

## Rainwater harvesting as an alternative for water supply in regions with high water stress

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### ABSTRACT

In this study, the reliability of using rainwater harvesting to cover the water demand of a transportation logistics company located in Mexico City was assessed. Water consumption in facilities and buildings of the company was determined. Rainwater potentially harvestable from the roofs and maneuvering yard of the company was estimated based on a statistical analysis of the rainfall. Based on these data, potential water saving was determined. Characterization of rainwater was carried out to determine the treatment necessities for each water source. Additionally, the capacity of water storage tanks was estimated. For the selected treatment systems, an economic assessment was conducted to determine the viability of the alternative proposed. Results showed that current water demand of the company can be totally covered by using rainwater. The scenario where roof and maneuvering yard rainwater was collected and treated together resulted in being more economic than the scenarios where roof and maneuvering yard rainwater was collected and treated separately. Implementation of the rainwater harvesting system will generate important economic benefits for the company. The investment will be amortized in only 5 years and the NPV will be on the order of US\$ 5,048.3, the IRR of 5.7%, and the B/I of 1.9.

**Key words** | benefits-investment ratio (B/I), internal rate of return (IRR), minimum acceptable rate of return (MARR), net present value (NPV), rainwater harvesting, total water supply

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### INTRODUCTION

Water scarcity and stress are reaching worryingly high levels worldwide due to the intensive exploitation and pollution of water resources. Furthermore, climate change is intensifying this pressure in some regions of the world, including Mexico, resulting in an infallible decrease in water resources in the coming years (Bates *et al.* 2008). On the other hand, the growing population, rapid urbanization, industrialization and intensive agriculture of Mexico are putting remarkable pressure on water resources availability to the

extent that Mexico City faces an extremely low water availability, on the order of 150 m<sup>3</sup>/person/day (CONAGUA 2015). Consequently, the interest in and necessity of the use of alternative water sources such as rainwater are also growing (Antunes *et al.* 2016). Rainwater harvesting may be an effective supplementary water source because of its many benefits and affordable costs (Imteaz *et al.* 2011, 2012; Cook *et al.* 2014; Gurung & Sharma 2014; Liuzzo *et al.* 2016). Information related to the use of rainwater to meet the water supply demands of urban dwellings is somewhat available; but, reports on rainwater harvesting to meet water demands for uses similar to that addressed in this paper are seldom found in the literature.

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Thus, in this study, the reliability of implementing rainwater harvesting to meet 100% of water demand of a transportation logistics company located in Mexico City was assessed. The importance of this study relies on (1) the fact that worldwide there exist emergent economies of highly dense population that are facing rapid industrialization, water scarcity and high pressure on water resources; thus, (2) the approach and results presented in this work can be replicated in regions with high water stress to achieve feasible, reliable, and economically viable solutions for water supply based on rainwater harvesting.

## MATERIALS AND METHODS

### Rainwater potentially harvestable from roofs and maneuvering yard

Figure 1 shows a view of catchment surfaces of the buildings and maneuvering yard considered in this study. The surfaces were grouped into two categories, areas with and areas without grease and oil contribution. The areas of the catchment surfaces were estimated by using AutoCAD® (Autodesk, San Rafael, CA, USA).

Rainfall was determined based on meteorological data collected from the nearest climatological station (No. 15059



Figure 1 | Catchment surfaces of buildings and maneuvering yard.

'Molino Blanco'). Daily precipitation registered from 1981 to 2010 (30 years) was used (SMN 2010). Kendall, Mann–Kendall, and Grubbs and Beck tests were applied to the data to determine the independence, homogeneity, and the presence of outliers that could deviate erroneously the monthly rainfall values. These tests were conducted by using the SEAF software (Expert System for At-Site Frequency Analysis of Hydrologic Variables) (De Oliveira & Naghettini 2008). The monthly rainfall was estimated for a confidence interval with a significance level of 95%. Once the monthly rainfall was estimated, the rainwater volumes were calculated using Equation (1):

$$V_{i,j} = P_i * A_j * C_r \quad (1)$$

where  $V_{i,j}$  is the volume of month  $i$  for the roof or maneuvering yard  $j$ ;  $P_i$  the precipitation of month  $i$ ;  $A_j$  the surface area of the roof or maneuvering yard  $j$ ; and  $C_r$  is the runoff coefficient, and for concrete and asphalt surfaces, a value of 0.85 is recommended (Chow et al. 1994).

