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Factors motivating Mexico City residents to earthquake mass evacuation drills

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ABSTRACT

Evacuation drills may constitute a key activity for preparing for an emergency due to an earthquake. The paper presents the results of an analysis of participants' motivations on the factors leading to conducting drills on 19 September every year in Mexico City; the sample size considered for the analysis was N = 2400. In particular, the following research question has been addressed: What factors predict the likelihood that respondents would report that they agree on conducting mass evacuation drills yearly? The approach has been the application of logistic regression technique to identify these factors. Of the 19 initial explanatory variables, in the final model, only seven variables and one interaction term, were significantly associated with the outcome variable; i.e.: age (Odds Ratio (OR) = 1.366; 95% Confidence Interval (CI) = 1.039–1.795); occupation (OR = 3.378; CI = 1.457–7.830); frequency of drills: one/year (OR = 2.128; CI = 1.610–2.812); knowledge vs. drills (OR = 1.394; CI = 1.172–1.658); 'perception vulnerability city' (OR = 1.271; CI = 1.091–1.480); warning time (OR = 1.266; CI = 1.1036–1.548); usefulness of the SASMEX (OR = 0.783; CI = 0.615-0.998); and 'perception vulnerability city' by occupation interaction (OR = 0.786; CI = 0.643-0.961). Further research may be needed to gain a better understanding of people's motivations on evacuation drills taking place anytime during the day or at night, and whether evacuation drills should be unannounced.

1. Introduction

Modern society is threatened by technological, natural and health related hazards. Further, modern society is highly interdependent in such a way that an adverse event occurring in any system/community have a significant impact on many other systems/communities, nations or even continents. Examples of such adverse events have come to the fore in dramatic ways in recent years, i.e.: technological disruptions [1, 2], volcanic eruptions, earthquakes & tsunamis [3–5], Sars & Covid-19 [6].

To effectively respond and to mitigate the impact of to such threats, it becomes necessary for communities to have an effective emergency response plan in place. Overall, any emergency preparedness cycle comprises the following key elements, namely, prevention, preparedness, response, recovery, and mitigation [7,8]. Preparedness refers to a continuous process of planning, organising, training, equipping, drills (exercises), evaluating and taking corrective action. Therefore, drills are a key activity of preparedness to respond to emergencies [7–10]. It also should be highlighted that there are two types of drills: discussion-based or desktop exercises, and operational-based exercises [10,11]. A detailed description of the features of each of these are given in Ref. [9–11]. Further, drills could be announced or unannounced [10, 11]. It may be argued that most earthquake evacuation drills are of the announced type.

A great deal of effort has been made, by NGO (non-governmental organizations), scholars, governmental agencies in charge with civil protection, among others, to conduct and assess the effectiveness of earthquake evacuation drills [12–20]. Most of the studies reported in the literature deal with drills being conducted in schools [12–14,16], and there are not that many on the general public [17,18]. Some of the issues being address are those related to children's perception on evacuation drills [13], protective action on CDH ("Cover, Duck, Hold on") [19], degree of preparedness [12], barriers for taking protective action [20].

However, there are not that many published studies addressing explicitly what are the factors that would prompt people to participate in mass evacuation drills; the present paper intends to address this gap, at least in the context of Mexico City. That is, following the devastating 1985 earthquake that hit the Capital City [21], the Seismic Alert System of Mexico (SASMEX), an earthquake early warning system (hereafter either EEW or SASMEX), was implemented and it is being regarded as

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the first such system in the world [22,23]. Further, in 2004, the mayor of the city implemented the policy to conducting earthquake mass drills on 19 September yearly [17,24,25]. To conduct the drill, the warning is issued in a predefined date and time. Since then, there have been about twenty-two mass drills being conducted in the city. In particular, the following research question was addressed in the paper: *What factors predict the likelihood that respondents would report that they agree on conducting mass earthquake drills yearly?* The approach taken to the analysis has been the use of logistic regression technique.

2. The 2017 earthquakes, the SASMEX and the mass evacuation drills on 19 September

2.1. The 2017 earthquakes

On 7 September, an earthquake with a magnitude of $M_w = 8.2$ hit Mexico City at 23:49:17 h, local time. The epicentre of the quake was located in the Gulf of Tehuantepec, Oaxaca, Mexico, 650 km from the capital city. It has been regarded as the strongest earthquake since the one that occurred in the country in 1975 ($M_w = 8.1$). As expected, several states of the southern region of the country were severely affected, and hundreds of people were killed; further details can be found in Ref. [26].

On 19 September, a second earthquake struck the city with a magnitude of $M_w = 7.1$ and occurred at 13:30 h. This time, the epicentre of the earthquake was located inland, 120 km from the capital city. Although, the quake with a relatively lower intensity than the previous one, the consequences were severe for the residents of the city. It caused the death of 370 people, 6000 were injured, and over 200 buildings were collapsed [27].

