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ECORFAN-Journal Bolivia

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Instructions for Scientific, Technological and Innovation Publication

Knowledge Area

The works must be unpublished and refer to topics of Engineering, Chemical, Optical, Resources, Food technology, Anatomy, Nutrition and other topics related to Medicine and Health Sciences.

Presentation of the Content

In the first chapter we present, *Turbine selection for hydraulic energy recovery in the Yuribia dam aqueduct*, by Quintanilla-Herrera, Jesús Antonio, Garrido-Meléndez, Javier, Espinosa-Arenal, Francisco and Rodríguez-García, Ernesto Raúl, with ascription in the Universidad Veracruzana, as a second article we present, *Skirt piles in foundation: a structural rehabilitation solution for fixed offshore platforms*, by Palemón-Arcos, Leonardo, Gutiérrez-Can, Yuriko, Naal-Pech, José Wilber and El Hamzaoui, Youness, with secondment in the Universidad Autónoma del Carmen, as the following article we present, *Spanish language trend on Twitter: an analysis of modern writing*, by Lara-Torres, Claudia Guadalupe, Velázquez-Macias, Jesús and Rodríguez-González, Beatriz Adriana, with affiliation at the Universidad Autónoma de Zacatecas, as final article we present, *Cost-benefit analysis of an irrigation unit with treated wastewater in Chihuahua, Mexico*, by Borja-Bravo, Mercedes, Sánchez-Toledano, Blanca Isabel, Arellano-Arciniega, Sergio and Ochoa-Rivero, Jesús Manuel, with affiliation at the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias.

Content

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Article

Turbine selection for hydraulic energy recovery in the Yuribia dam aqueduct

Selección de turbina para la recuperación de energía hidráulica en el acueducto de la presa Yuribia

Quintanilla-Herrera, Jesús Antonio†[a], Garrido-Meléndez, Javier*[b], Espinosa-Arenal, Francisco[c] and Rodríguez-García, Ernesto Raúl[d]

[a] Universidad Veracruzana • KCJ-8510-2024 • 0009-0005-6493-4990
[b] Universidad Veracruzana • C-9373-2018 • 0000-0001-9143-408X
[c] Universidad Veracruzana • 0000-0002-3800-757X
[d] Universidad Veracruzana • 0000-0001-6239-1797 • 597318

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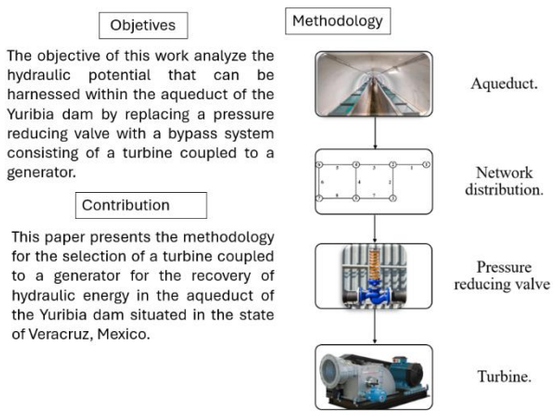
* ✉ [jgarrido@uv.mx]

Abstract

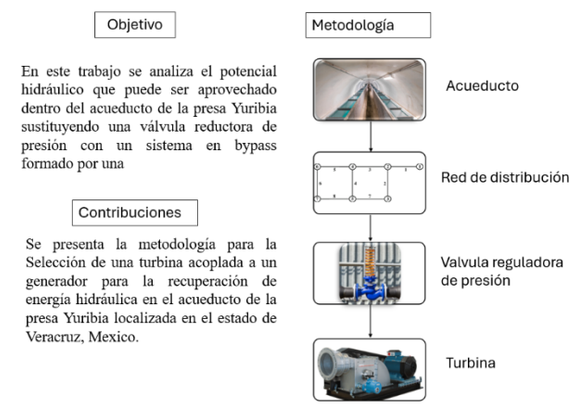
The recuperation of hydraulic energy in aqueducts is based on utilizing the energy dissipated by hydraulic devices aimed at regulating the flow or pressure within the system, in addition to fulfilling their primary purpose. This paper presents the methodology for the selection of a turbine coupled to a generator for the recovery of hydraulic energy in the aqueduct of the Yuribia dam situated in the state of Veracruz, Mexico. The results of system modeling, simulation, and calculation of the generated energy are presented.



Energy recovery, Turbine, Aqueduct

Resumen

La recuperación de energía hidráulica en los acueductos se basa en aprovechar la energía disipada por dispositivos hidráulicos buscando controlar el caudal o presión en el sistema, además de cumplir con la tarea principal por lo que fueron diseñados, en este este trabajo se presenta la metodología para la Selección de una turbina acoplada a un generador para la recuperación de energía hidráulica en el acueducto de la presa Yuribia localizada en el estado de Veracruz, Mexico. Se presentan los resultados del modelado del sistema, simulaciones y cálculos de la energía generada.



Recuperación de energía, Turbina, Acueducto

Citación: Quintanilla-Herrera, Jesús Antonio, Garrido-Meléndez, Javier, Espinosa-Arenal, Francisco and Rodríguez-García, Ernesto Raúl. Turbine selection for hydraulic energy recovery in the Yuribia dam aqueduct. ECORFAN Journal-Bolivia. 2024. 11-20:1-7.

Introduction

Hydropower is the most mature source of renewable energy, being one of the most efficient and reliable (YoosefDoost & Lubitz, 2020) and (Thyer & White, 2022). Hydroelectric plants show a higher generation efficiency than fossil fuel power plants, but they also affect the environment with the waste and gas emissions they generate. When comparing both sources, hydroelectric power is able to transform mechanical energy into electrical power with an efficiency of 90%, while in a thermoelectric plant it is around 60% (Thyer & White, 2022).

Thyler and White (2022) describe hydropower recovery as "hydropower installed in existing systems or structures where water is already being diverted from a natural watercourse". The idea is to harness the energy dissipated by hydraulic devices in different scenarios seeking to control the flow or pressure in the system, in addition to fulfilling the main task for which they were designed, e.g. pressure reducing valves (Loots et all., 2015).

Energy recovery consists of harnessing the potential and kinetic energy of water on a smaller scale than in a hydroelectric power plant, only taking advantage of the infrastructure of various types of distribution networks (Sari et all., 2018):

- Irrigation systems.
- Bridges.
- Flow measurement stations.
- Water distribution systems.
- Metering weirs.
- Wastewater treatment plants and industrial streams.

The use of energy recovery has the following advantages (The pros and cons of hydropower, 2020):

- They present the minimum affectation on ecosystems.
- They are more economical compared to hydropower plants.
- They do not disturb habitats.

This work analyses the hydraulic potential that can be harnessed within the aqueduct of the Yuribia dam by replacing a pressure reducing valve with a by-pass system consisting of a turbine coupled to a generator. The selection process of the turbine and the calculation of the electrical power generated are presented in this work.

The order in which the work is developed is as follows, in section 2 an analysis is carried out in the study area to model the hydraulic network of the aqueduct, as well as the flow reducing valve, finally, the selection of the hydraulic turbine is carried out based on the energy recovered in the system, in section 3 the results of the modelling, simulations and calculations of the energy generated are shown, finally the conclusions are presented.

Methodology

The block diagram in Figure 1 shows the steps to be followed for the selection of the turbine according to the hydraulic potential present in the hydraulic network, each of the stages is described below:

1. Collection of data from the aqueduct network to be analysed.

The data of the aqueduct under study is collected specifying its characteristics: physical and hydraulic characteristics of the potable water transport system from the Yuribia dam to the city of Coatzacoalcos.

Box 1

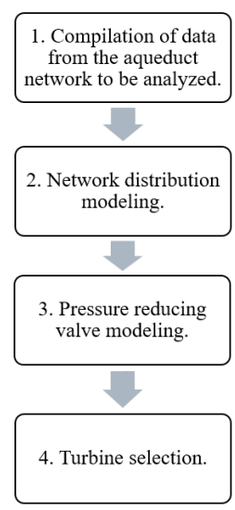


Figure 1
Block diagram of the development of the work]

Source *[Own authorship]*

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1. Distribution network modelling

The next stage is the use of the US Environmental Protection Agency's Epanet software (2023) for network modelling. The Epanet software was developed as a tool for understanding fluid mechanics within distribution systems.

2. Modelling of the pressure regulator valve

With the help of the Epanet software, the analysis and modelling of a pressure reducing valve located within the aqueduct network of the Yuribia dam, which is used to regulate the water pressure reaching a group of elevated tanks responsible for the distribution of drinking water to the city of Coatzacoalcos, is carried out.

3. Turbine selection

With the modelling of the network and the valve, the hydraulic energy losses in the system are calculated, which can be used and recovered by means of a turbine. These losses will be used to determine which turbine model fits the conditions of the network.

Next, the data collection of the hydraulic network, shown in section 1, is carried out.

Collection of data from the aqueduct network to be analysed

The work carried out takes the south of the state of Veracruz as the study area, specifically the city of Coatzacoalcos with coordinates 18°09' north latitude and 94°26' east longitude, as well as the municipality of Tatahuicapan de Juárez (Puerto Coatzacoalcos, n.d.). The Yuribia aqueduct is located in the municipality of Tatahuicapan and is responsible for supplying drinking water to the city of Coatzacoalcos, coming from the Texizapan and Ocotal rivers. The data of the aqueduct of the Yuribia dam are shown in table 1.

Box 2

Driving system	By gravity
Flow rate	1.5 m^3/s.
Diameter of the pipeline	1.22 m ó 48”
Pipeline length	60 Km.
Maximum daily flow	1.2 m^3/s on average.

Table 1
Aqueduct data

Source: Pulido Javier

Water from the Yuribia aqueduct is transported through steel pipelines with a diameter of 48", having a length of 60 km from a water treatment plant with an initial height of 175m above sea level (asl), to storage tanks located in various parts of the city of Coatzacoalcos, the tank used for the analysis is located in the colony of Palma Sola with an approximate height of 29m asl.

The Yuribia aqueduct has a pressure up to the pressure breaker point of 15 kg/cm^2 and after that it decreases to 7 kg/cm^2, losing half of the energy daily.

Modelling of the distribution network

Epanet software was used to model the network, and the modelling used the following components (Lewis et al., 2017):

Connections or nodes: these are points where the pipes join which are represented with lines.

Reservoirs: External sources of energy are represented, thus representing lakes, rivers, aquifers and connections to other systems.

Tanks: Within the programme these are modelled as nodes with storage capacity.

Pipelines: A pipeline is the medium through which water circulates, it is responsible for transporting water.

