Men, Women) in leaving the building without exposure to an earthquake. A: BMI (Under Weight), B: BMI (Normal), C: BMI (Obesity Mild), D: BMI (Average Obesity), E: BMI (Severe Obesity) and F: BMI (Very Severe Obesity)

Based on the results obtained in the experiments, if only the BMI (weight, height) of the person is used, the times of the normal and fast speed present a dispersion of $0,672$ depending on the BMI classification. Moreover, People on the ground floor will have a lower value than those found on the third floor (Figure 8). Therefore, the dispersion calculation that has been performed depends on the BMI classification and the Output, as shown in Table VIII, with the intervention of an earthquake (magnitude: 6.4711380880); separating in two sections ($> 100s$ and $< 100s$), this because of the location that the person is when he/she starts walking.

If the user's clothing is taken into consideration, there is a small variation in the BMI that affects the exit times of the building. This is due to the mobility provided by clothing, for example: If a woman goes in skirt and high heels, the speed with which she walks on a surface is reduced. Contrary to what happens if she is dressed in sportswear, as shown in *APPENDIX B*. Where, the times are presented for different combinations of clothes for men and women in normal and fast speed, these times are classified by BMI and the type of soil. Moreover, Table IX (Walking Normal Time), Table

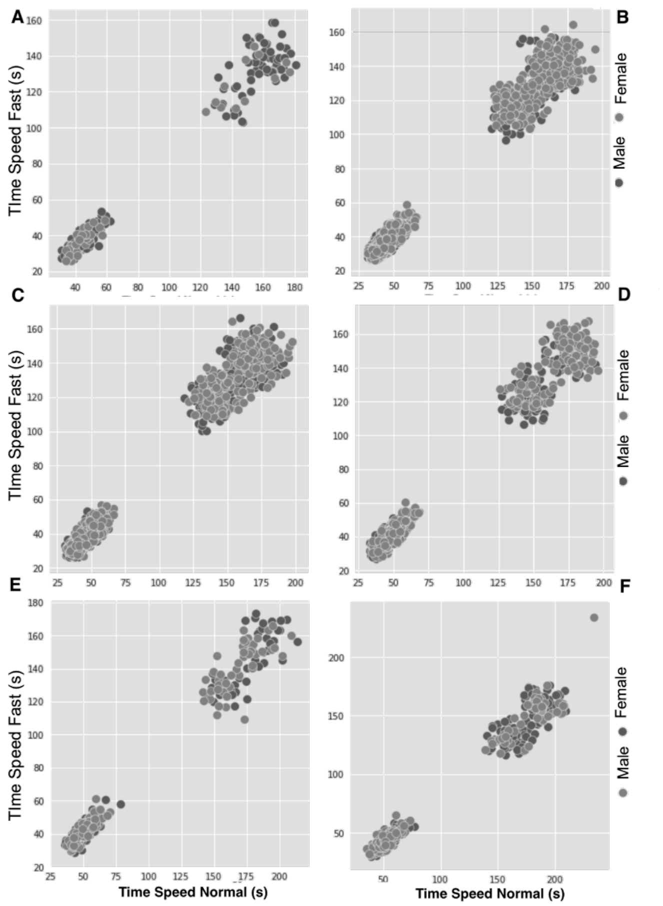

Fig. 9. Times of the users (Men, Women) in leaving the building with exposure to an earthquake (4.0186480949). A: BMI (Under Weight), B: BMI (Normal), C: BMI (Obesity Mild), D: BMI (Average Obesity), E: BMI (Severe Obesity) and F: BMI (Very Severe Obesity)

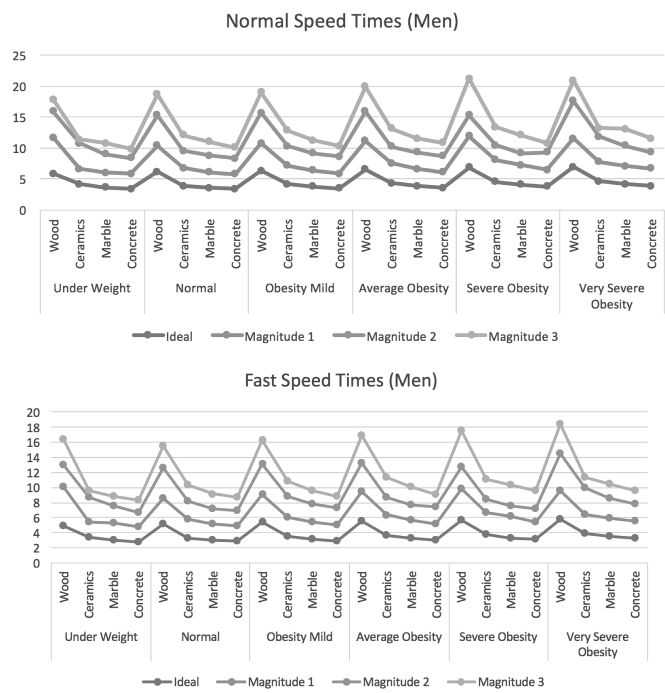

Fig. 10. The times that it takes men to leave the building, depending on the type of floor and BMI. Magnitude 1: 4.0186480949, Magnitude 2: 5.7565922936, Magnitude 3: 6.4711380880

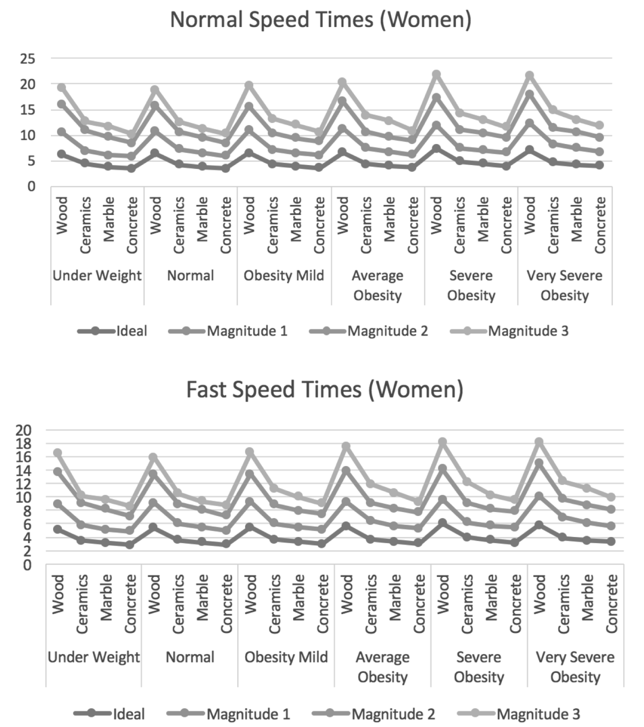

Fig. 11. The times that it takes women to leave the building, depending on the type of floor and BMI. Magnitude 1: 4.0186480949, Magnitude 2: 5.7565922936, Magnitude 3: 6.4711380880