2.2. The SASMEX

Following the devastating 1985 earthquake that struck the capital city of Mexico on September 19, 1985 [21], an earthquake early warning (EEW) system was envisage by the mayor of the city and other organizations [24,25]. It is believed that the SASMEX system was the first in its kind in the world and started its operation in 1991. A detailed description of the features of the SASMEX system are given in Ref. [22,23]. The SASMEX aim was to alert the residents of the city of earthquakes originating in the subduction zone along the Pacific coast of the country. It is believed that since 2015, the mayor of the capital city decided to disseminate the seismic alert to the general public through a network of over twelve thousand loudspeakers distributed throughout the city [23]. Further, the existing policy for issuing the alert is the following: no alert is issued for earthquakes with $M_b < 5.5$ (M_b = body-wave magnitude); relay a preventive alert if $5.5 \le M_b < 6.0$; and issue the alert when $M_b \ge 6.0$ [23, p.1453].

2.3. Evacuation drills in Mexico City

Building a resilient community to seismic risk is an essential component of a disaster management system. It may be argued that to be better prepared, earthquake drills may constitute a basic resource for an adequate training on what to do during an earthquake occurrence; therefore, it contributes to improving the level of preparedness of a community. As mentioned in the introduction section, there are two types of evacuation drills, those with an advance notice or drills without notice. In our case study, the evacuation drills conducted in the city are of the former type.

In 2004, the mayor of the capital city called for what it is known as "September, month of Civil Protection", and since then, various preventive activities have been carried out, such as the case of drills, in order to build the "culture of self-protection" [24]. Since then, there have been earthquake mass evacuation drills in the capital city on 19 September yearly [17,24]. It should be mentioned that the drill participations are voluntarily and there is no punishment for non-participation. Overall, the idea of conducting these exercises have been well accepted by the general public.

As with any evacuation drill, there should be a scenario to practice. The following is an example of the type of information given to the public on the mass drill (an example of the 2019 drill) [17]:

a) The evacuation drill will be held on Thursday, September 19 at 10:00 a.m.
b) An earthquake of magnitude 8.6 will be taken as the hypothesis.
c) You will hear the alert (issued by the SASMEX), as if it were a real earthquake.
d) Once the alert is issued, all the buildings' occupiers should evacuate.
e) The drills seek to improve the prevention measures and the response capacity of all the participants.
f) The mass earthquake drill serves to assess the capital city's seismic emergency plan.

Since its implementation, there have been several scenarios or hypothesises, but the one thing that never has changed is the date, i.e., 19 September. Further, in 2019, for example, about seven million participated in the drill, these included school children and the general public. The paper looks for the factors leading to the participants in the study agreeing on conducting drills on this particular date and yearly.

3. Materials & methods

3.1. Survey design and measures

Following the 2017 two earthquakes in Mexico City, a cross-sectional study was conducted by employing a survey questionnaire. The questionnaire was designed to assess, among other things, the Capital City's perception on the usefulness of the EEW system, the degree of residents' fear of earthquakes, the degree of preparedness, knowledge on what do during an earthquake, participation in drillings, the place they were when the earthquakes hit the capital city, etc., some other details are given in Ref. [26]. In what follows, the details of the dependent and independent variables considered in the analysis are given. See the questionnaire included in the Appendix.

3.1.1. Dependent variable

Given that we were interested in conducting a binary logistic regression analysis, respondents were asked the question on whether they agree on conducting mass earthquake drills in Mexico City, that is: "*Do you agree on conducting evacuation drills on 19 September every year?*" The possible answers to the question were "Yes" or "No".

3.1.2. Explanatory variables

Demographic characteristics. The demographic variables considered in the study were sex (1 = "Men", 2 = "Women"), age (Range = "13–65" years old, M = 34.5, SD = 345.67; the following two levels were considered: 1 = "13–50", 2 = "51–65" years old. One of the considerations in the study was that the over 50's were regarded as one of the most vulnerable population; moreover, we assumed that this category had a direct experience on the 1985 earthquake.), occupation (1 = "Students", 2 = "P&P (Public & Private organizations) Employees", 3 = "ES (Education Sector) Employees", 4 = "Other" (Retirees, etc)), and education level (1 = "Primary/Secondary", 2 = "High school", 3 = "Undergraduate", 4 = "Postgraduate"). In the subsequent process of the analysis, it was necessary to collapse the variable related to occupation into two levels (1 = "Students", 2 = "Employees"); in all cases dummy variables were created to perform the logistic regression analysis.

Location. The respondents of the study came from the capital city and the metropolitan area (1 = "CDMX", 2 = "EDOMX").

Earthquake experience. A question was included in the questionnaire regarding the respondents' experience on the 1985 earthquake [21];

that is, people who had a 'direct' experience on it; however, it should be mentioned that the approaches taken in the analysis of 'direct' and 'indirect' past experiences in Refs. [28,29] were not considered here. The possible answers to the question were the following: 1 = "Yes", 2 = "No". Again, dummy variables were created to perform the analysis.

Earthquake knowledge. There is evidence that those with more earthquake knowledge are more likely to prepare for earthquakes [30–32]. A question intended to assess whether respondents had the knowledge on what to do during an earthquake was included (1 = "Yes", 2 = "No"). Further, a question intended to measure respondents' degree of current knowledge on what actions to take during an earthquake was also included in the questionnaire; this variable was assessed on a scale ranging from 0-10 (0 = "Know Nothing", 10 = "Know Everything"). Finally, as mentioned in section 2, when conducting evacuation drills, the SASMEX (or any other EEW system) is an important element in this process; further, knowing the warning time is crucial in order to have a better response to earthquakes [26,33] (warning time means the time between the moment the alarm goes-off and the actual ground shaking); an item regarding whether respondents knew the warning time once the alert is issued until the actual ground shaking was included in the questionnaire. The possible answers to the question were the following: 1 = "The time varies", 2 = "Other" (i.e., "2 min", "60 s"). As discussed in Ref. [26], before the 2017 earthquakes, there was the general belief among the residents of the capital city that 60 s was the warning time before the ground shaking. However, this is the expected warning time if an earthquake is originated from the so-called "Guerrero-gap" along the Pacific coast of the country, but as mentioned in section 2.1, the 19 September earthquake epicentre was located inland and therefore the warning time was in fact zero.