Minor losses: These can be interpreted as a consequence of increased turbulence due to changes in direction, bends, fittings, etc.

Valves: Valves limit pressure and flow at specific points in the network.

Figure 3 shows the use of the aqueduct network components modelled with the data shown in the data collection section, starting on the left side of the diagram shows the tank located in the highest part of the diagram, pipes represented by the lines, nodes being the point of interconnection of the pipes and the tank located on the right being the final part of the system, the heights or elevations of these last two were provided thanks to the Google Earth programme.

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For the modelling of the network, the Google Earth programme was used to trace the route of the aqueduct, considering the elevations and changes in height that occur during the trajectory from the Yuribia dam to the location of the elevated tank, figure 2.

Box 3

Figure 2
Water mains trajectory
Source: Google Earth

The aqueduct model was made with approximations of minor losses obtained from a first model of the network, the system already made was transferred to pipes modelled by sections, distributing the value of the losses proportionally, being connected with nodes by adding their magnitudes of elevation in each one of them, figure 3.

Modelling of the pressure regulating valve

The pressure regulating valve (pressure breaker) decreases the pressure inside the aqueduct. To model it in the Epanet software, the load break valve is used, using the parameters shown in figure 4.

Box 4

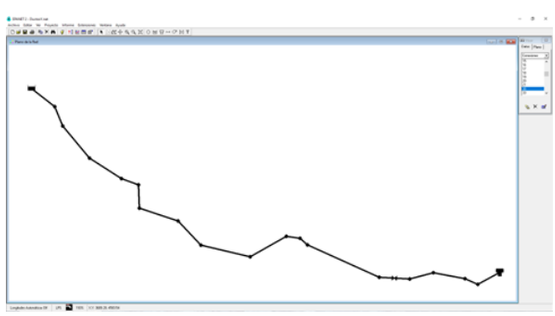

Figure 3
Final network modeling
Source: Own elaboration

Box 5

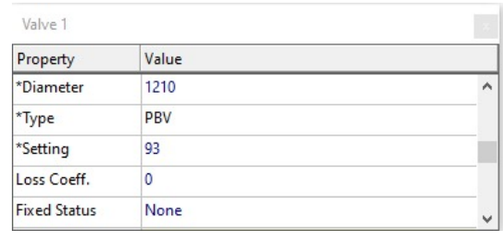

Figure 4
Valve modelling parameters
Source [Epanet]

The valve modlling data are specified below:

Diameter: This is the same as the diameter of the aqueduct pipe in millimetres.

Type: The load break valve was selected because it performs the same function in the program as the pressure breaker located in the aqueduct.

Fixed state: When the device is in operation, the "none" state is selected.

Loss coefficient: It is taken into account within the losses that the valve makes, presented in the setpoint section.

To obtain the setpoint parameter, a series of simulations were carried out in which, by means of the loss coefficients in the pipes, the pressure before the valve was approximated to a pressure of 16.3 kg/cm^2. Assigning to the valve setpoint a value with which an outlet pressure of 7.0 kg/cm^2 is obtained, as shown in figure 5.

Box 6

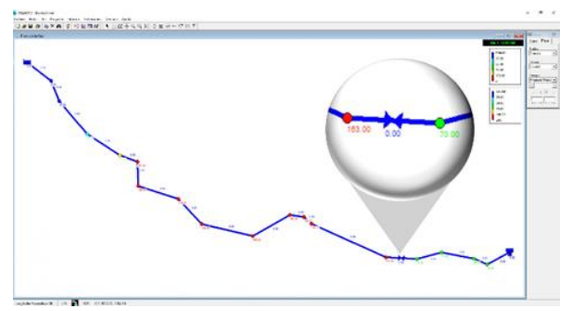

Figure 5
Static network pressure
Source: Own elaboration

Kinetically the pressure values before and after the load break valve which simulates the pressure breaker are shown in figure 6. It is important to mention that the units of pressure used by the software are water column metres.

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Box 7

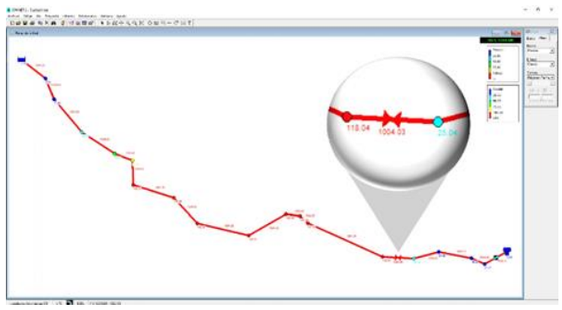

Figure 6

Pressure in the network in kinetic form

Source: Own elaboration

During the different months of the year, the value of the flow rate varies in low water seasons, so taking this into account, different set point values were proposed for the valve, obtaining different values for the flow rate.

4. Selection of the turbine.

Hydraulic turbines work under different operating ranges, these are represented by the useful head and the flow rate, as shown in figure 7. For the selection of the turbine, the energy dissipated by the load break valve is considered, considered as the head that can be recovered, the next operating parameter is the flow rate, whose magnitude depends on the setpoint value of the valve (losses, losses, etc.).

Box 8

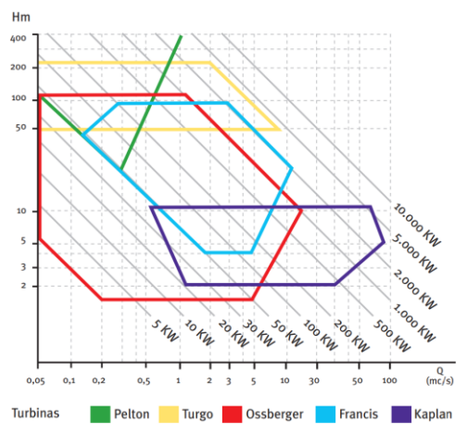

Figure 7

Operating range of turbines

Source: Castro Adriana

Results

Table 2 shows the data of the energy losses in the network, which were produced by making variations in the set point (losses) of the load break valve, showing the flow-pressure relationship in the system, obtaining a range of the same, foreseeing the different scenarios that may occur in the network at different times of the year.

Box 9

Table 2

Flow-loss ratio

Flow rate (m^3/s)	Loss (m)
1.142	78
1.097	83
1.051	88
1.004	93
0.953	98
0.901	103
0.845	108
0.785	113
0.651	123

Source: Own elaboration

Given the magnitudes presented in table 2 in the flow-head ratio, a turbine capable of covering the operating range is selected. With figure 7 presenting the operating capacities, it was observed that the Ossberger turbine is suitable to replace the pressure regulating valve.

The electrical energy that can be recovered by means of the turbine is calculated by equation 1.

$$P_T = \rho g Q H n_t \quad [1]$$

Where:

ρ: Water density (1000 kg/m^3)

g: Gravity acceleration (9.81 m/s^2)

Q: Flow rate (table 2)

H: Height (table 2)

n_t: Turbine efficiency (0.86 ó 0.85 depending on the value of the flow rate).

Applying equation 1 with the different values of flow and head, table 3 gives an approximation of the electrical energy that can be recovered by applying a turbine in the aqueduct network.

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Box 10

Table 3
Electrical power generated

Flow rate (m^3/s)	Loss (m)	Turbine power (kW).
1.142	78	751.4985
1.097	83	768.1608
1.051	88	780.2842
1.004	93	787.7422
0.953	98	787.9278
0.901	103	782.9417
0.845	108	760.9715
0.785	113	739.6666
0.651	123	667.6887

Source: Own elaboration

Conclusions

The modelling of the network was carried out to analyse the water behaviour in the load break valve and to obtain the energy losses in the system, obtaining the hydraulic potential that can be used by the turbine.

As mentioned above, there is a low water season, which affects the supply of drinking water to the city, which is taken into account in the calculation of the minimum amount of electricity generated at this time of year.

By means of the analyses carried out, it was determined that the turbine with the capacity to replace the load break valve is the Ossberger turbine, presenting an energy recovery with a maximum electrical power of 787.927 kW and a minimum of 667.688 kW.

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' contribution

Each of the authors contributed to and contributed to this paper.

Garrido Javier, Quintanilla Jesús and *Rodríguez Ernesto* carried out the first two sections of the methodology, compiling data from reliable sources on the locations of the components and carrying out a study of the area, taking into account their participation in the modelling of the network.

Espinoza Francisco and *Quintanilla Jesús* carried out the modelling of the pressure reducing valve and finally made the selection of the turbine adapted to the characteristics of the network, as well as fulfilling the function of the valve.

Availability of data and materials

The data and programs used in this article are available on request.

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Article

Skirt piles in foundation: a structural rehabilitation solution for fixed offshore platforms

Pilotes faldón en cimentación: una solución de rehabilitación estructural de plataformas marinas fijas

Palemón-Arcos, Leonardo*[a], Gutiérrez-Can, Yuriko[b], Naal-Pech, José Wilber[c] and El Hamzaoui, Youness[d]

[a] Universidad Autónoma del Carmen • KHW-2160-2024 • 0000-0001-9743-0434 • 49334
[b] Universidad Autónoma del Carmen • KHW-2340-2024 • 0000-0001-6358-2130 • 798108
[c] Universidad Autónoma del Carmen • KHW-2538-2024 • 0009-0006-2955-0382 • 1231951
[d] Universidad Autónoma del Carmen • AFN-6960-2022 • 0000-0001-5287-1594 • 292367

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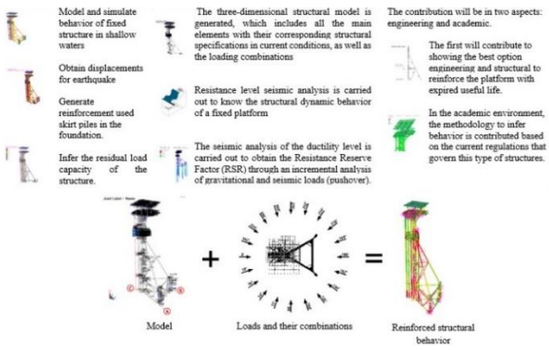
* ✉ [lpalemon@pampano.unacar.mx]

Abstract

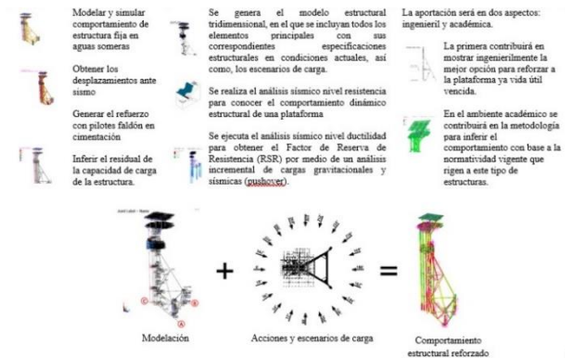
An analysis and structural design of strength and ductility level earthquake is presented in this paper. Numerical results show that structural failure under seismic loads is sensitive to the degree of deterioration of structural steel. The structural elements do not present any excess stress, that is, all stress ratios are less than unity. The maximum stress ratio is 0.942, in the superstructure of element 1586-1571, which corresponds to a main deck beam elevation (+) 15,850 m..