TABLE VIII
DISPERSION BETWEEN THE DIFFERENT TIMES (NORMAL AND FAST) FOR THE CLASSIFICATION OF BMI

BMI	Times	Speed	Male	Female
Under Weight	*>100*	*Normal*	39,873	67,579
		Fast	25,772	33,466
	<!00	*Normal*	10,725	10,934
		Fast	9,756	11,283
Normal	*>100*	*Normal*	51,991	67,287
		Fast	30,243	31,785
	<!00	*Normal*	11,867	11,411
		Fast	11,006	11,424
Obesity Mild	*>100*	*Normal*	64,512	75,115
		Fast	31,855	32,372
	<!00	*Normal*	11,190	11,522
		Fast	12,025	11,950
Average Obesity	*>100*	*Normal*	72,027	87,183
		Fast	34,554	43,849
	<!00	*Normal*	11,563	10,682
		Fast	11,831	12,094
Severe Obesity	*>100*	*Normal*	86,346	97,323
		Fast	40,961	50,331
	<!00	*Normal*	10,511	11,396
		Fast	12,114	12,143
Very Severe Obesity	*>100*	*Normal*	98,605	101,64
		Fast	38,027	57,279
	<!00	*Normal*	10,365	11,385
		Fast	11,915	11,751

X (Walking Fast Time), Table XI (Walking Normal Time), Table XII (Walking Fast Time) shows the minimum and maximum times it takes a man/woman with a variation in

BMI due to clothing (jean, pant, dress, skirt, short) without the intervention of an earthquake.

There is a small variation in the exit time of the building, as shown in detail in *APPENDIX B, C* (As the magnitude of the earthquake increases the exit time will increase). This is due to the wearer's clothing which has an alteration factor (mobility) that can help or hinder user speed. As can be seen in Table VIII, women present in the majority of BMI categories higher values than men.

When exposed to different magnitudes of earthquakes, in each type of soil, the time that leaves the surface increases, having a proportional relationship, IE: The greater magnitude of an earthquake, the greater the time it takes to leave a building. Similarly, it was found that people with a BMI (Under Weight, Normal) are more likely to reach an exit than BMI (Severe Obesity, Very Severe Obesity). Being able to indicate that:

$$BMI \propto ExitTime. \tag{2}$$

With this relation, it can be indicated that the weight of a person represents an important factor when predicting who will be able to leave a building in the necessary time before a collapse.

A. Survival Analysis

If we take into account the times (Normal, Fast) collected during the simulation for each magnitude of the earthquake and as a premise a time $t = 30s$ before a catastrophe occurs (building collapse, people trapped by debris and even death). The Table XIII presents an analysis of the people who could evacuate the building at the suggested time, with this information it can be concluded that people who are on lower floors are more likely to leave a building than those on upper floors. People who can not evacuate in these times, it is advisable to follow the rules of survival in an earthquake [36].

VII. Conclusions and Future Works

An earthquake can cause irreparable damage to the well-being of a community that is located on certain tectonic faults, which makes possible the loss of human lives inside buildings, this study that is based mainly on the buildings that on the polytechnic campus, which were carried out several experiments having as a reference the physical structure of the main building of the ESPOL, allowed to corroborate the impact of the BMI on the speed of the person leaving a building if there is an earthquake.

Based on the results obtained, it is possible to indicate that the BMI represents an important factor in the survival of a person, as well as the clothes that they wear at the moment of an emergency situation. Similarly, the surface where the user walks influences the exit times, so it is recommended to avoid wood in the buildings that are on the tectonic faults.

Considering the effects of an earthquake, the simulation will be execute in other scenarios that allow to verify psychosomatic factors in the people with relation to the times of exit of the building, as well as, use the results to make predictions or inferences of survival percentages in natural disasters [37]. On the other hand, It has been considered to design, program and develop an earthquake simulation tool that can be used in different scenarios of wireless sensor networks.

Appendix A
Scheme of the Different Floors of the Building with the Offices, Corridors, Stairs and Exits

This section shows the evacuation routes that users must follow to leave the building in the shortest possible time. Starting from the nodes (no) until arriving at the nodes (ne).

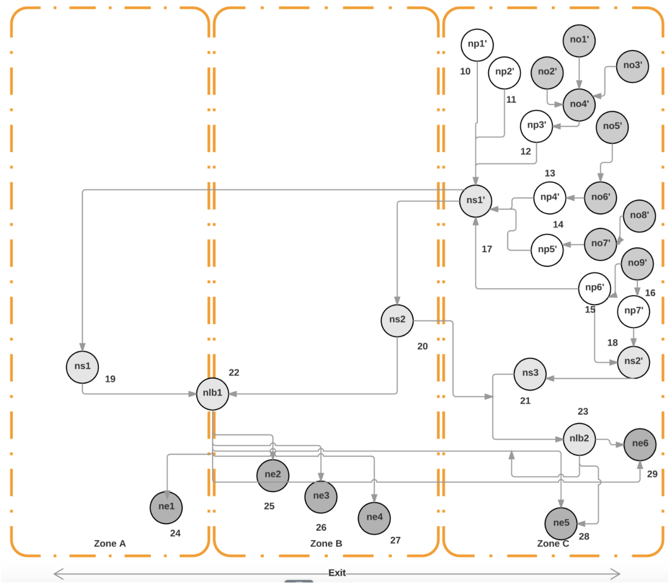

Fig. A.1. Second-floor escape routes that users should continue to rely on the distance between each of the nodes.

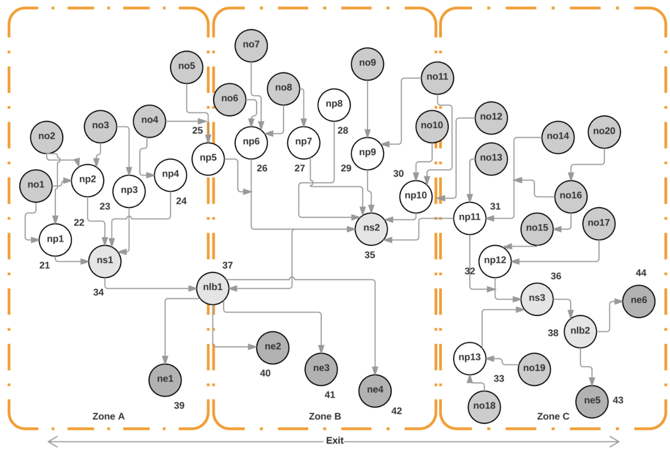

Fig. A.2. First-floor escape routes that users should continue to rely on the distance between each of the nodes.

Appendix B
Scenario Times without Earthquake Intervention (Mobility)

In this section, the different times for each of the scenarios (clothing, soil) are presented when they are not under the action of an earthquake. If there is an earthquake every value presents a slight variation in time (Figure 10, 11). Table B1, B2, B3, B4.

