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The economic impact of water supply disruption from the Selangor River, Malaysia

Asif Raihan [a], Joy Jacqueline Pereira[a,*], Rawshan Ara Begum[b] and Rajah Rasiah[c]

[a] Southeast Asia Disaster Prevention Research Initiative (SEADPRI), Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, Bangi, Selangor 43600, Malaysia
[b] Department of Finance, UTS Business School, University of Technology Sydney (UTS), Ultimo, NSW, Australia
[c] Asia-Europe Institute, University of Malaya, Kuala Lumpur 50603, Malaysia
*Corresponding author. E-mail: joy@ukm.edu.my

AR, 0000-0001-9757-9730

ABSTRACT

The insidious economic impact of water disruption has received less attention compared to palpable climate disasters, but climate change and water security concerns call for investigation on cost consequences of property values and business losses in an already fragile water supply-demand balance in many developing countries. The economic impact of frequent water supply disruptions from the Selangor River in Malaysia due to technical issues, water pollution, and climate-related problems was estimated using the stock flow measure to assess property at risk, and survey to estimate business loss. The findings revealed that commercial, residential, and industrial property valued at RM459,041 million in 2020 in the State of Selangor and parts of Kuala Lumpur were at risk due to frequent water supply disruptions. A survey of small and medium enterprises from the manufacturing, construction, and services sectors revealed that 46% of the respondents were affected with losses amounting to RM2,053 million. The total economic impact of water supply disruption in 2020, combining both property value at risk and business loss, amounted to RM461,094 million, which accounted for 34% of Malaysia's GDP. A number of recommendations are made to prevent the widespread occurrence of water disruptions.

Key words: business loss, climate change, economic impacts, water disruption, water security

HIGHLIGHTS

- Water supply disruption causes huge economic impacts in Malaysia.
- The main causes of water supply disruptions are technical problems, pollution, and climatic hazards.
- This study estimated total property value at risk and business loss due to water supply disruption.
- Climate change puts pressure on water resources in Malaysia.
- The findings offer long-term decision-making solutions for water resource management.

1. INTRODUCTION

Water is a vital natural resource which is essential for life and the production of numerous economic activities (Santos *et al.* 2021). The rapid development to suit human demands and requirements has resulted in a more limited and threatened supply of clean water (Rashid *et al.* 2021). Urbanization, fast population expansion, aging infrastructure, intensive agriculture, and unprecedented demand all pose both short- and long-term water supply disruptions which in turn exacerbate climate change, pollution, and biodiversity loss (Pagsuyoin & Santos 2021). Additionally, delivering dependable water service is a complex decision-driven process affected by a wide range of variables, including scarce resources, hydrological conditions, supply and demand shifts, rising per-capita water demand, water pollution, groundwater over-abstraction, poor distribution, and the timing and severity of accidents causing water disruption (Pecharroman *et al.* 2021). As water is essential to human life, people are in danger when there is not enough of it or when it is not of sufficient quality (Kujinga *et al.* 2014). Degraded water supplies, which may occur regularly and, more importantly, during droughts, have a significant impact on households and many businesses, which are becoming increasingly interconnected (Pagsuyoin & Santos 2021). Water is also a vital resource that drives economic growth. The majority of the world's working population, or around 42%, is predicted to be employed in what is known as 'heavily water-dependent sectors', which are those that use a significant amount of water in their operations (WWAP 2016). Moreover, over a third (36%) of the labor force is engaged in activities that are just somewhat dependent on water. Water is a crucial part of the value chains of these sectors despite the fact that they do not need huge amounts of it to function. As a result, water and economic growth are inextricably intertwined. Simultaneously, economic development and growth impose a significant strain on water supplies, posing a threat to water security for enterprises, individuals, and the environment (WWAP 2015). The lack of clean drinking water is a huge environmental issue that threatens entire communities. However, previous studies showed that the most influential factors of water scarcity or water problems are prolonged hot weather or drought, radiation, human density or the growing population, climate change, and so on, which will lead to various effects, such as altered economic growth, human activity, health, and water quality (Rashid *et al.* 2021).

Water scarcity is a global challenge to social activities, sustainable human life, economic growth, and environmental quality. As stated by the United Nations Water Report (UN-Water 2016), 700 million people in 43 countries are anticipated to be affected by water scarcity. By 2025, two-thirds of the world's population may face water scarcity. Water supply disruption events have become more common and severe in recent years, both in Southeast Asia and around the world. Climate change and extreme weather events are increasing in frequency and intensity, putting even more strain on the already tenuous water supply-demand balance (Nguyen *et al.* 2022). Droughts have hit Africa, South Asia, the Middle East, South America, Europe, and South America in recent decades, wreaking havoc on their economies, ecosystems, agriculture, energy generation, and water availability and quality (Herrera-Pantoja & Hiscock 2015). Since the effects of global warming are expected to exacerbate the vulnerability of water resources, putting economic development at risk, managing water resources in these regions is a challenge. Water scarcity and the effects of other extreme events such as droughts, flooding, storms, sea-level rises, and heat waves present a particular management challenge (Herrera-Pantoja & Hiscock 2015). For example, severe lack of water in California between 2012 and 2016, due to the state's prolonged drought, resulted in the extinction of animals and billions of dollars in economic damages (Lund *et al.* 2018). Due to the contamination of damaged mains, the 2011 flash flood in Copenhagen, Denmark, flooded homes and streets in a couple of hours, destroying infrastructure and leaving the city's drinking water supply contaminated for weeks (EEA 2012). The agro-economics of South Asia, the Middle East, and North Africa are predicted to suffer in the coming decades due to water scarcity (Schmitz *et al.* 2013). Droughts are expected to reduce maize planting areas in Sub-Saharan Africa by roughly 40% of present farmland, while rising temperatures may harm grassland ecosystems needed to graze cattle in other parts of the continent. Water availability will also appear bleak in the future. To keep up with economic and population expansion, the worldwide water shortage is expected to hit 40% by 2030 (Pagsuyoin & Santos 2021). Furthermore, aside from hydropower, water is one of the most important inputs in the production of electricity. Consequently, water scarcity can cause power outages, as observed recently in India and Brazil (Desbureaux & Rodella 2019). Inadequate water supplies, both in quantity and quality, pose a serious threat to the survival of households and their members (Kujinga *et al.* 2014). There may be a 9.16% decline in available water for groundwater recharge and runoff by the end of the 21st century due to future climate change predictions, such as a 4.8 °C increase in mean annual temperature and a 22% decrease in mean annual precipitation (George 2020). As a result, water resource management could face major issues unless governments implement effective water policies that consider the impact of climate change.

Water supply disruption has a detrimental impact on property value, livelihood, and business (Selelo *et al.* 2017). The effects of the water supply disruptions have been felt across a wide range of industries. Many small and medium enterprises (SMEs) have experienced business interruption losses as a result of the water supply disruption. Threats to uninterrupted water supplies are recognized as important business risks in many economic sectors since an interruption in the water supply might force enterprises to slow down or shut down production. Reducing the risk of water disruption events can have a variety of public and private benefits for property values, enterprises, and society as a whole. Achieving water security for the inhabitants is a goal shared by all nations, whether developed or developing (Kujinga *et al.* 2014). Understanding how disruptions affect businesses is critical to comprehending society's vulnerability (Sjöstrand *et al.* 2021). The lack of corporate awareness and preparedness, along with the potentially huge economic effects of water disruption, necessitates increased communication between municipalities and businesses, as well as thorough water supply planning, to reduce both emergency and predicted disasters (e.g., extreme drought). For this, data on how various user groups are impacted by water disruption are required. As a result, additional data on the economic repercussions of water disruption is needed. In addition, managing current and future water crises necessitates the development of diagnostic tools for planning adaptation strategies and the formulation of policies that recognize the inextricable links between competing sectors for water. To facilitate water supply planning and the selection of economically viable risk mitigation strategies, it is important to weigh the investment costs of potential solutions against the benefits of mitigation (Buck *et al.* 2016). The success of this endeavor depends on the ability to provide accurate quantitative estimates of the monetary costs associated with disruption, such as drops in property value and revenue. Water is a crucial resource for companies, yet research on the effects of water supply disruption on the economy is limited (Sjöstrand *et al.* 2021). The existing literature has largely focused on the economic consequences of long-term interruptions caused by big natural catastrophes (Brozović *et al.* 2007; Sjöstrand *et al.* 2021). Although water disruption events often yield significant economic impacts, they are not evaluated as frequently as major disasters. There is a research gap in estimating the economic impact of water supply disruption. Furthermore, in studies of the economic repercussions of water supply disruptions, property values at risk have gotten less attention.