Fixed offshore platforms, Seismic analysis of ductility level, Seismic analysis of resistance level

Resumen

En este artículo se presenta un análisis y diseño estructural del nivel de resistencia y ductilidad sísmica. Los resultados numéricos muestran que la falla estructural bajo cargas sísmicas es sensible al grado de deterioro del acero estructural. Los elementos estructurales no presentan ningún exceso de tensiones, es decir, todas las relaciones de tensiones son menores que la unidad. La relación de esfuerzos máximos es de 0,942, en la superestructura del elemento 1586-1571, lo que corresponde a una elevación de la viga del tablero principal (+) 15.850 m.



Plataforma fija, Análisis sísmico nivel ductilidad, Análisis sísmico nivel resistencia

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Introduction

Offshore structures built in the ocean to explore for and exploit oil and natural gas are found at depths ranging from shallow ocean waters to the deep sea, so the arrangement or structuring that will be possible to extract hydrocarbons will vary depending on the depth, Figure 1.

Box 1

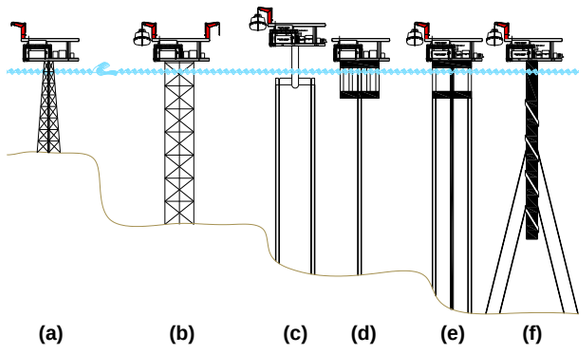

Figure 1

Offshore structures for hydrocarbon exploitation, (a) shallow water fixed platform, (b) shallow water tower platform, (c) intermediate water structure, (d) seabed anchored platform, (e) tensioned leg structure, (f) deep water platform, and (g) deep water platform.

Offshore platforms must operate for their entire lifetime and a remnant thereof, which is typically a minimum of up to 25 years. In shallow waters up to 120 m, the common type of platforms are fixed platforms, known as jackets in the offshore industry (Figure 1a), with a space on top, providing area for crew quarters, or to house facilities or to perform necessary exploration, production or exploitation manoeuvres, which consist of tubular structures fixed to the seabed by driven or drilled and grouted piles. The economic water depth limit for fixed platforms varies according to the environment, however, the fixed platform is economically feasible for installation in water depths of up to 450 metres (Sadeghi, 2007), i.e. beyond this water depth these platforms cannot be used, because it is simply not economical to build such slender structures. When the water depth exceeds these limits, compatible towers or floating production platforms become economically attractive (Schneider & Senders, 2010).

For shallow waters where fixed platforms are economically attractive, they consist structurally of three main parts: pile foundation, jacket and manoeuvring platform (Wilhoit & Supan, 2009; Poulos, 1988). During their lifetime they are subjected to various lateral dynamic loads, such as earthquakes, wave forces, ocean currents, wind forces and ship impacts. Their dynamic behaviour depends to a large extent on their structure and foundations.

The study area will be in the Gulf of Mexico, which is located in the southern part of the United States, surrounded by the Atlantic and Pacific Oceans, Figure 2, specifically in Ciudad del Carmen, Campeche, located at 18°38'18″N and 91°50'07″W in the Gulf of Mexico off the Yucatan Peninsula.

Box 2

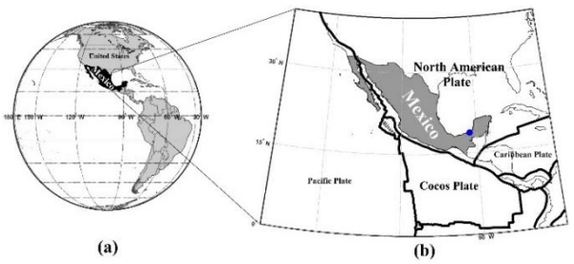

Figure 2

Study area, (a) Mexico in the world and (b) tectonic plates of Mexico

Methodology

Earthquakes are natural phenomena resulting from the interaction and release of enormous amounts of stored energy due to the elasticity and deformation of rocks which, when they yield or fail, produce telluric motion that travels radially in waves in all directions through the layers of the earth, reflecting and refracting at each interface, It is therefore necessary to perform strength and ductility seismic analysis, which is required to ensure that the platform has adequate strength and stiffness levels, as well as to avoid significant structural damage in the presence of an earthquake that has a reasonable probability of not being exceeded during the lifetime of the structure.

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The seismic analysis by resistance is carried out with the Structural Analysis Computer System (SACS) using its modules PSI, DYNAPAC, DYNAMIC RESPONSE, JOINT CAN and COLLAPSE with which the fundamental period of the structure has been obtained, the mechanical elements in the structural members, the nodal displacements, the stress ratios in elements (Unity Check), the revision of the piles and the analysis of joints under penetration shear stresses (Punching Shear), as well as obtaining the Resistance Reserve Factors (RSR) and determining the collapse mechanism (Sadeghi, 2007).

A three-dimensional structural model was generated, including all the main elements with their corresponding structural specifications collected in the field and the information gathered from the interventions that the platform has undergone. Likewise, the main accessories were modelled, such as the jetty, the conductor defence and the reinforcements foreseen for the correct functioning of the structure, Figure 3.

Box 3

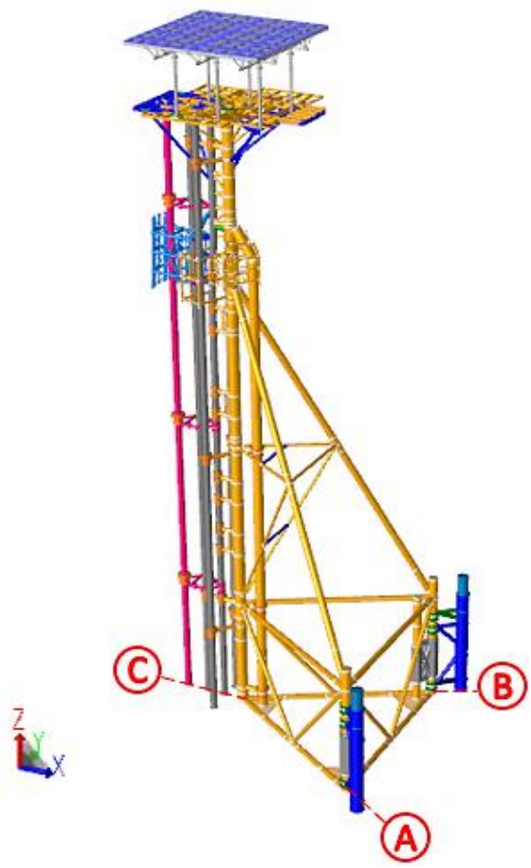

Figure 3
Three-dimensional model of the structure.

- The resistance level seismic analysis is to know the structural dynamic behaviour of a platform under seismic conditions, as well as to determine whether the stresses and displacements are less than those permissible according to current regulations.

- Ductility level seismic analysis is to obtain the Resistance Reserve Factor (RSR) by means of an incremental analysis of gravity and seismic loads (pushover), which shall comply with the provisions of the specification P.2.0130.01:2015 (PEMEX, 2015) Minimum Resistance Reserve Factor (RSR) required for ductility level analysis (design).

The presented Seismic Resistance Analysis consists of four steps or stages:

- The soil data for the first step corresponds to the Report of the platform, located in the Bay of Campeche, Gulf of Mexico, Geotechnical Report dated October 1988, from the company Solum, S.A. de C.V. The static soil conditions were factored by 1.4 to account for the temporary hardening of the soil that occurs during a seismic event. The stiffnesses at the pile heads were obtained using the PSI module of the SACS program iteratively considering initially a shear produced by environmental loads and subsequently adjusting with the seismic loads obtained in the third step of the analysis.

- The dynamic properties are obtained from a modal dynamic analysis where the modal shapes and their associated periods are obtained. The dynamic analysis must include the mass associated with gravity, the mass of the fluids contained in the legs of the structure and the aggregate or virtual mass. The distributed consistent mass criterion is used and is appropriate for fully or partially submerged structures.

- The specification P.2.0130.01:2015 states that the Resistance Level analysis shall be performed with the loads obtained from the resistance level design spectrum shown in Figure 4 and from the specification P.2.0130.01:2015 given in Table 1.

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Box 4

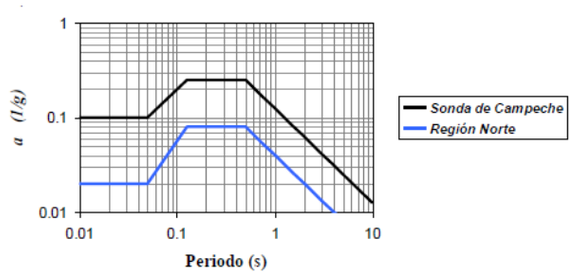

Figure 4

Design spectra at strength level for a critical damping coefficient of 5% for 200 years return period

Box 5

Table 1

Numerical data of the acceleration spectra for a return period of 200 years and a critical damping coefficient of 5%

Campeche Sound	
Period	Acceleration (g's)
0.010 – 0.050	0.100
0.125 – 0.504	0.250
10	0.013

- In addition, 5% structural critical damping will be used. Further guidelines for the analysis can be found in API-RP-2A WSD (2014), the full quadratic combination method (CQC) will be used to combine the modal responses and the sum of squares square root (SRSS) to combine the directional responses; the spectrum will be applied simultaneously and fully for two horizontal orthogonal directions and at 50% for the vertical direction. The SACS DYNAMIC RESPONSE module generates the equivalent static seismic forces in 20 different directions at every 18°. It is then possible to determine in which of these directions the greatest effects of the earthquake on the structure occur.

- The last step in the Strength Level Seismic Analysis is simply the application of the seismic forces generated in the previous step together with the gravity loads in a Linear Analysis. An increase of the allowable stresses of 70% must be applied in the Strength Analysis and the main structural elements resisting the seismic motion against the application of twice the seismic force must be checked. That is, for joints, piles, legs, columns and wind bracing. The rest of the members are checked against the single seismic force.