TABLE IX

THE TIMES THAT IT TAKES A MAN TO LEAVE A BUILDING WITH NORMAL SPEED DEPENDING ON THE CLOTHES (MINIMUM AND MAXIMUM)

			Formal Wear				**Informal Wear**			
			Light		**Heavy**		**Light**		**Heavy**	
BMI	**Type**	**Ideal**	**P**	**J**	**P**	**J**	**P**	**J**	**P**	**J**
Under Weight	*min*	20,79	20,64	20,91	20,73	20,73	20,81	20,78	20,88	20,88
	max	95,67	95,14	96,05	95,68	96,00	96,19	95,71	95,61	96,38
Normal	*min*	20,64	20,64	20,64	20,64	20,64	20,73	20,64	20,64	20,64
	max	97,13	96,73	96,95	96,99	96,95	97,13	96,77	96,69	96,99
Obesity Mild	*min*	21,22	21,22	21,22	21,22	21,22	21,22	21,22	21,22	21,22
	max	99,42	99,61	99,61	99,61	99,61	99,61	99,61	99,61	99,26
Average Obesity	*min*	22,03	21,93	21,93	21,93	21,93	21,93	21,93	21,93	21,93
	max	103,24	103,24	103,24	103,03	103,24	102,78	102,78	103,15	103,24
Severe Obesity	*min*	23,24	23,36	23,36	23,43	23,24	23,24	23,24	23,43	23,24
	max	108,97	109,24	109,10	109,10	108,73	109,20	109,06	108,77	108,97
Very Severe Obesity	*min*	114,00	110,40	110,08	109,88	110,53	110,64	110,08	110,16	110,40
	max	114,00	110,40	110,08	109,88	110,53	110,64	110,08	110,16	110,40

J: Jean, P: Pant — min: minimum, max: maximum

TABLE X

THE TIMES THAT IT TAKES A MAN TO LEAVE A BUILDING WITH FAST SPEED DEPENDING ON THE CLOTHES (MINIMUM AND MAXIMUM)

			Formal Wear				***Informal Wear***			
			Light		**Heavy**		**Light**		**Heavy**	
BMI	**Type**	**Ideal**	**P**	**J**	**P**	**J**	**P**	**J**	**P**	**J**
Under Weight	*min*	17,34	17,22	17,32	17,48	17,28	17,28	17,44	17,28	17,40
	max	79,55	79,88	79,40	79,79	79,93	79,24	79,88	79,41	80,03
Normal	*min*	17,61	17,67	17,61	17,61	17,61	17,61	17,61	17,61	17,61
	max	82,09	81,80	82,09	81,85	82,03	81,96	81,96	81,85	81,82
Obesity Mild	*min*	18,12	18,12	18,12	18,12	18,12	18,12	18,12	18,12	18,12
	max	84,57	84,57	84,57	84,57	84,57	84,57	84,29	84,57	84,57
Average Obesity	*min*	18,74	18,74	18,74	18,74	18,74	18,74	18,74	18,74	18,74
	max	87,50	87,56	87,65	87,71	87,71	87,71	87,71	8,65	87,71
Severe Obesity	*min*	19,38	19,25	19,33	19,25	19,33	19,25	19,25	19,33	19,25
	max	89,40	89,48	89,34	89,43	89,78	89,78	89,57	90,00	89,48
Very Severe Obesity	*min*	114,00	92,92	92,62	92,76	92,62	92,66	92,69	92,37	92,62
	max	114,00	92,92	92,62	92,76	92,62	92,66	92,69	92,37	92,62

J: Jean, P: Pant — min: minimum, max: maximum

TABLE XI

THE TIMES THAT IT TAKES A WOMAN TO LEAVE A BUILDING WITH NORMAL SPEED DEPENDING ON THE CLOTHES (MINIMUM AND MAXIMUM)

-			**Formal Wear**								**Informal Wear**			
			Light				**Heavy**				**Light**		**Heavy**	
BMI	**Type**	**Ideal**	**D**	**Sk**	**Sh**	**J**	**D**	**Sk**	**Sh**	**J**	**Sh**	**J**	**Sh**	**J**
Under Weight	*min*	21,16	21,16	21,31	21,31	21,16	21,16	21,16	21,16	21,16	21,16	21,25	21,16	21,16
	max	99,09	98,38	98,46	98,71	98,46	98,48	98,90	98,73	98,48	98,71	98,73	99,09	98,55
Normal	*min*	21,36	21,36	21,36	21,36	21,36	21,36	21,36	21,36	21,36	21,36	21,36	21,36	21,36
	max	100,12	100,12	99,86	100,12	100,12	99,93	100,12	100,12	100,12	99,93	99,75	99,86	99,75
Obesity Mild	*min*	21,90	21,90	21,90	21,90	21,90	21,90	21,90	21,90	21,90	21,90	21,90	21,90	21,90
	max	102,64	102,73	102,73	102,64	102,52	102,73	102,73	102,73	102,44	102,52	102,73	102,73	102,34
Average Obesity	*min*	22,61	22,61	22,61	22,61	22,61	22,61	22,61	22,61	22,72	22,61	22,72	22,61	22,61
	max	105,78	106,12	106,19	105,98	106,19	106,19	106,19	106,19	106,19	105,91	106,19	105,91	105,71
Severe Obesity	*min*	24,01	24,01	24,01	24,13	24,13	24,01	24,01	24,01	24,13	24,13	24,01	24,13	24,21
	max	112,14	112,59	112,05	112,59	112,73	113,05	112,51	112,81	112,59	111,80	112,53	112,56	113,05
Very Severe Obesity	*min*	24,31	24,31	24,31	24,31	24,31	24,31	24,31	24,31	24,31	24,31	24,31	24,31	24,31
	max	113,94	114,49	113,94	114,49	114,13	114,49	114,38	114,49	114,24	114,38	114,49	114,24	114,01

D: Dress, Sk: Skirt, Sh: Short, J: Jean — min: minimum, max: maximum

TABLE XII
THE TIMES THAT IT TAKES A WOMAN TO LEAVE A BUILDING WITH FAST SPEED DEPENDING ON THE CLOTHES (MINIMUM AND MAXIMUM)

-			Formal Wear								Informal Wear			
			Light				Heavy				Light		Heavy	
BMI	**Type**	**Ideal**	**D**	**Sk**	**Sh**	**J**	**D**	**Sk**	**Sh**	**J**	**Sh**	**J**	**Sh**	**J**
Under Weight	*min*	17,66	17,66	17,77	17,73	17,66	17,66	17,66	17,73	17,66	17,66	17,66	17,73	17,77
	max	81,82	81,97	81,87	81,79	82,21	82,08	81,72	81,79	82,21	82,08	81,91	81,92	81,95
Normal	*min*	18,07	18,07	18,07	18,07	18,07	18,07	18,07	18,07	18,07	18,07	18,07	18,07	18,07
	max	84,19	84,13	84,19	84,13	84,19	84,19	84,19	84,05	83,99	84,19	83,99	83,93	84,19
Obesity Mild	*min*	18,61	18,61	18,61	18,61	18,61	18,61	18,61	18,61	18,61	18,61	18,61	18,61	18,69
	max	86,65	86,80	86,80	86,65	86,51	86,80	86,80	86,80	86,80	86,53	86,80	86,53	86,80
Average Obesity	*min*	19,24	19,24	19,32	19,24	19,24	19,32	19,24	19,24	19,24	19,24	19,24	19,24	19,24
	max	89,54	89,79	89,84	89,52	89,84	89,68	89,84	89,49	89,47	89,47	89,84	89,54	89,84
Severe Obesity	*min*	19,80	19,89	19,94	19,80	19,80	19,80	19,89	19,89	19,94	19,80	19,89	19,80	19,80
	max	92,21	92,30	92,30	92,01	92,23	92,15	92,21	92,01	91,99	92,17	92,23	92,21	92,54
Very Severe Obesity	*min*	20,46	20,46	20,46	20,46	20,46	20,46	20,46	20,46	20,46	20,46	20,46	20,46	20,58
	max	95,70	95,63	95,29	95,37	95,63	95,70	95,35	95,70	95,21	95,53	95,70	95,70	95,53