Over the past few years, water supply disruption has become an extremely common event in Malaysia, particularly in Selangor and Kuala Lumpur because of the growing demand for domestic water usage due to the rapid growth of population, urbanization, and industrialization (Anang *et al.* 2019). Selangor is one of Malaysia's most prosperous and advanced states, contributing 23.70% to the country's GDP in 2018. Rapid development has accelerated urbanization, resulting in a momentous upsurge in the number of urban centers and an exponential rise in demand for clean water (Oral *et al.* 2020; Beceiro *et al.* 2022). In many areas of Malaysia, the demand for freshwater is likely to increase while supplies decrease, leading to water supply disruption. The rising demand for water as a result of population expansion has the potential to stress existing water infrastructure. According to a report by the Malaysian Water Association, Selangor accounted for 49.50% of all water supply concerns in Malaysia. In 2017, the percentage grew to 62.40% (Rahman 2021). The Selangor River is critical for supplying water to the Klang Valley, which is Malaysia's most developed region and the major source of wealth. In 2016, the GDP value of Malaysia was RM1.23 trillion, to which the Klang Valley contributed roughly 38%. But the frequency of water disruption has increased to the point that it is stunting development in the Klang Valley. In urban regions, where water plays an essential role in maintaining economic operations, decreased water supply can cause operational interruptions that harm individual industries as well as the wider regional economy (Blackburn *et al.* 2021). The *New Straits Times* (2018), a local newspaper, reported that water supply disruption for a month in the Klang Valley may result in economic losses of over RM2 billion due to the decline in production, cost increases, and productivity drops. However, there is a lack of research on the economic impact of water supply disruption in Malaysia. This study attempts to estimate the economic impact of water supply disruption from the Selangor River, Malaysia. The property value at risk due to water interruption is initially evaluated, followed by an assessment of business loss due to water disruption. The findings could be useful to the water management authority in Malaysia to make appropriate decisions on water supply and sustainable water resources management in the future.

2. METHODS

2.1. Stock measure

The Selangor River is the major source of treated water supply for about 6 million people in the State of Selangor and a large part of the capital city of Kuala Lumpur (Figure 1). Reports of the Selangor water management company (Pengurusan Air Selangor Sdn Bhd) indicate that the water reticulation system covers eight districts in Selangor and Kuala Lumpur. Reports of water cuts in the newspapers and other media and coverage of the water reticulation system were used as a basis for estimating the extent of water disruption. The media was also the source of data regarding the number of days with water disruption between 2005 and 2020. The land use within the disrupted areas was determined using data from Open Street Map (OSM) and validated using reports from the Town and Country Planning Department Malaysia. Land use categories consisting of residential, commercial, and industrial zones were evaluated to estimate the property value at risk (stock measure) due to water disruption. Agriculture land use was not included in the assessment as it does not receive a treated water supply. Property value losses, as well as structural and non-structural property damage, are commonly measured in stocks. When analyzing the impact of disruption events, the property value at risk (stock measure) is one of the costs considered (Lizarraga 2013). The study used the methodology of Gawande & Jenkins-Smith

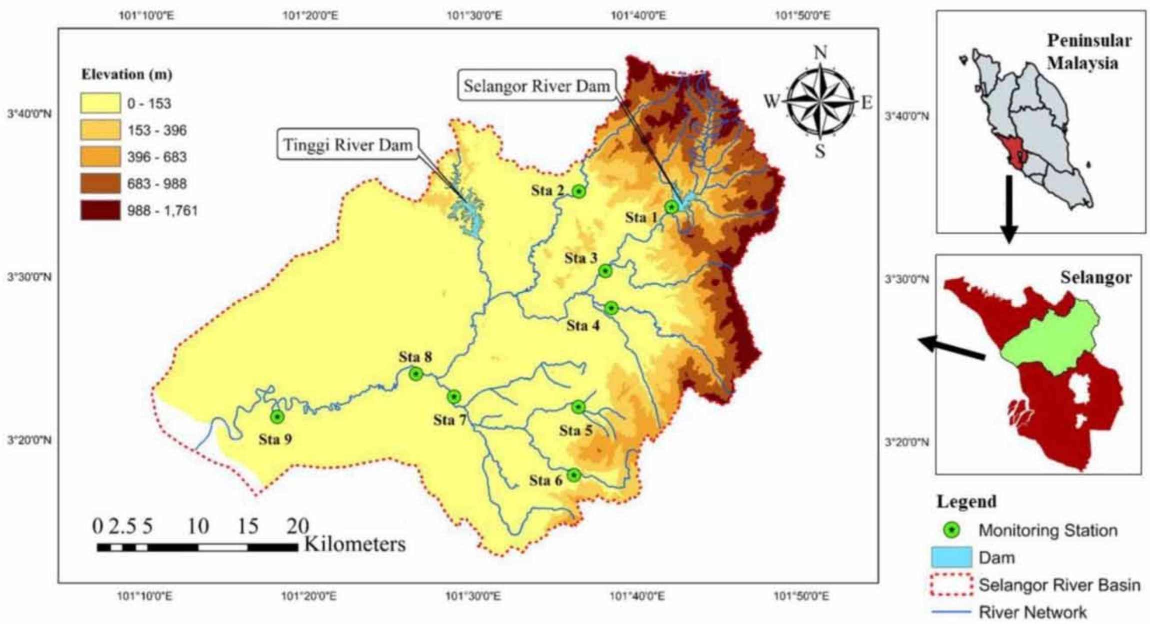


Figure 1 | The geographic location of the Selangor River basin. *Source*: Wong *et al.* (2021).

(2001) who used the average transaction value to measure the property value at risk due to nuclear waste transport in South Carolina, USA. Data regarding the number, price, and transaction of residential, commercial, and industrial property (stock) were collected from the National Property Information Centre (NAPIC). The Malaysian Accounting Standards Board (MASB 2011) reported that the transaction price is equal to the fair value for pricing the property at risk.

The number of properties (residential, commercial, industrial) in the water disruption area for each district is estimated by applying Equation (1):

$$NP = \frac{TP \times WDA}{TA} \tag{1}$$

where NP is the number of properties at risk due to water disruption, TP is the total number of properties in the district, TA is the total area of districts, and WDA is the water-disrupted area inside the districts.

The average value of each property (residential, commercial, industrial) in each district is estimated by employing Equation (2):

$$AVP = \frac{VPS}{NP} \tag{2}$$

where AVP is the average value of the property, NP is the number of properties sold in 2020, and VPS is the total value of properties sold in a particular year.

Property value at risk due to water supply disruption in each district is estimated by utilizing Equation (3):

$$PVR = AVP \times NP \tag{3}$$

where PVR is property value at risk, AVP is the average value of the property, and NP is the number of properties at risk due to water disruption.

The study estimated the total property value at risk (stock measure) by summing up the property value at risk in all eight districts in the study area.

2.2. Water disruption survey

A survey of the representatives, owners, and workers from SMEs was conducted to estimate the business interruption loss due to water supply disruption in 2020. The information on the number of SMEs was obtained from the Annual Report 2019, SME Corporation Malaysia, and the Ministry of Entrepreneur Development and Cooperatives (MEDAC). The survey involved 117 respondents from three main categories of SMEs comprising the manufacturing, construction and services sectors located in the areas that experienced water disruption. A purposive random sampling method was used to conduct the survey through phone calls, email, WhatsApp messages, and Google forms between May and June 2021. The respondents were selected based on their accessibility.

2.2.1. Pearson's Chi-squared test

The study employed Pearson's Chi-squared test to check the statistical relationship between water supply disruption and business loss (Selelo *et al.* 2017) by using Equation (4):

$$\chi^2 = \frac{\Sigma(O - E)^2}{E} \tag{4}$$

where O is the observed value and E is the expected value.

Pearson's Chi-squared test to investigate the relationship between the status of water disruption reported by the respondents and business loss due to water supply disruption, and the relationship between the number of days per month with water disruption and business loss by the SMEs.