Drills. As mentioned in subsection 2.3, earthquake drills have been organised by local decision-makers since 2004 and held every 19 September yearly; further, in some instances, there have been drills in schools and other organizations which are held not necessarily in the mentioned date, but at local level. Three questions were included in this category. Respondents' were asked whether they have participated in drills before the year 2017 (1 = "Yes", 2 = "No"). Moreover, a question was included in relation to the participants' perceptions on the frequency of earthquake evacuation drills they would like it to be (1 = "None", 2 = "1-drill/year", 2 = "2-drills/year", 3 = "3-drills/year", 4 = "4-drills/year", 5 = "6-drills/year", 6 = "12-drills per year"). Finally, respondents were asked the following question: Do you think that having a good knowledge on what to do during an earthquake, mass drillings are not necessary? The answer choices were 1 = "Yes", 2 = "No". This variable is denoted as '*Knowledge vs drills*' as shown in Tables 1–3. Similarly, in all cases dummy variables were created to perform the analysis.

Earthquake early warning (the SASMEX). A question related to the usefulness of the existing earthquake early warning (SASMEX) system was included in the questionnaire; the participants of the study were asked to assess this by responding with the following options: 1 = "Yes", 2 = "No". It should be highlighted that there have been several false alarms in the past, however, there is not data to assess people's perceptions on this. Nevertheless, a detailed discussion of the SASMEX's performance during the two 2017 earthquakes is given in Ref. [26].

Perception of seismic risk. Risk judgement includes an individual's estimate of the likelihood of harm to self, and his/her perception of the potential severity of that harm [34]; the likelihood of harm and the severity of it were measured on a scale ranging from 0-10, i.e.: (0 = "Absolutely no chance", 10 = "Absolutely certain") and (0 = "Not serious at all", 10 = "Severe"), respectively. Finally, the perception of the vulnerability of the city was measured with two sets of items representing a likelihood of a future big earthquake occurrence and its devastating consequences in the capital city. These two items were combined into a compound measure related to what it will be referred to as 'Perception vulnerability city' (α = 0.67).

Psychological reaction. Scholars argue that negative affect such as worry, or anger could influence an individual's sense of information sufficiency about the risk and prompt more active information seeking [34,35]. The authors also argue that positive emotions such as optimism might emerge from a disaster. In the present case study, negative emotions are considered, and five items were considered to measure it (α = 0.75) (see the Appendix for details about these). Further, the level of fear of the 19 September earthquake was measured at two levels (1 = "High", 2 = "Low"); finally, the level of fear of the 07 September earthquake was measured on a scale (0 = "No at all", 10 = "A lot").

3.2. Data collection

The study was for convenience. The survey was conducted a few weeks after the occurrences of the two earthquakes in the capital city, i.e., 4 October – 20 November 2017. The questionnaire was pre-tested prior to the final implementation. The survey took about 25 min to complete. A team comprising mainly postgraduate students administered the questionnaires to a sample of 2400 participants. Overall, the approach was to go and ask personnel from different organizations to participate in the study, such as shopping malls, public libraries, restaurants, and high rising buildings. We also visited schools, universities, and research centres; further, we randomly selected households located throughout the sixteen city councils that comprise the capital city. It should be highlighted that in some instances it was necessary to contact the public relations manager for his/her authorization to administer the questionnaires (e.g., high-rise buildings, schools, public libraries). As mentioned in Refs. [26], participants completed the questionnaires anonymously and were assured of the confidentiality of their answers. Moreover, they were given the contact details of the researchers. Also, the survey was approved by the institute ethics committee. The response rate (RR) was 95%, given the fact that people were very proactive and willing to participate at the time.

3.3. Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences software (SPSS 25.0, IBM Corp., Armonk, NY, USA). Descriptive analysis was conducted by frequency tables. For continuous variables, an unpaired *t-test* was conducted. In some instances, it was necessary to convert discrete items into a continuous variable by reporting the relevant Cronbach's alpha of internal consistency.

The independent variables were selected by conducting a univariate analysis; the results of such analysis are expressed as odds ratios (OR) and their 95% confidence intervals (CI). The explanatory candidate variables for a first multivariate model were those whose univariable test had a $p < .25$ [36–39]. These authors argued that the use of the traditional $p < 05$ often fail to identify important variables that should be considered in the analysis. In the present case, we adopted this criterion to review all variables added to a model critically before a decision on the final model. Finally, a multivariate logistic regression was conducted; this time, all significant variables with a $p < .05$ were entered into the multivariate analysis (Table 3 presents the details of the final model).

4. Results & discussion

4.1. Descriptive analysis

We begin the analysis by employing basic descriptive statistics to provide initial insights into the structure of the data. For example, in relation to the dependent variable (i.e., agreeing to earthquake mass evacuation drills on 19 September yearly), the results showed that 53.5% of respondents considered "Yes" and 46.9% responded "No" to the question.