- To calculate the ultimate forces in joints and elements, the gravity, seismic, buoyancy and hydrostatic pressure loads must be combined simultaneously.

Through a Collapse Analysis of the platform, the Resistance Reserve Resistance Factors (RSR) of the platform to seismic loads will be known. For this purpose, it is necessary to apply the gravity loads in their totality, as well as to gradually apply the Seismic Loads until the collapse mechanism of the structure is achieved. This will be achieved by taking into account the following considerations:

- After having obtained the seismic loads, the Collapse Analysis is carried out. The collapse analysis is carried out for twenty directions of incidence of seismic loads separately, corresponding to 0°, 18°, 36°, 36°, 54°, 54°, 72°, 90°, 108°, 126°, 144°, 162°, 180°, 198°, 216°, 234°, 252°, 270°, 288°, 306°, 324° and 342°.

- The detailed results are presented only for the most critical direction, while for the remaining directions only the calculation of the corresponding RSRs is included.

The Ductility Seismic Analysis presented consists of 4 distinct steps or stages:

- Soil Liberalisation. In order to carry out a Dynamic Analysis it is necessary to represent the soil and the foundation in the form of an equivalent linear system. This is in accordance with the curves presented in the structure, Bahía de Campeche, Gulf of Mexico, Geotechnical Report dated October 1988, Cía. Solum, S. A. of C.V.

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- Obtaining the Dynamic Properties. In this part, the mass, stiffness and modal forms or modes of vibration of the structure are obtained, which define the structural behaviour under dynamic loads.

- Dynamic Response. With the dynamic properties and by means of the Response Spectrum Method, the equivalent static earthquake loads in different directions are obtained.

- Incremental Load Analysis. This is carried out by increasing the gravity loads up to 100% and then increasing the seismic loads until the structure collapses. This stage of the analysis must be carried out for each of the directions of incidence of the seismic loads considered.

The basic loads to which the structure was subjected are shown in Table 2.

Box 6

Table 2
Basic loads on the offshore platform

Position ID	Description	Weight (ton)
1	Self-weight of the structure	750.948
2	Dead load on substructure	41.223
3	Dead load on main deck	10.819
4	Live load on main deck	81.605
5	Pipe load on main deck	9.535
6	Load of equipment on main deck	18.895
7	Dead load on sub level	8.303
8	Live load on sub-level	8.475
9	Heliport dead load	4.710
10	Heliport live load	40.748
20-39	Seismic Loads @ 18°	

For the case of the foundation

Because dynamic analysis employs a linear, modal superposition theory, the non-linearity of the foundation must be represented by an equivalent linear system for the purposes of dynamic analysis.

The linear model of the foundation (super-element) by means of a series of "fictitious" elements or "springs" located at the pile-head whose elastic stiffness matrix replaces the non-linear behaviour of the real soil-pile.

To obtain the above-mentioned super-element, environmental loads have been initially considered under operating conditions for the orthogonal pairs of directions 0º-90º, 45º-135º, 180º-270º and 225º-315º. Subsequently, after step three of the analysis and returning to this first step, the combinations in the 0°, 90° directions are used to generate the equivalent linear foundation with more typical stresses.

Subsequently, the stiffness matrices of the super element corresponding to each of the piles are presented and will be included in the subsequent steps of this analysis. All this information is available in the output file DYNSEF which is to be used as input for the next step of the analysis.

Results

The SACS software converts weights into masses by means of its DYNAPAC module, therefore, the model must contain the loads to be converted into masses in addition to the structural self-weight. Dynamic degrees of freedom were incorporated at the appropriate nodes to participate in the modal shapes of interest and represented by 222000 in the JOINT lines.

In this section, the Spectral Modal Seismic Analysis of the Drilling Platform is shown, considering the masses and dynamic properties obtained previously.

The seismic forces were obtained using the SACS program by means of the Earthquake module with the recommendations of API-RP-2A (2014).

For the analysis, the seismic design spectrum was considered at the resistance level for a critical damping coefficient of 5% of the P.2.0130.01:2015 standard and in accordance with NRF (PEMEX, 2009 and 2007).

The dynamic response of the structure to seismic loads is shown below, consisting of basal shear and overturning moment.

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********** CQC SHEAR AND MOMENT VERSUS DIRECTION **********

POINT	ANGLE DEG	BASE SHEAR KG	OVERTURNING MOMENT KG-M	VERTICAL LOAD KG
1	0.0	97862.0	1206949.6	50571.9
2	18.0	96125.4	1287308.4	50571.9
3	36.0	90911.9	1442057.6	50571.9
4	54.0	85848.5	1611309.9	50571.9
5	72.0	80669.9	1732999.9	50571.9
6	90.0	75186.2	1790784.2	50571.9
7	108.0	76293.3	1757502.6	50571.9
8	126.0	83503.6	1641223.6	50571.9
9	144.0	91003.6	1466123.6	50571.9
10	162.0	96139.9	1284960.9	50571.9
11	180.0	97862.0	1206949.5	50571.9
12	198.0	96125.4	1287308.2	50571.9
13	216.0	90911.9	1442057.5	50571.9
14	234.0	85848.5	1611309.9	50571.9
15	252.0	80669.9	1732999.9	50571.9
16	270.0	75186.2	1790784.0	50571.9
17	288.0	76293.3	1757502.6	50571.9
18	306.0	83503.5	1641223.6	50571.9
19	324.0	91003.6	1466123.9	50571.9
20	342.0	96139.9	1284960.9	50571.9

The analysis was carried out in 20 directions applied to the structural model.

Box 7

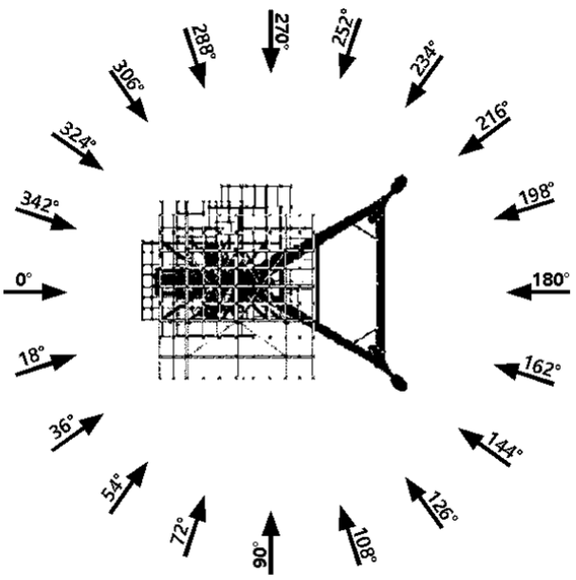

Figure 5

Analysis directions to obtain the Basal Shear and Tipping Moment

The maximum displacements that occurred during the seismic events on the simulated platform are described below. It is worth mentioning that the actual combinations to check the displacements are when the single seismic load is applied, i.e. the load combinations (C000, C018, C036, C342). **Figure 6** is also shown with the displacements in the -X direction (C180º) which was the most critical of the analysis.

********** MAXIMUM JOINT DEFLECTION REPORT **********

LOAD CASE	**X-DIRECTION** JOINT	DEFLECTION CM	**Y-DIRECTION** JOINT	DEFLECTION CM	**Z-DIRECTION** JOINT	DEFLECTION
C000	H001	15.5123	H187	21.8839	1559	-3.9230
C018	H011	7.2424	H195	18.3887	1677	-6.8887
C036	H011	5.9577	H195	16.4703	1677	-6.5305
C054	H001	4.8052	H010	13.5045	1677	-6.5420
C072	H001	4.9445	H010	13.6896	1677	-6.5825
C090	H001	4.9619	H010	14.6268	1677	- 6.9954
C108	H187	- 9.0742	H196	13.5675	1677	-6.2149
C126	H187	-8.8109	H196	13.2527	1663	-5.9613
C144	H187	-9.2739	H196	13.9388	1663	-6.1266
C162	H187	-10.3418	H196	15.5691	1663	-6.3308
C180	H187	21.7288	H196	30.1005	H001	-6.1655
C198	H196	11.6676	H187	10.2114	H011	-3.8751
C216	H196	10.3439	H187	-8.2927	1809	-3.6812
C234	H187	10.9113	H001	-7.1093	1809	3.8820
C252	H187	11.0541	H001	-7.2942	1809	-3.9054
C270	H187	11.1789	H001	-8.2415	1809	-4.3350
C288	H011	4.0333	DN82	-6.6600	1559	-3.7507
C306	H011	3.7881	DN82	-6.2553	1559	-3.8259
C324	H011	4.2659	H001	-8.6580	1559	-3.8742
C342	H011	5.3960	H001	-8.5953	1559	3.9513

Box 8

Figure 6

Maximum Displacement in the 180º Earthquake Condition (X).

The structural elements of the KAX-1 Drilling Platform were checked considering the combination of Gravity forces with the forces of the Spectral Modal Seismic Analysis following the recommendations of API-RP-2A (WSD) 22nd edition.

The review of the platform members was performed with the SACS program by means of the Element Code Check module. It should be noted that the review of the elements was performed as described below.

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The main elements of the structure were checked with a Factor 2.0 of the seismic load, in accordance with API-RP-2A (WSD) 22 edition, Figure 7.

Box 9

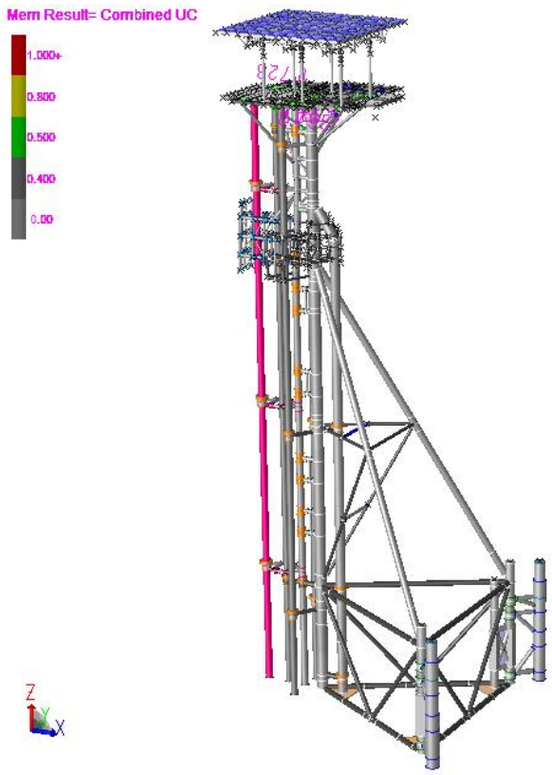

Figure 7
Interaction relations (Unity Checks).