### Water consumption from the public network

Water from the public network consumed in facilities and buildings was estimated based on the consumptions registered on the last 4-year water bills paid by the authorities of the company.

### Characterization of rainwater and determination of treatment necessities

Necessities of rainwater treatment were assessed based on its physical, chemical and bacteriological characteristics. Quality parameters were selected from Mexican Official Standards for wastewater discharge into water bodies and soil (Ministry of Environment 1996) and wastewater reuse with direct and indirect contact (Ministry of Environment 1997). Each parameter was measured based on the protocols described in *Standard Methods for the Examination of Water and Wastewater* (APHA/AWWA/WEF 2005). Rainwater samples were taken from discharges of three representative surfaces, two with grease and oil contribution (administrative building roof and maneuvering yard) and the other free of them (building roofs).

## Determination of volumes to be treated and sizing of water storage tanks

Rainwater flowrates to be treated and dimensions of the storage tanks were determined regarding three scenarios: (1) when only rainwater from roofs is collected, (2) when rainwater from the maneuvering yard is stored alone, and (3) when both rainwater sources are collected together. The flowrate to be treated and the size of the storage tank for each scenario were estimated by conducting monthly water balances, where rainwater contributions were the inflows, and water demands from the public network for building services and vehicle washing were the outflows. The equation reported by [Khastagir & Jayasuriya \(2010\)](#) was used for this purpose:

$$S_{t+1} = S_t + Q_t - D_t, 0 \leq S_{t+1} \leq C \quad (2)$$

where  $S_{t+1}$  is the storage volume in the tank at the end of the month;  $S_t$  the storage value at the beginning of the month;  $Q_t$  the runoff from the catching surface in the month;  $D_t$  the total demand of water in the month; and  $C$  is the active tank capacity. Overflows of the storage tanks in times of high water production were taken into consideration for the water balances, but overflows were not considered in the volumes to be treated. Dimensioning of the storage tank was conducted with regard to 100% of the water demand being guaranteed.

## Selection and design of treatment processes for rainwater

Selection of operations, processes, and systems needed to achieve the level of treatment required was conducted according to the following criteria: final use of the treated rainwater, efficiency in removing contaminants and cost effectiveness. Once selected, the treatment systems were designed. Additionally, modifications of the current water distribution network and the pumping system were conducted to incorporate and distribute the treated rainwater into the buildings and facilities of the company. Because the design of the systems was not part of the scope of this paper, details of the design process are not presented; only the main results, such as the dimensions of the systems and selected equipment, are included.

## Economic assessment

### Determination of the investment and operation costs of the selected treatment systems

Based on the design, the investment needed to implement the treatment systems for rainwater was estimated. Thus, the costs of equipment, construction, and implementation of the treatment systems were calculated. Additionally, operation and maintenance costs associated with those systems were also estimated.

### Determination of benefits

The economic benefits derived from the implementation of the rainwater harvesting system were determined by multiplying the saved volume of water from the public network per the corresponding tariff.

### Cash flows and metrics

The cash flows were prepared based on the investments, operation and maintenance costs, and previously estimated benefits. The metrics used to conduct the economic assessment of the technological alternatives proposed in this study to replace the water consumption from the public network were the net present value (NPV), the internal rate of return (IRR), and the benefits-investment ratio (B/I). The minimum acceptable rate of return (MARR) used in this evaluation was estimated as follows:

$$\text{MARR} = \text{inflation} + \text{risk} \quad (3)$$

The inflation rate was set at 5.76%, based on the information provided by the Bank of Mexico ([BANXICO 2017](#)), and the risk was fixed at 3% due to the low risk associated with this type of investment project ([Urbina 2010](#)). The NPV was estimated using Equation (4):

$$\text{NVP} = -I_0 + \frac{\text{NCF}}{(1+i)^1} + \frac{\text{NCF}}{(1+i)^2} + \dots + \frac{\text{NCF}}{(1+i)^n} \quad (4)$$

where  $I_0$  is the initial investment; NCF the net cash flow of year  $n$ , corresponding to the net benefits after taxes of

year  $n$ ; and  $i$  the reference interest rate, set as MARR (Urbina 2010).