Table 1 shows a descriptive summary of the explanatory variables considered in the present analysis. As described in section 3.1.2, these are organised under the following eight categories: demographics, location, earthquake experience, earthquake knowledge, drills, the SAMEX, perception of seismic risk, and psychological reactions to earthquakes. The results showed that in the sample of 2400 participants of the study, the proportion of participants agreeing to mass evacuation drills were: a) higher for women than men; b) lower for over 50's; c) highest for those participants that considered the frequency of conducting mass drills once a month; d) interestingly, higher for those participants that considered that the earthquake early warning (i.e., SASMEX) was useless during the 19 September 2017 earthquake; e) lower for respondents that experienced the 1985 earthquake than those that did not; and f) as expected, respondents experienced a considerable level of fear during the 19 September earthquake. These are examples of some of the most relevant aspects of the frequency data.

Finally, it should be mentioned that in Table 1 there is not a cell with a zero frequency that could lead to problems associated with having odds ratios of either zero or infinity.

Table 1 also shows some descriptive statistics such as the group means, standard deviations and the *p*-values of the continuous variables considered in the analysis. In general, it was found that there is no significant difference between the means of the two groups (if $p < .05$). However, as mentioned in section 3.3, the adopted criterion in the present analysis ($p < .25$), the variables related to 'Perception vulnerability city' ($p = .165$) and 'Current knowledge' ($p = .127$) were considered as candidates in the initial process of the analysis as demonstrated in the univariate analysis (see Table 2).

4.2. *Factors that motivate respondents to agree on conducting evacuation drills*

4.2.1. *Univariate analysis*

At this stage, we began by looking at the unadjusted effects of each of the explanatory variables and so included a single variable in the model at a time. Table 2 shows the results when fitting a univariable logistic regression model for each explanatory variable.

The results showed that the independent variables related to the demographics of the participants of the study, only age was significantly associated with the outcome ($\chi^2(1, n = 2368) = 4.337, p < .05$). Regarding the location of where the participants reside, it was found that there was not association with the outcome. The variable related to the frequency of drills per year also showed a significant relationship with the dependent variable ($\chi^2(6, n = 2329) = 41.665, p < .001$), but not with the variable related to drill participation. Three variables considered within the earthquake knowledge category, from these only knowledge vs drills was significantly associated with the outcome ($\chi^2(1, n = 2356) = 19.280, p < .001$). Similarly, the variable related to knowledge on the warning time had a significant effect (χ^2 $(1, n = 2368) = 4.855, p \leq .05$).

However, the first multivariable model (Model 1, Table 3) was fitted by considering the explanatory variables that were significant in the univariate analysis at $p < .25$. It should be mentioned that a significance level of 0.20 or 0.25 as a screening criterion for initial variable selection have been proposed by Refs. [36–39]. As a result of this process, eleven variables have been selected by employing the criterion of $p < .25$.

Each variable of Model 1 was analysed at the traditional level of significance ($p < .05$). The results showed that sex (demographics), drill participation (drills), current knowledge (earthquake knowledge), and the variable related to fear of the 19 September earthquake (Psychological reactions) were not significant and therefore removed. Model 2 is the result of this process; moreover, these variables were checked whether they confound or are needed to adjust the effects of the independent variables remaining in the model. The results showed that the variables' coefficients did not become significant. Table 3 shows the final fitted model (Model 3) when considering an interaction term (i.e., "Perception vulnerability city" x "Occupation").

It should be highlighted that there are several strategies that might

Table 1
Descriptive summary of the explanatory variables considered in the analysis.

	Value levels	Mass evacuation drills 19 September yearly?*		
		Yes	No	Total**
		n (%)	*n* (%)	*n* (%)
Demographics:				
Sex	Men	585 (46.2)	476 (43.2)	1061 (44.8)
	Women	681 (53.8)	626 (56.8)	1307 (55.2)
Age	13–49 years old	1125 (88.9)	948 (86.0)	2073 (87.5)
	50–65 years old	141 (11.1)	154 (14.0)	295 (12.5)
Education level	Elementary School	111 (8.8)	96 (8.7)	207 (8.7)
	High School	775 (61.2)	691 (62.7)	1466 (61.9)
	Undergraduate	295 (23.3)	247 (22.4)	543 (22.9)
	Postgraduate	85 (6.7)	68 (6.2)	153 (6.5)
Occupation	Students	531 (41.9)	484 (43.9)	1015 (42.9)
	Employee	735 (58.1)	618 (56.1)	1353 (57.1)
Location	CDMX	858 (67.8)	756 (68.6)	1614 (68.2)
	EDOMX	408 (32.2)	346 (31.4)	754 (31.8)
Earthquake experience:				
1985 earthquake experience	Yes	381 (30.2)	323 (29.4)	704 (29.8)
	No	882 (69.8)	776 (70.6)	1658 (70.2)
Drills:				
Drill past participation	Yes	1178 (93.4)	1008 (91.9)	2186 (92.7)
	No	83 (6.6)	89 (8.1)	172 (7.3)
Frequency of drills	0 per year	57 (4.6)	42 (3.9)	99 (4.3)
	1 per year	207 (16.6)	94 (8.7)	301 (12.9)
	2 per year	85 (6.8)	80 (7.4)	165 (7.1)
	3 per year	35 (2.8)	20 (1.9)	55 (2.4)
	4 per year	39 (3.1)	55 (5.1)	94 (4.0)
	6 per year	332 (26.6)	324 (30.0)	656 (28.2)
	12 per year	493 (39.5)	466 (43.1)	959 (41.2)
The SASMEX:				
Knowledge warning time	Time varies	310 (24.5)	228 (20.7)	538 (22.7)
	Other	956 (75.5)	874 (79.3)	1830 (77.3)
Usefulness SASMEX	Yes	168 (13.3)	172 (15.6)	340 (14.4)
	No	1097 (86.7)	930 (84.4)	2027 (85.6)
Earthquake knowledge:				
Knowledge what to do	Yes	979 (77.3)	866 (78.6)	1845 (44.8)
	No	287 (22.7)	236 (21.4)	523 (44.8)
Knowledge vs. drills	Yes	836 (66.4)	632 (57.6)	1468 (62.3)
	No	423 (33.6)	465 (42.4)	888 (37.7)
Psychological reactions:				
Fear 19 Sept. earthquake	High	890 (71.0)	799 (73.4)	1689 (72.1)
	Low	363 (29.0)	290 (26.6)	653 (27.9)
Continuous variables		*Mean (SD)*	*Mean (SD)*	*p*
Perception of seismic risk:				
Likelihood of harm	Scale (0-10)			.818