2.2.2. Flow measure

Business interruption losses, impact on wages, salaries, and profits, transportation expenses, remedial activities, and their opportunity costs, utility revenue loss, household interruption losses, and fatalities are all flow measurements in the literature on economic analysis (Lizarraga 2013). The study followed the methodology of several previous studies (Chang *et al.* 2002; Livernois 2002; Brozović *et al.* 2007; Lizarraga 2013; Heflin *et al.* 2014) that surveyed residents and businesses affected by water disruption events to estimate the business interruption loss.

This research estimated the marginal forecasted loss per day for all the three categories of SMEs (manufacturing, construction, services) by utilizing Equation (5):

$$F_n = \frac{A_{n-1} + A_{n-2} + A_{n-3} + \cdots + A_{n-n}}{n} \tag{5}$$

where F is the forecasted loss and A is the actual business loss by SMEs.

The averaged marginal forecasted loss per SME (ML) in 2020 is estimated for three categories of SMEs by using Equation (6):

$$\mathrm{ML} = F_n \times N_\mathrm{D} \tag{6}$$

where N_D is the number of days with water disruption in 2020.

The study used the following Equation (7) to estimate total business loss (TL) for each of the three categories of SMEs:

$$\mathrm{TL} = N_\mathrm{S} \times \mathrm{ML} \tag{7}$$

where N_S is the number of SMEs in the water disruption area and ML is the averaged marginal forecasted loss (RM) per SME in 2020.

The study estimated the total business loss (flow measure) due to water supply disruption in 2020 by summing up the total business loss for all three categories of SMEs.

3. RESULTS AND DISCUSSION

3.1. Water supply disruption

Water disruption was reported in eight districts comprising Gombak, Hulu Langat, Klang, Kuala Langat, Kuala Selangor, Sepang, Petaling, and Kuala Lumpur. Figure 2 depicts the area of the water disruption within and outside of the Selangor River basin. The total area of water disruption is about 673 km^2 whereas Klang (214 km^2), Kuala Lumpur (162 km^2), and Petaling (150 km^2) districts experience extreme water disruption that covers approximately 78% of the total water supply disrupted area in Selangor. Figure 3 presents the total area of eight districts and the area with water supply disruption along with the percentage of area inside the water disruption boundary.

Furthermore, the land use category inside the water disruption boundary is depicted in Figure 4, and Table 1 presents the residential, industrial, and commercial land use area inside the water disruption boundary by the districts. The outcome of the land use map shows that residential, industrial, and commercial land use inside the water disruption boundary covers 125.53, 8.60, and 29.49 km^2, respectively. The Petaling district comprises

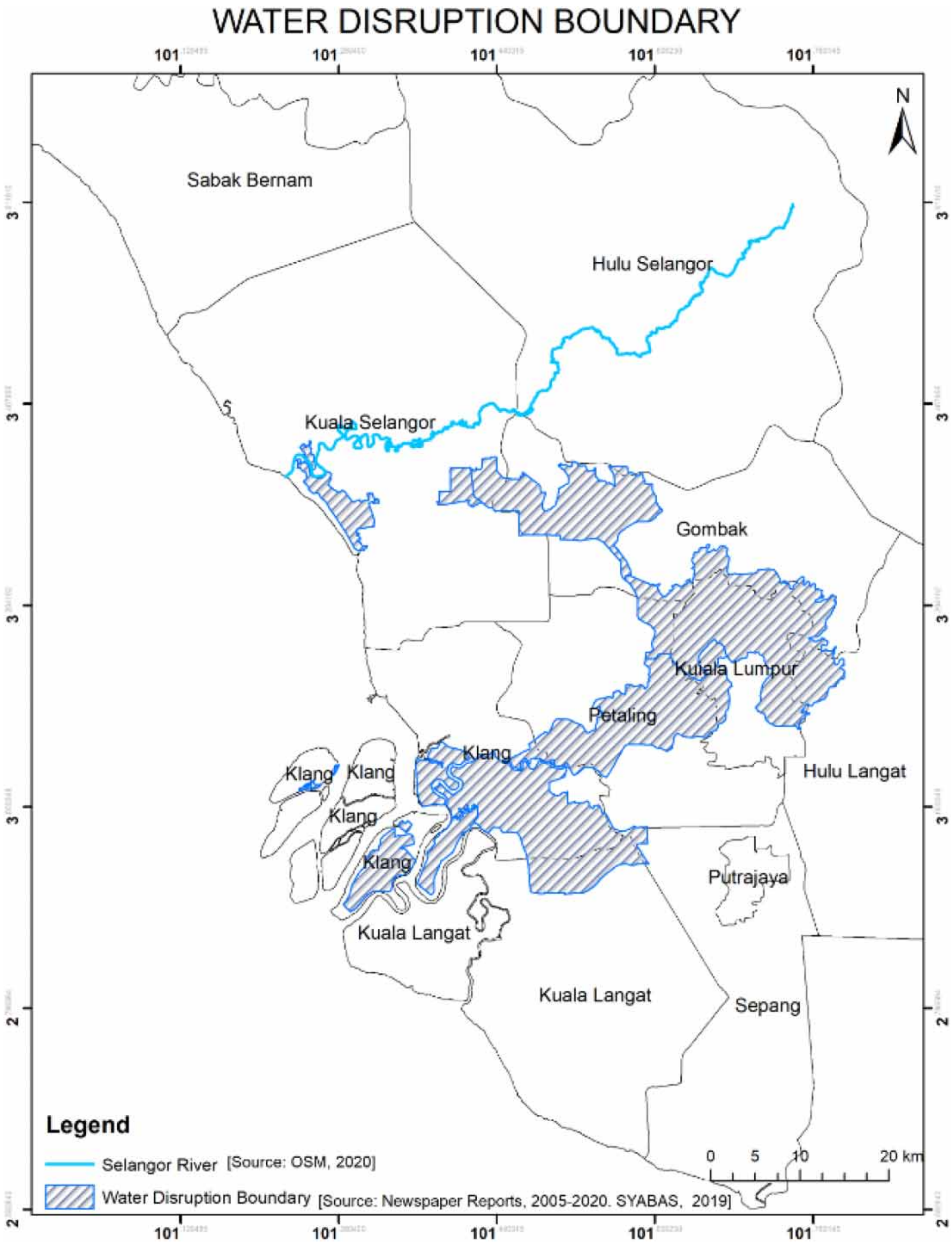
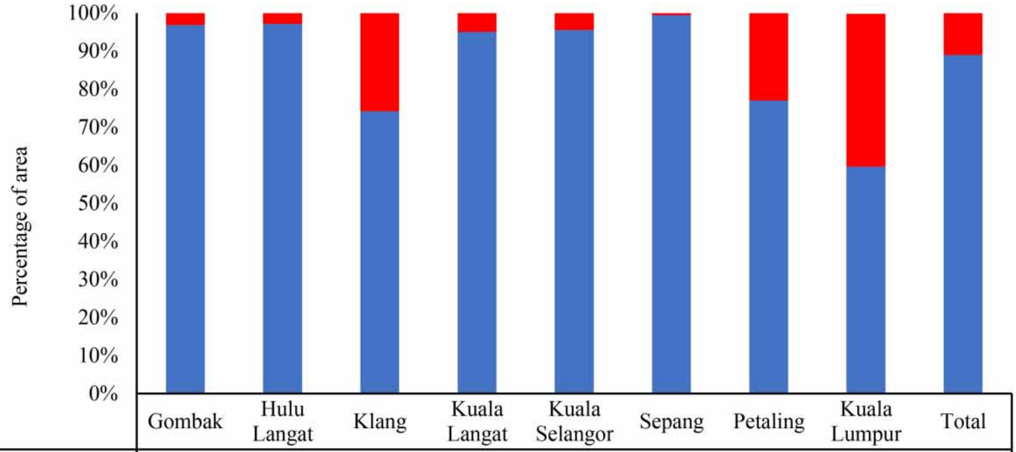


Figure 2 | Area of water supply disruption.