D: Dress, Sk: Skirt, Sh: Short, J: Jean — min: minimum, max: maximum

TABLE XIII
PERCENTAGE OF EVACUATION OF THE BUILDING

			Magnitude of earthquakes		
Floor	**Sex**	**Q**	**M1**	**M2**	**M3**
Ground	*M*	933	86%	84%	81%
	F	588	83%	82%	73%
First	*M*	845	20%	18%	17%
	F	723	13%	12%	10%
Second	*M*	382	5%	4%	2,3%
	F	1314	2%	1,8%	0,5%

M: Male, F: Female, Q: Quantity, M1: 4.0186480949
, M2: 5.7565922936, M3: 6.4711380880

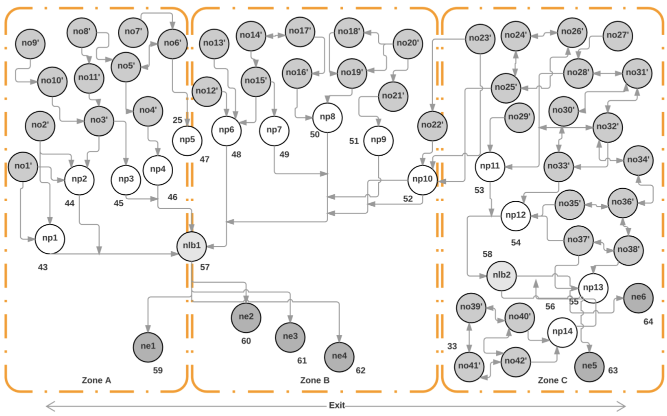

Fig. A.3. Ground floor escape routes that users should continue to depend on the distance between each of the nodes.

APPENDIX C
SCENARIO TIMES WITH EARTHQUAKE INTERVENTION (MAGNITUDE: 4.0186480949)

In this section, the different times for each of the scenarios (clothing, soil) are presented when there is an earthquake of magnitude: 4.0186480949. Table C1, C2, C3, C4.

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TABLE B.1
AVERAGE TIME IT TAKES A MAN TO LEAVE A BUILDING USING NORMAL SPEED

				Formal Wear (s)				Informal Wear (s)			
				Light		*Heavy*		*Light*		*Heavy*	
BMI	**Type of soil**	**Normal (m/s)**	**Ideal**	**P**	**J**	**P**	**J**	**P**	**J**	**P**	**J**
Under Weight	*Wood*	1,45±0,02	5,859	5,747	7,970	7,058	6,458	5,006	5,597	6,741	6,648
	Ceramics	1,47±0,02	4,111	3,988	4,879	4,547	4,171	3,552	3,587	4,556	4,294
	Marble	1,48±0,02	3,569	3,477	4,354	3,948	3,787	3,142	3,311	4,120	3,702
	Concrete	1,50±0,02	3,340	3,329	3,347	3,337	3,334	3,323	3,316	3,328	3,332
Normal	*Wood*	1,42±0,02	6,138	6,194	6,301	6,171	6,175	6,274	6,235	6,218	6,352
	Ceramics	1,49±0,02	3,849	4,031	4,174	4,033	3,912	4,103	4,014	4,031	4,057
	Marble	1,46±0,02	3,538	3,652	3,728	3,654	3,551	3,706	3,639	3,657	3,685
	Concrete	1,49±0,02	3,354	3,356	3,359	3,357	3,356	3,360	3,355	3,355	3,356
Obesity Mild	*Wood*	1,40±0,02	6,323	6,393	6,333	6,319	6,526	6,306	6,262	6,362	6,301
	Ceramics	1,44±0,02	4,175	4,205	4,223	4,127	4,281	4,194	4,143	4,187	4,177
	Marble	1,43±0,02	3,733	3,753	3,762	3,718	3,824	3,740	3,709	3,745	3,722
	Concrete	1,45±0,02	3,449	3,451	3,448	3,448	3,449	3,447	3,448	3,449	3,447
Average Obesity	*Wood*	1,35±0,02	6,553	6,562	6,640	6,352	6,405	6,408	6,836	6,764	6,773
	Ceramics	1,39±0,02	4,287	4,366	4,410	4,130	4,202	4,207	4,587	4,407	4,423
	Marble	1,38±0,02	3,838	3,884	3,956	3,728	3,754	3,776	4,052	3,966	4,001
	Concrete	1,41±0,02	3,547	3,554	3,546	3,550	3,545	3,549	3,546	3,550	3,544
Severe Obesity	*Wood*	1,27±0,02	6,871	6,907	7,292	7,376	7,305	6,628	7,233	6,976	7,382
	Ceramics	1,31±0,02	4,533	4,384	4,727	5,099	4,840	4,414	4,915	4,553	4,908
	Marble	1,30±0,02	4,047	3,960	4,228	4,482	4,333	3,923	4,303	4,123	4,354
	Concrete	1,33±0,02	3,761	3,760	3,758	3,754	3,757	3,758	3,765	3,756	3,766
Very Severe Obesity	*Wood*	1,26±0,02	6,918	7,381	7,031	7,007	6,972	6,664	6,772	6,972	6,772
	Ceramics	1,30±0,02	4,603	5,036	4,649	4,702	4,656	4,572	4,434	4,563	4,358
	Marble	1,29±0,02	4,135	4,427	4,110	4,166	4,133	4,043	4,006	4,077	3,953
	Concrete	1,31±0,02	3,827	3,817	3,822	3,823	3,812	3,814	3,818	3,818	3,814