(*continued on next page*)

Table 1 (*continued*)

	Value levels	Mass evacuation drills 19 September yearly?*		
		Yes	No	Total**
		n (%)	*n* (%)	*n* (%)
		5.96 (2.27)	5.98 (2.26)	
Severity of the harm	Scale (0-10)	7.06 (2.18)	7.03 (2.12)	.748
Perception vulnerability city	(α = .75)	4.13 (.835)	4.08 (.856)	.165
Current knowledge[a]	Scale (0-10)	5.92 (2.02)	6.05 (1.93)	.127
Negative emotions[b]	(α = .67)	3.03 (.920)	3.05 (.856)	.550
Fear 07 Sept. earthquake[b]	Scale (0-10)	4.97 (3.09)	5.07 (3.11)	.448

*Total percentages in columns may not add up to 100% because of decimal rounding; only data within the outcome variable (column) is given.
**Differences in total n = 2400 are due to missing values in items.
[a] Variable withing the category of Earthquake knowledge.
[b] Variable within the category of Psychological reactions.

be applied to selecting a final model. In the present case study, it was opted for a two-way approach to interactions of model terms that had each been demonstrated to have a significant main effect on the agreement to the outcome variable. As a result of this process, only "Perception vulnerability city" x "Occupation" interaction term was significant (Wald: $\chi^2(1) = 5.497$, $p = .019$). Fig. 1 shows the interaction graphically (see section 4.4. for the limitations of the study).

4.2.2. The multivariate analysis

As described in the previous section, the explanatory variables that have a significant effect on the outcome were those related to age, occupation, frequency of drills, warning time, usefulness of the SASMEX, knowledge vs drills, 'perception vulnerability city' (Table 3). For example, respondents whose age ranged from 13-49 years old have 1.366 times the odds of agreeing on conducting mass earthquake drills on 19 September yearly compared to older participants (50–65 years old) (95% CI 1.039 – 1.795). All those employees that participated in the study have 3.378 times the odds of agreeing on conducting mass earthquake drills compared to students (95% CI 1.457 – 7.830).

The results also highlighted that the two most influential factors to the outcome variable were those related to the frequency of drills and knowledge vs drills. That is, respondents considering one and three evacuation drills per year have 2.128 and 1.708 times the odds of agreeing on conducting drills yearly compared to those considering one per month (95% CI 1.610 – 2.812 & 95% CI 1.006 – 3.151, respectively). However, it appears that respondents who answered one drill per year were more likely to agree in conducting drills yearly (Wald: $\chi^2(1) = 28.181$, $p < .001$). To find out whether this was the case, we rerun the model by setting the frequency of drills "1/year" as the base or reference category. The results showed that effectively, the frequency of "3/year" does not contribute significantly to explaining the outcome variable (Wald: $\chi^2(1) = 0.331$, $p = .565$).

On the other hand, the odds of agreeing on conducting mass evacuation drills are 1.394 times higher for participants that considered that an adequate knowledge on what actions to take during the ground shaking, respondents feel that it is not necessary to participate in drills compared to those that responded "No" to the question (95% CI 1.172 – 1.658).

The odds of agreeing on conducting drills are 1.266 higher for those that consider that the warning time (which is issued by the SASMEX) varies before the ground shaking to those that answer "Other" (e.g., 50 min, 2 min, see the Appendix) (95% CI 1.036 – 1.548). Further, the odds of agreeing on conducting mass earthquake drills yearly are 0.783 times higher for participants that consider the usefulness of the SASMEX

Table 2
Univariate analysis of the explanatory variables considered in the analysis.