	Gombak	Hulu Langat	Klang	Kuala Langat	Kuala Selangor	Sepang	Petaling	Kuala Lumpur	Total
Water disrupted area (%)	3.25%	3.00%	34.75%	5.22%	4.66%	0.56%	29.80%	67.29%	12.37%
Water disrupted area (km2)	20.39	25.06	213.95	43.59	55.16	3.35	150.13	161.77	673.40
Total area (km2)	627.92	835.17	615.63	834.35	1184.38	600.65	503.81	240.42	5442.34

Figure 3 | Areas with water supply disruption in eight districts.

a maximum residential and commercial area, while the Klang district covers most of the industrial area inside the water supply disruption boundary.

3.2. Duration and causes of disruption

The number of days with water supply disruption from the Selangor River, Malaysia from 2004 to 2020 is presented in Figure 5. The maximum number of days with water supply disruption occurred in 2014 (83 days) when 52 days of water disruption occurred due to climatic hazards. However, a total of 43 days of water supply disruption occurred in 2020. Figure 6 presents the number of days with water supply disruption from the Selangor River in 2020 by months. The highest number of days with water disruption was experienced in October (13 days) whereas there was no water supply disruption in the months of January and April. In addition, Figure 7 depicts the total number of days with water disruption in 2020 based on the major causes of water supply disruption from the Selangor River. Based on the data presented in this paper, Selangor's water supply disruptions are mainly the result of technical problems (repair works, valve replacement), water pollution (odor, contamination, oil spill), and climatic hazard (landslides, dry spells).

The need for clean, treated water is on the rise, yet Malaysia's water supplies are being stressed by climate change, pollution, and building in its catchment areas. Several factors, including Selangor's rapidly expanding population, poor water governance, a dearth of finance, changing climate, rising water demand, and pollution, pose serious challenges to Malaysia's water resources management. According to Anang *et al.* (2019), climate change negatively impacts Malaysia's water supply. Furthermore, because of its age and broad nature, water delivery infrastructure is particularly vulnerable to disruption during natural catastrophes (Brozović *et al.* 2007). Heavy metals, medicines, endocrine disruptors, perfluorinated chemicals, flame retardants, and biocides have contaminated water supplies in both developing and developed countries (Ternes *et al.* 2015). When treated drinking water is transferred to the distribution system, it carries with it a variety of contents, including physical, microbiological (cells), and nutritional (organic and inorganic nutrients). It is just as important to get clean water to where it needs to go as it is to make it. If the pipes are in bad shape, then the water coming out of the tap won't be very nice either. In Malaysia, many different state administrations are responsible for the rivers that supply the country with its raw water. It is now widely recognized that industrialization negatively influences river water quality (Rashid *et al.* 2021).

3.3. Property value at risk

The average transaction value of the property is estimated based on the property sales quarterly data for 2020 obtained from NAPIC. The average transaction values of the residential, commercial, and industrial property for 2020 are presented in Table 2. The average transaction value is highest for industrial property, followed by

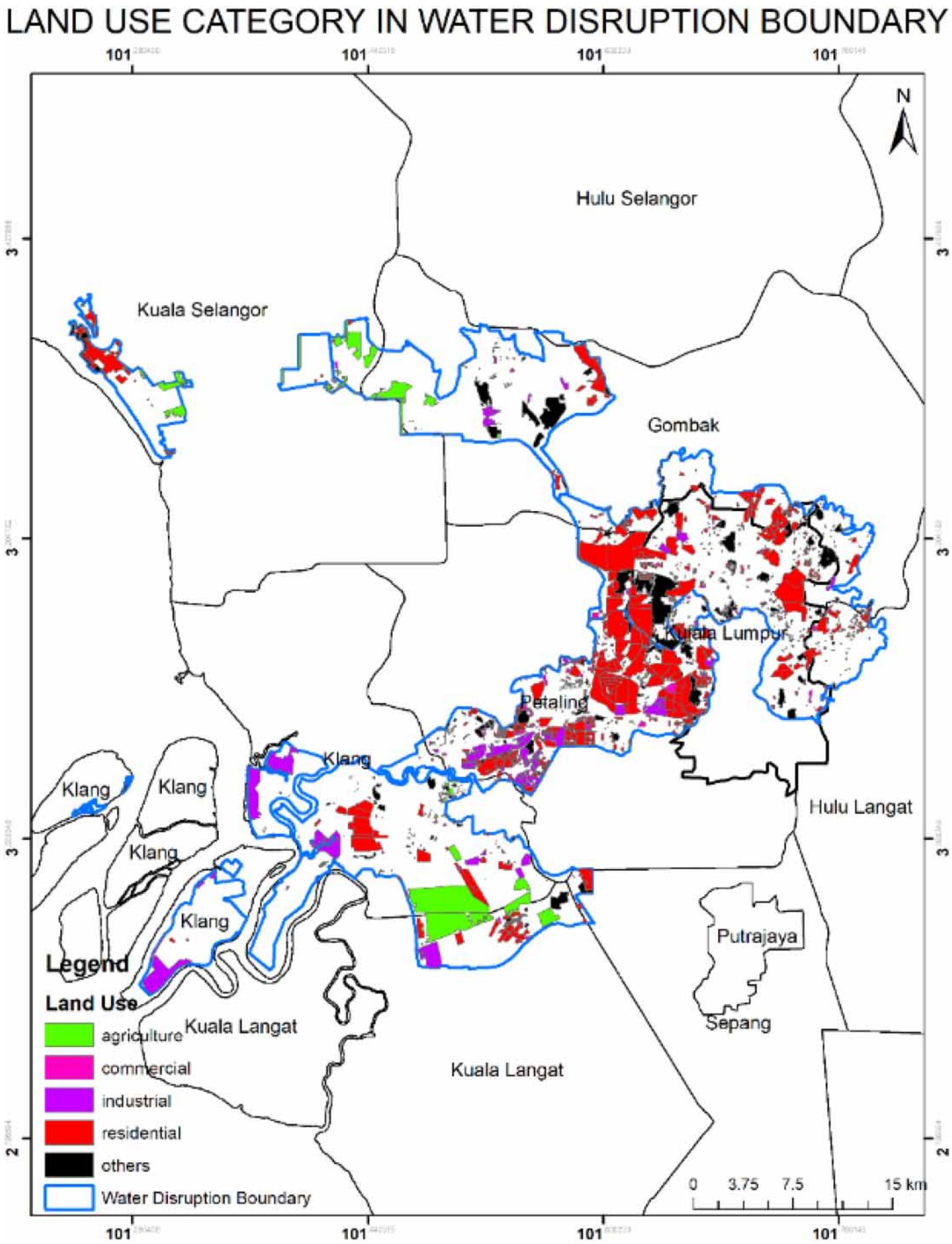


Figure 4 | Areas that experienced water disruption.

commercial and residential property. The average residential property value is highest in the Kuala Lumpur district and lowest in the Kuala Langat district. Moreover, the average commercial property value is highest in Sepang while the average industrial property value is highest in the Kuala Langat district. Furthermore, the lowest value of both commercial and industrial property was found in the Kuala Selangor district.

Property value at risk due to water supply disruption in the study area is presented in Table 3. The number of residential stocks inside water-disrupted areas in 2020 was 586,069 where Kuala Lumpur (333,748) had the maximum number of residential stocks followed by Petaling (157,573), Klang (70,903), Hulu Langat (11,274), Gombak (6,643), Kuala Langat (2,770), Kuala Selangor (2,724), and Sepang (435). Residential property value at risk due to water disruption in 2020 is estimated at approximately RM414,329 million where Kuala Lumpur (RM271,433 million) shows the maximum residential property value at risk followed by Petaling (RM101,232 million), Klang (RM30,594 million), Hulu Langat (RM5,492 million), Gombak (RM3,046 million), Kuala Selangor (RM1,176 million), Kuala Langat (RM1,114 million), and Sepang (RM241 million). Furthermore, the number of commercial stocks inside the water-disrupted area in 2020 was 362 whereas Kuala Lumpur (303) shows the

Table 1 | Residential, industrial, and commercial areas that experienced water disruption