The IRR is the interest rate that makes the NPV zero, and was estimated using Equation (5):

$$NPV = 0 = -I_0 + \frac{NCF}{(1 + IRR)^1} + \frac{NCF}{(1 + IRR)^2} + \dots + \frac{NCF}{(1 + IRR)^n} \quad (5)$$

## RESULTS AND DISCUSSION

### Rainwater potentially harvestable from roofs and maneuvering yards

Due to the median result being more representative than the average, the median was used to determine the monthly rainfall for a confidence interval with a significance level of 95%. The rainwater volumes were calculated using Equation (1) for the three types of catchment surfaces. The catchment area without grease and oil contribution (roofs) was estimated at 6,602.0 m<sup>2</sup> and the areas with grease and oil contribution were estimated at 10,093.8 m<sup>2</sup> for the maneuvering yard and 365.1 m<sup>2</sup> for the administrative building

(with air conditioning equipment). Table 1 summarizes the results of these calculations. As seen, the highest rainwater volume was estimated for August; meanwhile, December resulted in the lowest rainwater volume. The annual rainwater volume potentially harvestable from the roofs and maneuvering yard of the company was about 10,586.3 m<sup>3</sup>.

### Water consumption from the public network

The annual water consumption was estimated at 2,608.8 m<sup>3</sup> and the greatest water demand occurred in the period May–June with a consumption of 543.7 m<sup>3</sup>. Figure 2 shows the bimonthly water consumption from the public network.

### Characterization of rainwater and determination of treatment necessities

Physical, chemical and bacteriological characteristics of rainwater are presented as supplementary material (available with the online version of this paper). Concentrations of fecal coliforms in rainwater from roofs were much greater than the permissible values; rainwater from the mechanical workshop presented the greatest concentration. On the maneuvering yard, the fecal coliform contribution was negligible.

**Table 1** | Monthly rainfall and rainwater volumes for a confidence interval with a significance level of 95%,  $n = 30$  years

Month	Rainfall (mm)	Volume (m <sup>3</sup> )			Total
		AB <sup>a</sup> roof	Other roofs	Maneuvering yard	
January	5.2	1.6	29.2	44.6	75.4
February	5.9	1.8	33.1	50.6	85.6
March	6.7	2.1	37.6	57.5	97.2
April	17.2	5.3	96.5	147.6	249.4
May	55.0	17.1	308.6	471.9	797.6
June	139.7	43.4	784.0	1,198.6	2,025.9
July	139.7	43.4	784.0	1,198.6	2,025.9
August	158.4	49.2	888.9	1,359.0	2,297.1
September	136.3	42.3	764.9	1,169.4	1,976.6
October	55.5	17.2	311.5	476.2	804.8
November	5.4	1.7	30.3	46.3	78.3
December	5.0	1.6	28.1	42.9	72.5
Total	730.0	226.5	4,096.6	6,263.2	10,586.3

<sup>a</sup>Roof of the administrative building.

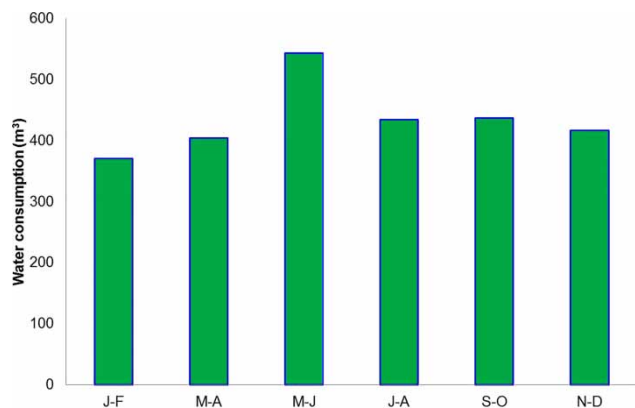


Figure 2 | Water consumption of the company.

Suspended solids for all rainwater samples did not meet the standard values; especially the rainwater from the administrative building roof, which was the most concentrated in suspended solids with 122.0 mg/L. On the other hand, the concentration of suspended solids in rainwater samples from the maneuvering yard was surprisingly low; dust and other dirtiness adhering to the tires of vehicles was expected to contribute more importantly to this parameter.