Box 10

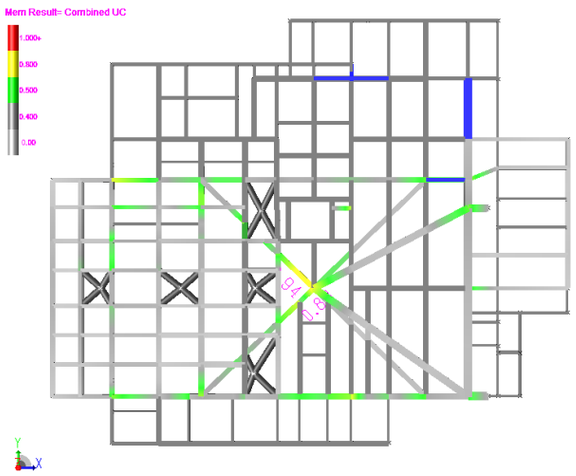

Figure 8
Interaction relationships in superstructure secondary elements.

The secondary elements of the structure were checked with a factor of 1.0 of the seismic loading only as described in API-RP-2A (WSD) 22nd edition, Figure 8. The stress ratios are shown separately in Substructure and Superstructure.

The stress ratios in the skirt piles above the seabed Platform are shown in Figure 9.

Box 11

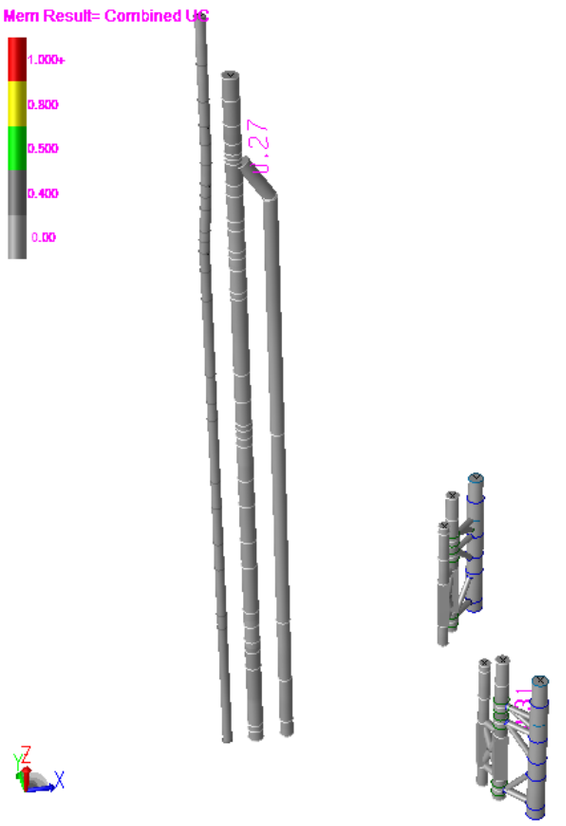

Figure 9
Interaction ratios in the pile skirt piles

The Resistance Reserve Factor (RSR) shall comply with the minimum required for ductility level analysis considering the specification P.2.0130.01:2015.

$$RSR = \frac{V_{last}}{V_{ref}} \quad (1)$$

Where:

V_{last} = Ultimate basal shear associated with the load at which the collapse mechanism of the structure is present.

Vref = Cutting

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The ultimate shear considering a 180° direction is:

```
** SACS COLLAPSE PILE HEAD REACTIONS REPORT **
 INCREMENT  66        LOAD FACTOR    5.600
  *** STRUCTURAL PILE HEAD REACTIONS ***


 PILE   FX      FY      FZ      MX      MY      MZ
 JOINT  KG      KG      KG      CM-KG   CM-KG   CM-KG

C100  11803.71 -8144.59  518386.03  2418061.2  1397208.5 -548425.6
P11   79714.23 -71821.85  531197.88  ********** **********  886690.2
PR1A  49951.71 -20453.39  179672.75  -325098.4 ********** -2261247.8
PR2A 49968.40   -4575.62  -25179.59  -3281179.2 **********  1701761.2
PR3A 30249.70   -3912.69  105998.98  -1701143.6 **********  2043134.1
P31   39678.51    -754.46   91382.59    293280.5 **********  2560363.0
P21   77496.11   -7200.65 -140690.27  -7533638.0 **********  1880843.4
C400  11989.19   -5698.38   32124.92    178561.3  2293584.5   21030.8
C200  11626.64  -10785.41   59035.50   1243584.6  1690722.9   33580.1
C300  16261.89  -12071.82   59276.41      5588.6   228449.8   278996.3
11CN  9168.25   -4129.87   32633.64   2671727.2  3587292.0  -598217.7
PN1   42754.63   25041.86    9463.22  19185356.0 **********  3525187.8
PN21 117207.11 -23559.22 -428325.16  ********** **********  1570184.6


      *** TOTAL PILEHEAD REACTION ***

    FX .............  547870.06 KG
    FY ............. -148066.08 KG
    FZ ............. 1024976.88 KG

     REACTED BASE SHEAR  567525.50 KG
```

Substituting the magnitudes gives an RSR of 5.80, which is higher than the regulation of 1.60.

$$RSR = \frac{567.53 ton}{97.86\ ton} = 5.80 \quad (2)$$

Conclusion

From the results obtained from the seismic analysis at Resistance Level for the Platform it is concluded:

The structural elements do not present any overstress, i.e. all stress ratios are less than unity. The maximum stress ratio is 0.942, in the superstructure of element 1586-1571, which corresponds to a main beam of the deck of elevation (+) 15.850 m; which belongs to group T7E, while in the substructure it is 0.31 in element C131-P1S which corresponds to group D10.

Regarding the analysis of tubular joints, the joint with the highest stress ratio is P2X with a ratio of 0.931, which is less than unity and is therefore considered acceptable.

The periods presented in the structures are within the tolerance range for this type of structure. In accordance with the above, it can be concluded that the Platform structure adequately supports the stresses imposed during the occurrence of an earthquake, with acceptable levels of stresses in both joints and elements, in accordance with the applicable regulations.

For the conditions of the seismic analysis by Ductility, the following is concluded:

The platform has been analysed by means of an incremental process of loads (pushover) which was applied in increments of 10% in Gravity Loads and 5% in Seismic Loads, until the collapse in the superstructure, specifically in the main beams, occurred. The Resistance Reserve Ratio (RSR) of the PP-KAX-1 Platform was calculated in 20 directions analysed 0°, 18°, ..., 342°, the lowest factor being in the 180° direction with an RSR of 5.80 and in all cases it is greater than the minimum (1.60) required by the regulations.

The collapse mechanism is present in the main beams of the deck (+) 15.850 m of the superstructure (see figure 5).

The Resistance Reserve Resistance Factors (RSR) of the platform are higher than the minimum required value of 1.60 by the specification P.2.0130.01:2015 in the Campeche Sound. Therefore, the structure has sufficient ductility reserve required by the specification, consequently, the structure forming the platform is considered acceptable.

Declarations

Conflict of interest

The authors and co-authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported in this paper.

Authors' contribution

The first author performed the analysis and interpretation of the results; the first co-author contributed to the modelling and simulation of the structure; the second co-author performed the processing of raw data for input into the model; and the third co-author performed the comprehensive review as well as the conclusion of the research results.

Availability of data and materials

The data obtained from this research are available for consultation at any time as required.

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Abbreviations

API American Petroleum Institute

CQC Complete Quadratic Combination

NFR Reference Standards

PSI Stack-Soil Interaction

RSR Resistance Reserve Factor

SACS Structural Analysis Computational System SACS

SRSS Sum-of-Squares Square Root

WSD Working Stress Design

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Background

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Article

Spanish language trend on Twitter: an analysis of modern writing

Tendencia del lenguaje español en Twitter: un análisis de escritura moderna

Lara Torres, Claudia Guadalupe* [a], Velázquez Macias, Jesús [b] and Rodríguez González, Beatriz Adriana [c]

[a] Universidad Politécnica de Zacatecas • KIB-8474-2024 • 0000-0002-3066-2967 • 905451
[b] Universidad Politécnica de Zacatecas • I-6696-2018 • 0000-0003-0180-023X • 431443
[c] Universidad Autónoma de Zacatecas • KIC-3996-2024 • 0000-0001-7133-2596 • 99443

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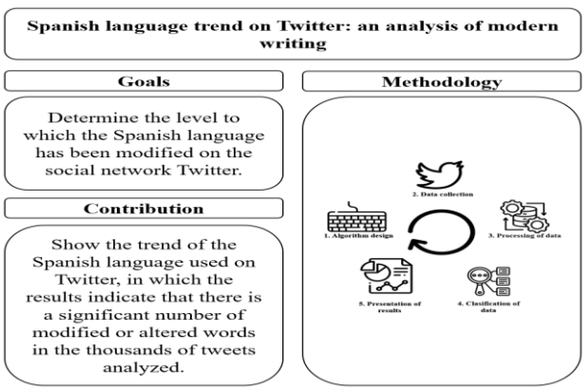
* ✉ [jvelazquez@upz.edu.mx]

Abstract

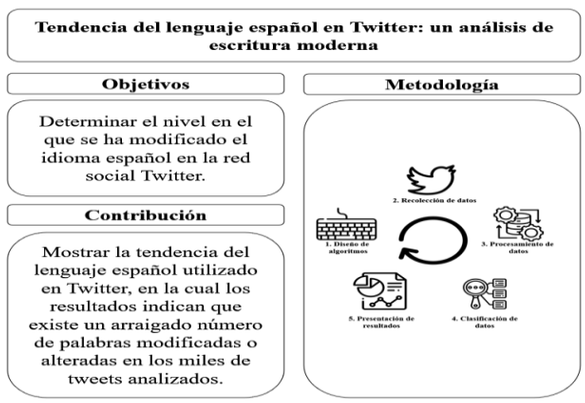
Forms of digital communication have positioned themselves as the preferred method for people to interact regardless of age, situation or condition, which is why the need arises for rapid communication on social networks using abbreviations, letter changes or the use of codes. of writing. The objective of the research is to determine the level at which the Spanish language has been modified on Twitter, using an exploratory and descriptive analysis with data science. The results obtained indicate that there are quite a few modified words, the word "guey" standing out. These tweets are mostly sent en masse during the night; and its use intensified during the Covid-19 pandemic. It is worth mentioning that the evolution of this type of language arises from the need for increasingly efficient communication that new generations demand.