Districts	Residential area (km²)	Residential area (%)	Commercial area (km²)	Commercial area (%)	Industrial area (km²)	Industrial area (%)
Gombak	10.44	8.32	0.24	2.81	1.59	5.37
Hulu Langat	2.06	1.64	0.19	2.21	0.00	0.01
Klang	11.17	8.90	0.86	9.95	13.21	44.80
Kuala Langat	3.65	2.91	0.22	2.53	2.31	7.82
Kuala Selangor	6.04	4.81	–	–	0.10	0.35
Sepang	1.18	0.94	–	–	–	–
Petaling	59.43	47.35	4.94	57.45	11.15	37.80
Kuala Lumpur	31.57	25.15	2.16	25.06	1.14	3.85
Total	125.53	100	8.60	100	29.49	100

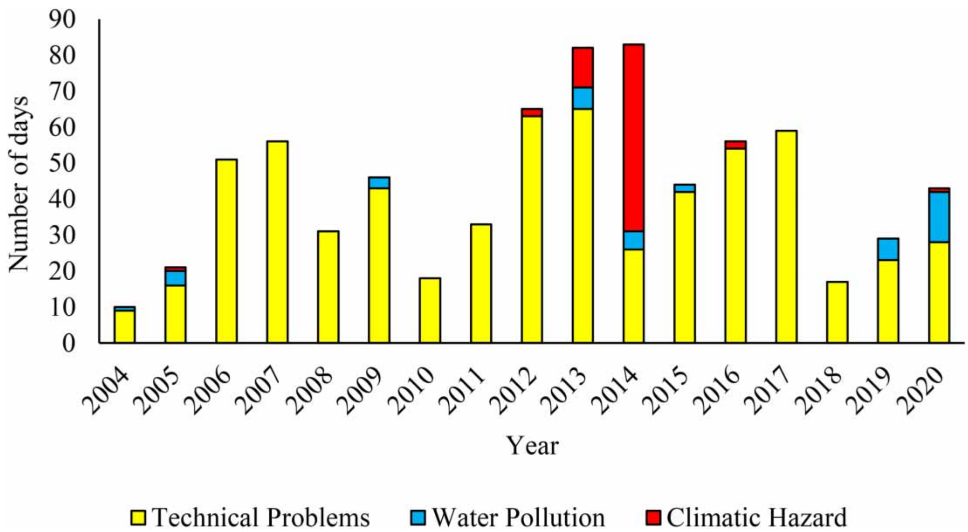


Figure 5 | The number of days with water supply disruption from the Selangor River from 2004 to 2020.

maximum number of commercial stocks followed by Petaling (51) and Klang (6). Commercial property value at risk due to water disruption in 2020 is estimated at approximately RM532 million whereas Kuala Lumpur (RM468 million) shows the maximum commercial property value at risk followed by Petaling (RM56 million) and Klang (RM7 million). Moreover, the number of industrial stocks in water-disrupted areas in 2020 was 11,094 where Petaling (4,284) shows the maximum number of industrial stocks followed by Kuala Lumpur (3,457), Klang (2,932), Hulu Langat (221), Gombak (152), Kuala Langat (30), Kuala Selangor (12), and Sepang (5). Industrial property value at risk due to water disruption in 2020 is estimated at approximately RM44,181 million where Petaling (RM16,129 million) shows the maximum industrial property value at risk followed by Kuala Lumpur (RM8,927 million), Klang (RM16,593 million), Hulu Langat (RM1,195 million), Kuala Langat (RM670 million), Gombak (RM626 million), Sepang (RM22 million), and Kuala Selangor (RM17 million). The findings show that the total property value at risk due to water supply disruption in 2020 is estimated at approximately RM459,041 million. This covers residential property valued at RM414,329 million, industrial property valued at RM44,181 million, and commercial property valued at RM532 million. The Kuala Lumpur district shows the highest amount of property value at risk followed by Petaling, Klang, Hulu Langat, Gombak, Kuala Langat, Kuala Selangor, and Sepang districts. The findings are supported by Anang *et al.* (2019) who reported that water supply disruption damages the infrastructure in Malaysia. Water disruption caused by man-made or climate disasters can have long-term economic consequences for both corporate and

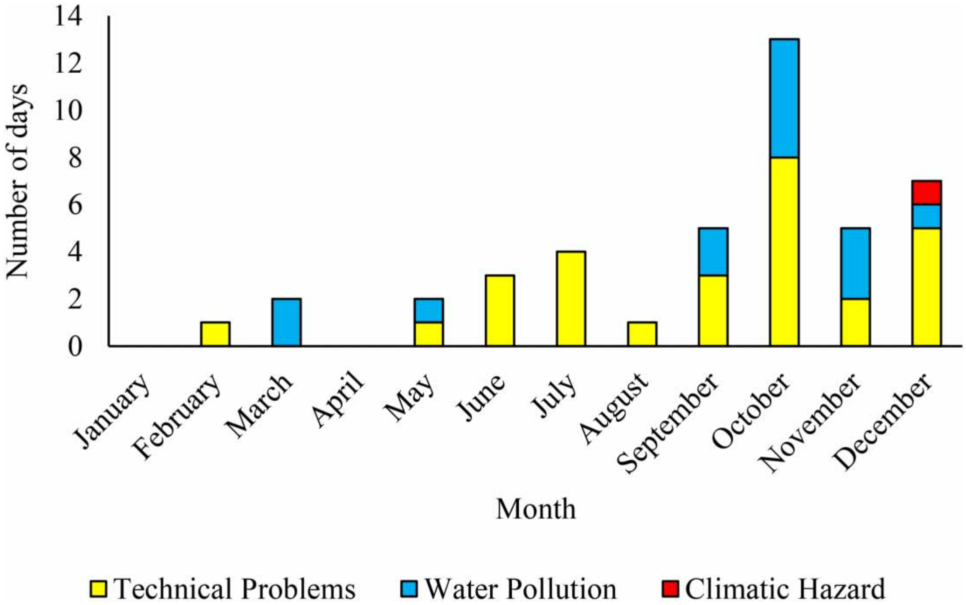


Figure 6 | The number of days with water supply disruption from the Selangor River in 2020 by months.

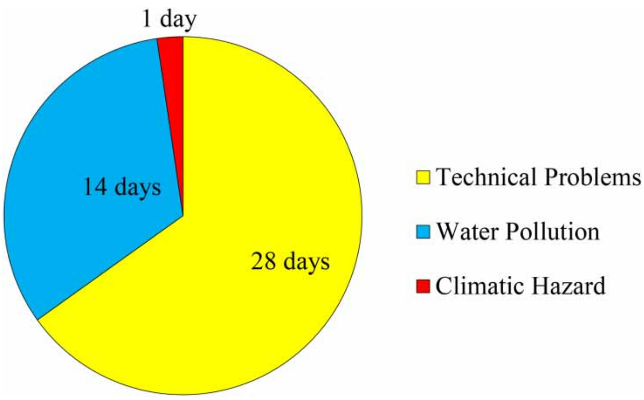


Figure 7 | The number of days with water disruption in 2020 by the major causes.

household users. Therefore, the total economic losses due to damaged infrastructure may be far higher than the value of the infrastructure (Brozović *et al.* 2007).

3.4. Water disruption and the business loss

The response from the questionnaire survey regarding business loss due to water supply disruption is presented in Table 4. The survey includes the responses from a total of 117 SMEs where the number of respondents under the manufacturing, construction, and services categories are 15, 25, and 77, respectively. According to MEDAC (2019), 90% of the SMEs in Malaysia are under the services category. Thus, while conducting the survey the present research considered the maximum respondents from the SMEs under the services category. Figure 8 illustrates the number of respondents in each district inside the water disruption boundary. The number of respondents experiencing business loss due to water disruption is 54 (46.15%) whereas 63 respondents (53.85%) reported that they do not experience business loss due to water disruption in their area. Figure 9 shows the number of days with water disruption events per month reported by the respondents. The different responses on the number of water disruption events are mostly dependent on the locations of enterprises.