All rainwater samples did not meet the permissible limits for biological oxygen demand (BOD<sub>5</sub>). Organic matter in rainwater samples from the roofs might be the result of

biological activity. In the case of the administrative building roof, the concentration of grease and oils in rainwater samples was greater than the limit established by the standard. Greater concentration of grease and oils was associated with the leakage of these compounds from the air conditioning equipment. In the case of maneuvering yard rainwater, the presence of organic load and grease and oils might be linked to leakage of organic compounds from vehicle engines. Elimination of fecal coliforms and removal of organic load, suspended solids, and grease and oils from the rainwater of some surfaces is needed to avoid nuisance problems and health risks to workers when rainwater is used in the buildings and facilities of the company.

#### Determination of volumes to be treated and sizing of water storage tanks

The water balance results are presented in Table 2. As can be seen, the storage capacity of the tank to meet 100% of the water demand, when only rainwater from roofs is collected, is 925.0 m<sup>3</sup> and the month with the maximum volume to be treated in this scenario is June with 827.3 m<sup>3</sup>. When only rainwater from the maneuvering yard is collected, the storage capacity of the tank is 804.0 m<sup>3</sup> and the month with the

Table 2 | Volumes of rainwater to be treated and storage tank capacity (m<sup>3</sup>)

Month	Water consumption (m <sup>3</sup> )	Roofs		Maneuvering yards		Both	
		Balance	To be treated	Balance	To be treated	Balance	To be treated
January	185.6	414.8	30.8	335.3	44.6	205.7	75.4
February	185.6	264.2	34.9	200.4	50.6	105.7	85.6
March	202.4	101.5	39.7	55.4	57.5	0.4	97.2
April	202.4	0.9	101.9	0.6	147.6	47.5	249.4
May	271.9	54.8	325.7	200.6	471.9	573.2	797.6
June	271.9	610.2	827.3	<b>804.0</b>	875.3	<b>582.0</b>	280.7
July	217.4	<b>925.0</b>	532.2	804.0	217.4	582.0	217.4
August	217.4	925.0	217.4	804.0	217.4	582.0	217.4
September	218.7	925.0	218.7	804.0	218.7	582.0	218.7
October	218.7	925.0	218.7	804.0	218.7	582.0	218.7
November	208.5	748.5	32.0	641.8	46.3	451.8	78.3
December	208.5	569.6	29.6	476.2	42.9	315.8	72.5
Total	2,608.8		2,608.8		2,608.8		2,608.8

Note: Capacity of the storage tank for each scenario is written in bold and italic fonts.

maximum volume to be treated is also June with 875.3 m<sup>3</sup>. Meanwhile, when both rainwater sources are collected together, the storage tank capacity needed is 582.0 m<sup>3</sup> and the month with the greatest volume to be treated is May with 797.6 m<sup>3</sup>. Even though there are differences in the monthly volumes to be treated among the three scenarios, the total volume of rainwater to be treated is the same, 2,608.8 m<sup>3</sup>. It is important to remark that in dry months all the rainwater captured is treated; meanwhile, in rainy months only the volume needed to cover the demand is treated.

The dimensions of the storage tanks resulting from the monthly water balances are presented in Table 3. To minimize the costs, the storage tanks were conceived as lining water reservoirs made of linear low-density polyethylene (LLDPE) geomembranes with a formulated sheet density of 0.939 g/ml and 1 mm thickness, and covered by concrete slabs. The cross-section of the reservoirs was trapezoidal, with 1:1 sloped embankments.

As can be seen in Tables 1 and 3, it is clear that greater rainwater harvesting contributes to having a smaller size of storage tank. This result is interesting to analyze because a small size of the storage tank will imply lower investment; but, greater water volume harvested will contribute to having high operating and maintenance costs linked to treatment necessities. Further discussion is conducted in the section below on economic assessment.

