The Impact of the September 7th 2017 Earthquake on the Businesses of the Municipal Market of Juchitán De Zaragoza Due to Property Damage

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Research Article

Keywords: Chiapas 2017 earthquake, business interruption, loss due to earthquake, damages and rehabilitation in the Juchitán Market

Posted Date: March 29th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1443626/v1

Abstract

Earthquakes of great intensity often affect businesses because the buildings where they operate are severely damaged, in this sense, the municipal market of Juchitán de Zaragoza represents an interesting case study. This investigation identifies the damage to property during the 8.2 Mw earthquake that occurred on September 7th, 2017, observing that the short column problem occurred in most of the columns, a settlement and shear failures in beams and non-structural walls, and later the structural and non-structural rehabilitation are detailed. Likewise, a statistical report is presented on a survey applied in November 2020 to 165 businesses established in the market to evaluate the business impact of the loss of the building's operability due to the destructive event. According to the results obtained, only 4.24% of the economic units surveyed did not have direct losses due to the earthquake, on the other hand, 45.46% could not operate for more than a month and 33.94% considered that they stopped earning more than $ 3,000 MXN ($ 160 USD) during the time of absolute stoppage of its activities.

1 Introduction

1.1. Brief description of the problem and objective of the research

According to the National Seismological Service (2017), on September 7th, 2017, there was an earthquake with a magnitude of 8.2 Mw at 23:49:18 hours (Local time, Mexico City), whose epicenter was located in the Gulf of Tehuantepec, in front of the coast of Chiapas, 133 km southeast of the municipality of Pijijiapan. The coordinates for the hypocenter were 14.761 N and − 94.103 W, and the depth was 45.9 kilometers. The focal mechanism of the earthquake evidenced a failure of the normal type. Two days after, 482 aftershocks were recorded and, 15 days later, 4326 aftershocks, whose distribution covered all the Tehuantepec Gulf. On the other hand, based on a report made by the Engineering Institute at UNAM (2017), in the Niltepec station (NILT), there was a Maximum Soil Acceleration registered, PGA, of the 500 cm/s^2 order, while, in Mexico City, the registered PGA in University City was 8.9 cm/s^2 (Fig. 1).

This earthquake affected different infrastructure of several states of the Mexican Republic, among them, Chiapas, Tabasco, Veracruz, Mexico State and Oaxaca (Archundia et al. 2018; Pozos-Estrada et al. 2019; Tapia y García 2019; Aguilar et al. 2020; Guzman et al. 2020). Particularly, Juchitán de Zaragoza was the municipality of Oaxaca that suffered the biggest amount of damages because of this destructive event, given that thousands of houses, the church, city hall, several educational institutions and hundreds of commercial buildings suffered severe damages or a total or partial collapse. It was observed that the entrepreneurial sector was gravely damaged, which represented a socio-economic problem, due to the fact that, at the moment, businesses of all types and sizes are essential for the functioning of every community and the economic strength of a country, given that they generate employment, pay taxes, provide goods and services, etc. that's why, when they can't restart their activities after the earthquake, the individual and communal living conditions worsen, which leads to a considerable delay in the recovery of

affected zones (Chang y Lotze 2014; FEMA 2015; Ortiz et al. 2020, Ortiz et al. 2021a). In that sense, the municipal market of Juchitán represents an interesting case study.

The objective of this research is to analyze the impact of businesses of the municipal market of Juchitán de Zaragoza, Oaxaca, caused by the property damage during the Chiapas earthquake, which occurred on September 7th, 2017. Particularly, the effects and the rehabilitation of the property are detailed, and then, for a representative sample, we estimated direct and indirect losses incurred by interruption of activities. We identified the strategies that were implemented to maintain and increase the habitual level of profit, we indicate the incentives they received for entrepreneurial reactivation and examined the recovery of productivity.

1.2 Impact on businesses due to some historical earthquakes

Destructive earthquakes, on top of the deaths and injuries they cause, have always brought serious economic and social problems, among them, negative impacts on economic units, such as increased economic losses for structural and non-structural damage on buildings and their content. These direct effects have also provoked businesses to have to interrupt their operations and therefore, stop generating profit. However, there have also been a cease in production even if the buildings didn't turn out damaged. We have even observed some companies that suffered a decrease in income without having ever closed due to the earthquake, because they stopped having clients after the big event (Arce et al. 2014; Ortiz y Reinoso 2019; Ortiz et al. 2021b).

"All economic units mut take into account all the risks to which they are exposed to reasonably maintain themselves in function. It is crucial that they incorporate practical solutions to mitigation into their commercial and planning decisions" (FEMA 2015). It has been demonstrated that micro and small businesses are more vulnerable to natural risks than big ones (Lo et al. 2021), however, it has been evidenced that those that have previous experience in disasters and problems with money flux, have less probability to disappear after a new catastrophic event (Marshall et al. 2015).

Research has been performed on the commercial consequences of the most catastrophic earthquakes in California, including the 1983 Coalinga (Durkin 1984; French et al. 1984), 1989 Loma Prieta (Kroll et al. 1991) and 1994 Northridge (Gordon et al. 1995; Boarnet 1998). According to the poll performed by Tierney (1997), it was recorded that due to this event, the four main reasons for companies temporarily closing were: 1) loss of power (58.7%), 2) inability of the employees to reach the place of business (56.4%), 3) damages to the owner's house (44.4%) and 4) loss of clients (40%). Also, there is a study base don a poll in which the direct and interruption of business losses were estimated after the Kocaeli, Turkey 1999 earthquake (Durukal y Erdik 2008) and in another study, the economic impact on Shifang was estimated, which was caused by the interruption in roads as a result of the Wenchuan earthquake, which occurred in 2008, demonstrating that a failure of the transport network leads directly to impacts in the interruption of business in the road transport sector, which directly leads to impacts in the interruption of

business, which unchains a domino effect in other sectors due to economic interdependence (Shi et al. 2015).

Furthermore, based on the data recollection of 541 organizations affected by the earthquakes in Canterbury, it was registered that the most disruptive impact of these was due to the problems the clients had to face, and also, it was evidenced that those economic units that rented a building recovered a little bit better than the ones that owned the place (Brown et al. 2015). On the other hand, based on the poll that was applied to 226 retailers of the Central Market at Portoviejo, 22% couldn't offer their products for between 1 and 15 days due to the earthquake that occurred on april 16th 2016, in Ecuador, while 46% was between 15 and 30 days, and 32% was for more than 30 days (Valdiviezo 2019). Additionally, it was observed that, because of the September 2017 earthquakes in Mexico, out of 2,041 million businesses, 39.3% suspended activities at some point, out of which 43.2% was for one day, 23.4% for two days, 10.8% for three days and at least 22.6% for more than three days (INEGI 2017). There was also an analysis of damages to houses and commercial buildings by the Puebla earthquake in september 19th 2017, noting that, in Mexico City, the buildings of between 1 and 10 stories, and that were built between the 1960s and 1980s, were the most affected (Buendía y Reinoso 2019) and in another investigation, reasons for closure were identified in businesses for this event, registering the cuts in power, post seismic inspection of the structure, complications in access ways, the collapse of neighboring businesses with human victims, among others, caused a potential pause in business (Ortiz y Reinoso 2020).

Recently, an analytical framework was developed to model the recovery times of companies after seismic events considering multiple downtimes such as building recovery, general community disruption, and mitigation tactics employed by companies using information from 22 economic units affected by the 2011 Mw 6.1 earthquake in Christchurch, New Zealand (Cremen et al. 2020). In addition, a probabilistic model was carried out to quantify and predict the recovery of businesses through a Bayesian linear regression, taking into account the interaction between households and businesses, which was applied in a community in Lumberton, North Carolina, which was deeply impacted by Hurricane Matthew in 2016 (Aghababaei, 2020).

2 Research Method

The present scientific investigation has a mixed approach. It is qualitative, because the pathology of the Juchitán market was recorded based on field investigations, while it is also quantitative, since a statistical report was made on the effects on the businesses of this property due to the earthquake of September 7th 2017.

2.1. Research techniques and instruments for data collection

A direct observation was made, in addition, structured interviews were applied to Civil Engineers in order to collect the damage in the Juchitán market building during the earthquake and to know how this property was rehabilitated, being necessary for such purposes a device to take photographs and record.

Likewise, in November 2020, a face-to-face survey was conducted to business owners or employees in the market to determine how they were affected by the earthquake, requiring a questionnaire with closed, brief and objective questions. Finally, the documentary analysis allowed us to collect information from scientific journals, technical reports, newspapers, among others, using the data record sheet as an instrument.

2.2 Population and sample size

On the other hand, according to the representative of the tenants, the Juchitán de Zaragoza market located in Oaxaca has the capacity to house approximately 1082 businesses, including those established on the sidewalks attached to the property. However, due to the COVID-19 pandemic, when the field investigation was carried out, only about 70% were operating. Therefore, in this work a total population of 758 economic units was considered. To calculate the size of the representative sample, the following equation was used for a population with finite size:

$$n = \frac{N\sigma^2 Z_\alpha^2}{e^2(N-1) + \sigma^2 Z_\alpha^2} (1)$$

Where:

$n =$ sample size

$N =$ population size

$\sigma =$ population standard deviation. It is usually assigned a value of 0.5 to be conservative.

$Z_a =$ number of standard deviations that a given proportion deviates from the mean. For a confidence level of 95%, a value of 1.96 corresponds.

e = acceptable limit of sampling error. Usually a value that varies between 1% and 9% is used. In this case, a margin of 6.77% is considered.

Therefore,

$$n = \frac{(758)\left(0.5^2\right)\left(1.96^2\right)}{\left(0.0677^2\right)(758-1) + \left(0.5^2\right)\left(1.96^2\right)} = \frac{727.9832}{4.6687} \approx 165$$

Consequently, 165 businesses were surveyed, as shown in Table 1. A type of random sampling was used, so that all the elements of the population had the possibility of being chosen in the sample.

Table 1
Number and percentage distribution of businesses considered in the survey according to the type of product or service they offer

Business Type	Absolute frecuency	Relative frequency	Percentage (%)
Typical crafts of the region	29	0.18	17.58
Drinks or food	38	0.23	23.03
Beef or pork, chicken, or seafood	39	0.24	23.64
Fruits or vegetables	9	0.05	5.45
Clothing or footwear	36	0.22	21.82
Stationery	3	0.02	1.82
Other	11	0.07	6.67
Total	165	1.00	100.00

3 Pathology Of The Juchitán Market

3.1 Structuring the property

The City Hall of Juchitán de Zaragoza, Oaxaca was built in the 19th century and covered the entire respective block. At the beginning of the 20th century, it was decided to locate a public market using the infrastructure of this building, roofing the central patio and converting the accessories on the ground floor into commercial premises. However, in 1970 this market caught fire, so that part of the palace's structure was damaged. Once the area that had been affected had been demolished, the building that today is known as "Mercado 5 de Septiembre" was built there, which was inaugurated in January 1973.

The market building consists of a structural system based on two-level reinforced concrete frames. It has a trapezoidal-shaped plan, so that on the widest side, it has 6 longitudinal axes and on the narrower it has 5. On the transverse side it has 18 axes, resulting in a total of 85 columns.

The columns are supported on isolated footings linked with beams, while the mezzanine slab is lightened around the perimeter and in a central section, in addition to linking the longitudinal sections in the transverse direction, leaving two free areas on the floor of the slab. Meanwhile, the roof slab has a novel geometry due to the pyramidal shapes and the use of pre-forces in the short sense. Likewise, the perimeter walls are made of red annealed partition from the Isthmus region, they rest on continuous footings and are cast monolithically with the columns, in such a way that the mezzanine slab does not bind.

3.2 Downtime of building occupancy

Due to the fact that the building presented a level of severe global damage due to the earthquake that occurred on September 7th, 2017, it was disabled for a little more than two years and two months until its reconstruction, so that businesses could not operate there during that period. In Fig. 2, a Gantt chart is shown with the activities that were carried out to be able to reopen the market.

According to a structured interview applied to the Director Responsible for Construction, the tasks for the recovery of the operation of the building began in September 2017 with the call of the municipal government to civil engineers and architects to form a working group for the sake of reconstruction. in Juchitán de Zaragoza. In October 2017, the Municipal Reconstruction Coordination was formed, which was in charge of carrying out post-seismic inspections and simplified evaluations of damages in the market and other buildings in the municipality that had been affected by the Chiapas earthquake, in addition, this month the local government requested financial support from the state and federal governments to rehabilitate the market. Likewise, during these two months, the areas near the main columns of the building were simultaneously propped up.

A more detailed evaluation of the structural safety in the property was carried out in October by a company specialized in rehabilitation, which ruled the viability of the reconstruction of the market, in contrast to the opinion of other engineers and most of the tenants, who suggested its demolition. The structural and non-structural damages identified in the building are described in detail in subtopic 3.3. Between November and December 2017, agreements were carried out between all parties involved (government, tenants, construction company and funders) and simultaneously, the design of the rehabilitation project was carried out, in addition activities of cleaning and rubble removal.

After the financial support of different foundations and donations from company employees, in January 2018, the works for the reconstruction of the market began, which are described in detail in subtopic 3.4. During this month, the mezzanine slab was shoring using wooden blocks. Likewise, in January and February, the perimeter walls were demolished and the footings and columns were prepared in order to reinforce them with steel rods and pour them with concrete, including the capitals of the mezzanine slab. On December 10th, 2018, the completion of the cladding of all the columns was reported. In general, at the end of this month, it was indicated that the property had 85% of total progress in its reconstruction, not only considering the structural part, but also the architectural, hydro-sanitary and electrical, as well as the conditioning of the commercial premises.

Although the rehabilitated market in Juchitán was inaugurated on April 11th, 2019, it was not opened to the public because it was necessary to complete the electrical rehabilitation and also for safety reasons, since the rehabilitation works of the municipal palace located nearby had not yet been completed. Therefore, tenants continued to offer their products or services on a provisional basis, mainly in the Benito Juárez central park.

Finally, with the financing of the tenants, it was possible to finish rehabilitating the electricity supply and, given the economic need, a little more than 800 businesses restarted activities in the Juchitán market property on November 23rd, 2019, despite the fact that the municipal palace he was not rehabilitated.

3.3 Damage to the property

As shown in Fig. 3, the columns were severely damaged due to the short column effect, which consists of a partial restriction of the lateral displacement of the structural element, which forces all the stress and deformation demand to be concentrated in its free portion, which are substantially greater than those that would appear in the same column if it were free throughout its height. It was observed that this problem occurred because the non-structural masonry walls did not span the full height of the respective columns, but there were voids, in some cases for the windows. Among the local effects produced by the short column problem were the increase in lateral stiffness and shear stress, as well as the decrease in ductility. The global effects were derived from the incompatibility of deformations between the short columns and the rest of the structural members resistant to lateral actions, since the former failed prematurely and a chain reaction was generated (Beauperthuy and Urich 2011).

Likewise, in the northeast corner, there was a subsidence of the footing, which caused the prestressed girder of the second level to fail, so that there was an approximate difference in level in the corner area of 10 to 15 cm with respect to the horizontal. In Fig. 4, a beam shear failure is shown, which is characterized by the presence of diagonal cracks. On the other hand, Fig. 5 shows some non-structural damage, such as broken windows, detachment of finishes and shear cracking in non-structural walls.

3.4 Rehabilitation of the building

According to what was observed, the Juchitán de Zaragoza market building was rehabilitated approximately a year and a half after the occurrence of the earthquake of September 7th, 2017, however, businesses returned to operate in this construction at a little more than two years after the catastrophic event. Due to the very severe damage, a reconstruction of the property was necessary, which required an investment of more than 35 million Mexican pesos. Here are some of the activities that were carried out to restore the functionality of the building:

1. To rehabilitate the columns of the ground floor and the first floor, the cladding technique was used, which according to Ayala and Giraldo (2018) consists of a way to reinforce a structural element that has undergone changes in its resistant capacity, increasing its section wrapping it with an additional section of suitably reinforced concrete, in order to increase its load capacity against compression, bending, shear and torsion, guaranteeing simultaneous work between different elements. The foregoing in order to comply with the provisions of current regulations (resistance, safety factors, quality of materials, functionality and useful life). The construction process is shown in Fig. 6 and consisted of the following:

- Shoring of the slab of the first level.
- Excavation (on the ground floor this activity was carried out for re-laying).
- Scarifying of damaged columns with mechanical equipment and hand tools (Fig. 6a).
- Fitted and reinforced with steel for the new footing connected to the columns on the ground floor (Fig. 6b).

- Fitted and reinforced with steel for the columns (Fig. 6c).
- Forming the columns (Fig. 6d).
- Casting of the columns whose final section was 50x80 cm or 55x55 cm. CEMEX ready-mixed concrete was used with a compressive strength of f'c = 300 kg/cm^2 (Fig. 6e).
- Filling of the excavation with cyclopean concrete in the columns of the first floor.

2. The previous waterproofing was removed, the existing cracks were repaired and the upper and lower beds were waterproofed in the roof slab and the edge beams, applying four layers: sealer, preliminary waterproofing, reinforcing membrane and waterproofing to seal the final pore.

3. Construction of a cistern and a machine room, Fig. 7.

4. Gussets were built located only on the 50x80cm columns, using CEMEX concrete with f'c = 300 kg/cm^2

5. As shown in Fig. 8, several concrete bars were built for the business tables.

6. Various works on the east, west, south and north facades, including the construction of:

- Counterbeams
- Brick walls
- Foundation beams to bind
- Strip footings
- Retaining walls with Cemex ready-mixed concrete of f'c = 250 kg/cm^2
- Lattice walls
- Intermediate reinforced concrete structural chains
- Reinforced concrete columns
- Furring walls

7. For the reconstruction of the commercial premises on the ground floor and the first floor (Fig. 9), the following activities were required:

- Construction of dividing walls (Fig. 9a).
- Construction of short walls for the tables of the premises.
- Floor laying using electro-welded mesh reinforcement.
- Placement of Armex 10x15 cm (2m high) at the end of the walls of the premises on the outside on the first floor. The Armex was overlapped to four number three rods, which were anchored to the mezzanine slab.
- Blacksmith work (Fig. 9b), such as the placement of posts, grids and metal curtains, welding of windowsills to the posts and application of gray and white paint.

- Regarding the electrical installation (Fig. 9c), a channel was placed in all the premises, each one with two shafts for polarized contacts and switches. It was of two circuits and galvanized pipe was used. The voltages that were taken into account for the switches were 120 and 220 volts.

8. Demolition of the floor and some walls on the two floors, in addition to the sidewalk on the north façade and of the stair on the west side, as well as detachment of the latticework on the upper floor.

9. Reconstruction of toilets.

10. Hydraulic installation, in which 1 ¼ diameter CPVC was used.

11. Sanitary installation in the bathrooms using 2' and 4" pvc pipes for draining soapy water from sinks and 4" and 6" pipes for connection to the WC.

4 Statistical Report Of The Effects On Businesses In The Juchitán De Zaragoza Market Due To The Earthquake Of September 7th, 2017

4.1 Direct losses in business

For the purposes of this research, direct business losses are defined as damage to tangible assets (sales products, furniture, equipment, machinery or any other property, except the building) caused directly by the earthquake, as well as the theft or loss of these after the evacuation of the property. Also included are products that, although not damaged by the earthquake, were spoiled due to the stoppage of business activities.

Of the 165 businesses surveyed, 36.36% stated that the earthquake that occurred on September 7, 2017 did not directly cause damage to their tangible assets, while 60% indicated that there was. On the other hand, there were five unanswered cases and one business that was not yet operating during the catastrophic event (not applicable), which represented 3.64% of the total.

As shown in Fig. 10, only 7 economic units did not have direct losses (4.24%), on the contrary, 83 businesses estimated that this economic loss was $ 3,000 MXN or less (50.30%), while 61 businesses considered which was for more than $ 3000 MXN (36.97%).

4.2 Losses due to interruption of activities

For the purposes of this research, business interruption losses are defined as the gains that economic units ceased to have during the time that they were unable to offer their products or services anywhere.

According to the applied survey, most of the tenants were forced to relocate their businesses predominantly in the main square of Juchitán and exceptionally in their homes due to the need for an economic reactivation, instead of waiting until the market building Juchitán will regain its functionality. It was recorded that only 12.12% of the 165 businesses considered in the investigation did not have the

possibility to offer their products or services on a provisional basis elsewhere while the property was being rehabilitated.

Regarding the time that the businesses were unable to operate, those with an inactivity of 8 to 30 days prevailed, with an absolute frequency of 71 (43.03%), on the other hand, only 13 cases were presented in which this occurred between 1 and 7 days (7.88%). Another recurring response was the one in which it was indicated that the stoppage of operations was from 31 to 90 days, because this happened on 44 occasions (26.67%). Even 31 businesses assured that they could not offer their products or services for more than 90 days (18.79%). In Fig. 11 the respective percentage structure is shown.

Figure 12 shows the number of economic establishments according to the loss due to interruption of business activities. It can be inferred that approximately a third of the surveyed businesses estimated that they stopped earning more than $ 3,000 MXN during the time they were unable to operate, while a little less than another third of the representative sample considered that it was between $ 1,000 MXN and $ 3000 MXN.

4.3 Recovery of economic units

Another aspect addressed in the survey was the recovery of business. In the first instance, it was of interest to know the strategy implemented by the tenants to try to maintain or increase their usual profits after the reopening of their economic unit. As shown in Table 2, it was mainly indicated that the sale prices of the products or services offered had to be modified and there were only seven responses in which it was indicated that no strategy was carried out.

Table 2
Number and percentage distribution of businesses according to the strategy implemented to try to maintain or increase the usual level of profits once they were reopened

Alternative	Absolute frecuency	Relative frequency	Percentage (%)
Increase advertising	48	0.29	29.09
Incorporate new products or services	23	0.14	13.94
Modify sale prices	56	0.34	33.94
I did two or all of the above strategies	23	0.14	13.94
I made another strategy	1	0.01	0.61
None	7	0.04	4.24
Does not apply	1	0.01	0.61
Unanswered	6	0.04	3.64
Total	165	1.00	100

On the other hand, according to the field research, 116 responses were registered indicating that no incentive was received to be able to reactivate the respective business (70.30%), on the contrary 21, 17 and 5 tenants affirmed, correspondingly, that they received a bank loan (12.73%), financial support from a relative or acquaintance (10.30%) and financial support from the government (3.64%). Likewise, no response was obtained from 5 respondents, in addition to the fact that the question did not apply to a business that indicated that it was not yet established in the market when the earthquake occurred (3.03%). The percentage structure is shown in the graph of Fig. 13.

Regarding how sales were during the first month in which the businesses were back in operation (Fig. 14), the majority agreed that sales decreased (92.12%). In particular, those who considered this situation to be significant prevailed, with the absolute frequency of 77 for this alternative (46.67%).

Likewise, the respondents who perceived that their profits decreased during the first month in which their business returned to operate (57.58%), followed by those who stopped making profits (36.97%) and only a minority indicated that their profits increased (1.82%). In addition, 5 members of the representative sample chose not to respond (3.03%) and this case did not apply to a business (0.61%). The corresponding absolute frequency is shown in Fig. 15.

Finally, in the survey it was of interest to know how long the businesses recovered their usual level of profits (the one they had before the earthquake) after reopening. As shown in Fig. 16, those who perceived that they had not yet recovered their usual earnings at the time of having applied the survey prevailed (40.61%). On the contrary, 13.94%, 24.24% and 17.58% of the total representative sample indicated respectively that it took them to recover their usual earnings between 1 and 30 days, from 31 to 90 days and in more than 90 days.

5 Conclusions

The earthquake that occurred on September 7th, 2017 caused very severe structural and non-structural damage to the municipal market building of Juchitán de Zaragoza, so that it was disabled for about two years and two months until its reconstruction, so the businesses were not able to operate there during that period. It was documented that a large part of the inactive time of occupation of the property was not due to the execution of rehabilitation works, but to the obtaining of financial resources, the agreements between the parties involved and the insecurity of operating due to the damage to the City Hall deputy.

According to the data collection techniques used, it is concluded that the columns of the market building were severely damaged due to the short column effect. In addition to this, there were several non-structural damages in the property, such as broken windows, detachment of finishes and shear cracking in non-structural walls. Likewise, it was recorded that several interventions were necessary to recover the functionality of the building, including the cladding of columns, a re-foundation, the construction of a

cistern and bars for business tables, and the waterproofing of the upper and lower beds of the slab rooftop.

Based on a survey applied to 165 economic units in the market, 60% declared that the earthquake directly caused damage to their tangible assets, additionally, considering that there was theft or loss of property after the evacuation from the premises, in addition to some products becoming spoiled due to the stoppage of business activities, only about 4% of those surveyed indicated that they didn't have any direct losses derived from the catastrophic event. In addition, it was documented that most of the tenants were forced to relocate their businesses predominantly in the main square of Juchitán and, exceptionally, in their homes due to the need for an economic reactivation, instead of waiting until the Juchitán market building recovered its functionality, even so, approximately 45% of the representative sample could not operate for more than a month and about 34% considered that they stopped earning more than $ 3,000 MXN ($ 160 USD) during the time of absolute stoppage of their activities. Even 41% of the economic units responded that they still had not recovered their usual earnings at the time of having applied the survey.

6 Recommendations

The present study allowed us to show that at present there are still highly vulnerable constructions seismically, which, when damaged, can cause not only high direct losses, but also large losses due to the cease of business activities, as happened with the Juchitán market. We intend to help alert tenants about these risks, as well as to generate knowledge that will be useful to formulate strategies that minimize economic losses due to earthquakes in businesses. We believe that this socio-economic, policy and engineering problem can be solved with the collaboration of all sectors and this is what motivated us to develop this research. Therefore, the authors suggest the following:

- Constant monitoring and maintenance, not only of the Juchitán de Zaragoza market building, but also of all existing buildings. It is important to reinforce buildings in a timely manner in order to reduce their seismic vulnerability and thereby minimize the risk of financial losses in the event of a future high-intensity earthquake, instead of carrying out interventions once very severe damage occurs.
- In the face of a possible catastrophic event, we recommend that all business owners formulate or improve their continuity and contingency plans. For this, it is important that they have well identified the threats to which their economic units are exposed and investigate how these could affect them. Among the actions that can be carried out are:
    - Treat the risk by transferring it to an insurance company. For this, direct damage insurance can be purchased to protect the structural system, non-structural elements and building contents, as well as insurance against loss due to interruption of activities.
    - Mitigate risk by taking or reinforcing measures to minimize the impact of the event. For example, businesses can establish themselves in buildings that are not highly seismically vulnerable,

have a reserve stock and even carry out a market study to detect strategic places where they could relocate in case their buildings need to be rehabilitated.

Declarations

Acknowledgments: In the first instance, we would like to thank Alejandro López, Eduardo Hernández and Arath A. Guerra, who are students at the Tecnológico Nacional de México (TecNM), Instituto Tecnológico del Istmo for their collaboration in the application of a considerable percentage of the surveys.Likewise, we give special recognition to Eng. Alfonso Torres and Arch. Ángel Gallegos for having provided us with valuable information on the rehabilitation of the Juchitán market building.In addition, we want to thank the tenants who agreed to be surveyed to provide information on the impact on their economic units by the earthquake in Chiapas in 2017, as well as the Engineers Juan Castillo and Guillermo Fernández, and the market administrator, Juan Blas, for having provided us with relevant information on the damage to the Juchitán market building.

Financing: We thank the Consejo Nacional de Ciencia y Tecnología (CONACYT) for the financial support provided to the first author during the conduct of this research.

Conflicts of interest: The authors have no relevant financial or non-financial interest to disclose.The authors declare that they have no conflicts of interest that are relevant to the content of this article.All authors certify that they are not affiliated or participating in organizations or entities that have financial or non-financial interests in the subject or the materials discussed in this manuscript.The authors have no financial or proprietary interests in any material discussed in this article.

Ethical approval: All surveys were anonymous.A statement on ethical approval from the university was not required because it is only necessary for research that directly involves human beings, rather than specifically related to business operations.Regarding Fig. 1, we do not require informed consent issued by the UNAM, because this university allows the use of the information it publishes for academic or research purposes, provided that the corresponding credits are granted.

References

1. Aghababaei M, Koliou M, Watson M, Xiao Y (2020) Quantifyingpost-disasterbusinessrecoverythroughBayesianmethods. StructInfrastruct Eng 17(6):838–856. https://doi.org/10.1080/15732479.2020. 1777569
2. AguilarJA, GonzálezR, Guerrero V, Jara M (2020) Comportamiento de templos coloniales en el sismo del 7 de septiembre de 2017 en Chiapas. Revistade Ingeniería Sísmica 102:26–41. DOI: 10.18867/RIS.102.502
3. ArceC, RiveraD, Monroy F, Delgado JC, Delgado CH (2014) Bussiness interruption: ante el daño sismico, enfoque financiero. XIX Congreso Nacional de Ingeniería Estructural, Sociedad Mexicana de Ingeniería Estructural

4. Archundia HI, FernándezLR, García F, Guerrero H, Peña F (2018) Efectos de los sismos de septiembre de 2017. XXI Congreso Nacional de Ingeniería Estructural, Sociedad Mexicana de Ingeniería Estructural
5. Ayala JA, Jiraldo MA (2018) Estudio del método de recrecido en concreto armado para el refuerzo de vigas y columnas de una edificicación. Dissertation, Universidad Distrital Francisco José de Caldas
6. Beauperthuy JL, Urich AJ (2011) El efecto de columna corta - Estudio de casos.B.R.S. Ingenieros, C.A., Venezuela
7. Boarnet M (1998) Business Losses, Transportation Damage, and the Northridge Earthquake. Journal of Transportation and Statistics 49-63. https://doi.org/10.21949/1501575
8. Brown C, Stevenson J, Giovinazzi S, Seville E, Vargo J (2015) Factors infuencing impacts on and recovery trends of organisations: evidence from the 2010/2011 Canterbury earthquakes. Int J Dis Risk Reduct 14(1):56–72. https://doi.org/10.1016/j.ijdrr.2014.11.009
9. Buendía L, Reinoso E (2019) Análisis de los Daños en Viviendas y Edificios Comerciales Durante la Ocurrencia del Sismo del 19 de Septiembre de 2017. Revista de Ingeniería Sísmica 101: 19-35. DOI: 10.18867/RIS.101.508
10. ChangS, LotzeA (2014) Infrastructure contribution to business disruption in earthquakes: model and application to North Vancouver, Canada. Tenth U.S. National Conference on Earthquake Engineering: Frontiers of Earthquake Engineering
11. Cremen G, Seville E, Baker JW (2020) Modelingpost-earthquakebusinessrecovery time: ananalyticalframework. Int J DisRiskReduct. https://doi.org/10.1016/j.ijdrr.2019.101328
12. Durkin M (1984) The Economic Recovery of Small Businesses After Earthquakes: The Coalinga Experience. International Conference on Natural Hazards Mitigation
13. DurukalE, ErdikM (2008) Physical and economic losses sustained by the industry in the 1999 Kocaeli, Turkey earthquake. Natural Hazards 46: 153–178. https://doi.org/10.1007/s11069-008-9218-6
14. Engineering Institute at UNAM (2017) Reporte Preliminar: Parámetros del Movimiento del Suelo, Sismo de Tehuantepec (Mw 8.2), 7 de septiembre de 2017. Ciudad de México: UNAM
15. FEMA (2015) Herramienta QuakeSmart para Empresas. FEMA, Washington D. C.
16. French S, Ewing C, Isaacson M (1984) Restoration and Recovery Following the Coalinga Earthquake of May, 1983. Institute of Behavioral Science, Natural Hazards Research and Applications Information Center, University of Colorado, Boulder
17. Gordon P, Richardson H, Davis B, Steins C, Vasishth A (1995) The Business Interruption Effects of the Northridge Earthquake. Lusk Center Research Institute, School of Urban and Regional Planning, University of Southern California, Los Angeles
18. Guzmán J, Williams F, Riquer G, Vargas A, Leyva R (2020) Fallas de licuación de suelos inducidas por el sismo de Tehuantepec del 7 de septiembre de 2017 (Mw 8.2) en la Ciudad de Coatzacoalcos, Veracruz, México. Revista de Ingeniería Sísmica 102: 82–106. DOI: 10.18867/RIS.102.526

19. INEGI (2017) Estadísticas sobre las afectaciones de los sismos de septiembre de 2017 en las actividades económicas. INEGI, Ciudad de México
20. Kroll C, Landis J, Shen Q, Stryker S (1991) Economic Impacts of the Loma Prieta Earthquake: A Focus on Small Business. University of California, Transportation Center and the Center for Real Estate and Economics, Berkeley
21. LoAY, LiuS, ChowASY, Cheumg LTO, Fok L (2021) Business vulnerability assessment: a firm-level analysis of micro- and small businesses in China. Natural Hazards 108: 867–890. https://doi.org/10.1007/s11069-021-04710-z
22. MarshallMI, NiehmLS, SydnorSB, Schrank HL (2015) Predicting small business demise after a natural disaster: an analysis of pre-existing conditions. Natural Hazards 79: 331–354. https://doi.org/10.1007/s11069-015-1845-0
23. National Seismological Service (2017) Reporte especial sismo de Tehuantepec (2017–09–07 23:49 MW 8.2). Ciudad de México: SSN - UNAM
24. Ortiz D, Reinoso E (2019) Elementos que Contribuyen a la Interrupción de Negocios en Edificios por Sismo. XXII Congreso Nacional de Ingeniería Sísmica, Sociedad Mexicana de Ingeniería Sísmica
25. Ortiz D, Reinoso E (2020) Tiempo de interrupción de negocios en la Ciudad de México por daños directos y efectos indirectos en edificios a causa del sismo del 19S de 2017. Revistade Ingeniería Sísmica 104:1–31. https://doi.org/10.18867/RIS.104.538
26. Ortiz D, Reinoso E, Villalobos JA (2020) Daños observados en negocios por el sismo del 23 de junio de 2020 en Oaxaca.In: Academia Journals (ed) Investigación en la Educación Superior: Puebla 2020. Academia Journals, Puebla, p.p. 656–662
27. OrtizD, ReinosoE, VillalobosJA (2021a) Assessment of business interruption time due to direct and indirect effects of the Chiapas earthquake on September 7th 2017. Natural Hazards 108: 2813–2833. https://doi.org/10.1007/s11069-021-04801-x
28. Ortiz D, Reinoso E, Villalobos JA, Calderón MO (2021b) Pérdida de la operatividad de unidades económicas por distintas amenazas. XXII Congreso Nacional de Ingeniería Estructural, Sociedad Mexicana de Ingeniería Estructural
29. Pozos-Estrada A, Chávez MM, Jaimes MÁ, Arnau O, Guerrero H (2019). Damages observed in locations of Oaxaca due to the Tehuantepec Mw8.2 earthquake, México. Natural Hazards 97: 623–641. https://doi.org/10.1007/s11069-019-03662-9
30. ShiY, ShumiaoJ, Seeland K (2015) Modeling business interruption impacts due to disrupted highway network of Shifang by the Wenchuan earthquake. Natural Hazards 75: 1731–1745. https://doi.org/10.1007/s11069-014-1391-1
31. TapiaE, GarcíaJS (2019) Comportamiento de estructuras de acero durante los sismos de septiembre de 2017. Revistade Ingeniería Sísmica 101:36–52. DOI: 10.18867/RIS.101.499
32. Tierney K (1997) Business impacts of the Northridge earthquake. Journal of Contingencies and Crisis Management 5:2: 87-97. https://doi.org/10.1111/1468-5973.00040

33. Valdiviezo RJ (2019) El desastre natural y su impacto socioeconómico en los comerciantes minoristas del mercado central de la ciudad de Portoviejo. Dissertation, Universidad Estatal del Sur de Manabí

Figures

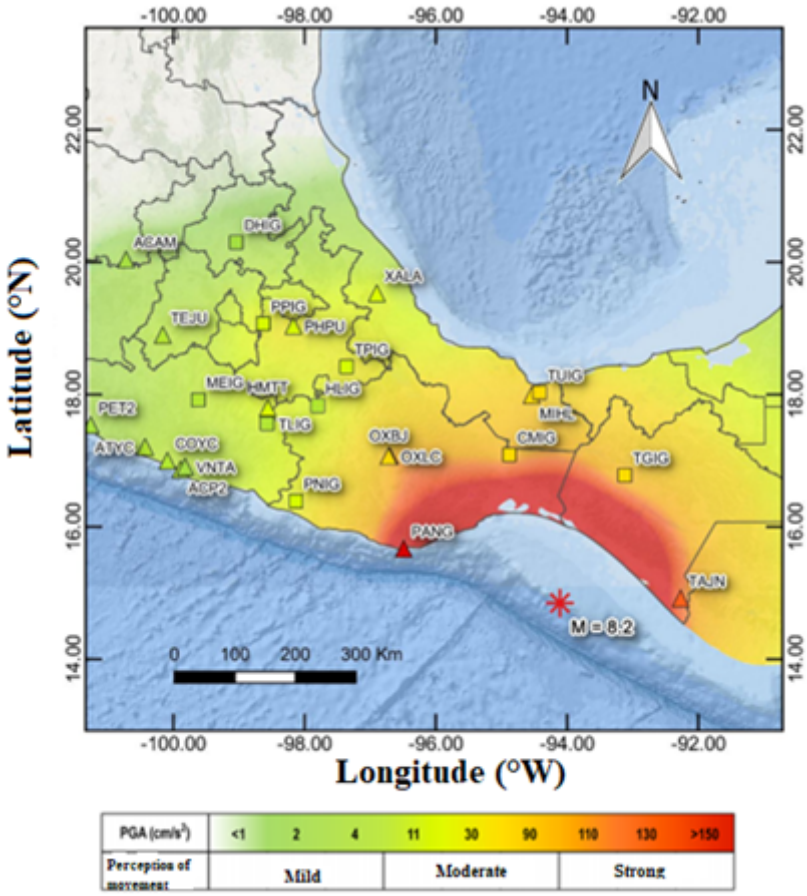

Figure 1

Map of Maximum Soil Acceleration (PGA), for the September 7th2017 earth quake. Source: Engineering Institute, UNAM.

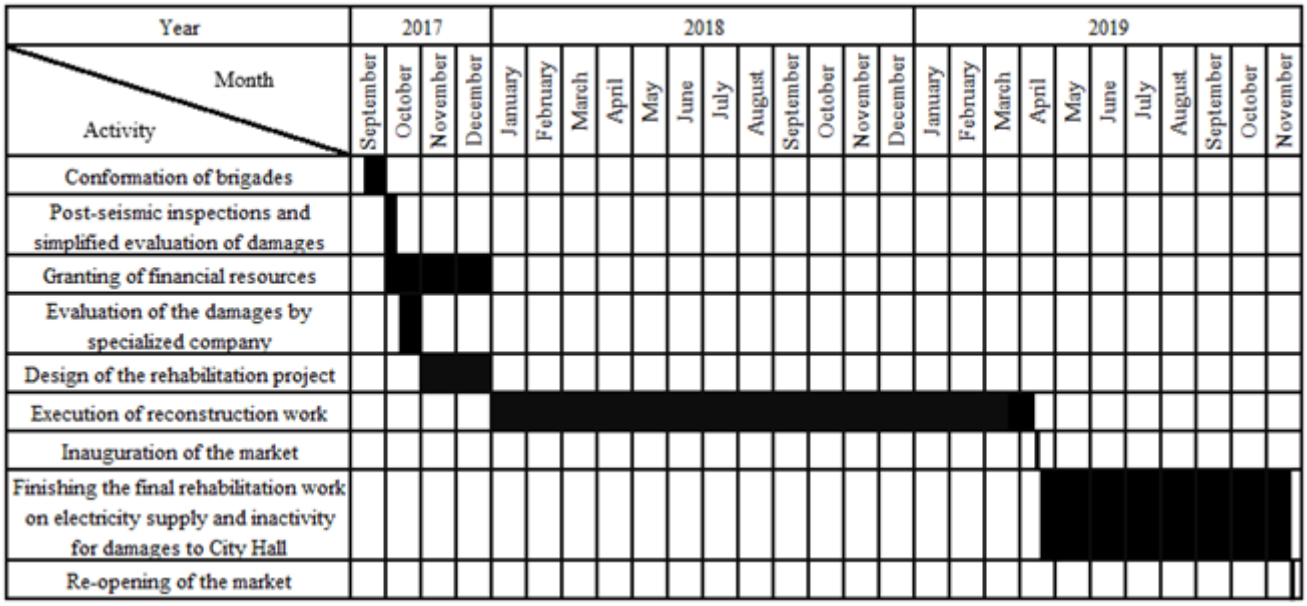

Figure 2

Gantt chart showing the activities carried out to achieve the reopening of the Juchitán market

Figure 3

Short column effect on columns of the Juchitán market building

Figure 4

Settlement in the Juchitán market property, which caused damage to the mezzanine

a) b)

Figure 5

Damage nonstructural to market Juchitán **a)**release finishes and broken windows;**b)** shear cracking in non-structural wall

Figure 6

Stages ofthe construction process for the jacketed columns of the Juchitán market building:**a)** scarifying;**b)** enabled and reinforced with steel for the new footing;**c)**enabled and reinforced with steel for the column;**d)** column bending;**e)** concrete casting

Figure 7

Top slab form work of the tank and the **Fig. 8** Construction of bars for business tables machine room

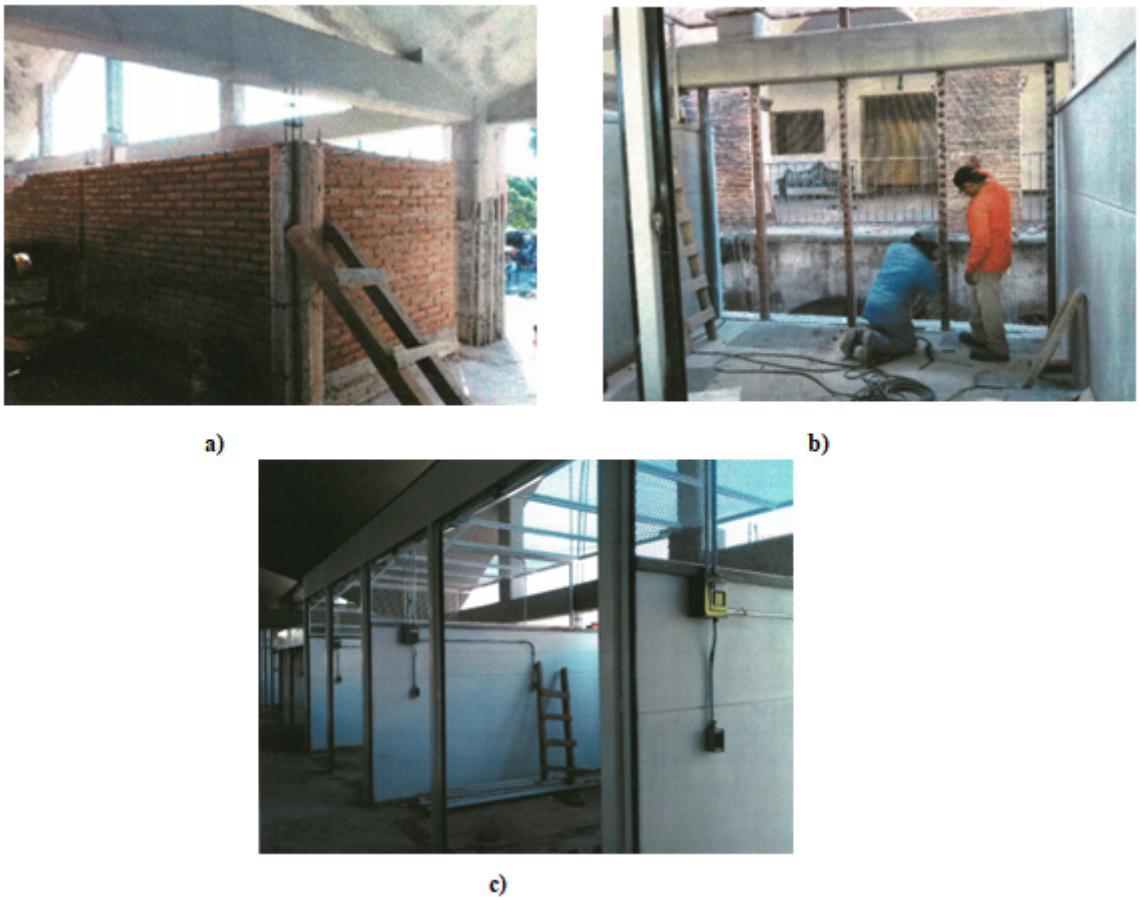

Figure 8

Activities for the reconstruction of the retail premises **a)** construction of dividing walls;**b)** smithy work;**c)** electrical installation

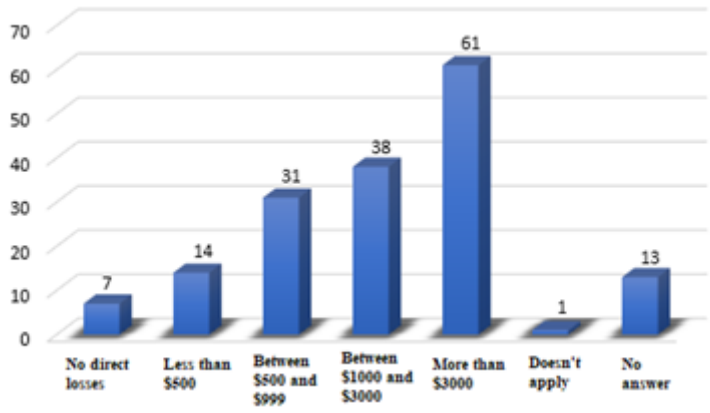

Figure 9

Number of businesses according to the estimated direct loss (in Mexican pesos) due to the earthquake

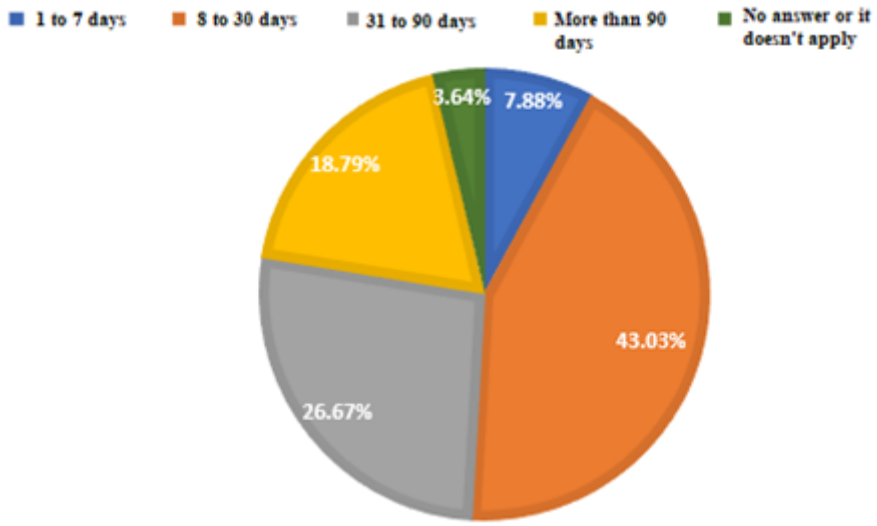

Figure 10

Percentage structure of businesses according to the number of days that they suspended their activities