	Value levels	OR	[95% CI] [Lower – Upper]	*p*
Demographic characteristics:				
Sex	Men	1.130	[.960–1.320]	.141[a]
	Women	base		
Age	13–49 years old	1.296	[1.015 – 1.655]	.037[a]
	50–65 years old	base		
Education level	Elementary School	base		
	High School	.970	[.725–1.299]	.838
	Undergraduate	1.033	[.749–1.449]	.843
	Postgraduate	1.081	[.710–1.645]	.716
Occupation	Students	base		
	P&P Employee	1.051	[.877–1.259]	.593
	ESE Employee	1.042	[.749–1.449]	.808
	Other (Jubilee, etc.)	1.209	[.936–1.560]	.146[a]
Location	CDMX	base		
	EDOMX	1.039	[.874–1.236]	.655
Earthquake experience:				
1985 earthquake experience	Yes	1.038	[.870–1.239]	.681
	No	base		
Drills:				
Drill past participation	Yes	1.253	[.918–1.710]	.155[a]
	No	base		
Frequency of drills				.000[a]
	0 per year	base		
	1 per year	1.623	[1.017 – 2.589]	.042
	2 per year	.783	[.474–1.293]	.339
	3 per year	1.289	[.654–2.542]	.463
	4 per year	.522	[.295 - .926]	.026
	6 per year	.755	[.493–1.157]	.197
	12 per year	.780	[.513–1.184]	.243
The SAMEX:				
Knowledge warning time	Time varies	1.243	[1.024 – 1.509]	.028[a]
	Other	base		
Usefulness SASMEX	Yes	base		
	No	1.208	[.960–1.520]	.108[a]
Perception of seismic risk:				
Likelihood of harm	Scale	.966	[.961–1.032]	.818
Severity of harm	Scale	1.006	[.969–1.045]	.748
Perception vulnerability city	(α = .67)	1.070	[.973–1.177]	.165[a]
Earthquake knowledge:				
Knowledge what to do	Yes	.930	[.765–1.130]	.324
	No	base		
Knowledge vs drills	Yes	1.454	[1.230 – 1.719]	.000[a]
	No	base		
Current knowledge	Scale	.969	[.930–1.009]	.128[a]
Psychological reactions:				
Negative emotions	(α = .75)	.973	[.888–1.065]	.551
Fear 07 September	Scale	.990	[.964–1.016]	.448
Fear on earthquake 19 sept.	High	base		
	Low	1.124	[.937–1.347]	.208[a]

[a] The selected variables at significance criterion $p < .25$ [36–39].

compared to those that considered it useless (95% CI 0.615 – 0.998).

Finally, when considering the 'perception vulnerability city' by occupation interaction, the results showed that conducting mass earthquake drills of students are predicted to be increasing gradually with higher degree of agreement on the vulnerability of the city to a big earthquake, while the opposite was observed for employees (95% CI 0.643 - 0.961) (Fig. 1). Thus, it may be argued that if students were more pessimistic (or aware of the importance of the need to be better prepared to earthquakes) than employees and therefore were more likely to agree on conducting drills every year on 19 September. However, this tendency was not observed in employees.

4.3. Discussion

Earthquake evacuation drills may be regarded as a key activity

Table 3
Multivariate logistic regression analysis results of the participants' motivations to carry out earthquake drills on 19 September yearly.

VariableValues		Model 1			Model 2			Model 3		
		B	S.E.	OR [95% CI]	B	S.E.	OR [95% CI]	B	S.E.	OR [95% CI]
Demographics:										
Sex	Men	.119	.089	1.126 [1.015–1.242]						
	Women (base)									
Age	13–49	.300*	.142	1.349 [1.015–1.242]	.334*	.139	1.396 [1.063–1.834]	.312*	.139	1.366 [1.039–1.795]
	50-65 (base)									
Occupation	Employees	.255**	.094	1.290 [1.074–1.551]	.236**	.092	1.266 [1.057–1.515]	1.217**	.429	3.378 [1.457–7.830]
	Students (base)									
Drills										
Drill participation	Yes	.247	.167	1.280 [.922–1.776]						
	No (base)									
Frequency of drills	0/year	.255	.223	1.291 [.833–2.000]	.262	.219	1.299 [.847–1.994]	.248	.219	1.281 [.834–1.968]
	1/year	.747***	.143	2.111 [1.593–2.795]	.760***	.142	2.138 [1.619–2.824]	.775***	.142	2.128 [1.610–2.812]
	2/year	.053	.174	1.054 [.750–1.482]	.048	.171	1.049 [.750–1.468]	.047	.171	1.048 [.749–1.467]
	3/year	.648*	.301	1.912 [1.061–3.447]	.568*	.290	1.756 [.999–3.117]	.577*	.291	1.708 [1.006–3.151]
	4/year	-.387	.227	.679 [.436–1.059]	-.347	.222	.707 [.458–1.092]	-.347	.222	.707 [.458–1.092]
	6/year	.014	.104	1.014 [.827–1.245]	-.013	.103	1.013 [.828–1.241]	.015	.103	1.016 [.829–1.244]
	12/year (base)									
The SASMEX										
Warning time	Time varies	.232*	.104	1.261 [1.029–1.545]	.240*	.102	1.272 [1.041–1.554]	.236*	.102	1.266 [1.036–1.548]
	Other (base)									
Usefulness SASMEX	Yes	-.253*	.125	.776 [.607-.992]	-.248*	.123	.781 [.613-.994]	-.244*	.124	.783 [.615-.998]
	No (base)									
Earthquake knowledge										
Knowledge vs drills	Yes	.323***	.089	1.382 [1.209–1.709]	.340***	.088	1.404 [1.181–1.670]	.332***	.089	1.394 [1.172–1.658]
	No (base)									
Current knowledge	Continuous	-.038	.022	.963 [.922–1.005]						
Psychological reactions										
Fear 19 Sept. earthquake	Low	.077	.098	1.080 [.890–1.310]						
	High (base)									
Perception seismic risk										
Perception vulnerability city	Continuous	.116*	.052	1.123 [1.015–1.242]	.103*	.051	1.108 [1.003–1.225]	.240**	.078	1.271 [1.091–1.480]
Interaction Perception vulnerability city x Occupation								-.241*	.103	.786 [.643-.961]
Constant		−1.148***	.347	.317	−1.052***	.285	.349	−1.580***	.365	.206