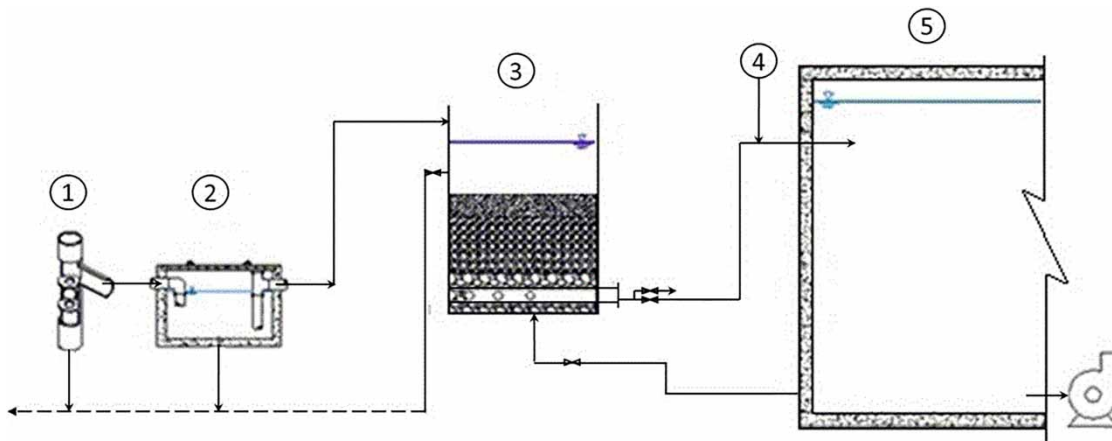
### Selection and design of treatment processes for rainwater

The end rainwater uses were vehicle washing, floor cleaning and building services such as toilet flushing. Grease and oil traps, anthracite-sand filter and disinfection, represented schematically in Figure 3, were the systems proposed in this study to meet the maximum permissible limits set by the Mexican Standards (NOM-001-SEMARNAT-1996;

**Table 3** | Dimensions of the storage tanks for rainwater

Scenario	Volume (m <sup>3</sup> )	Upper base		Lower base		Height (m)
		Length (m)	Width (m)	Length (m)	Width (m)	
Roofs	925	20.5	20.5	14.5	14.5	3.0
Maneuvering yards	804	19.3	19.3	13.3	13.3	3.0
Both	582	17.0	17.0	10.7	10.7	3.0

Note: The cross-section of the reservoirs is trapezoidal with 1:1 sloped embankments.



**Figure 3** | Schematic representation of the treatment systems for rainwater.

NOM-003-SEMARNAT-1997) and achieve the treatment level required to remove suspended solids, organic constituents, grease and oils and eliminate fecal coliforms from the rainwater.

In Figure 3, ① represents a first-flush diverter of rainwater. A volume of 2.5 L for every square metre was considered to be diverted as a first flush (Brown *et al.* 2005). Fifteen first-flush diverters were selected. ② is the grease and oil traps for the administrative building roof rainwater. Three traps of galvanized steel were selected with 90 L/min capacity each. ③ is an anthracite-sand filter that includes a dual lateral Leopold underdrain. Backwash was set every 4 days. Additionally, a drying bed was designed to dry out the impurities contained in the backwash effluent. Characteristics of the anthracite-sand filter and drying bed are presented as supplementary material (available online). ④ is the chlorination system. Sodium hypochlorite pentahydrate (NaOCl·5H<sub>2</sub>O) was selected as the disinfectant with doses of 4.4 mg/L, ensuring a free residual chlorine concentration of 1.5 mg/L. A dosing pump (Chem-Tech 120 GPD 80 psi, AquaQuality, Acapulco, Mexico) was selected to apply the disinfectant. ⑤ represents the storage tanks for rainwater (WSTs) after disinfection.

Modifications of the current water distribution network and the pumping system were conducted to distribute the treated rainwater into the different buildings and facilities of the company. Details of such modifications are not presented in this paper because it is not within the scope; however, the costs associated with such modifications were considered in estimating the investment and operation costs.

## Economic assessment

### Determination of the investment and operation costs of the selected treatment systems

Table 4 presents the investment needed to implement the treatment systems. The cost of first-flush diverters was estimated based on the prices provided by RainHarvest Systems (Cumming, GA, USA). The investment needed for grease and oil traps was determined based on the prices provided by Helvex (Mexico DF, Mexico). The cost of the anthracite-sand filters (ASF), including the drying bed for the backwash effluent, was calculated based on the prices provided by a local company (Aquamex SA de CV, Monterrey, Mexico). The cost of chlorine dosifiers was determined based on the prices provided by AquaQuality (Acapulco, Mexico). The investment linked to WSTs included costs associated with soil excavation, construction of embankments, placement of the LLDPE geomembrane, concrete structures (slabs and columns), and others. Such costs were calculated based on the unit prices included in the costs catalog of the Mexican Chamber of Construction Industry.