Language, Twitter, Data science

Resumen

Las formas de comunicación digital se han posicionado como el método preferido de las personas para interactuar independientemente de la edad, situación o condición, por ello surge la necesidad de una comunicación rápida en las redes sociales utilizando abreviaciones, cambios de letras o el uso de códigos de escritura. El objetivo de la investigación es determinar el nivel que se ha modificado el idioma español en Twitter, utilizando un análisis exploratorio y descriptivo con la ciencia de datos. Los resultados obtenidos, indican que existen bastantes palabras modificadas, sobresaliendo la palabra "guey", estos tweets en su mayoría se envían de forma masiva durante la noche; y su uso se intensificó durante la pandemia por Covid-19. Cabe mencionar que la evolución de este tipo de lenguaje surge de la necesidad de comunicación cada vez más eficiente que exigen las nuevas generaciones.



Lenguaje, Twitter, Ciencia de datos

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Introduction

Historically, human beings have had the need to communicate, which has allowed them to evolve and grow to discover new methods that allow this activity, thus achieving increasingly complex interactions with their peers. Social communication was one of the main objectives to be developed by technology, in order to search for scenarios and tools that would allow communication with the minimum of problems (Pulido et al., 2021). That is why, nowadays, technology and globalization have transformed the way we communicate and interact with our environment, and within this context, social networks on the Internet have become increasingly relevant because there is also an excessive and widespread use of mobile devices.

Therefore, the present research analyzes one of the main effects that the writing of the Spanish language has on the different interactions in social networks. For this reason, the present study seeks to know the influence that social networks, mainly Twitter, have on the language of users. To achieve the above, a survey was conducted among high school students to identify the main words used in social networks and that due to their use or way of writing (spelling mistakes or discretionary abbreviations) are considered to distort the Spanish language, since the Real Academia Española does not recognize such words as correctly written or simply does not (yet) include them as commonly used in Spanish so they do not appear in the Dictionary of the Spanish Language.

The main objective of the study in question is to highlight the characteristics and properties of these words in the social network Twitter, as well as their incidence and frequency of use over the years, as noted above, these words were previously selected through a structured survey applied to students of different semesters of the Bachelor's Degree in Business Administration and Management, Computer Systems Engineering and Automotive Engineering of the Polytechnic University of Zacatecas.

With the survey, information was obtained from the years 2019 to 2022, and the words that resulted with the most frequency of use by respondents were: “holi”, “muxo”, “nop”, “ontas”, “pork”, “sip”, “tagueno” and “wey”.

Using methods, techniques and computer programs, the content of the tweets in Spanish was explored in order to find coincidences of these eight terms in the tweets published in the months of July 2019 to 2022, so that their level of use in this social network could be studied throughout these four years. In addition to the frequency of use, it was also possible to determine some of the characteristics of the tweets with identified matches such as the date and time of publication, the operating system used by the user and other data of lesser relevance for this study such as the number of replies, number of “likes”, location, user name, etc.

In addition to the above, this research aims to expose the communication processes of Twitter users, showing the use of misspelled or abbreviated words in messages and the problem that this represents for the established linguistic norms. Due to the fact that, on many occasions, users of social networks do not care about spelling or writing, but are also influenced by the idioms that circulate in social networks and that motivate abbreviations, codes or misspelled words, and still manage to engage in communication. Therefore, it is important to analyze the changes in language generated by Twitter users, regardless of gender, age and location, in order to establish strategies to improve the language that, although not formal, should be instilled a correct use of words.

Writing in social networks

Nowadays, social networks are considered as an element to which people give too much importance, that is, they are becoming part of their daily lives. Users are connected to social networks a great deal of time, sometimes regardless of the time, condition or situation in which they are. Consequently, nowadays we live with an immediacy of communication and one of the main means to carry it out are the different popular social networks, because they are a way to socialize and establish contacts, as well as to keep informed.

Social networks have become new forms of expression and communication among young people regardless of how they contribute to or affect the daily life of each individual (Pazmiño Benavides, 2012).

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This dynamism has led to some alterations related to the way people write Spanish, since 2008, Fernandez stated that in recent years it has been seen that spelling mistakes have increased and the Internet has had to do in this situation because, in it, forms are neglected and consequently writing is deformed, because, being an informal and uncontrolled medium, users do not pay too much attention to this aspect. This leads to the instantaneousness of communication, and it is usually assumed that it is normal to make mistakes in writing, and even the abbreviation of some words that prevent them from being written correctly. Thus, in terms of content, we can affirm that new technologies are changing the way we communicate, consume, think, work and access information (Avila Burgos et al., 2016).

However, it seems that what is important is the meaning of the message without considering the way it is written, if there is any spelling mistake or if abbreviated words are used, which are not official. Indeed, as Torres (2017) indicates, the first changes in the way a message is transmitted in writing came with the need to shorten the number of characters used in text messages with the expansion of the use of cell phones in the 1990s. However, at present, regardless of the number of characters used to send a message or establish a communication through a social network, changes in writing continue to have an exponential increase, knowing that many times there are no limits as to the length of must contain some message, it is opted for its abbreviation (Torres, 2017).

As is well known, the Internet is a medium in which, as a general rule, the most basic tool of communication, language, is systematically neglected (Fernandez, 2008). Therefore, written verbal communication is the medium par excellence in the network, leaving out phone calls between cell phones and local phones, since written verbal communication is considered as a colloquial and oral style, due to the fact that one speaks as one writes, regardless of grammar, spelling and syntax (Peñalver, 2019). Therefore, spelling mistakes in social networks are usually attributed to the lack of concentration or laziness of the user before the communicative proximity, since they know that the person who is going to read it knows the conventions of use of social networks (Mancera Rueda and Pano Alamán, 2014).

However, the freedom of writing and easy access to the Internet, promotes the lack of interest in good spelling, and users with unorthodox writing habits are commonly found (Torres, 2017).

On the other hand, it is important to consider that Spanish is the third most used language on the Internet (behind English and Chinese) and the second most used language on Twitter and Facebook, considered the two main social networks in the world (Peñalver, 2019). However, the growth of Facebook users in Spanish, is very high compared to English, likewise, Spanish is the second most used language on Twitter, in English-speaking cities such as London or New York, to mention a few (Mocanu et al., 2013).

Based on these data that demonstrate the weight of Spanish in communication on the Internet today, the present study aims to know the main words that are orthographically misspelled or abbreviated in the social network Twitter, as well as to determine to what extent the Spanish language and its spelling have been modified.

To obtain the above, data science is a tool that has become fundamental in the exploitation of data, among its main objectives are the creation of models to describe standards of behavior, in order to facilitate decision-making or make predictions of some specific phenomenon (García et al., 2018), it is also considered as something novel for information retrieval and analysis in different disciplines (Lemus-Delgado and Pérez Navarro, 2020). In addition to the above, it is a discipline that in recent years has had a great growth, due to its implementation in scenarios where large volumes of data have been generated, and which arises as a result of the insufficiency of classical methods and analysis to process large volumes of data, it is also established as multidisciplinary since it involves statistics, mathematics and data engineering among other fields (Britos, 2020).

Therefore, once the literature has been analyzed, the main research question is determined: At what level has the Spanish language been modified in the social network Twitter?

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Going further into the research and in order to answer the research question and the research objective, the following secondary questions were established:

What are the main characteristics of the words that are modified on the social network Twitter?

What are the words modified and most used on Twitter?

What is the trend in the use of these words?

What is the main operating system from which the tweet is issued?

On the other hand, the present work aims to determine at what level the Spanish language has been modified in the social network Twitter, covering the writing trends in the tweets made, as well as highlighting the characteristics and properties of those words in the social network and their incidence and frequency of use over the years.

Finally, it is worth mentioning that currently the social network called Twitter changed its name to X, however, the general functions continue to function normally, the only thing that seems to have changed regardless of its administrative issues, is the logo and the name of the network. Therefore, in this study, the name Twitter is still used, since at the time of obtaining the information for this research, the network was still in force.

Methodology

For the present study, the descriptive approach was used, which made it possible to specify the properties and characteristics of the phenomenon studied as it is presented in reality, so that its main objective is to obtain a detailed and precise understanding of a specific phenomenon. It is also quantitative in nature, adapted to the specific needs of the study in question. A quantitative methodology is based on the collection and analysis of numerical data to answer research questions and/or test hypotheses. This approach is based on the collection of information that can be measured and analyzed statistically, allowing objective and generalizable results to be obtained (Hernández-Sampieri et al., 2018).

Participants

An experimental design was used to conduct the study, in addition, to carry out the data collection a survey was applied to 385 students of the Polytechnic University of Zacatecas of the academic programs of the Bachelor's Degree in Administration, Computer Systems Engineering and Automotive Engineering, which are on average between 18 and 23 years old, in order to collect the words they use in the social network Twitter and that meet the criteria of alteration or abbreviation mentioned in previous paragraphs, the survey is available in the next section of this document. The words with the highest number of appearances were used to extract the tweets and the results obtained are analyzed, according to the opinion of the students surveyed the most used words are: “holi”, “muxo”, “nop”, “ontas”, “pork”, “sip”, “tagueno” and finally “wey”.

Strategies and instruments

To determine which are the words most used by young people on the social network Twitter, the following instrument was used, consisting of 3 questions, once the most used words were determined, data extraction began.

1. Of the following words, which are the ones you use the MOST to communicate in your social networks (you can select several):

01 muxo; 02 holi; 03 oki; 04 xk; 05 xro; 06 mui; 07 xd; 08 pq; 09 pk; 10 uwu; 11 tqm; 12 tkm; 13 crack; 14 todxs; 15 sip; 16 sipi; 17 nop; 18 nopi; 19 tlj; 20 xfa; 21 wey; 22 jaja; 23 jeje; 24 gpi; 25 bn; 26 pork; 27 lol; 28 gueno; 29 ontas; 30 xd.

2. Of the following words which ones do you use the LEAST to communicate in your social networks (you can select several):

01 muxo; 02 holi; 03 oki; 04 xk; 05 xro; 06 mui; 07 xd; 08 pq; 09 pk; 10 uwu; 11 tqm; 12 tkm; 13 crack; 14 todxs; 15 sip; 16 sipi; 17 nop; 18 nopi; 19 tlj; 20 xfa; 21 wey; 22 jaja; 23 jeje; 24 gpi; 25 bn; 26 pork; 27 lol; 28 gueno; 29 ontas; 30 xd.

3. If you use other words that are not in the above lists, write them here.

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Procedure

Because studies on communication and sentiment analysis in social networks are becoming more frequent and determinant for a myriad of purposes, especially marketing, tools developed in Python were used, implementing libraries designed for the extraction of data published within the social network Twitter (Abdulsalam et al., 2024). The searches were designed based on various filters, using some of the words in question as the main parameter and restricting the search to tweets written in Spanish.