* = $p < .05$; ** = $p < .01$; *** = $p < .001$.
Summary of the final model (Model 3): -2LL = 3118.214; χ^2 = 83.885; df = 13; p < .001; Nagelkerke R^2 = 0.047; Hosmer & Lemeshow test, p = .891.

within the emergency preparedness process. Since 2004, mass drills have been conducted on 19 September every year in the capital city of the country. The aim of the present study was to address the following research question: What factors predict the likelihood that respondents would report that they agree on conducting mass evacuation drills yearly? Logistic regression was employed to identify these factors. First, we assessed the unadjusted relationships between the outcome and each potential predictor variable singly. Then, we adjusted these relationships for potential confounding effects. Finally, we considered the possibility of interaction effects between some of the variables. Of the 19 explanatory variables considered initially in the process of building the model (Table 3), only seven variables and one interaction term were significantly related to the dependent variable; i.e.: age & occupation (Demographics), frequency of drills (Drills), knowledge vs drills (Earthquake knowledge), 'perception vulnerability city' (Perception of seismic risk), warning time & the usefulness of the SASMEX, and the 'perception vulnerability city' by occupation interaction.

Before discussing these findings, it is worth mentioning that in relation to the dependent variable, the results showed that 53.5% of respondents agreeing to conducting drills. It may be argued that this proportion may not be that high as one would have expected (i.e., 46.9% responded "No"). However, these findings are consistent with those reported in Refs. [7–10] in the sense that earthquake drills are important in building a resilient community to seismic risk. For example, it is believed that more than 57 million people participated in drills across 56 countries and most of the US (this is according to the ShakeOut.org as cited in Ref. [20]). Similarly, in New Zealand, in 2012 about 1.3 million people registered to participate in "ShakeOut" drill [20]. Further, by participating in drills, people will act if they believe that by doing this (i. e. drill participation) will increase their chance of survival and recovery; therefore, they will be more likely to undertake that action [20,40,41]. However, there is evidence that drill participation in some countries are low, for example, the 2005 evacuation drill participation in Japan was 19% [18]; similarly, the participation rate in the 2014 evacuation drill that took place in the city of Ishinomaki (Japan) was only 7.3% [18]. The low participation is attributed, among other things, to embarrassment [20], lack of motivation value of such drills [18]. It should be highlighted that we could not compare the lack of drill participation, if any, of the residents of the capital city because there is not available data. Similar studies on the effectiveness of evacuation drills should be

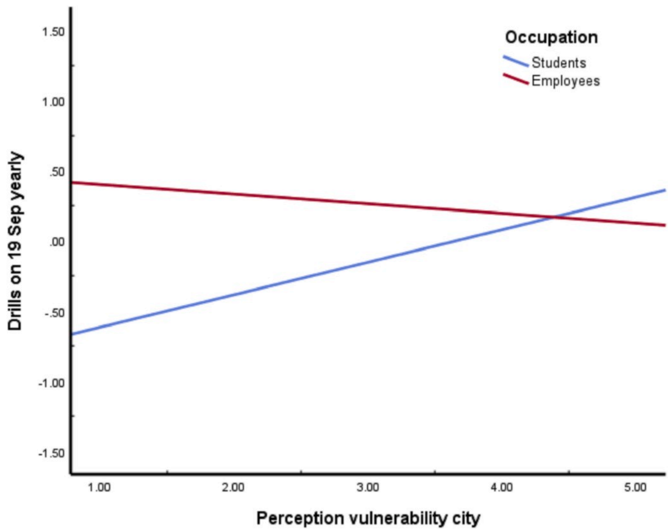

Fig. 1. Mexico City vulnerability to seismic risk.

investigated in the context of our case study.

In our study, the frequency of drills was one of the most important contributors to the outcome variable. Respondents were more likely to consider one drill per year than were those who consider one per month. In short, respondents in our study considered that one drill per year may be enough (section 4.4.2). Our results contrast with those reported in Refs. [20], where it has been argued that "more effort could be made in normalizing these actions (i.e., drills on DCH (Duck, Cover, Hold on)) in the future, including more drills …". Also, in the report on the "ShakeOut" survey, in relation to school drill frequency, it has been found that 56% and 54% of school and district respondents, respectively, considered the need to conduct four or more drills per year [19, p.31]. Further research is needed to explain this difference; for example, by conducting a similar analysis in relation to the two questions that have not been addressed here, i.e., those related to whether respondents agree on conducting mass evacuation drills anytime during the day and night (see the Appendix).