The pumping systems cost was determined based on the prices provided by a local company (Hidroservicios Ambientales-Sistemas de Bombeo, Monterrey, Mexico). Costs associated with the modification of the water distribution system (WDS) included concepts such as excavation, pipes and accessories. They were calculated based on the unit prices included in the costs catalog of the Mexican Chamber of Construction Industry. As can be

**Table 4** | Investment and annual operation and maintenance cost for the implementation of the treatment systems for rainwater (US\$)

Scenario	Investment						Total	Annual O&M costs
	FFD <sup>a</sup>	GOT <sup>b</sup>	ASF <sup>c</sup>	CD <sup>d</sup>	WST <sup>e</sup>	PWDS <sup>f</sup>		
Roofs	450	2,048	9,528	964	26,604	2,975	42,569	906
Maneuvering yard	–	–	10,152	964	23,789	2,843	37,745	1,146
Both	450	2,048	10,389	964	18,616	2,843	35,302	1,682

<sup>a</sup>First-flush diverters.

<sup>b</sup>Grease and oil traps.

<sup>c</sup>Anthracite-sand filter.

<sup>d</sup>Chlorine dosifiers.

<sup>e</sup>Water storage tanks.

<sup>f</sup>Pumping and water distribution system.

seen, the lowest investment corresponded to the scenario where roofs and maneuvering yard rainwater is collected together, with a total investment of US\$ 35,302; meanwhile, the most expensive alternative was when only rainwater from roofs is collected, with an investment of US\$ 42,569. The most costly component was the water storage tank, representing 62.5%, 63.0% and 52.7% of the total investment when the roofs and maneuvering yard rainwater are treated separated and when both sources are treated together, respectively. Meanwhile, the anthracite-sand filter (ASF) and the pumping and modifications of the water distribution system (PWDS) varied from 22.4% to 29.4% and from 7.0% to 8.1%, respectively. These results are in accordance with those reported in the literature, where the storage tank represents 50% to 70% of the total cost of the rainwater-harvesting systems (Li *et al.* 2010).

Annual operation and maintenance (O&M) costs are also shown in Table 4. Costs associated with chlorination, pumping of treated rainwater to the buildings and facilities and backwash are included. A chlorination cost of approximately US¢ 1.3/m<sup>3</sup> was estimated based on the local price of sodium hypochlorite pentahydrate (AquaQuality, Acapulco, Mexico). The pumping cost of treated rainwater was calculated based on the electricity consumption linked to the pumping and the local electricity tariff, resulting in approximately US\$ 0.13/m<sup>3</sup>. The backwash cost was determined regarding the pumping cost of backwash water, the air supply cost and the treatment cost of backwash water, resulting in about US\$ 0.31/m<sup>3</sup>. Other maintenance costs were determined based on the unit prices included in the costs catalog of the Mexican Chamber of Construction Industry. As can be seen, the greatest annual O&M costs were those linked to the scenario where roof and maneuvering yard rainwater was collected and treated together; meanwhile, the lowest O&M costs were obtained for the scenario where roof rainwater was collected and treated separately. This result was because backwash costs increased with the size of the anthracite-sand filter. On the other hand, regarding both the investment and the O&M costs, the cheapest alternative corresponded to the scenario where roof and maneuvering yard rainwater was collected and treated together. This scenario was used for conducting the cash flows and metrics.

## Determination of benefits

The benefit expected from the implementation of the rainwater harvesting system was estimated based on the economic savings obtained from the replacement of water consumption from the public network (Table 5). The cost of public network water was estimated based on the tariffs set by the authorities of Mexico City; for 2017 the tariff was integrated from a basic tariff of US\$ 301.5 per the first 120 m<sup>3</sup> consumed and an additional tariff of US\$ 4.4 per each additional cubic metre consumed. As can be seen, replacing 100% of the public water supply by rainwater in the buildings and facilities of the company will signify a saving of approximately US\$ 8,787.2/year. The water savings considered in this study (100%) are much greater than those reported in the literature for individual houses (36%) and multi-story residential buildings (42%) (Ghisi & de Oliveira 2007; Ghisi & Ferreira 2007).