Other parameters limit and shorten the searches by means of their publication date, specifically obtaining the date and time of publication; the results of this search are stored in comma-separated files (CSV) for subsequent main analysis. The algorithm used has the capacity to extract and store approximately 100,000 tweets per hour as long as they meet the search criteria and have a stable internet speed, as well as a computer with at least 8 GB of RAM available.

This large amount of information is analyzed by means of data science using some advanced statistical functions and some algorithms that allow its classification, for these tasks the Python programming software and the implementation of some external libraries such as Pandas allow to represent and sort such information.

The Snscrape library is a tool for searching and extracting information in social networks (Abednego et al., 2022). The library is able to filter tweets by setting various conditions; such as date, keywords, language or number of "likes" received, (Sarkar and Rajadhyaksha, 2021). The choice of the social network Twitter in this study is based basically on the ease with which it presents to extract information, functionality that is not available in other social networks, this allows retrieving information without limitations on the number of queries or number of records retrieved (Williams et al., 2013). Twitter is therefore, an immense generator of information, because it produces large amounts of data that can be subsequently analyzed with advanced statistical methods, numerous studies of general topics, which apply data mining have focused on this social platform (Zarrabeitia-Bilbao et al., 2022).

The retrieval of tweets was performed during the month of July (considering that it is a holiday period, and even times of pandemic) in the years 2019, 2020, 2021 and 2022 using various words colloquially used to communicate on Twitter and that are not recognized by the Real Academia Española. In addition, a comparison of the word "holi" in the months of July and December 2019 and 2020 was carried out to analyze the evolution of its forms of use in that period.

Data analysis

In order to process the information, each month of July of the years mentioned above was analyzed, considering the following variables: number of tweets made, date and time of the tweet and the device from which it was published. Table 1 shows a comparison of the number of tweets made in the month of July for each of the aforementioned years:

Box 1

Table 1

Comparative analysis of the number of tweets with selected word usage in the month of July by year.

Word	2019	2020	2021	2022
Holi	33,817	99,999	97,198	59,655
Muxo	7,430	8,369	9,146	11,833
Pork	5,156	10,576	9,074	9,654
Tagueno	634	982	747	775
Nop	4,494	62,526	63,881	46,998
Ontas	4,494	2,043	3,182	1,135
Sip	34,162	72,893	82,844	57,067
Wey	329,048	579,019	522,858	499,262

Source: Own elaboration based on the analysis of the extracted data.

As can be seen in Table 1, the word "wey" is the most used word in the social network Twitter, showing a notable increase from 2019 to 2020. Likewise, it is shown that the use of the word "sip", in the same years mentioned above, had a strong increase in its use, the same case happens with the word "holi", so in comparison with the other words there is a significant difference. It is worth mentioning that the increase in the use of the words described above was observed more frequently in times of pandemic due to COVID-19, probably attributable to the time people stayed at home. Therefore, the most used words on Twitter, even with the passage of time were: "wey", "sip" and "holi" respectively (there is a tendency to grow in 2020 and 2021 due to the pandemic and then the use of almost all of them is reduced).

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On the other hand, the word with the least amount of reported coincidences is “tagueno” by obtaining in each of the years analyzed less than 1000 tweets, this because users generally tend to use the word “ok” better to say that something is right or that they agree with the idea embodied in the message by the issuer. It can be deduced that users prefer to use the term “ok”, because it is a short word, used very frequently in social networks, and finally because it means the same as the word “tagueno”, it could be said that they are synonyms in the context of abbreviated and simplified writing.

On the other hand, once analyzed the results obtained, it is found that the operating systems mostly used to post tweets are firstly Google's Android, secondly Apple's IOS, thirdly, if you use a personal computer browser, tables 2, 3 and 4 show the results of the operating system variable and its behavior over the years in the month of July by word.

Box 2

Table 2

Operating system from which the tweet is issued with word analyzed by year (Android).

Word	2019	2020	2021	2022
Holi	17,950	62,656	59,739	35,874
Muxo	3,822	4,738	5,267	6,478
Pork	2,909	6,431	5,378	4,925
Tagueno	355	564	435	457
Nop	2,154	37,733	39,531	28,383
Ontas	2,157	1,036	1,953	585
Sip	18,022	43,324	50,326	33,628
Wey	144,475	256,896	234,387	218,262

Source: Own elaboration based on the analysis of the extracted data

Box 3

Table 3

Operating system from which the tweet is issued with word analyzed by year (IOS).

Word	2019	2020	2021	2022
Holi	8,932	24,788	23,958	16,084
Muxo	2,521	2584	2,729	4,154
Pork	1,392	2,789	2,509	3,440
Tagueno	182	268	187	183
Nop	1,733	14,992	14,128	11,603
Ontas	1,730	786	911	458
Sip	8,455	16,969	18,575	13,985
Wey	154,535	273,658	245,143	244,324

Source: Own elaboration based on the analysis of the extracted data

Box 4

Table 4

Operating system from which the tweet is issued with word parsed by year (Web app).

Word	2019	2020	2021	2022
Holi	4,636	11,053	11,504	6,589
Muxo	822	988	1,074	1,128
Pork	455	1,028	955	1,124
Tagueno	82	130	114	128
Nop	325	8,722	9,597	6,455
Ontas	325	208	299	87
Sip	5,480	11,139	12,846	8,352
Wey	21,974	43,114	39,534	33,370

Source: Own elaboration based on the analysis of the extracted data

According to the analysis of the records obtained for all the words, the operating system most used to publish tweets is Android developed by Google, except for the word “wey”, which in all years was used more by the IOS operating system developed by Apple, being the word most used by the social network Twitter in relation to the other words analyzed in this study. On the other hand, the tweets that use the word “wey” were analyzed to detect in what sense they express it, due to the fact that the word is a Mexicanism used as an offense, however, people, on many occasions, use it to colloquially address a person without calling him/her by name, since said word can be applied in the same way in the masculine or feminine context (Sinave, 2010).

However, the word “wey” can also be used as a synonym for anger, admiration or affection. According to the Real Academia Española and the Dictionary of Mexico, the correct way to write this word is “güey”, and it is defined as an unknown and despised person and often refers to being dumb. Therefore, in the present research, most of the expressions in the tweets when using the word “wey” are basically to start a conversation and make an expression of admiration.

On the other hand, when analyzing the messages that carry the word “pork”, they are used to ask or answer a question, in most of the comments they refer to giving an answer, however, grammatically it is not well written nor is it possible to differentiate the meaning of that word, as when it is written correctly: por qué; it is interrogative and is used to ask questions, or porque, to answer questioning.

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According to the Real Academia Española, the use of “por qué” is a sequence formed by the preposition por and the interrogative or exclamative qué, commonly used in direct and indirect interrogative and exclamatory sentences (RAE, 2022).

Box 5

Table 5

Comparative analysis of the number of tweets containing the word “holi” in the months of July and December by year.

Tweets	2019/Jul	2019/Dec	2020/Jul	2020/Dec
Total	33,817	37,412	99,999	99,757
Android	17,940	21,878	62,649	60,570
Iphone	8,932	9,594	24,788	26,260
Ipad	175	179	570	675

Source: Own elaboration based on the analysis of the extracted data

As can be seen in Table 5, regarding the number of tweets sent in the months of July and December of the same year there is not much variation, however, from the year 2019 to 2020 if there is a significant difference, coupled with this on the results of the operating system used continues to predominate Google's Android, even when adding the information of users who use Apple's IOS.

Regarding the use of the word “holi” during the years 2019 and 2020, considering the months of July and December, the number of tweets containing it was obtained showing their totals in Table 5. “Holi” refers to the word “hello”, which according to the Real Academia Española is used as a familiar greeting, strangeness, or to call inferiors (RAE, 2020a), although it is also commonly used to start an informal conversation. According to Cabrejas (2012) the word “hola” is an Iberian acronym, which is defined as an interjection that is used in colloquial language in a friendly way, it is an exclamation that is used amicably, upon the arrival of a meeting or when shaking hands. It could also be related to the English “hello” and the German “hallo”.

As for the word “muxo” used in the social network Twitter, it is a way in which users abbreviate the word mucho, written in this way correctly, and sometimes use it as an adjective or adverb and indicates abundance or intensity of doing something.

Particularly in the tweets analyzed the messages are oriented to show affection towards other people, according to the Real Academia Española the word mucho refers to something abundant, or that exceeds the ordinary (RAE, 2020b).

On the other hand, the use of the word “tagueno” by Spanish speakers on Twitter is very common, and is used to indicate that something “is good” or “is fine”, and to express a feeling of conformity or that one agrees with something, even when the words are misspelled, communication flows and the meaning of the message fulfills the objective. In another sense, the word “no” is an adverb of negation that is placed before the verb to construct negative sentences and indicate that the user opposes an indication, however, in the world of chat and even in oral language, it is very common to observe the use of the word “nop” to deny, mainly in response to a question (RAE, 2020c), because since long ago there has been the habit of suffixing some words with endings that evoke English, mainly. However, nowadays and mainly with young people, the word game that seeks to use and create similar words, and that serve as forms of communication, is widely used. The same case happens with the word “sip”, which means affirmation, which denotes definitive assertion (RAE, 2020d), and the same modification is used as the word no, by adding the “p” at the end.

Finally, the word “ontas”, is used as a shorthand for asking where are you, and is supposed to refer to knowing the user's current location. It is an expression mainly of Mexican origin, however, in social networks it has generated a lot of confusion among users about the meaning of this question, because it can be used to propose a sexual encounter. The word “ontas” had a viral meaning in different social networks in 2019 especially on Twitter, and created controversy because at first it was used by Mexican fans to contact celebrities, who, not knowing usual expressions in Spanish, were victims of jokes product of the confusion, however, what seemed to be a local challenge became a trend mainly because of its true meaning in social networks (The Republic, 2019).

Likewise, an analysis of the incidence of tweets by each hour of the day was carried out, Graph 1 shows the corresponding distribution.

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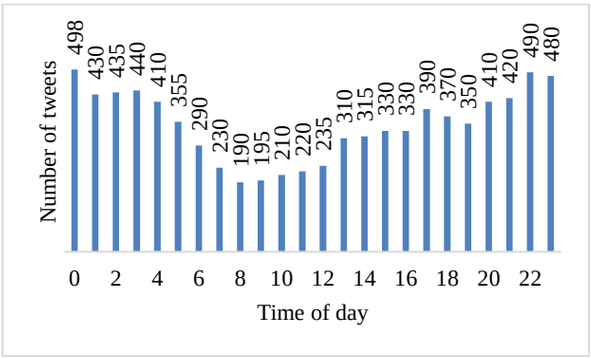
Box 6



Graphic 1

Average incidence of tweets per hour

Source: Own elaboration based on the analysis of the extracted data.