The variable related to knowledge vs drills, on the other hand, was the other most important contributor to the outcome variable in our study. Respondents were more likely to agree on conducting drills even with an adequate knowledge on what to do during the ground shaking than those who responded "No" to the question. In general, this finding is consistent with those reported in Refs. [30,42]; for example, it has been found that those with more knowledge about earthquakes were more likely to prepare for one [30]. However, what is less clear is, why those participants that do not have adequate knowledge, were also not interested in participating in drills. It may be argued that there are other precursors outside their personal control besides drills, e.g., the quality of the drill exercises, among others; for example, in Ref. [18], it was reported that drills have become increasingly stereotypical and boring. More research is needed to better understand why this kind of people's behaviour in relation to mass evacuation drills.

As mentioned in section 2, a key component of the Mexican earthquake disaster management system is the earthquake early warning system (the SASMEX). In general, the aim of an EEW system is to alert people by proving a few seconds/minutes to take some sort of action before the actual ground shaking [22,23,26]. The results showed that the variable warning time was significantly associated with the dependent variable. Respondents that considered the warning time varies were more likely to agree on conducting drills than those that responded "Other" (e.g., 50 s, 2 min, etc.). This may be explained given the fact that during the 07 September 2017 earthquake, the warning was issued in time (i.e., about 2 min before the actual shaking). However, the 19 September earthquake (the earthquake that occurred twelve days after the first one), the warning was issued almost simultaneously with the ground shaking. Because of this, respondents may have perceived the need for drills in order to enhance their response capabilities during the emergency. Again, a detailed analysis of the performance of the SAMEX during the two earthquakes is presented in Ref. [26]. The importance of knowing the warning time before the shaking is consistent with similar studies [19,20,26,43–46].

Similarly, respondents that considered the SAMEX as useful were more likely to agree on conducting drills than those that considered it useless. As mentioned above, respondents were very surprised to know that the SASMEX was not very useful during the 19 September earthquake, but afterwards respondents may have understood that the warning system was not functional for cases where the earthquake epicentre was located only 120 km from the capital city [26]. Given the fact that earthquakes cannot be predicted, earthquake early warning systems are essential in alerting people to take actions and prevent fatalities [22,23,26,33,47], but people should be educated on their features, warning time, etc; in other words, EEW systems should be people-centred [26].

When considering the 'perception vulnerability city' by occupation interaction, the results showed that students were more pessimistic than employees and therefore were more likely to agree on conducting drills every year on 19 September. These results may be consistent with those reported in Ref. [20]; for example, schools represented the highest proportion of drill participation (49% in 2012 and 50% in 2015) [20, p.5]; this was followed by personnel from business (15%) government (5%), and health organizations (4%) [20, p.6]. Effectively, more research may be needed to better understand why people do not participate in drills. Finally, when considering the variable age, it has been found that respondents whose age ranged from 13-49 years old were more likely to agree on conducting drills yearly than those over 50's.

Several questions have arisen from the study, for example, the following in the context of the case study: why conducting earthquake drills on 19 September yearly? Why not evacuation drills in other dates? Why not any time during the day? Why not at any time during the night? More generally, should earthquake evacuation drills be unannounced? These questions need to be addressed because of their implications in the way people may respond to the emergency [47]. That is, historical data shows that earthquakes have occurred anytime during the day and night and with devastating consequences. For example, the 07 September that hit Mexico City in 2017 occurred at 23.49 h local time, where most people were about to go to bed (or some were sleeping already); it may be argued that people's reaction to earthquakes at night may be different than during daylight, for example, the evacuation from high rising buildings [48]. More research should be conducted on these issues to gain a better understanding on peoples' response under these (or any other) scenarios.

4.4. Some limitations

As with any analysis such as the presented in here, is not without limitations. Most of the weaknesses in this study stem from the participants sample that was gathered. That is, while a sample of 2400 residents may be regarded as acceptable and more than appropriate for the employed multivariate logistic regression techniques, the results should not be generalized to the population of Mexico City. However, it sheds some light on issues that may be required to 'validate' with a probability sample. As mentioned in section 2.2, a two-way interaction approach has been considered in the present analysis. As it has been argued in Ref. [49,50], a potential pitfall may be that higher order interaction (e.g. a three-way) effects that do not coincide, for example, with the employed approach effects might be missed. Further research may be needed to further explore this.

5. Conclusions

Earthquake evacuation drills may constitute a key process for preparing for a seismic emergency. The paper has presented the results of an analysis of participants' perceptions on the factors leading to conducting drills for the case of Mexico City. The sample size considered for the analysis was N = 2400. In particular, the following research question has been addressed: What factors predict the likelihood that respondents would report that they agree on conducting mass earthquake drills yearly? The approach has been the application of logistic regression to identify these factors. Of the 19 initial explanatory variables, in the final model, only seven variables were significantly associated with the outcome variable; i.e.: age & occupation (Demographics), frequency of drills (Drills), knowledge vs drills (Earthquake knowledge), 'perception vulnerability city' (Perception of seismic risk), warning time & usefulness of SASMEX (EEW), and the 'perception vulnerability city' by occupation interaction.

Further research may be needed to gain a better understanding of people's motivations on evacuation drills taking place anytime during the day or at night, and whether evacuation drills should be unannounced.

Finally, it is hoped that the results presented here may contribute to further discussion on the need for implementing EEW systems to those regions lacking them; moreover, the need to conduct earthquake drills to better prepare to earthquakes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ijdrr.2020.101661.

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