## Cash flows and metrics

Based on Tables 4 and 5, the cash flow was prepared and it is presented in Table 6. A MARR of 8.76% was set in this study. It was calculated using Equation (3) regarding an inflation rate of 5.76% and a risk of 3.0%, based on the information provided by the Bank of Mexico (BANXICO 2017).

**Table 5** | Economic benefits expected after implementing the systems for rainwater harvesting

Month	Water consumption (m <sup>3</sup> )	Water saving (m <sup>3</sup> )	Water cost (US\$)	Savings (US\$)
January	185.6	185.6	591.6	591.6
February	185.6	185.6	591.6	591.6
March	202.4	202.4	665.9	665.9
April	202.4	202.4	665.9	665.9
May	271.9	271.9	973.2	973.2
June	271.9	271.9	973.2	973.2
July	217.4	217.4	732.2	732.2
August	217.4	217.4	732.2	732.2
September	218.7	218.7	737.9	737.9
October	218.7	218.7	737.9	737.9
November	208.5	208.5	692.8	692.8
December	208.5	208.5	692.8	692.8
Total	2,608.8	2,608.8	8,787.2	8,787.2



**Table 6** | Cash flow for implementing the systems for rainwater harvesting (US\$)

Year	0	1	2	3	4	5	6	7	8	9	10
<b>Costs</b>											
Initial investment	-35,302.1	-	-	-	-	-	-	-	-	-	-
Investment during the project	-	-	-	-	-	-250.0	-	-	-	-	-250.0
Operation and maintenance	-2,051.9	-2,225.0	-2,412.7	-2,616.5	-2,837.7	-3,077.8	-3,338.5	-3,621.4	-3,928.5	-4,261.8	-4,623.8
<b>Benefits</b>											
Water saving from public network	8,787.2	9,557.0	10,394.2	11,304.7	12,295.0	13,372.1	14,543.5	15,817.5	17,203.1	18,710.1	20,349.1
Annual flow	-28,566.8	7,332.0	7,981.5	8,688.2	9,457.3	10,064.2	11,205.0	12,196.1	13,274.6	14,448.2	15,495.3
NPV	-28,566.8	-21,825.3	-15,077.8	-8,324.4	-1,565.3	5,048.3	11,818.4	18,593.9	25,374.5	32,160.1	38,851.4
IRR (%)	-	-76.4%	-38.2%	-15.4%	-2.2%	5.7%	10.9%	14.4%	16.8%	18.5%	19.7%
B/I	0.2	0.5	0.8	1.1	1.5	1.9	2.3	2.7	3.2	3.7	4.3
Amortization year	5.0	-	-	-	-	-	-	-	-	-	-

and Urbina (2010). As can be seen, the investment will be amortized in 5 years and the NPV will be on the order of US\$ 5,048.3, the IRR of 5.7%, and the B/I of 1.9. The project will present an IRR greater than the MARR from the sixth year. In a decade, the IRR, NPV and the B/I will be 19.7%, more than twice the MARR, US\$ 38,851.4 and 4.3, respectively, denoting economic feasibility. Based on these results, it is clear that the implementation of the rainwater harvesting system resulted in being feasible and reliable to meet the company's total demand of water; furthermore, the investment can be amortized in a short period.

## CONCLUSIONS

Rainwater harvesting is presented in this study as a potential alternative to cover the total water demand (100%) of a transportation logistics company. Implementation of the rainwater harvesting system will contribute not only to reducing water consumption from the public network, but also to achieving important economic savings for the company and for the public water system operator, denoting that rainwater harvesting is a feasible and reliable strategy for other uses different to the conventional urban and commercial uses. Such a scheme becomes economically viable and the investment can be amortized in a short period, only 5 years.

The water storage tank represented more than half of the total investment cost of the rainwater harvesting system. The results obtained in this study show that, despite the high cost of the water storage tank, the approach is feasible, reliable, and economically viable when rainwater is used for other uses different to the conventional urban and commercial uses.

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