The study employed Pearson's Chi-squared test to investigate water supply disruption events as a factor affecting the performance of SMEs. Table 5 presents Pearson's Chi-squared test outcomes for the relationship between

Table 2 | The transaction values of residential, commercial, and industrial property in the study area

	Residential	Commercial	Industrial
Kuala Selangor			
Total Units in Transactions (Units)	897	69	20
Total Transaction value (RM Million)	387.43	47.63	29.90
Average Transaction Value (RM/property)	431,914.22	690,355.22	1,495,150.20
Gombak			
Total Number in Transactions (Units)	2,036	129	84
Total Transaction value (RM Million)	933.65	100.79	345.53
Average Transaction Value (RM/property)	458,570.42	781,347.98	4,113,437.98
Kuala Lumpur			
Total Units in Transactions (Units)	4,832	1,301	35
Total Transaction value (RM Million)	3,929.81	2,006.68	90.37
Average Transaction Value (RM/property)	813,287.51	1,542,411.01	2,582,069.71
Hulu Langat			
Total Units in Transactions (Units)	4,233	331	125
Total Transaction value (RM Million)	2,061.98	295.01	675.91
Average Transaction Value (RM/property)	487,119.29	891,260.02	5,407,296.97
Petaling			
Total Units in Transactions (Units)	4,960	901	178
Total Transaction value (RM Million)	3,186.53	993.08	670.10
Average Transaction Value (RM/property)	642,444.73	1,102,201.68	3,764,587.84
Klang			
Total Units in Transactions (Units)	2,981	315	155
Total Transaction value (RM Million)	1,286.29	375.72	877.06
Average Transaction Value (RM/property)	431,494.57	1,192,759.05	5,658,456.36
Kuala Langat			
Total Units in Transactions (Units)	963	99	21
Total Transaction value (RM Million)	387.36	95.38	473.62
Average Transaction Value (RM/property)	402,244.10	963,402.91	22,553,376.24
Sepang			
Total Units in Transactions (Units)	1,460	160	42
Total Transaction value (RM Million)	808.05	292.58	182.29
Average Transaction Value (RM/property)	553,456.38	1,828,628.23	4,340,134.31

the status of water disruption reported by the respondents and business loss due to water supply disruption. Furthermore, Table 6 shows Pearson's Chi-squared test results for the relationship between the number of days with water disruption per month and business loss by SMEs. Both Pearson's Chi-squared test results indicate that there is a relationship between water supply disruptions and the business loss of SMEs. Significance of Pearson's Chi-squared value ($p < 0.01$), a relatively high likelihood ratio (>10), the significance of likelihood ratio, Cramér's value (>0.50), and the significance of Cramér's V ($p < 0.01$) indicate a strong association between the variables. Cramér's V is an effect size measurement for the Chi-squared test of independence, which evaluates the degree of connection between two category sectors. The results suggested that the status or frequency of water supply disruption events had a negative impact on SME profits. Therefore, protracted water supply interruptions may increase the likelihood of SME business losses. Water-related dangers and reliability issues may have a significant effect on a company's revenue and expenses, thereby impeding its growth and profitability. The present study's finding is aligned with Selelo *et al.* (2017) who discovered a positive and statistically significant association between water supply disruptions and SMEs business loss in Botswana using the Chi-squared test. According

Table 3 | Property value at risk due to water supply disruption in the study area

	Residential		Commercial		Industrial		Total
Districts	**Number of stocks in water-disrupted area**	**Property value at risk (RM Million)**	**Number of stocks in water-disrupted area**	**Property value at risk (RM Million)**	**Number of stocks in water-disrupted area**	**Property value at risk (RM Million)**	**Property value at risk (RM Million)**
Kuala Selangor	2,724	1,176.40	0	0	12	17.48	1,193.87
Gombak	6,643	3,046.45	0	0	152	626.19	3,672.64
Kuala Lumpur	333,748	271,433.09	303	468.08	3,457	8,926.94	280,828.11
Hulu Langat	11,274	5,491.69	0	0	221	1,194.65	6,686.33
Petaling	157,573	101,231.88	51	56.16	4,284	16,129.28	117,417.32
Klang	70,903	30,594.06	6	7.46	2,932	16,593.14	47,194.67
Kuala Langat	2,770	1,114.31	0	0	30	670.44	1,784.76
Sepang	435	240.70	0	0	5	22.46	263.16
Total	586,069	414,328.57	362	531.70	11,094	44,180.58	459,040.85

Table 4 | Cross-tabulation of the response from SMEs regarding business loss due to water disruption

		Status of business loss due to water disruption		
Type of SMEs		**Yes**	**No**	**Total**
Manufacturing	Number of surveys with response	7	8	15
	Percentage of response	46.67%	53.33%	100.00%
Construction	Number of surveys with response	11	14	25
	Percentage of response	44.00%	56.00%	100.00%
Services	Number of surveys with response	36	41	77
	Percentage of response	46.75%	53.25%	100.00%
Total	Number of surveys with response	54	63	117
	Percentage of response	46.15%	53.85%	100.00%

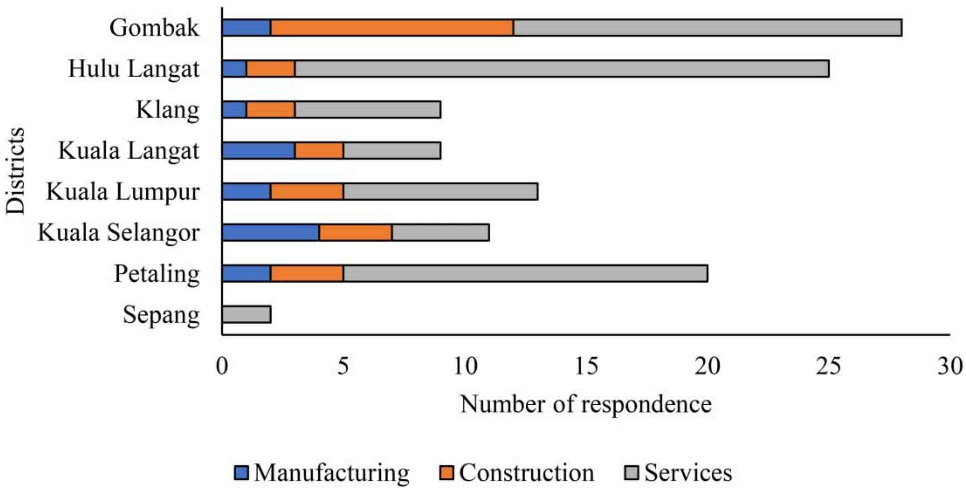


Figure 8 | The number of respondents by district.

to Obokoh & Goldman (2016), water supply disruptions considerably impede SMEs' operations and revenue, resulting in limited business growth in Nigeria.

SMEs create skilled and unskilled jobs, generate new technology, and boost economic growth (Selelo *et al.* 2017). These enterprises account for over half of GDP and employment in emerging and high-income nations

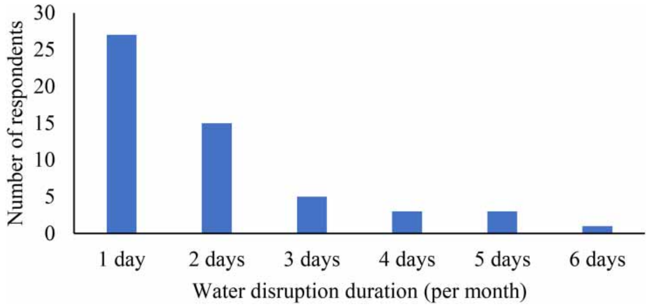


Figure 9 | Water disruption duration reported by the respondents.