J: Jean, P: Pant

TABLE B.2
AVERAGE TIME IT TAKES A MAN TO LEAVE A BUILDING USING FAST SPEED

				Formal Wear				Informal Wear			
				Light		*Heavy*		*Light*		*Heavy*	
BMI	**Type of soil**	**Fast (m/s)**	**Ideal**	**P**	**J**	**P**	**J**	**P**	**J**	**P**	**J**
Under Weight	*Wood*	1,74±0,02	4,869	4,812	6,650	5,890	5,379	4,182	4,680	5,628	5,589
	Ceramics	1,78±0,02	3,402	3,304	4,021	3,775	3,428	2,932	2,955	3,771	3,550
	Marble	1,77±0,02	2,979	2,912	3,631	3,318	3,156	2,631	2,764	3,462	3,095
	Concrete	1,79±0,02	2,798	2,794	2,784	2,781	2,798	2,792	2,803	2,789	2,786
Normal	*Wood*	1,70±0,02	5,131	5,176	5,259	5,159	5,153	5,243	5,211	5,190	5,299
	Ceramics	1,74±0,02	3,294	3,449	3,576	3,449	3,347	3,516	3,437	3,453	3,471
	Marble	1,73±0,02	2,985	3,080	3,144	3,086	3,003	3,129	3,073	3,088	3,109
	Concrete	1,75±0,02	2,858	2,858	2,854	2,858	2,858	2,858	2,859	2,856	2,858
Obesity Mild	*Wood*	1,65±0,02	5,366	5,423	5,370	5,353	5,536	5,349	5,313	5,397	5,347
	Ceramics	1,69±0,02	3,558	3,584	3,601	3,516	3,649	3,574	3,530	3,570	3,559
	Marble	1,68±0,02	3,174	3,193	3,206	3,162	3,260	3,183	3,159	3,185	3,167
	Concrete	1,70±0,02	2,941	2,941	2,941	2,942	2,941	2,944	2,940	2,941	2,943
Average Obesity	*Wood*	1,59±0,02	5,569	5,576	5,638	5,382	5,440	5,445	5,796	5,739	5,754
	Ceramics	1,63±0,02	3,661	3,723	3,757	3,521	3,585	3,587	3,913	3,764	3,774
	Marble	1,62±0,02	3,269	3,309	3,364	3,177	3,200	3,219	3,449	3,378	3,408
	Concrete	1,65±0,02	3,030	3,033	3,029	3,033	3,032	3,032	3,034	3,030	3,029
Severe Obesity	*Wood*	1,55±0,02	5,632	5,661	5,967	6,055	5,978	5,432	5,926	5,727	6,037
	Ceramics	1,59±0,02	3,728	3,618	3,887	4,200	3,987	3,642	4,051	3,758	4,048
	Marble	1,58±0,02	3,320	3,267	3,479	3,685	3,560	3,219	3,553	3,387	3,579
	Concrete	1,60±0,02	3,123	3,122	3,129	3,123	3,130	3,125	3,125	3,133	3,124
Very Severe Obesity	*Wood*	1,50±0,02	5,810	6,198	5,902	5,884	5,857	5,583	5,681	5,837	5,676
	Ceramics	1,54±0,02	3,894	4,244	3,916	3,966	3,934	3,854	3,740	3,848	3,685
	Marble	1,53±0,02	3,480	3,737	3,468	3,512	3,481	3,409	3,372	3,440	3,333
	Concrete	1,55±0,02	3,224	3,227	3,229	3,227	3,229	3,228	3,227	3,231	3,226

J: Jean, P: Pant

TABLE B.3
AVERAGE TIME IT TAKES A WOMAN TO LEAVE A BUILDING USING NORMAL SPEED

				Formal Wear								**Informal Wear**			
				Light				***Heavy***				**Light**		**Heavy**	
BMI	**Soil**	**Normal (m/s)**	**Ideal**	**D**	**Sk**	**Sh**	**J**	**D**	**Sk**	**Sh**	**J**	**Sh**	**J**	**Sh**	**J**
Under Weight	*Wood*	1,41±0,02	6,200	6,455	6,431	6,346	5,861	6,087	6,128	6,370	6,412	5,909	6,678	6,358	6,379
	Ceramics	1,45±0,02	4,390	4,250	4,409	4,238	3,817	3,869	4,003	4,176	4,163	3,767	4,406	4,159	4,115
	Marble	1,42±0,02	3,755	3,836	3,969	3,824	3,498	3,623	3,708	3,771	3,779	3,504	3,994	3,782	3,754
	Concrete	1,46±0,02	3,424	3,423	3,428	3,426	3,428	3,425	3,427	3,419	3,425	3,429	3,430	3,434	3,427
Normal	*Wood*	1,40±0,02	6,355	6,335	6,280	6,365	6,419	6,469	6,324	6,037	6,375	6,405	6,463	6,260	6,134
	Ceramics	1,43±0,02	4,241	4,115	4,158	4,217	4,292	4,312	4,185	4,005	4,243	4,253	4,311	4,119	4,086
	Marble	1,41±0,02	3,807	3,737	3,762	3,798	3,895	3,868	3,765	3,624	3,815	3,829	3,867	3,744	3,708
	Concrete	1,45±0,02	3,447	3,448	3,450	3,450	3,448	3,446	3,449	3,448	3,449	3,446	3,448	3,449	3,450
Obesity Mild	*Wood*	1,36±0,02	6,482	6,383	6,488	6,610	6,373	6,656	6,598	6,377	6,498	6,587	6,499	6,403	6,689
	Ceramics	1,40±0,02	4,258	4,214	4,168	4,352	4,123	4,328	4,278	4,239	4,281	4,335	4,286	4,158	4,414
	Marble	1,37±0,02	3,881	3,830	3,836	3,968	3,789	3,933	3,883	3,842	3,878	3,923	3,878	3,820	4,016
	Concrete	1,41±0,02	3,547	3,546	3,546	3,548	3,546	3,544	3,545	3,547	3,550	3,548	3,547	3,547	3,551
Average Obesity	*Wood*	1,32±0,02	6,631	6,642	6,603	6,808	6,776	6,612	6,787	6,591	6,893	6,931	6,662	6,781	6,597
	Ceramics	1,35±0,02	4,328	4,544	4,374	4,550	4,503	4,357	4,447	4,340	4,637	4,662	4,357	4,565	4,394
	Marble	1,33±0,02	3,926	4,057	3,953	4,088	4,034	3,921	4,040	3,936	4,162	4,147	3,942	4,059	3,955
	Concrete	1,37±0,02	3,651	3,652	3,644	3,650	3,653	3,651	3,652	3,648	3,650	3,653	3,651	3,649	3,651
Severe Obesity	*Wood*	1,24±0,02	7,356	7,125	7,087	7,392	6,908	6,882	6,997	6,976	6,501	7,117	7,194	7,751	7,027
	Ceramics	1,27±0,02	4,856	4,818	4,523	4,859	4,731	4,623	4,643	4,661	4,342	4,676	4,616	5,069	4,575
	Marble	1,25±0,02	4,364	4,308	4,187	4,388	4,213	4,187	4,169	4,206	3,963	4,242	4,225	4,594	4,156
	Concrete	1,29±0,02	3,879	3,878	3,868	3,874	3,870	3,880	3,873	3,887	3,877	3,889	3,877	3,879	3,881
Very Severe Obesity	*Wood*	1,22±0,02	6,966	7,231	6,932	7,202	7,076	7,236	7,091	7,311	7,098	7,339	7,378	7,220	7,301
	Ceramics	1,26±0,02	4,666	4,570	4,472	4,787	4,745	4,785	4,599	4,752	4,556	4,737	4,866	4,903	4,742
	Marble	1,23±0,02	4,196	4,228	4,106	4,302	4,270	4,337	4,239	4,323	4,196	4,322	4,416	4,392	4,330
	Concrete	1,27±0,02	3,936	3,938	3,935	3,941	3,934	3,938	3,936	3,934	3,940	3,936	3,939	3,939	3,938