Graphic 1 considers all the words analyzed, observing that in the early morning hours this incidence is at a low level, while during the course of the day, in the afternoon and evening, this number increases.

Results

The present study examined, by means of statistical and computational methods, the incidence of various misspelled or abbreviated words in the social network Twitter, which were carefully selected through a questionnaire applied to young university students. It can be concluded that the current forms of digital communication have completely invaded the interaction between people, which causes that, in the messages sent or received, there are misspelled words, abbreviations or writing codes that often affect the way in which the Spanish language is written. After performing the pertinent analysis of the information obtained, it was determined that the word "wey" is the most used word by Twitter users during the period of analysis, and its use worsened during the pandemic period.

Likewise, the operating system most used for sending messages on Twitter is Google Android, followed by Apple IOS, with the exception of the word "wey" which is most used on mobile devices with Apple IOS.

On the other hand, it is interesting to analyze the messages to be able to interpret the sense in which they are sent to users, that is, if it is an offense, or a form of affection or anger and to be able to make a comparison with the true meaning of the word by the Real Academia Española.

Due to the immense amount of information, the analysis was limited only to the month of July in the period contemplating the years 2019 to 2022, and in a special case the analysis of the word "holi" in the months of July and December of the years 2019 and 2020, since in some occasions the incidence of certain words in a month exceeds 50,000 tweets. Another limitation was that, when using the corresponding library to extract the tweets, since it was neither official nor recognized by Twitter, it showed failures or intermittencies that delayed the obtaining of information.

Finally, when analyzing the messages issued by Twitter users, it is possible to detect that they adopt these forms of writing due to the constant interaction in social networks and it can be concluded that the message is expressed in a natural and unconscious way that becomes part of their daily vocabulary.

Discussions

The findings in this study suggest that the use of misspelled or abbreviated words is a growing trend among people who use the social network Twitter in Spanish, and that on the other hand it does not mean that the idea of conveying a message, idea or feeling among users is not affected.

In addition, it was found that users make use of the services provided by Twitter mostly at night and in the early hours of the morning, reducing their use in the mornings, which means that users are more active in non-working hours for most or in hours of rest either at school or at work.

Due to the nature of the information obtained, it was not possible to determine precisely the location of the users from where they use the social network, so we only have a record of the language they use, with the following locations being varied but not decisive: Latin America, United States, Spain, among others.

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Surprisingly, an infinite number of tweets were found that at first glance do not include a precise and direct message for most people, but in certain groups of people, mainly young people, they have a perfectly understandable meaning, these messages are highly abbreviated and may include one or more of the words mentioned in this study and often accompanied by emojis, of the latter it is recommended to conduct a precise and detailed study on their meaning, frequency and conditions of use.

Likewise, it can be considered that the results of this research will be a contribution to the language and promotion of good writing, using technology as a basic tool to develop skills because by making use of predictive text the message can have an adequate quality in writing and thus inversely the user can deduce the correct way to write without modifying the Spanish language. However, nowadays it should be understood that social networks became part of people's daily lives, but what should not be normalized is bad writing regardless of the social network used, especially when the same technology through the mobile device "suggests" you to write the right word, even predicts common phrases.

This leads to good practices in the writing of Spanish, such as the form and speed of issuing a message, but it also leads to certain patterns of use of social networks and that make users no longer think, identify or manage to see if a message is written correctly or not, and therefore reduce the capacity and ability of the user in the correct writing of the Spanish language. In addition, it is not only the way of writing, but sometimes it is the spoken use of these misspelled words, and even the users have normalized their use. In addition, "the style of written communication used by young people on social networks Facebook and Twitter is fundamentally informal, spontaneous, free, unplanned and not subject to rules, and basically it is a daily conversation" (Vanegas Ramírez, 2014).

Because young people find in the various social networks a space for entertainment, fun and freedom, they are aware of what they write and the transformation of words causing them to develop in a digital context where speed, brevity and immediacy predominate.

For his part, Parra (2015) states that:

> "The factors that influence students to misuse virtual language are to use fast and quick communication that complements the way they want to communicate, adopt a personal language and basically show disinterest in maintaining our correct language. Although it is very complicated, this is a problem that arises since puberty and when we start using social networks, then it becomes a habit, it is in each of us to change this ideology, to think about the future and professional working life, to be interested in having a correct writing to get to form great performances" (p. 87).

Likewise, Llopis-Susierra (2019) mentions four main ideas about writing in social networks:

> "The first is that the language of social networks is in the process of transformation due to a change of attitude in adolescents and the use of spellcheckers; the second, that the influence of social networks on writing has a double aspect: positive and negative; the third, that the negative impact is greater in students whose spelling is less established; and finally, that spellcheckers are instruments for learning spelling" (p. 16).

Conflicts of interest

The authors declare that they have no conflicts of interest.

Contribution of the authors

The contribution of each researcher in each of the points developed in this research was defined on the basis of the following:

Lara-Torres, Claudia Guadalupe: Contributed to the idea of the project, methodology, elaboration of the strategies and instruments. She supported the application of the instrument as well as the analysis of results and the final revision of the research.

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Velázquez-Macias, Jesús: Contributed to the bibliography search for the elaboration of the background and theoretical framework. I supported in the writing of the article as well as in the elaboration of tables and graphs, and in the systematization of the results and revision of the bibliographic citations.

Rodríguez-González, Beatriz Adriana: I contributed to the preparation of the summary, introduction, discussion of the results and conclusions. She also participated in the drafting of the article and revision of the bibliography.

Availability of data and materials

The data collected for this study were obtained by means of computational algorithms from the Twitter social network in a free form.

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Abbreviations

CSV	Comma Separated Values
GB	Gigabyte
IOS	iPhone Operating System
RAE	Real Académia Española
RAM	Random Access Memory

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Article

Cost-benefit analysis of an irrigation unit with treated wastewater in Chihuahua, Mexico

Análisis costo beneficio de una unidad de riego con aguas residuales tratadas en Chihuahua, México

Borja-Bravo, Mercedes [a], Sánchez-Toledano, Blanca Isabel* [b], Arellano-Arciniega, Sergio [c], Ochoa-Rivero, Jesús Manuel [d]

[a] Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias - Campo Experimental Pabellón • E-3770-2016 • 0000-0001-7743-6003 • 168419

[b] Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias - Campo Experimental Zacatecas • KIC-3288-2024 • 0000-0002-3460-334X • 206399

[c] Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias - Campo Experimental Pabellón • KIC-3376-2024 • 0000-0001-9158-7019 • 526563

[d] Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias - Campo Experimental La Campana • G-882-2015 • 0000-0003-0015-6593 • 387384

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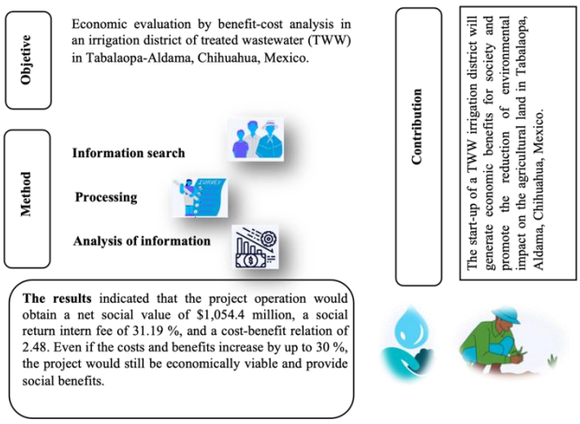
* ✉ [sanchez.blanca@inifap.gob.mx]

Abstract

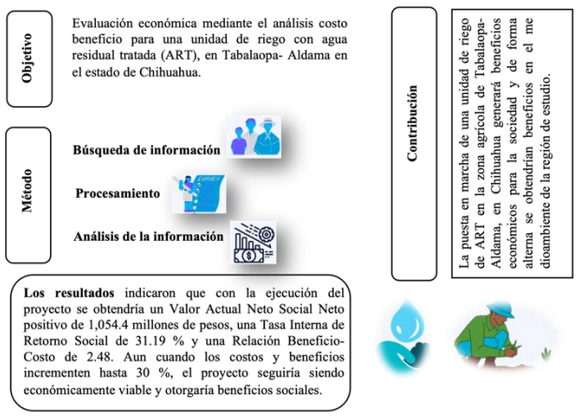
The reuse of water in agriculture is an alternative to guarantee food security in Mexico and efficient management of this resource. The objective was to conduct an economic evaluation by benefit-cost analysis in an irrigation district of treated wastewater (TWW) in Tabalaopa-Aldama, Chihuahua, Mexico. The cost-benefit methodology was used to estimate the economic assessment of public projects. The results indicated that the project operation would obtain a net social value of $1,054.4 million, a social return intern fee of 31.19 %, and a cost-benefit relation of 2.48. Even if the costs and benefits increase by up to 30 %, the project would still be economically viable and provide social benefits. The start-up of a TWW irrigation district will generate economic benefits for society and promote the reduction of environmental impact on the agricultural land in Tabalaopa, Aldama, Chihuahua, Mexico.



Social benefits, profitability, water, reuse

Resumen

La reutilización del agua en la agricultura es una alternativa para garantizar la seguridad alimentaria en México y hacer un uso más eficiente de este recurso. El objetivo fue realizar una evaluación económica mediante el análisis costo beneficio para una unidad de riego con agua residual tratada (ART), en Tabalaopa- Aldama en el estado de Chihuahua. Se utilizó la metodología del análisis de costo beneficio para la evaluación económica de proyectos públicos. Los resultados indicaron que con la ejecución del proyecto se obtendría un Valor Actual Neto Social Neto positivo de 1,054.4 millones de pesos, una Tasa Interna de Retorno Social de 31.19 % y una Relación Beneficio-Costo de 2.48. Aun cuando los costos y beneficios incrementen hasta 30 %, el proyecto seguiría siendo económicamente viable y otorgaría beneficios sociales. La puesta en marcha de una unidad de riego de TWW en la zona agrícola de Tabalaopa-Aldama, en Chihuahua generará beneficios económicos para la sociedad y de forma alterna se obtendrían beneficios en el me dioambiente de la región de estudio.



Beneficios sociales, rentabilidad, agua, reutilización

Citation: Borja-Bravo, Mercedes, Sánchez-Toledano, Blanca Isabel, Arellano-Arciniega, Sergio, Ochoa-Rivero, Jesús Manuel. