New Risk Assessments Due to Climate Change in Metropolitan Peripheral Areas. The Water Shortage Case in the Region IV of the State of México

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Abstract. A National Risk Assessment is a policy tool encouraged by the OECD since the 2010's decade to identify and analyse a range of events that can cause a shock in a country and to have adequate preparedness and response measures. As disaster risks are an always-changing phenomenon, especially since the climate change emergency has been acknowledged, it requires systematic monitoring and analysis to adapt the risk management policies to the changing situation. The paper adjusts the National Risk Assessment into a micro-regional scale to present the case of the water shortage emergency due to climate change in a peripherical urban area of Mexico City. In the paper, it is explained why it should be included as a Risk Assessment by local and regional authorities with the objective to create more resilient peripherical urban territories. Eventually, the research can serve as a base to create a National Risk Assessment for water shortage in metropolitan areas on a national scale. The paper presents the current situation of the water shortage in the case study, explains why it should be considered a risk, and analyses water shortage in urban areas within the Risk Assessment rationale, using the Region IV of the State of Mexico as the case study.

Keywords: disaster planning · risk assessment · water shortage

1 Introduction

Territories around the world are exposed to different kinds of risks that can transform into emergencies provoking an impact on society and economics [1, 2]. For this reason, different international organizations such as the OECD, European Union, and World Economic Forum present recommendations to prepare and respond in case of an emergency by identifying and evaluating risks that national governments can use and adapt according to their necessities. Among the different types of risks, environmental risks have gained relevance due to the climate change emergency [3, 4]. According to the World Economic Forum, climate change is striking harder and more rapidly than some experts on the topic expected, as consequence natural disasters are becoming more intense and more frequent [3, 5].

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Accordingly, in the Global Risks Perception Survey 2022 [6], environmental concerns dominate the top long-term risks by likelihood among the members of the World Economic Forum; also, three of the top five risks by impact are environmental [6]. In 2022 Climate change continues to be perceived as the gravest threat to humanity among the 12,000 leaders interviewed in 124 countries who ranked a list of 35 risks [6]. These leaders rate climate action failure as the risk with the potential to inflict the most damage on a global scale over the next decade. In this context, the water shortage contingency in the Region IV of the State of Mexico fits as an Environmental Risk of the Human-made environmental disasters type [3], because of the overexploitation and pollution of the local water sources, the lack of a proper federal water supply infrastructure, and poor prevention and response of the local authorities.

The Cutzamala system is one of the main providers of potable water for Mexico City Metro with approximately 26% of the water supply. In recent times, the loss of capacity of water collection of the basins that supply the dams that composes the system has put at great risk the supply of potable water in Mexico City Metro [7]. It has been reported that in 2021 the water levels of the Cutzamala system are at their lowest in the last 25 years [7]. This situation is associated with a drought of categories D2 and D3 (The United States Drought Monitor scale goes from D0 to D5 and considers D2 and D3 categories as severe and extreme drought [8]) derived from climate change in the supply basins for the system [7]. The local water bodies that can serve as an alternative to guarantee the water supply have reported high levels of contamination and exploitation [9, 10].

Mexico City Metro is one of the biggest cities in the world with more than 20 million inhabitants [11]. The peripheral areas of the city lack the same quality of services and infrastructure as the city's original centre causing the marginalization of the periphery's inhabitants [11]. One of the services that suffer from this situation, can be the water supply service. Like many peripheral areas of Mexico City Metro, the Region IV of the State of Mexico has suffered from water shortage in the last years [12]. Currently, the authorities in Mexico haven't acknowledged the Water Shortage in urban areas as a risk neither in the national nor local disaster management plans [13–15], which led to the necessity of a proper Risk Assessment in order to have adequate preparedness and response tools.

The research's main objective is to introduce water shortage in urban peripheral areas as a risk assessment using the Region IV of the State of Mexico as a case study. Other secondary objectives are to analyse and understand the water shortage contingency in the Region IV of the State of Mexico, adapt the National Risk Assessment indicators to the microregional peripherical context and the water shortage contingency, and present strategies to have better preparedness and response for the water shortage contingency. All the statements said before lead to the research question: How a simplified and adapted Risk Assessment can help Mexican authorities to address the water shortage risk in urban areas, with a special interest in the peripherical urban areas?

Territories are vulnerable to different kinds of risks, that eventually can become emergencies and cause a shock in a system. In that context, authorities develop Risk Assessments to prevent damages, have a proper response, and have a quick recovery process. Societies and territories adapt to the risks that they faced consequently becoming more resilient territories [16]. Risks are in constant change [2], and societies need to

adapt to a constantly changing reality, that is why is recommended that authorities and organizations continue to search, update, and create Risk Assessments to identify new risks and have proper preparedness and response in case of emergency.

Water shortage in peripherical urban areas like in the case of Mexico City Metro has become a more common phenomenon in recent times, greatly affecting the quality of life of its inhabitants [17]. For that reason, it is proposed the water shortage in peripheral areas as a new Risk Assessment, using the Region IV of the State of Mexico as a case study. The study aims to use the case study as an example that can be adapted in different urban areas and become a National Risk Assessment that Mexico can use for its metropolitan areas. The innovation of this paper is to define a new risk assessment that is a direct consequence of climate change and man-made environmental damage. Another relevant aspect is to adapt the methodology of National Risk Assessments at a micro-regional level. Finally identifying new risk assessments is a useful practice to have more resilient territories that can adapt better to emergencies and their consequences.

The paper firstly presents a literature review of basic concepts and definitions to understand the research such as disaster planning, National Risk Assessments, and the water shortage crisis around the world. The next part is explained the chosen methodology and it is shown the basic structure of the paper. The third section of the paper presents the case study and explains why it is relevant for the study's purposes. Next, the research findings are presented. In the findings section, the field study results and the proposal of water shortage in peripherical urban areas as a Risk Assessment are shown. In the fourth part, a discussion about the results is presented. Finally, the conclusion argues for the importance of renewing and updating risk assessments to have more resilient territories.

2 Literature Review

2.1 National Risk Assessment

According to the United Nations Office for Disaster Risk Reduction (UNISDR) a disaster is defined as "A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts" [18]. In this paper, one of the main focuses is the evaluation and prevention of the breaking points, because a breaking point can be of natural, economic, or social matter [3]. In the case of an emergency, five main phases can be found: prevention, mitigation, preparedness, response, and recovery [19]. In the five phases, urban planners can intervene in the form of policies, methodologies, and other different instruments.

Since the first decade of the 2000's European and North American governments, began to analyse and report the possible hazards their national territory could face and result in major contingencies. The reasons each country creates these initiatives are different but can be categorized as follows [20]:

– The need for a systematic and organized approach for risk identification and the identification of weaknesses in the case of a contingency.

– The need for a comprehensive approach to preparedness that addresses the different types of risks according to a common set of criteria such as natural or man-made hazards and build consensus across different government levels concerning infrastructure and other investments in a territory.
– The need to better understand linkages between the different types of risks, and to understand how responses developed to treat the consequences of risk can in fact be useful to respond to different types of risks.

This led governments to create instruments to report possible risks, but without a unified criterion. In this context, international organizations presented recommendations to create a common policy tool. A National Risk Assessment is a policy tool encouraged by the OECD, the European Union and North American governments since the 2010's decade to identify and analyse a range of events that can cause a shock in a territory to have adequate preparedness and response tools [20]. This tool can be used in an urban or regional context to identify, prepare and respond to a possible contingence in a more specific territory.

The Risk Assessment is a part of the Risk Management Process, which involves the systematic application of policies, procedures, and practices for communicating and consulting, establishing the context, assessing, treating, monitoring, reviewing, recording, and reporting the risk [21]. The steps and stages to elaborate a National Risk Assessment according to ISO 31000 guidelines [22] and used in the European Union are the next: Risk Identification, Risk Analysis, and Risk Evaluation. The next table (see Table 1) presents the basic structure and steps to create a National Risk Assessment inside the Risk Management framework.

Table 1. Steps of the National Risk Assessment. (Source: ISO 3100)

Context	Risk Identification	Risk Analysis	Risk Evaluation	Risk treatment
Legal context Consider the scale of the available data Define 1. assets to protect 2. geographical scale 3. main hazards 4. potential impacts 5. time window 6. evaluation criteria 7. classification of impact and like hood levels 8. protocol to use expert opinion 9. evaluation criteria	1. Identify risk 2. Identify the risk drivers - hazard - exposure - vulnerability - capacities 3. Budling scenarios	Calculate the like hood and the relevant impacts Choosing an approach -Qualitative -Quantitative	1. Sharing the outputs of the risk analysis 2. Comparing and confronting risk to the evaluation criteria 3. Decide which risk to reduce	Describe the possible measures
	Risk Assessment			

It is important to mention that the Context and Risk Treatment phases even though are not formally part of the National Risk Assessment are key elements in their development

of them. The Context phase serves to understand and prepare the National Risk Assessment, meanwhile, the Risk Treatment phase helps to apply the results of the National Risk Assessment.

In the North American case, The United States Environmental Protection Agency proposes a different methodology in the Risk Management Process for Human health risks and Ecological risks [23]. Since the paper treats the environmental and health risk associated with the water shortage in peripherical urban areas, it is adequate to refer to this risk assessment methodology.

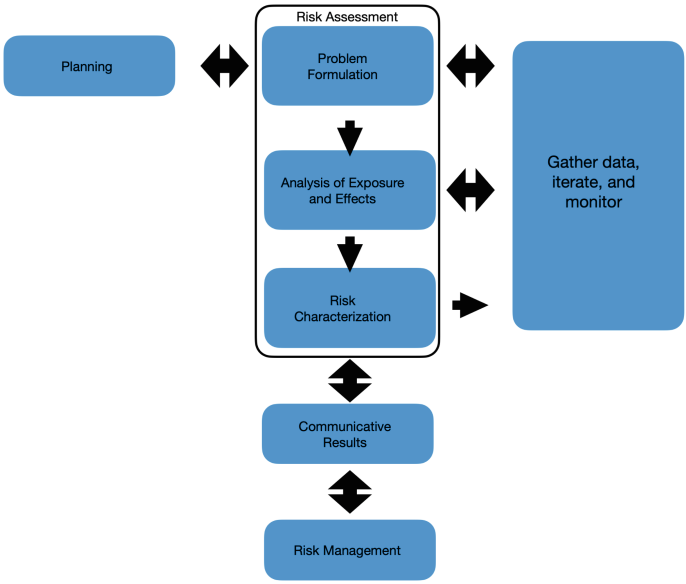

Fig. 1. Risk Management Process. Source: elaboration of the authors with data from the United States Environmental Protection Agency.

As seen in the diagram (see Fig. 1) the US EPA uses different names for each phase including the ones involving the Risk Assessment. Even though, many features and concepts and features are shared with the ISO 31000 guidelines, according to the authors the US EPA guidelines use a simpler approach specifically in the Risk Identification and Risk Characterization phases.

2.2 The Water Shortage Crisis

Access to potable water is recognized by the United Nations as a human right, supporting the fundamental nature of this natural resource in the life of every human being [24]. The lack of access to a sufficient, safe, and affordable water source has a devastating impact on the health and prosperity of a society and it has consequences for the realization of other human rights [24].

A useful tool to measure the shortage of water in a territory is the Level of Water Stress presented by the FAO (Food and Agriculture Organization) [25] and is used

by national governments such as the Mexican for the case of study purposes. This indicator measures the quantity of available water that is used for human consumption. The indicator is divided into five categories, from no stress (below 25% of consumption), to critical (when the extraction is more than 100% of the available potable water, which means the water comes from other territories). The FAO has established 25% as the threshold of safe water stress, globally the water stress is below the threshold with 18% [25]. There are countries that surpass the threshold in a moderate way like Italy (30%), Mexico (33.3%), and the United States (28.16%). These countries need special policies to avoid the problematic escalates. But there are countries that surpass the threshold in a preoccupant way like Pakistan (118.2%), Saudi Arabia (992.8%), and the United Arab Emirates (1667.3%) [25].

The case of Mexico is interesting because although the water stress at a national level is moderate (33.2%) there are specific regions like the Valley of Mexico water region where Mexico City Metropolitan area is located, which have a critical water stress level (127.8%), where water is imported from other regions in order to supply water to more than 20 million inhabitants [26]. The water supply in Mexico City Metro problem increases due to polluted and over-exploited sources, and an inefficient water supply infrastructure, causing a shortage crisis in the city, mainly in the peripherical areas, like the case study region. This situation has become a constant in the last few years, making water shortage an authentic emergency in Mexico City Metro [27]. The importance of reviewing the water stress levels at a regional level rather than a national level gives valuable insight into the impact of big urban areas on natural resources such as water.

3 Methodology

Based on a documental investigation combined with a field study in the Region IV of the State of Mexico, the research was able to obtain an insight into the water shortage in the area, and why it should be considered a contingency that must have a proper risk assessment. With the data and experiences gathered during the research, it was possible to propose some strategies to increase the preparedness and response for this emergency. The investigation type for the project is the explorative type. Exploratory studies are used when the objective is to examine little-known research topics, which have not been addressed before, or there are still doubts [28]. This research type is useful when the bibliographic review reveals that there are only non-researched guides or ideas vaguely related to the study problem, or if the research project inquiries about topics and areas from a new perspective.

The paper was structured based on a systemic method [29], where the object is determining its elements, as well as the relationships that exist between them. Also, concepts of Strategic Planning were used, which is a very useful management tool that helps organizations, companies or governments make decisions, as well as the objectives

that are intended for the future to obtain the biggest benefit in the projects that are developed [30]. The paper follows the next structure:

- Understand the water shortage crisis in urban areas as an emergency that needs a proper risk assessment by reviewing the literature on international organisms and the Mexican government.
- Analyse and understand the water shortage contingency in the case study region by a field study developed from late 2020 to mid-2021.
- Determine the variables required to evaluate and analyse the risk of water shortage in urban peripherical areas.
- Define a strategic plan draft that includes preparedness and response tools for the water shortage contingency in urban peripherical areas.

4 The Region IV of the State of Mexico. A Microregional Periphery

Urban areas are constantly growing around the world. The UN estimates that in 2050 68% of the world population will inhabit urban areas therefore metropolitan areas will be a more diffused phenomenon [31]. Metropolitan processes need to be studied and analysed to create instruments, policies, and methodologies that help to understand them and improve the administration of these big complex urban areas where cooperation between the different government levels will be essential. To develop a proper metropolitan risk assessment first is important to know and understand the territory and its social, cultural, and economic dynamics to evaluate the polycentric metropolitan urban systems.

Mexico City metropolitan area according to the United Nations is a Mega City with more than 20 million inhabitants and the 5th populated in the world in 2018 and is estimated that in 2030 will be the 8th most populated city in the world remaining as one of the biggest cities in the Latin America region [31]. In this context, according to Globalization and World Cities Research Network (GaWC), based on the theories of Peter Hall [32] and Saskia Sassen [33], Mexico City is considered an Alpha City which means that the city has a global influence [34]. Mexico City Metro involves three states and seventy-six municipalities [11] making the administration of the metropolitan area challenging because of the involvement of different government levels as municipal and state level that doesn't adjust to a changing metropolitan reality. This situation makes difficult the development of common urban and regional projects, like a common disaster planning strategy.

The Region IV of the State of Mexico was created after the State of Mexico Development Plan 2017–2023 [35]. It is a peripherical territory of Mexico City that includes three municipalities and a population of more than 1.5 million inhabitants. The Region IV is composed by the municipalities of Atizapán de Zaragoza, Nicolás Romero and Cuautitlán Izcalli (see Fig. 2). Inside the region are different realities that converge such as rural settlements, semi-urban areas, irregular urban areas, industrial polygons, and high-end residential areas, but as a functional region, they share common risks that are considered in the state civil protection such as flooding, fire, earthquakes, and landslides [13–15]. But as mentioned before there is a need to adapt to the new risks the territories are facing such as the climate change emergency and other social and economic emergencies. The research project aims to help to identify new risks and propose new risk

assessments to give the different government levels tools to prepare and respond in case of a contingency.

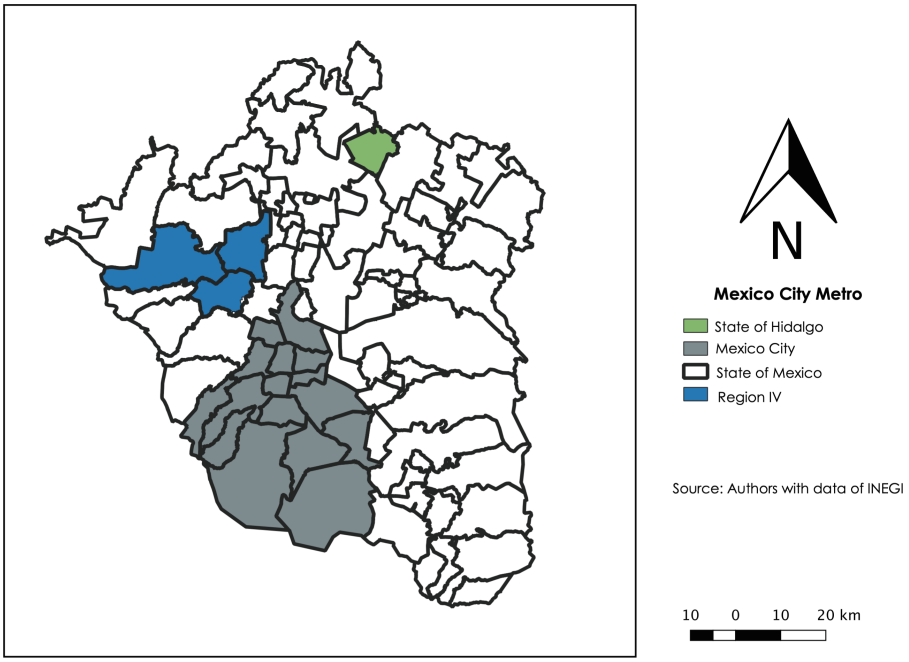

Fig. 2. Map of the Region IV of the State of Mexico in the Mexico City Metro context. Source: elaboration of the Authors with data of INEGI

5 Findings

5.1 The Water Shortage Contingency in the Region IV of the State of México

The water supply of Region IV mainly comes from the Cutzamala System which is also the main provider of water for the rest of the Mexico City Metro territory, which is part of the federal water system. Cutzamala system among other minor federal water networks represents more than 70% of the water supply for the Region IV of the State of Mexico [9], which makes the region highly dependable on federal water resources. Local water sources come from highly stressed wells or contaminated dams like the Madín dam in Atizapán de Zaragoza [36] and the Guadalupe dam in Cuautitlán Izcalli [10] which cannot fulfil the water needs of the local population. Regarding local water wells, it is reported great stress on the Metropolitan Water Mantle and the Cuautitlán-Pachuca Mantle which provides most of the water that supplies the region's wells [17, 37]. Worsening the situation, according to the federal government and the local water agencies due to poor maintenance in the Cutzamala system, there is an approximate loss of 40% of the water flow because of leaks [9].

A field study was carried out in the time-lapse between October 2020 and October 2021, where the water crisis was evaluated and analysed. During this time, it was possible to visualize the escalation of the contingency, from a manageable crisis to an emergency that greatly affected the normal development of activities of the population causing civic protests and a conflict with the local government. The study was carried out with visits to different districts of Region IV to obtain a general panorama of the situation, interviews with the inhabitants of the region (mainly in Atizapán de Zaragoza municipality), and informal interviews with the local public water agencies and private water supply agencies.

The next table as a result of the field study (see Table 2) it is presented the reported water supply cuts and reductions in the Region IV of the State of Mexico. The water shortage type is categorized into three levels: water supply with low pressure (1–3 L per min), water supply just in the morning (3–5 h) and water supply cut.

Table 2. Water shortage report for the Region IV of the State of Mexico. (Source: field study)

Date	Water supply shortage type	Duration
October 2020	Water supply with low pressure	Intermittent until the end of the study
November 28, 2020	Water supply with low pressure and Water supply just in the morning	February 2021
December 26, 2020	Water supply cut	4 days
March 16, 2021	Water supply with low pressure and Water supply just in the morning	Until the end 2021
March 25, 2021	Water supply cut	2 days
May 8, 2021	Water supply cut (Atizapán de Zaragoza)	2 days
June 11, 2021	Water supply cut	3 days
October 4, 2021	Water supply cut for 3 days each week (Atizapán de Zaragoza)	1 month

Table 2 indicates the contingency is real and constant, during the time frame of one year. This table gives an interesting insight of the dimension of the crisis in the region and why it should be acknowledged as a risk and therefore produce a Risk Assessment.

The water shortage contingency impacts differently depending on the water storage capacity of each household (see Table 3). The study identified three levels of water storage and what is the time each household can function without water supply. The criteria used come from the Mexican government that establishes that each person should be provided with 150 L–200 L per day [38]. Also considering that each household in Mexico on average has 4 persons [11].

Contamination and Drought of the Water Sources

Recent reports establish that the Cutzamala System is under great stress where the water levels are at their lower levels in the last 25 years which is associated with drought on D2

Table 3. Water storage report for the Region IV of the State of Mexico. (Source: field study)

Type	Water storage capacity	Days without water
Household with large cistern	6000 L–4000 L	200 L per day 7–5 days 150 ltrs 10–7 days
Household with small cistern	2000 L–3000 L	200 L per day 4–2.5 days 150 ltrs 5–3 days
Household without cistern	0 L–1000 L	200 L per day 1–0 days 150 L 2–0 days

and D3 intensity due to the climate change [7], another problem is the poor infrastructure that transports the water, it is estimated that about 40% of the water flow is lost due to leaks around the system [9]. This directly affects the water supply of Mexico City Metro, including the study area.

Other important source of water for the region is the Madín Dam, located in the south part of Atizapán de Zaragoza, this dam provides water to the municipalities of Atizapán de Zaragoza, Tlalnepantla de Baz, and Naucalpan de Juárez. In recent times it has been reported contamination and a significant reduction of the water reserves of the dam [36]. A study held by the National Polytechnic Institute (IPN) [36], has proven the contamination of the water that is directly affecting the life of the fish that live in the dam and the quality of the potable water that the inhabitants consume [39]. Another situation that affects the water supply in Region IV is overexploitation, recently it has been announced that part of the water of the dam will go to Mexico City's central municipalities, reducing the supply quantity for the local population.

Government Response to the Water Shortage Contingency

The government's response to the contingency can be divided into two parts. The first part is the response of the federal and state-level agencies like CONAGUA and the State of Mexico Water commission that held the labours of rehabilitation of the water supply network of the Cutzamala system to provide a regular potable water supply [7]. The second part of the response is the local authorities at the municipal level that provided a free service of water supply with trucks [40].

The field study reports that the government response in both mentioned parts was insufficient and inefficient according to the field study. The water cuts due to the labours of rehabilitation of the federal water network were more and longer than expected. When information was requested by the authors and the interviewed inhabitants about the duration of the cuts and rehabilitation of the water network the answer was vague and no specific dates were given, leaving the population of Region IV in uncertainty. The second part of the government response in charge of the municipal authorities was

to provide potable water with a truck was insufficient. It was reported during the field study that the average response to a request of a water truck to fill the cistern of a house was between 4 and 7 days, an inefficient response to households with a small cistern or no cistern. This led some citizens turned to private water services that charged around 70 USD for each trip. The situation led to civil protests where citizens around the region blocked the streets in the months of July and October demanding a proper water supply [41].

Water Shortage as an Environmental Risk

The constant growth of Mexico City Metro and the densification of the peripheries have put under considerable water stress levels (127.8%) in the Valley of Mexico water region [26]. At the local level, the water sources are also under heavy stress which led to the prohibition to build new wells due to the low levels of the water mantles [9] like the Metropolitan Water Mantle and the Cuautitlán-Pachuca Mantle. The fast and unorganized urbanization has affected the absorption capacity of water mantles. The overexploitation of the basins that feed the Cutzamala system and the rain scarcity in the region due to climate change is affecting the natural process of water recuperation lowering the levels of the system. According to the National Commission of Water (CONAGUA) the rain levels of the hydric region of the Valley of Mexico had a drastic reduction from 581 mm in 2018 to 355 mm in 2020 [42]. Worsening the problem is the contamination of water bodies with littering and the discharge of sewage waters making it more difficult to obtain potable water from the local water bodies. The contamination of water bodies has led to the reduction of aquatic water life in Region IV. In the case of presa Madín it has been reported that high levels of aluminium in the water are affecting the life of aquatic wildlife [36, 39]. This situation has led to a reduction of the water supply for the inhabitants of Mexico City Metro, including Region IV. If the scarcity of natural water sources and the pollution of the water bodies continues, can provoke a risk in the natural equilibrium of the region and make the territory unhabitable because of the lack of potable water for a constantly increasing population. The next table presents a cause-effect of the environmental crisis derived from climate change regarding water shortage in Region IV.

Table 4. Logic-based cause-effect table of the environmental risk in Region IV. (Source: field study)

Cause	Effect
Overexploitation of Cutzamala system basins	Reduction of the potable water flow to the inhabitants of Region IV
Reduction of precipitation levels	Worst drought in the last 25 years
Pollution of local water sources	-Reduction of aquatic wildlife -Bigger costs for the purification of water
Overexploitation of local water mantles	Restriction for building new wells and reduction of levels of the current ones

The table (see Table 4) gives a basic insight into how the climate change emergency is affecting different aspects, that overall is creating a new contingency that was not

considered before. The water shortage in urban peripherical areas like Region IV is a consequence of different environmental emergencies. To understand and eventually present a solution to the contingency is important to know the main drivers that provoked the water shortage in the form of a cause-effect table.

5.2 Water Shortage in Urban Areas as a Risk Assessment

Using as a base the guidelines provided by ISO 31000, the United States Environmental Protection Agency, OECD, World Economic Forum, and the Mexican Government, is presented the proposal of Water Shortage in urban areas as a Risk Assessment with the data collected in the time frame October 2020 to October 2021 for the case study area. The paper proposes five phases for a preliminary Risk Assessment in the context of a Risk Management Process using a qualitative approach, due to the limitation of the study for collecting reliable statical data.

Context

The context section introduces the problematic and presents basic aspects before starting the proper risk assessment. This section is important because establishes the scale of the study, the time frame, hazards, evaluation criteria, assets to protect and the expert opinion.

Table 5. Risk Assessment context. (Source: authors using as reference the guidelines of ISO 31000 and US EPA)

Scale	Region IV of the State of Mexico. Composed of three municipalities, with an approximate population of 1.5 million inhabitants and an extension of 432.64 km^2
Assets to protect	- Local water sources - Cutzamala system - Local economic activity - The population of the Region IV - The floating population of Region IV Aquatic wildlife
Hazards	- Overpopulation in the peripheries - Overexploitation of the local water mantles - Cutzamala system infrastructure in poor conditions - The drought affecting water sources Contamination of local water sources
Time Frame	Considering the contingency is currently happening. The temporal horizon for the risk assessment is the Immediate future (2 years)
Expert opinion	Create an expert committee that includes academics of urban planning, civil engineering, and environmental sciences
Evaluation criteria	- Days with constant water supply - Quality of the potable water - Quality of the water sources in the region - Days the regular commercial activity was affected due to water shortage

The context defines the basic features of the analysed contingency (see Table 5). First, the scale of the case study is defined, where the territorial extension and population are presented, in this way the decision-makers can know the scale of the study. In the second instance, the Assets to protect are identified, which means the elements that can be affected by the possible contingency. Next, the Hazards are listed, these are the current realities of the case study that can be a source of potential damage. The time frame is basic because actions need to be taken in a short period to avoid further damage since the contingency is currently affecting Region IV. The expert opinion section serves to identify the professionals that can provide knowledge to prevent and reduce the effects of the contingency. Finally establishing the basic evaluation criteria to measure the scale of the contingency is key to identify the signs of a possible contingency and act according to the situation.

Risk Identification

After the context section, the Risk Identification stage is the first proper step of the Risk Assessment. In this part, the main risks are identified and analysed to establish risk scenarios. Firstly, five main risks were identified, using a logic-based cause-effect diagram. The next figure (see Fig. 3) explains how the authors came to identify them.

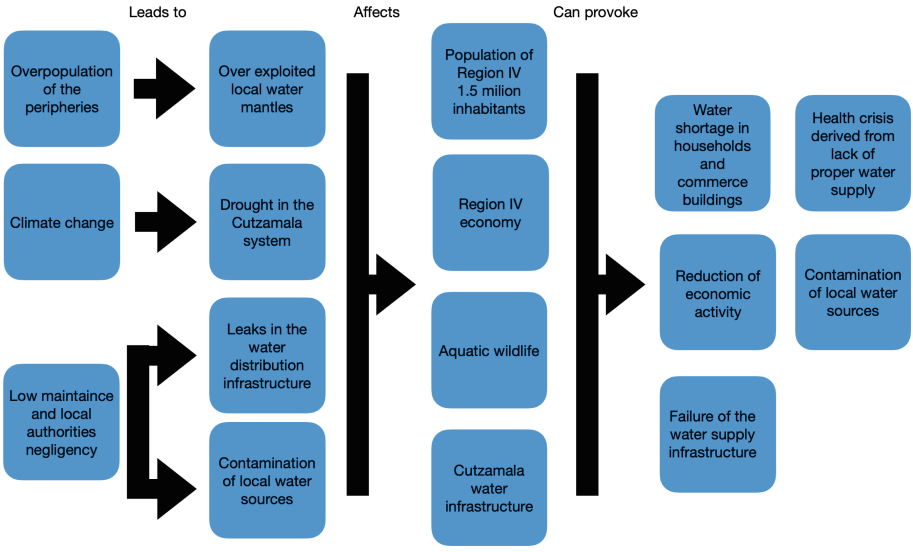

Fig. 3. Risk identification diagram. Source: elaboration of the authors.

Using as reference the World Economic Forum classification of risk types [3], the identified risks were categorized (see Table 6). This classification helps to understand the risks and how it affects the territory, society, and environment. Eventually, it will help to present specific solutions for each risk.

Table 6. Identified Risk types. (Source: authors)

Risks	Type
Water shortage in households and commerce buildings	Societal
Health crisis derived from lack of proper water supply	Societal
Reduction of economic activity	Economic
Failure of the water supply infrastructure	Technological
Contamination of local water sources	Environmental

Categorizing the risks for the study helps to understand how a contingency can affect multiple dimensions of the territory. Two of the risks are identified as societal because affect directly the inhabitants of the Region IV. An economic type of risk was identified because water shortage can eventually lead to a reduction in economic activity because many businesses rely on a constant water supply according to the field study. Even though one environmental risk was identified has a lot of weight in the study since is linked to the climate emergency. Finally, a technological risk linked to the quality of the water supply infrastructure was addressed, because if the water network does not function properly the population suffer from water shortage even if potable water is available in the basins.

The five main risks were evaluated using a qualitative approach where the impact and probability of the event were established (see Table 7). During the field study, several vulnerabilities were spotted from the water storage capacity of households to the capacity of public hospitals in case of a health emergency derived from lack of water. The vulnerabilities come from different aspects of the territory because the water shortage in Region IV has the capacity to affect multiple aspects of the Region IV urban system. It is important to mention the economic value of Region IV at the state level which represents around 9% of the State of Mexico's GDP [35]. These three municipalities although they are in the peripheric have an important value and a contingency like water shortage can have a bigger impact on the economy of Mexico City Metro and the State of Mexico. Finally, the induced risk gives an interesting result, where the risk of suffering from a reduction of potable water flow is rather constant than sporadic.

Building scenarios is a basic aspect when comes to building a Risk Assessment. Scenarios are widely used to better understand a contingency and plan future actions. A successful scenario tells the story of a defined event and its specific impacts. It helps decision-makers to visualize specific impacts that are based on currently accepted scientific knowledge [43].

Table 7. Risk Assessment identification. (Source: authors)

Dangerousness	- Water shortage in households and commerce buildings: Highly possible/Middle impact - Health crisis derived from lack of proper water supply: Possible/High impact - Reduction of economic activity: Less possible/Low impact - Failure of the water supply infrastructure: Less Possible/High impact - Contamination of local water sources: Possible/High impact
Vulnerability	- Water shortage in households and commerce buildings: There are houses with little capacity for water storage in case of contingency. Depending on the water storage capacity 10–0 days - Health crisis derived from lack of proper water supply: In the region currently are operating 10 public hospitals for 1.5 million people Reduction of economic activity: Gyms and restaurants rely on a constant water supply - Failure of the water supply infrastructure: Due to leaks in the system, it is estimated that 40% of the water flow is lost - Contamination of local water sources: It has been reported that the water in Madín Dam might be contaminated The Cutzamala system due to poor maintenance brings water with sediment Locals have reported the death of fishes at Madín Dam
Exposure	The Region IV has a population of approximate 1.5 million people. The region GDP is 7148.82 million USD that represents around 9% of the State of Mexico GDP
Induced risk	- 6.3% of probability that a water cut happens in a year - Around 70% of probability of water supply with low pressure in a year

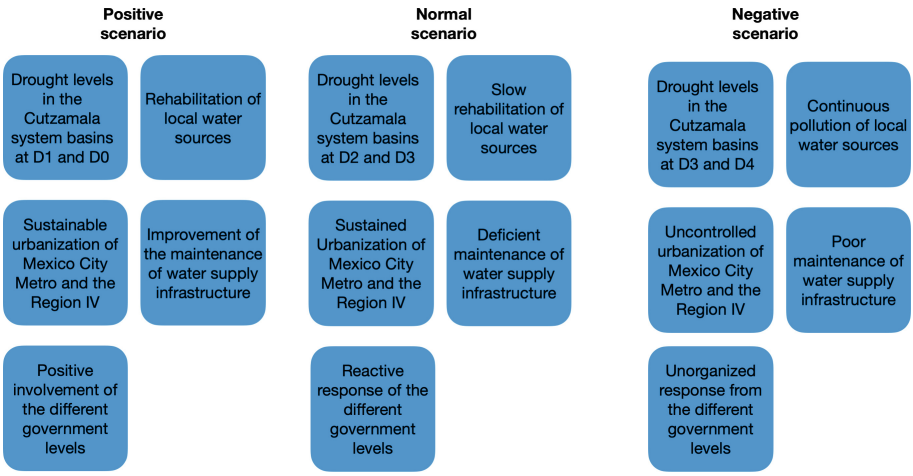

Fig. 4. Risk identification scenarios. Source: elaboration of the authors.

The figure above (see Fig. 4) shows a basic diagram of the proposed risk scenarios for the water shortage contingency. It is structured in three storylines: positive, normal and negative. In these scenarios are hypothesized the rhythm of urbanization, drought levels,

government involvement, maintenance of the Cutzamala system and rehabilitation of local water sources. This helps decision-makers to have a context in which the water shortage contingency in Region IV can be developed.

Risk Analysis

After the field study and the documental investigation, considering the limitations of the study and the scale, it was decided for this research project to use a qualitative approach, where the risks were analysed based on observation, interviews, and documental investigation. To analyse the risks, it was used the 5 × 5 Risk Matrix [44], which is a useful tool to classify risks in a simpler way. Two dimensions were evaluated on the proposed risks: probability and impact. Giving values from 1 to 5 where 1 has the lowest impact and probability, while 5 has the highest impact and probability. The result of the evaluated dimensions gives the value of the risk, going from low risk to high risk. This first approach to the production of a Risk Assessment gives a basic insight into the impact of the water shortage contingency in the Region IV of the State of Mexico.

		Very Low Impact 1	Low Impact 2	Medium Impact 3	High Impact 4	Very High Impact 5
Very High Risk	Almost certain 5			Water shortage in households and commerce buildings (Societal risk)		
High Risk	Likely 4					
Medium Risk	Possible 3				Contamination of local water sources (Environmental risk)	Health crisis derived from lack of proper water supply (Societal risk)
Low Risk	Unlikely 2		Reduction of economic activity (Economic risk)			Failure of the water supply infrastructure (Technological risk)
Very Low Risk	Very rare 1					

Fig. 5. 5 x 5 Risk Matrix for the water shortage contingency in urban areas. Source: elaboration of the Authors.

The matrix (see Fig. 5) gives an interesting insight into the dimension of the risks that Region IV of the State of Mexico is facing. Of the five risks that were identified in the study, four of them can be considered High Risk. This can be explained due to the constantly reported water cuts and the poor state of the water network. This confirms the necessity of elaborating a risk assessment for Region IV because the contingency is real and can cause a big impact in the region, that is why it is important to create tools, and public policies to afront the contingency. As seen on the matrix the environmental risk is one in the high-risk category, while the economic risk is categorized as low risk. These can help to guide the priorities of decision-makers to focus more on the environmental and societal related risks.

Risk Evaluation

After identifying the main risks derived from the water shortage crisis and the impact

that can cause in the Region IV of the State of Mexico, the research project after the field study and a documental review proposes possible risk reducers.

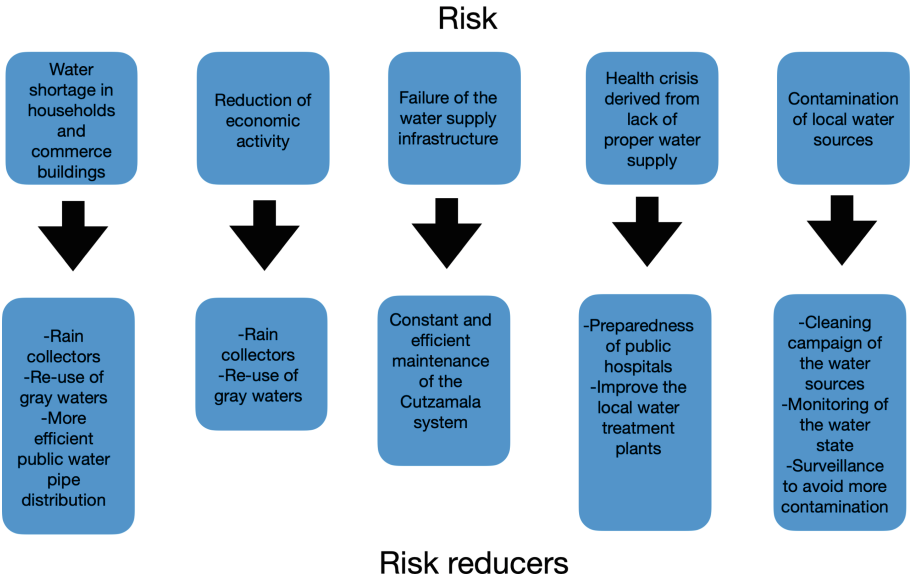

Fig. 6. Risk evaluation and reducers diagram. Source: elaboration of the authors

The risk reducers (see Fig. 6) were proposed based on the field study and observation of the Region IV reality. In the paper, most of the proposed risk reducers are based on sustainable practices, like the utilization of grey waters and the collection of rainwater, with the intention to increase the water storage capacity. Also is proposed the investment in improving the water treatment plants, and constant monitoring of the state of the potable water to avoid the supply of contaminated water. Is recommended that the federal government improve the maintenance protocol of the Cutzamala System to reduce the water cuts due to repairs of the water network. In the case of a health crisis, it is also mentioned the importance of preparedness for public hospitals in case of a health crisis derived from the consumption of contaminated water. Finally, a conscientization campaign regarding the importance of saving water and protect natural sources.

Evaluation Criteria

To measure the size of the contingency and how and when to activate the intervention protocols, it is important to establish a criterion to evaluate each of the proposed risks. In future research, the ranges to set the dimension of the water shortage contingency will be established.

The proposed evaluation criteria (see Table 8) use basic indicators due to the limitation of the study but can be further improved in future papers by establishing specific ranges to define the state of emergency. Firstly, it is advised to evaluate the days without constant water supply, to know if the storage capacity of water is surpassed in the households to intervene before reaching the shock point. In the second instance, it is

Table 8. Risk evaluation criteria (Source: authors)

Risks	Evaluation criteria
Water shortage in households and commerce buildings	Days without constant water supply
Health crisis derived from lack of proper water supply	Quality of the potable water
Reduction of economic activity	Days the regular commercial activity was affected due to water shortage
Failure of the water supply infrastructure	Percentage of water leak in the distribution network of the Cutzamala system
Contamination of local water sources	Quality of the water sources in the region

proposed to constantly measure the quality of the potable water that citizens consume to know if the levels of purity are adequate for human consumption. The next criteria are the days when businesses were affected by water shortage, this is to know the economic activity was reduced due to the water shortage contingency. To evaluate the state of the water distribution network the study considers it pertinent to measure the percentage of the water lost due to the leaks. The last criteria are the evaluate the water quality in the local water sources to prevent the loss of aquatic wildlife.

Risk Treatment

After the three phases that consist of a risk assessment, it is presented the final phase proposed in this research is the Risk Treatment using Strategic Planning criteria [30]. The research proposes the next recommendations.

As mentioned before this paper has the function of an introductory study on disaster planning for the water shortage contingency in urban peripherical areas, using as a case study the Region IV of the State of Mexico. The table above summarizes (see Table 9) the recommendations proposed by the authors after the field study and documental research. In the first instance, it is recommended to acknowledge the risk of water shortage and update the local and statal civil protection risk assessments. In the second instance is proposed the creation of a specific budget to deal with the contingency, raise awareness and participation of the citizens and the improvement of maintenance of the Cutzamala system. Next the creation of a permanent academic commission that watches over the water shortage crisis evolution and propose preparedness and response plans. Finally, is recommended sustainable techniques to preserve the local water sources and increase the water shortage capacity by recycling water.

6 Discussion

The results of the research describe and present the impact of water shortage in an urban peripherical area. This situation can continue and grow due to the constant urban expansion and the lack of preparedness for this new contingency due to climate change

Table 9. Risk treatment proposal (Source: authors)

Risk treatment proposals for the Region IV of the State of Mexico	Update the State of Mexico Risk Atlas and include water shortage as a risk assessment
	Update the local Risk Atlas at municipal level and include water shortage as a risk assessment with special emphasis on the local needs
	Improve the participation of the civil society in the distribution of the water resources
	Create a specific budget for water shortage at local and statal level
	Improve the maintenance of the Cutzamala system with preventive works and constant monitoring
	Create an academic commission that studies and evaluates the water shortage in its different dimension
	Propose a plan of action to clean the local water sources
	Encourage sustainable techniques in households and commercial buildings to save and recycle potable water

and man-made environmental damage. The situation of the Region IV of the State of Mexico is not unique and happens in many cities around the world that struggle to provide a proper water supply for their inhabitants [45].

The research presents a simplified form to create a risk assessment using a combination of different criteria from different organizations and governments in different countries. This can serve as a reverence for local authorities to develop their own risk assessments adapted to their own reality without the massive use of resources and data that implies a National Risk Assessment. In the findings section can be found the dimension of the water shortage contingency in Region IV and how it impacts different aspects of the region's proper function.

The paper presents the first approach to propose the water shortage in urban areas as a risk assessment that eventually can transform into a National Risk Assessment that can be used in the metropolitan areas around Mexico. The study uses a micro-regional scale because of the limited resources to gather data and do a field study. In Mexico, the data regarding disaster planning is limited at a local level [11] so it is important to present studies that can serve to encourage studies to promote resilient communities.

Due to the time frame of the field study and the lack of precise data at a local level the research project used a qualitative approach based on observation and interviews. It is expected that the qualitative approach can serve as a reference for further quantitative

studies. The 5 × 5 Risk Matrix used in this project brings uses a basic 1 to 5 qualitative scale based on observations and interviews but can be improved by including more specific indicators and solid data. Regarding the evaluation criteria, it is important to mention that is required further research to establish concrete ranges. The final recommendations use basic criteria of strategic planning but need deeper research to turn into a full disaster planning strategic plan for the water shortage contingency in urban areas.

7 Conclusions

The climate change emergency is impacting harder than expected [3] for that reason, it is important constantly monitor, create, and update risk assessments. The water shortage in urban areas is a relatively recent phenomenon that hasn't been developed in deep. The research gives an introductory insight about the crisis and a simplified proposal of risk assessment due to the limitation of the study, but with further studies can become a National Risk Assessment useful for urban areas at a national level. The main five risks that were identified show the multi-dimensional condition of the contingency with risks of different categories. Also, the identified risks are not exclusively for the Region IV of the State of Mexico and can be present in other urban peripherical areas.

To build more resilient territories and communities it is important to have proper risk management tools and policies to respond and adapt easily and faster in the case of a contingency. As urban territories and populations are constantly growing urban emergencies is still an important topic in the disaster planning field of study. For that reason, the study gathers relevance and is pertinent in this time of transition to more sustainable and resilient territories.

A proper potable water supply is a human right that in Mexico City Metro is in danger because of the water shortage contingency that is currently happening in the city. The study explains the main drivers of the crisis, like poor maintenance of the current water infrastructures, the overpopulation of the urban areas, overexploitation of local water sources, poor preparedness and response of the local authorities and contamination of water sources. These drivers lead to five main risks that are water shortage in households and commerce buildings, health crisis derived from lack of proper water supply, reduction of economic activity, failure of the water supply infrastructure and contamination of local water sources. Identifying five basic risks serves as an important reference for further studies that want to continue the investigation on the topic. After identifying the risks, the next phase in this study was to identify the risk reducers that help to reduce the impact of the water shortage contingency. Finally, some basic measures were proposed. The construction of a simplified risk assessment according to the research can be a useful tool for local authorities that do not have the data or resources to conduct a full risk assessment.

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