Table 5 | Pearson's Chi-squared test results for the relationship between water disruption status and business loss

	Value	*p*-value
Pearson Chi-square	55.92***	0.000
Likelihood ratio	69.84***	0.000
Cramér's V	0.69***	0.000

***, **, and * denote significance at the 1, 5, and 10% levels, respectively.

Table 6 | Pearson's Chi-squared test results for the relationship between disruption duration and business loss

	Value	*p*-value
Pearson Chi-square	239.12***	0.000
Likelihood ratio	130.11*	0.073
Cramér's V	0.58***	0.000

***, **, and * denote significance at the 1, 5, and 10% levels, respectively.

(Ado & Josiah 2015). SME competitiveness, aptitude, and capacity require water infrastructure (Kujinga *et al.* 2014). Due to water shortages, SMEs have trouble cleaning dishes, flushing toilets, and making products (Essien 2014). Thus, an unreliable water supply could affect SMEs' operations. Water's high cost and unpredictability reduce output, business certainty, and competitiveness (Obokoh & Goldman 2016). Water supply outages shock and hinder the local economy (Lizarraga 2013). Figure 10 shows how water supply disruptions affect

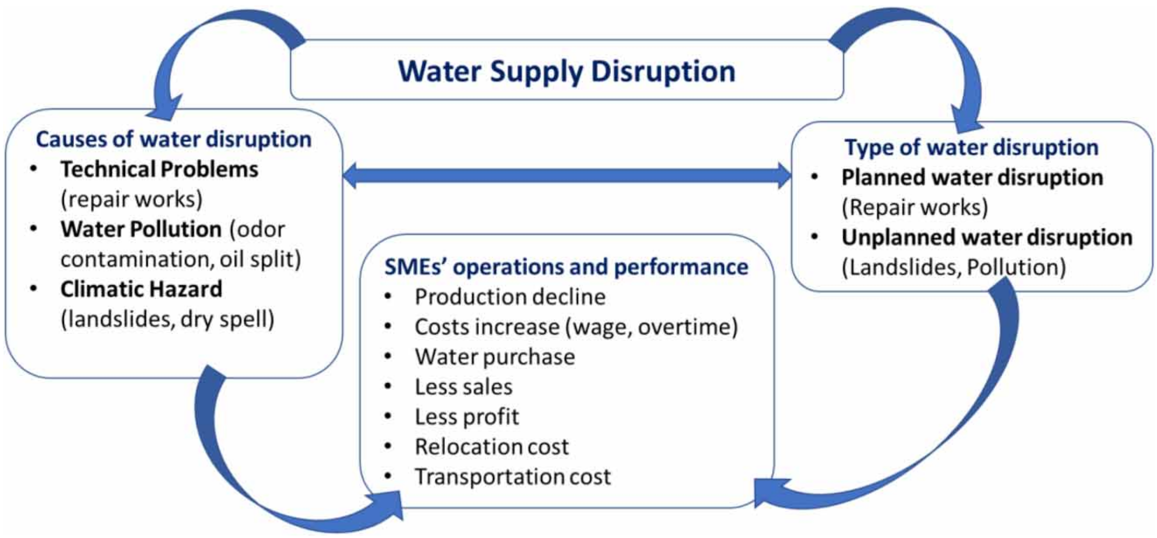


Figure 10 | Linkages between water supply disruption, and SMEs' operations and performance.

SMEs' operations and performance. Malaysia has planned and unforeseen water supply disruptions due to technological issues, water contamination, and environmental hazards. Due to infrastructure maintenance and repair, the water supply authority announces planned water disruptions. Alternative water sources, such as built-in tanks, might reduce monetary losses from water supply interruptions, making scheduled outages more palatable (Ado & Josiah 2015). Businesses must pay for these alternative sources to improve water reliability. Businesses suffer quick and unforeseen financial losses when water supplies are shut off due to pollution or natural disaster (Ado & Josiah 2015). These unforeseen disruptions significantly influence SMEs' functioning and efficiency and cause huge economic repercussions and expenditures, including output reduction, pay and overtime cost increases, relocation, transportation, and water purchase costs.

3.5. Estimation of business loss

About 46% of the respondents in the survey reported business loss due to water supply disruption events. Thus, this study estimated the total business loss due to water disruption in 2020 in two scenarios: Scenario 1 (if all the SMEs inside the water disruption area are affected and Scenario 2 (if 46% of the SMEs inside the water disruption area are affected). Table 7 presents the business interruption loss due to water disruption in the study area. In a scenario where all the SMEs were affected by the water disruption in 2020, the total business loss due to water disruption is estimated at RM4,464 million. In comparison, if only 46% of the SMEs are affected, the loss is estimated at RM2,053 million in 2020 alone. SMEs under the Services category showed the maximum business loss, followed by Manufacturing and Construction. The results showed that water supply disruption causes huge economic impacts in the SMEs due to business interruption because of production decline, costs increase (wage, overtime), water purchases, fewer sales, less profit, relocation costs, and transportation costs. The findings suggest that prolonged water disruptions will have a significant impact on the country's economic development as the extended water disruptions have a severe impact on SMEs' operations, growth, competitiveness, and profitability.

The findings of the study are consistent with Rashid *et al.* (2021) who reported that the effects of water disruption would result in affected economic activities in Malaysia. Extended water disruptions compelled the operators of several hotels, food, and cleaning facilities to return guests unserved on many occasions, according to interviews with SME stakeholders. However, several of the enterprises that were more than 10 years old had reliable water supply options and were less reliant on government water supplies. Water disruption has a negative impact on SMEs' competitiveness and entrepreneurial activity, especially those that rely on water as a primary input or resource. Businesses and water providers need to be prepared for a variety of risk scenarios, including an increase in the frequency and severity of water scarcity events, deteriorating water infrastructure, and potential operational water supply breakdowns (Sjöstrand *et al.* 2021). Since an interruption in the water supply can cause significant financial losses for both individual businesses and society as a whole, there is a significant demand for (re)investments and improvement measures both internationally and in Malaysia.

3.6. Ensuring water security

Water supply disruption from the Selangor River is predicted to cost RM461,094 million to RM463,505 million, or 34% of Malaysia's 2020 GDP (RM1,342,026 million). The study suggests long-term water resource supply and management planning that incorporates all options. Considering the needs of different settlement types is necessary. Malaysia needs an integrated water resources management (IWRM) strategy to mitigate water disruption in different settlement types. Identifying Selangor's water supply issues may help policymakers and planners find solutions. Selangor should consider settlement classes when managing water resources. Large cities must

Table 7 | Business interruption loss due to water supply disruption in the study area

Category of SMEs	Number of SMEs in water disruption area (Population)	Number of SMEs experiencing business loss due to water disruption (46%)	Averaged Marginal Forecasted Loss per SME in 2020 (RM)	Total business loss in 2020 (RM)	
				Scenario 1 100% of SMEs	Scenario 2 46% of SMEs
Manufacturing	5,271	2,424	155,875	821,617,125	377,841,000
Construction	4,327	1,990	68,083	294,595,963	135,485,548
Services	89,409	41,128	37,410	3,347,827,914	1,539,995,598
Total	99,006	45,543		4,464,041,002	2,053,322,146

manage climate, hydrology, population, urbanization, management, and water supply infrastructure. Selangor must build a framework for water legislation and policy that considers both the operational environment and modern water supply ideas to improve water governance and supply. Such a framework must highlight water resources management techniques that ensure uninterrupted water supply.

The government should prioritize reducing non-revenue water (NRW). Malaysia's water infrastructure causes insecurity. Some states lose 38–50% NRW due to aging water infrastructure. This loss impacts states' finances. Malaysia's NRW averages 35%, despite the World Bank's 25% limit (Rahman 2021). One-third of the water meant for distribution disappears. Operational efficiency is vital because modest water tariffs barely covered 78% of operating costs. The National Water Services Commission (SPAN) has acknowledged Malaysia's NRW response's shortcomings. Information technology system weaknesses, data collection system weaknesses, a lack of understanding of leakage management, and a failure to value water as a scarce resource led to a lack of an active leakage control program or planning, a small maintenance allocation, lack of competent staff, poor asset management, unsystematic implementation, and maintenance of the water supply system (Sani & Rindam 2017). Lack of water treatment plant capacity, maintenance, water rationing by water managers, contaminated water supply, leaking water pipelines, prolonged hot weather, waste of water consumption, and water management defects cause water supply disruption in Malaysia (Rashid *et al.* 2021). Poor management and leadership cause Malaysia's NRW problem (Lai *et al.* 2020). Public participation is often overlooked in the development of water policy. The average daily household water use in Malaysia is over 220 liters, proving that the country's citizens have not practiced water conservation. Due to delayed or indirect consequences, NRW concerns are poorly known. If informed of the health and economic benefits, people are more prepared to pay for better water infrastructure (Lai *et al.* 2020).