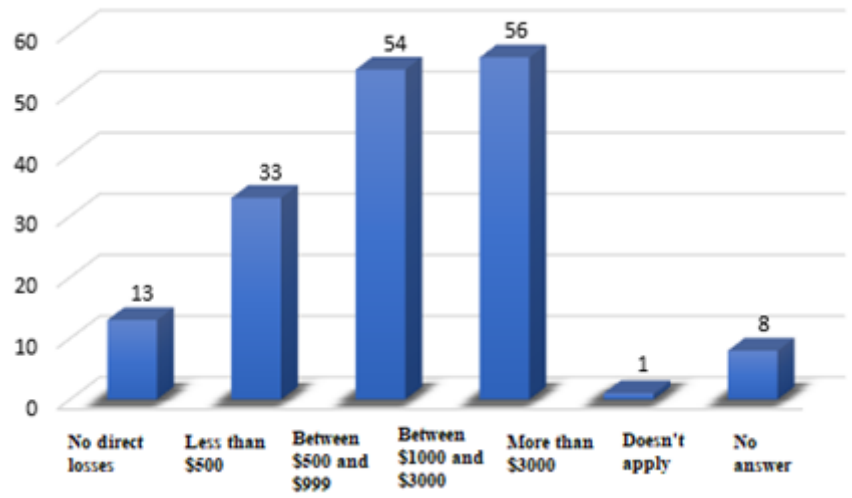

Figure 11

Number of businesses according to the estimated loss (in Mexican pesos) during the time they were unable to operate

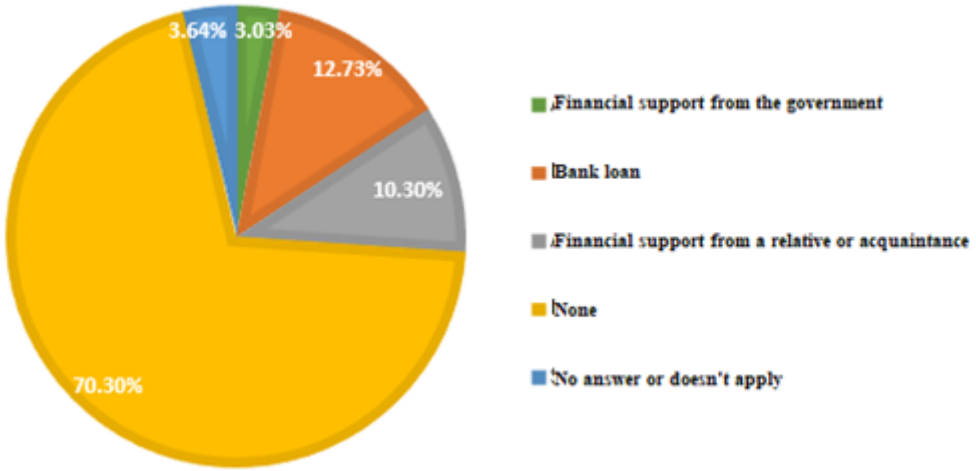

Figure 12

Percentage structure of the businesses according to the main incentive they received for their reactivation after the earthquake

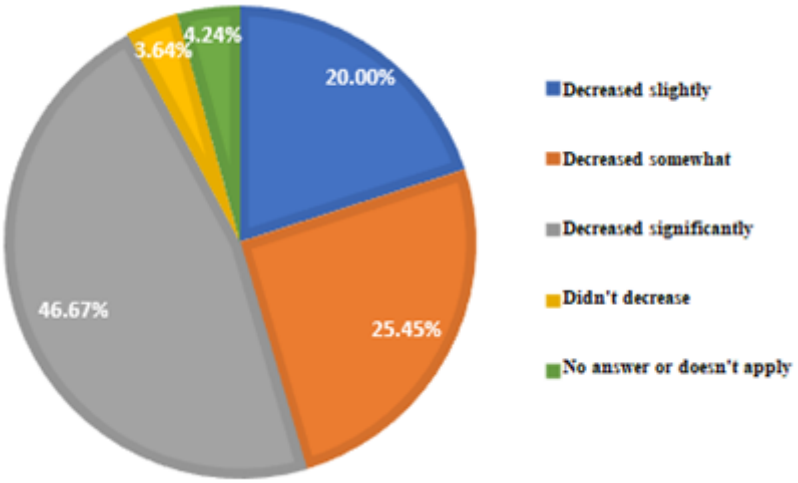

Figure 13

Percentage structure of businesses with respect to how their sales were during the first month in which they were able to offer their products or services

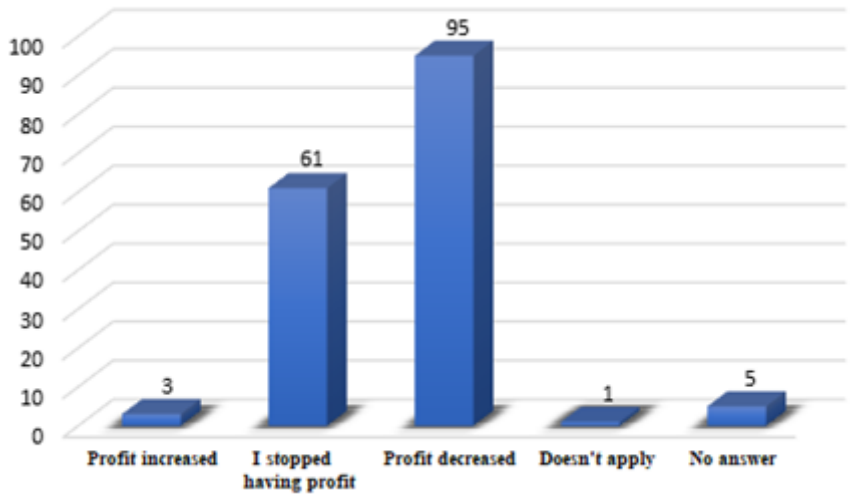

Figure 14

Number of businesses according to their perception of how their earnings were during the first month that they returned to operating

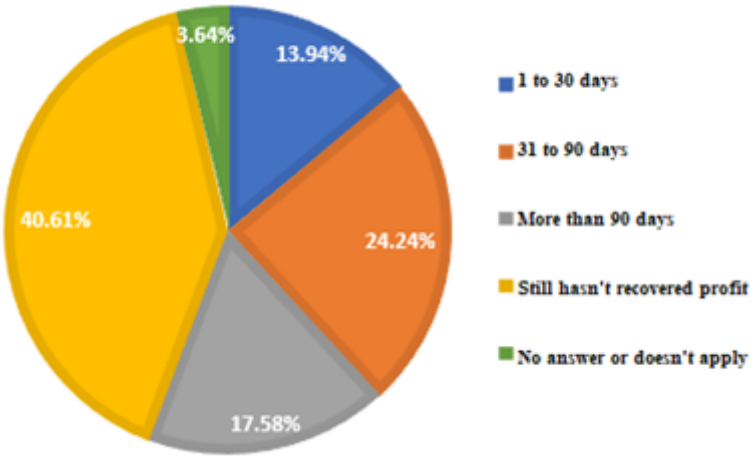

Figure 15

Percentage structure of the businesses according to their perception about the time it took to recover their usual level of profits after they reopened