D: Dress, Sk: Skirt, Sh: Short, J: Jean

TABLE B.4
AVERAGE TIME IT TAKES A WOMAN TO LEAVE A BUILDING USING FAST SPEED

				Formal Wear								**Informal Wear**			
				Light				***Heavy***				***Light***		***Heavy***	
BMI	**Soil**	**Fast (m/s)**	**Ideal**	**D**	**Sk**	**Sh**	**J**	**D**	**Sk**	**Sh**	**J**	**Sh**	**J**	**Sh**	**J**
Under Weight	*Wood*	1,70±0,02	5,144	5,350	5,325	5,432	4,867	5,059	5,091	5,277	5,324	4,902	5,551	5,272	5,285
	Ceramics	1,74±0,02	3,451	3,539	3,678	3,747	3,183	3,225	3,331	3,475	3,469	3,132	3,671	3,460	3,426
	Marble	1,71±0,02	3,118	3,190	3,297	3,337	2,904	2,998	3,083	3,137	3,143	2,912	3,305	3,144	3,119
	Concrete	1,75±0,02	2,858	2,863	2,855	2,861	2,854	2,858	2,859	2,855	2,857	2,857	2,852	2,857	2,858
Normal	*Wood*	1,66±0,02	5,362	5,347	5,296	5,409	5,409	5,467	5,335	5,091	5,371	5,400	5,453	5,283	5,170
	Ceramics	1,70±0,02	3,568	3,460	3,494	3,631	3,610	3,627	3,524	3,367	3,569	3,578	3,625	3,464	3,437
	Marble	1,67±0,02	3,216	3,160	3,179	3,248	3,288	3,264	3,176	3,063	3,223	3,230	3,269	3,162	3,128
	Concrete	1,71±0,02	2,925	2,924	2,926	2,924	2,924	2,926	2,925	2,925	2,925	2,926	2,923	2,921	2,924
Obesity Mild	*Wood*	1,61±0,02	5,466	5,383	5,483	5,429	5,389	5,618	5,574	5,385	5,487	5,570	5,489	5,409	5,643
	Ceramics	1,65±0,02	3,612	3,577	3,534	3,528	3,496	3,674	3,632	3,596	3,632	3,677	3,636	3,525	3,747
	Marble	1,62±0,02	3,282	3,234	3,246	3,216	3,200	3,327	3,287	3,249	3,280	3,320	3,278	3,228	3,395
	Concrete	1,66±0,02	3,013	3,011	3,013	3,012	3,012	3,013	3,012	3,015	3,015	3,013	3,014	3,012	3,011
Average Obesity	*Wood*	1,56±0,02	5,625	5,615	5,587	5,876	5,735	5,594	5,744	5,572	5,823	5,859	5,628	5,740	5,583
	Ceramics	1,59±0,02	3,674	3,855	3,712	3,951	3,821	3,699	3,775	3,684	3,935	3,959	3,694	3,874	3,732
	Marble	1,57±0,02	3,325	3,431	3,351	3,510	3,419	3,326	3,422	3,338	3,533	3,514	3,343	3,441	3,352
	Concrete	1,61±0,02	3,108	3,104	3,103	3,109	3,106	3,108	3,107	3,109	3,107	3,106	3,103	3,104	3,109
Severe Obesity	*Wood*	1,51±0,02	6,046	5,846	5,824	5,770	5,673	5,659	5,740	5,734	5,331	5,863	5,918	6,388	5,770
	Ceramics	1,55±0,02	3,975	3,947	3,713	3,595	3,870	3,796	3,803	3,821	3,552	3,830	3,785	4,155	3,748
	Marble	1,52±0,02	3,583	3,549	3,449	3,359	3,466	3,448	3,427	3,453	3,263	3,488	3,476	3,780	3,418
	Concrete	1,56±0,02	3,206	3,204	3,204	3,202	3,207	3,208	3,206	3,202	3,202	3,207	3,209	3,205	3,204
Very Severe Obesity	*Wood*	1,46±0,02	5,830	6,041	5,782	6,124	5,915	6,040	5,925	6,109	5,928	6,124	6,162	6,042	6,093
	Ceramics	1,50±0,02	3,918	3,839	3,754	3,883	3,985	4,025	3,861	3,994	3,827	3,981	4,088	4,117	3,978
	Marble	1,47±0,02	3,510	3,543	3,437	3,566	3,568	3,629	3,543	3,621	3,510	3,613	3,691	3,675	3,626
	Concrete	1,51±0,02	3,310	3,310	3,311	3,314	3,311	3,308	3,309	3,314	3,314	3,314	3,313	3,310	3,308

D: Dress, Sk: Skirt, Sh: Short, J: Jean

TABLE C.1
AVERAGE TIME IT TAKES A MAN TO LEAVE A BUILDING USING NORMAL SPEED (EARTHQUAKE)

				Formal Wear (s)				Informal Wear (s)			
				Light		*Heavy*		*Light*		*Heavy*	
BMI	**Soil**	**Normal (m/s)**	**Ideal**	**P**	**J**	**P**	**J**	**P**	**J**	**P**	**J**
Under Weight	***Wood***	1,45±0,02	11,675	10,198	9,827	11,228	9,237	11,840	10,651	10,082	10,386
	Ceramics	1,47±0,02	6,602	6,721	6,777	8,587	5,751	8,303	6,921	6,912	6,552
	Marble	1,48±0,02	5,985	5,678	5,187	7,423	5,167	7,488	6,304	6,349	5,973
	Concrete	1,50±0,02	5,845	5,736	5,507	5,812	5,876	5,865	5,771	5,420	5,875
Normal	***Wood***	1,42±0,02	10,380	10,659	10,845	10,992	10,273	10,416	10,437	11,190	10,527
	Ceramics	1,49±0,02	6,750	6,877	6,907	7,285	6,605	6,878	6,758	7,160	6,749
	Marble	1,46±0,02	6,085	6,255	6,252	6,602	5,950	6,315	6,141	6,416	6,147
	Concrete	1,49±0,02	5,724	5,705	5,719	5,667	5,714	5,672	5,707	5,681	5,764
Obesity Mild	***Wood***	1,40±0,02	10,786	10,686	10,894	10,612	10,719	10,747	10,807	10,711	10,825
	Ceramics	1,44±0,02	7,114	7,219	7,229	6,986	7,161	7,090	7,096	7,075	7,332
	Marble	1,43±0,02	6,363	6,366	6,458	6,254	6,377	6,340	6,416	6,299	6,465
	Concrete	1,45±0,02	5,869	5,877	5,871	5,879	5,905	5,869	5,835	5,890	5,881
Average Obesity	***Wood***	1,35±0,02	11,171	10,907	11,317	11,609	11,042	11,111	10,832	10,941	10,886
	Ceramics	1,39±0,02	7,546	7,249	7,435	7,624	7,018	7,179	7,054	7,189	7,085
	Marble	1,38±0,02	6,630	6,498	6,663	6,737	6,345	6,530	6,376	6,350	6,348
	Concrete	1,41±0,02	6,028	6,038	6,066	5,982	6,055	6,112	6,031	6,067	6,100
Severe Obesity	***Wood***	1,27±0,02	11,913	12,058	12,349	11,493	12,230	11,207	12,337	11,817	11,440
	Ceramics	1,31±0,02	8,051	8,004	8,081	7,477	8,032	7,486	8,276	7,938	7,077
	Marble	1,30±0,02	7,243	7,169	7,281	6,717	7,141	6,626	7,375	7,004	6,400
	Concrete	1,33±0,02	6,432	6,377	6,359	6,436	6,350	6,271	6,447	6,341	6,364
Very Severe Obesity	***Wood***	1,26±0,02	11,487	13,107	11,765	11,238	11,626	12,681	12,531	12,920	12,143
	Ceramics	1,30±0,02	7,724	8,797	7,439	7,276	7,445	8,648	8,426	8,225	7,723
	Marble	1,29±0,02	7,042	7,657	6,762	6,761	6,733	7,673	7,340	7,399	6,974
	Concrete	1,31±0,02	6,673	6,45	6,534	6,526	6,490	6,456	6,406	6,549	6,417