This study suggests helping impacted areas recover from water disruptions. Reduce the gap between water treatment plants' production capacity (supply) and clean water usage (demand) to reduce water disruption's economic impact. New water treatment facilities, upgrades, pipe replacement, and service tank repairs help reduce water disruption. This study also recommends long-term solutions that involve federal and state governments, laws and policies, stakeholders (water resources management authorities, companies), and alternative water management technologies like urban-scale rainwater harvesting systems, groundwater, recycled, and reclaimed water for conjunctive use. Virtual water may also cross municipal borders through trade. Thus, to build resilience to urban water shortages, commerce and service transactions must consider the roles of both real and virtual water. Long-term water supply planning could include a secure, rainfall-independent water source. Many water catchments are unprotected. Without this, development exploitation cannot be prevented. Thus, they are subject to many environmental disasters, making water resources unsustainable. Since humans create water pollution, authorities should take it seriously. Current events require a rethink of most water laws. Existing guidelines are overly general and insufficient to manage current water challenges. Pollution control laws should be strengthened to prevent water contamination and frequent outages. River polluters should be punished. As a precaution, the government should issue pollution licenses and adopt new measures to reduce pollution. Water pollution in Malaysia jeopardized its long-term water supply. When purifying filthy water is expensive, the water supply decreases.

Malaysia boasts some of the world's highest rainfall, yet its water price should be adjusted to discourage water waste. Due to the region's low prices, Malaysians view water as a cheap commodity compared to other necessities (Rahman 2021). Thus, to avoid future water disruptions, current malpractices by people and other industries and water authority mismanagement must be addressed. Malaysia's excessive water use disturbs its water supply due to low residential and business water costs. Malaysians use more water per capita than neighboring countries due to the environmentally dangerous policy of subsidizing residential water tariffs. The SPAN estimates that Malaysians use 201 liters of water per day, compared to the WHO's 165. Excessive water consumption causes pollution, groundwater depletion, and land clearing for water infrastructure. SPAN claims that filtering 1,000 liters of water costs RM2.31, but domestic users pay 52 cents. Most residents use 20,000 liters per month, resulting in a bill of RM10.40 despite the actual cost being RM46.20. Low tariffs affect water providers and the environment. Malaysia's water is cheaper than Thailand's, which costs over RM1 per cubic meter. The Philippines charges RM2 for 1,000 liters of water, whereas Malaysia's neighbor Singapore charges RM4 (Rahman 2021). Consumers must change their water habits. Awareness of water use is the first step to preventing waste. This can be done simply by keeping track of the monthly water bill. With non-domestic water demand predicted to rise annually, firms, especially water-intensive ones, must cut water use. Many global companies have conserved water and money by recycling water. Industries save more because their water tariff is much higher than that of homeowners.

Water management in Malaysia requires assessing the local and regional economic impacts of climate disasters like water stress. Impact evaluation methodologies must consider direct and indirect flow losses, stock losses, and infrastructure damage. To develop regional adaptation strategies, risk assessments should identify individual and sector vulnerabilities. Dry spells reduce supplies; therefore, river basin law, regional urban water management, and use priority must account for economic and operational sector interruptions. Water stress can hurt city economies, especially in productive areas. Most contamination threat assessments focus on mitigation efforts like sensor placement and response actions like event detection and source identification (Berglund *et al.* 2020). Implement countermeasures, install water quality sensors, design network sectors, install chlorine boosters, maintain disinfectant residuals, and control valves and pumps for pressure to mitigate contamination concerns (Berglund *et al.* 2020). Physical dangers and component failures can be minimized through mitigation policies. Pipes can be reinforced or sized to reduce natural dangers. Policymakers could balance vulnerabilities and consider the region's effects while designing water stress mitigation methods. Integrating water resources will help respond to future climate change. Malaysia has used subterranean storage, recycling, efficient irrigation systems, organized urban construction, and drought-resistant crops to manage variable water needs. Better water use and sustainable development are needed to establish robust, low-cost responses to climate change and enormous urban population expansion. Planning and investing in policies that promote system variety and resilience can lower future climate change costs.

One of the world's biggest health challenges is unsafe water. Almost 56% of the world's population had unsafe water in 2015 (Gizaw *et al.* 2022). Goal 6 of the Sustainable Development Goals (SDGs) is universal and equitable access to safe and inexpensive drinking water by 2030. SDG 6 recommends measuring progress toward reducing inequalities by adjusting socioeconomic inequalities indices to safe drinking water availability (Jesus *et al.* 2023). Even when a water supply is safe, households may avoid water with unpleasant organoleptic features like odor, taste, and color. The SDG metrics for safe water do not reflect how organoleptic features may prevent households from using securely managed water sources and lead to them consuming unimproved sources (Smiley & Stoler 2020). In Malaysia, many homes connected to the public water supply do not drink it due to the taste, odor, or color. Safe drinking water and adequate sanitation (sewage management) are basic human rights, so it's crucial to maintain a sustainable and consistent water supply in all communities (Hall *et al.* 2022). The sole water services provider in central Malaysia, Selangor Water Management (Air Selangor), abstracts, treats, and distributes clean, safe water to 8.4 million customers. Their 34 water treatment plants create 5,000 million liters of treated water each day, which is distributed through 29,000 km of pipe length. They must arrange regular maintenance and cleaning. To safely maintain chlorine levels, chamber workers must inspect regularly (Ngah *et al.* 2022).

Furthermore, monitoring dam capacities daily, optimizing daily drainage, cloud seeding, and promoting water conservation among users are just a few of the many water management methods. Malaysia has implemented to ensure a steady supply of water, but these measures will be ineffective unless the public is aware of their importance. All water-related development projects should involve public water resource management. While government and allied authorities manage these water resources, all parties, including customers, may help. People could then offer to micromanage their community's water supplies. Malaysians must protect their water supply to preserve security. Clean water is essential for town safety. By reporting leaking pipes to authorities, the community shows compassion. On-the-ground training, seminars, and workshops can help young people and the community understand these issues and establish joint solutions. Water management should be more 'people-friendly' with citizens and NGOs engaged and included in all decisions and projects. Everyone must work together to ensure that water resources are exploited economically and sustainably without harming the ecosystem, that everyone has access to clean water, and that future generations' needs are satisfied. These preemptive steps will help create a holistic water management system throughout the country.

By investing in water disruption mitigation techniques, SMEs can boost water resource reliability. This study also suggests that Selangor Water Management (Air Selangor) notify SMEs of water supply disruption schedules so they can develop production contingencies. SMEs cannot plan production and distribution without Selangor Water Management's water shortage alerts. An accurate, earlier announcement of water disruptions could help Selangor's water supply difficulties and allow SMEs to plan their output and take alternative options. The Malaysian government must create a national water management policy to educate businesses about potential improvements and encourage a better-prepared and resilient society. However, the present study's survey conducted on the business loss due to water supply disruption was severely hindered by the low response rate and limited sample size that the COVID pandemic had caused. Furthermore, this research only focuses on the economic consequences of water disruptions of SMEs. It is suggested that a long-term study of the Selangor River basin be conducted with more extensive assessment of multi-national companies and household demographics. A diverse sample size might aid in determining the long-term consequences of water supply disruptions on households and the entire business landscape. Future research could also look into the extent to which water management measures can improve the sector's and region's resilience. Lastly, the study of business preparedness, reaction, and recovery is a crucial next move. Future studies could concentrate on the extra societal benefits that enhanced preparedness and effective management of water disruption threats might provide.

4. CONCLUSION

The Selangor River is a critical source of water supply to the State of Selangor and the city of Kuala Lumpur. Water shortages have resulted in protracted and unanticipated water supply outages that have impacted households and SMEs. The overall property value at risk as a result of water supply disruption from the Selangor River is estimated at nearly RM459,041 million. This includes commercial property valued at RM532 million, residential property valued at RM414,328 million, and industrial property valued at RM44,181 million. Pearson's Chi-squared test results indicate that there is a positive and significant association between water supply disruptions and the business losses of SMEs. Nearly half of the survey respondents reported that their company suffered losses when the water supply was disrupted. A loss of RM2,053 million is estimated for 2020 alone if only 46% of SMEs are impacted. The estimated overall business loss due to water disruption will double in a scenario where all the SMEs are affected. The total economic impact of water supply disruption from the Selangor River, combining the overall property value at risk and business loss, is estimated to represent 34% of Malaysia's GDP in 2020. This highlights the importance of ensuring undisrupted water supply from the Selangor River Basin. Given the scope of losses, it is critical to implement IWRM and initiate transformation of the water sector. Recommendations include changes to laws and policies, improved corporate governance, appropriate water rates, and alternative water management technology. The findings indicate that it is urgent for decision-makers to implement appropriate policies that consider climate change impacts at the river basin level, to prevent potential disruption of water supply, which may be more frequent and intense in the future.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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