J: Jean, P: Pant

TABLE C.2
AVERAGE TIME IT TAKES A MAN TO LEAVE A BUILDING USING FAST SPEED (EARTHQUAKE)

				Formal Wear				Informal Wear			
				Light		*Heavy*		*Light*		*Heavy*	
BMI	**Type of soil**	**Fast (m/s)**	**Ideal**	**P**	**J**	**P**	**J**	**P**	**J**	**P**	**J**
Under Weight	***Wood***	1,74±0,02	10,090	7,752	7,515	9,577	7,512	10,184	8,451	9,103	9,079
	Ceramics	1,78±0,02	5,412	5,260	5,538	7,288	4,808	6,867	6,064	5,574	5,473
	Marble	1,77±0,02	5,236	4,572	4,536	5,631	4,131	6,051	5,338	5,025	5,169
	Concrete	1,79±0,02	4,826	4,517	4,853	4,859	4,983	4,536	4,609	4,913	4,807
Normal	***Wood***	1,70±0,02	8,612	8,999	8,997	9,167	8,463	8,806	8,869	9,198	8,711
	Ceramics	1,74±0,02	5,752	5,935	5,861	6,198	5,649	5,885	5,784	6,100	5,826
	Marble	1,73±0,02	5,125	5,252	5,332	5,546	5,026	5,209	5,209	5,518	5,169
	Concrete	1,75±0,02	4,941	4,885	4,859	4,883	4,865	4,867	4,841	4,882	4,839
Obesity Mild	***Wood***	1,65±0,02	9,093	9,019	9,286	9,026	9,037	9,120	9,252	9,144	9,279
	Ceramics	1,69±0,02	6,068	6,149	6,146	5,986	6,116	6,016	6,034	6,049	6,221
	Marble	1,68±0,02	5,375	5,448	5,502	5,299	5,429	5,380	5,427	5,442	5,598
	Concrete	1,70±0,02	4,993	5,043	4,991	4,990	5,041	4,962	4,977	5,024	5,005
Average Obesity	***Wood***	1,59±0,02	9,476	9,269	9,606	9,978	9,412	9,457	9,209	9,197	9,278
	Ceramics	1,63±0,02	6,366	6,238	6,360	6,498	6,006	6,163	6,020	6,052	6,021
	Marble	1,62±0,02	5,645	5,525	5,699	5,759	5,460	5,453	5,430	5,409	5,475
	Concrete	1,65±0,02	5,132	5,227	5,193	5,140	5,159	5,142	5,102	5,096	5,193
Severe Obesity	***Wood***	1,55±0,02	9,865	9,689	10,412	9,212	10,034	9,180	10,258	9,514	9,348
	Ceramics	1,59±0,02	6,673	6,538	6,583	6,212	6,568	6,089	6,829	6,538	5,770
	Marble	1,58±0,02	6,182	5,865	5,972	5,469	6,023	5,472	5,913	5,736	5,266
	Concrete	1,60±0,02	5,362	5,194	5,436	5,384	5,266	5,279	5,189	5,317	5,383
Very Severe Obesity	***Wood***	1,50±0,02	9,601	10,787	9,721	9,370	9,826	10,544	10,579	10,700	10,129
	Ceramics	1,54±0,02	6,436	7,363	6,284	6,266	6,297	7,366	7,162	6,889	6,549
	Marble	1,53±0,02	5,985	6,488	5,801	5,735	5,685	6,524	6,203	6,234	5,892
	Concrete	1,55±0,02	5,583	5,677	5,487	5,440	5,480	5,565	5,486	5,509	5,497

J: Jean, P: Pant

TABLE C.3
AVERAGE TIME IT TAKES A WOMAN TO LEAVE A BUILDING USING FAST SPEED (EARTHQUAKE)

				Formal Wear (s)								Informal Wear (s)			
				Light				Heavy				Light		Heavy	
BMI	**Type of Soil**	**Normal (m/s)**	**Ideal**	**D**	**Sk**	**Sh**	**J**	**D**	**Sk**	**Sh**	**J**	**Sh**	**J**	**Sh**	**J**
Under Weight	***Wood***	1,41±0,02	10,44	10,00	10,94	10,80	10,40	10,65	10,54	10,31	10,43	11,53	11,09	10,24	10,06
	Ceramics	1,45±0,02	6,884	6,805	7,258	7,217	7,054	7,025	6,775	6,655	6,929	8,040	7,506	6,676	6,875
	Marble	1,42±0,02	6,079	5,987	6,628	6,523	6,141	6,498	6,255	6,128	6,264	7,136	6,703	6,237	6,162
	Concrete	1,46±0,02	5,847	5,855	5,763	5,812	5,748	5,827	5,939	5,960	5,899	5,875	5,957	5,902	5,856
Normal	***Wood***	1,40±0,02	10,71	10,76	10,77	10,32	10,63	10,83	10,93	10,68	10,73	10,52	10,73	10,53	10,73
	Ceramics	1,43±0,02	7,188	7,082	7,293	6,793	7,093	7,076	7,150	7,092	7,269	6,977	7,247	7,142	7,108
	Marble	1,41±0,02	6,471	6,394	6,531	6,148	6,408	6,442	6,486	6,499	6,494	6,275	6,518	6,355	6,342
	Concrete	1,45±0,02	5,885	5,870	5,894	5,916	5,874	5,910	5,909	5,898	5,893	5,925	5,923	5,935	5,900
Obesity Mild	***Wood***	1,36±0,02	10,88	11,10	11,49	10,94	10,76	10,97	11,22	11,38	10,97	10,94	10,93	11,03	11,10
	Ceramics	1,40±0,02	7,133	7,281	7,429	7,260	7,239	7,212	7,448	7,406	7,116	7,201	7,177	7,245	7,338
	Marble	1,37±0,02	6,477	6,597	6,755	6,526	6,526	6,622	6,788	6,714	6,538	6,590	6,543	6,592	6,637
	Concrete	1,41±0,02	6,031	6,038	5,991	6,055	5,992	6,076	6,078	6,017	6,095	6,086	6,040	5,999	6,039
Average Obesity	***Wood***	1,32±0,02	11,21	10,76	11,93	11,36	11,70	11,82	11,09	11,68	12,01	11,49	11,82	11,31	10,96
	Ceramics	1,35±0,02	7,490	7,093	7,773	7,163	7,581	7,687	7,275	7,742	7,740	7,716	8,015	7,574	7,306
	Marble	1,33±0,02	6,686	6,608	6,958	6,574	6,848	6,930	6,597	6,912	6,969	6,974	7,147	6,873	6,647
	Concrete	1,37±0,02	6,190	6,264	6,214	6,206	6,259	6,211	6,228	6,224	6,285	6,183	6,177	6,253	6,219
Severe Obesity	***Wood***	1,24±0,02	11,88	12,38	12,47	12,41	11,50	11,62	11,69	12,46	11,57	10,58	12,67	12,74	12,25
	Ceramics	1,27±0,02	7,478	8,452	8,036	7,977	7,445	7,569	7,662	8,684	7,812	6,991	8,156	8,596	8,324
	Marble	1,25±0,02	6,978	7,471	7,277	7,427	6,773	6,869	7,025	7,851	6,892	6,512	7,191	7,598	7,404
	Concrete	1,29±0,02	6,630	6,505	6,511	6,546	6,637	6,655	6,701	6,447	6,674	6,577	6,641	6,658	6,533
Very Severe Obesity	***Wood***	1,22±0,02	12,36	12,37	12,17	12,31	12,37	12,16	11,91	11,75	12,68	11,88	12,37	12,27	12,33
	Ceramics	1,26±0,02	8,220	8,106	8,000	8,103	7,978	8,129	7,727	7,779	8,324	7,604	7,921	8,164	8,077
	Marble	1,23±0,02	7,434	7,321	7,339	7,464	7,386	7,381	7,045	6,958	7,576	7,048	7,250	7,348	7,350
	Concrete	1,27±0,02	6,683	6,621	6,664	6,744	6,743	6,718	6,821	6,694	6,668	6,750	6,766	6,729	6,729

D: Dress, Sk: Skirt, Sh: Short, J: Jean

TABLE C.4
AVERAGE TIME IT TAKES A WOMAN TO LEAVE A BUILDING USING FAST SPEED (EARTHQUAKE)

				Formal Wear								Informal Wear			
				Light				*Heavy*				*Light*		*Heavy*	
BMI	**Type of Soil**	**Fast (m/s)**	**Ideal**	**D**	**Sk**	**Sh**	**J**	**D**	**Sk**	**Sh**	**J**	**Sh**	**j**	**Sh**	**J**
Under Weight	***Wood***	1,70±0,02	8,876	8,513	9,006	8,998	8,655	9,047	8,648	8,620	8,546	9,459	9,275	8,374	8,529
	Ceramics	1,74±0,02	5,784	5,653	6,048	6,074	5,910	5,881	5,703	5,565	5,745	6,866	6,232	5,536	5,751
	Marble	1,71±0,02	5,121	5,242	5,389	5,444	5,181	5,339	5,218	5,137	5,049	5,953	5,595	5,030	5,119
	Concrete	1,75±0,02	4,902	4,905	4,859	4,793	4,950	4,896	4,889	4,805	4,824	5,032	5,009	4,808	4,794
Normal	***Wood***	1,66±0,02	9,094	9,016	9,086	8,801	8,931	9,050	9,284	9,095	9,116	8,952	9,154	9,059	8,920
	Ceramics	1,70±0,02	6,014	5,929	6,152	5,724	5,948	5,983	6,010	6,009	6,096	5,836	6,051	5,947	5,969
	Marble	1,67±0,02	5,495	5,341	5,498	5,185	5,416	5,441	5,449	5,447	5,564	5,327	5,439	5,397	5,415
	Concrete	1,71±0,02	4,961	5,007	4,910	4,961	4,999	4,994	4,955	4,998	4,962	4,992	4,980	4,979	4,964
Obesity Mild	***Wood***	1,61±0,02	9,210	9,403	9,601	9,340	9,166	9,176	9,586	9,646	9,189	9,304	9,264	9,257	9,391
	Ceramics	1,65±0,02	6,014	6,183	6,325	6,152	6,167	6,110	6,345	6,294	6,044	6,165	6,106	6,181	6,202
	Marble	1,62±0,02	5,512	5,617	5,722	5,604	5,549	5,581	5,697	5,668	5,535	5,568	5,551	5,611	5,582
	Concrete	1,66±0,02	5,102	5,189	5,115	5,143	5,080	5,130	5,104	5,142	5,162	5,140	5,105	5,076	5,106
Average Obesity	***Wood***	1,56±0,02	9,257	9,191	10,01	9,594	9,894	9,987	9,161	10,01	10,05	9,882	9,963	9,512	9,368
	Ceramics	1,59±0,02	6,460	6,057	6,570	6,141	6,438	6,465	6,192	6,586	6,636	6,531	6,790	6,538	6,260
	Marble	1,57±0,02	5,681	5,587	5,925	5,545	5,814	5,828	5,544	5,876	5,783	5,967	6,013	5,774	5,677
	Concrete	1,61±0,02	5,295	5,254	5,250	5,316	5,280	5,267	5,284	5,327	5,322	5,310	5,188	5,251	5,321
Severe Obesity	***Wood***	1,51±0,02	9,629	10,43	10,19	10,19	9,508	9,533	9,604	10,56	9,415	8,596	10,10	10,44	10,30
	Ceramics	1,55±0,02	6,211	6,968	6,545	6,488	6,008	6,217	6,331	7,192	6,428	5,681	6,663	7,025	6,899
	Marble	1,52±0,02	5,726	6,309	6,011	6,152	5,717	5,623	5,732	6,599	5,614	5,207	6,073	6,315	6,170
	Concrete	1,56±0,02	5,515	5,395	5,435	5,410	5,485	5,511	5,484	5,522	5,475	5,388	5,509	5,429	5,446
Very Severe Obesity	***Wood***	1,46±0,02	10,11	10,31	10,29	10,38	10,40	10,22	9,930	9,887	10,68	9,701	10,34	10,28	10,30
	Ceramics	1,50±0,02	6,927	6,740	6,707	6,838	6,733	6,808	6,379	6,557	7,001	6,369	6,785	6,855	6,823
	Marble	1,47±0,02	6,165	6,076	6,167	6,157	6,204	6,101	5,928	5,891	6,341	5,776	6,104	6,161	6,180
	Concrete	1,51±0,02	5,624	5,648	5,621	5,599	5,716	5,593	5,688	5,624	5,577	5,684	5,740	5,619	5,599

D: Dress, Sk: Skirt, Sh: Short, J: Jean

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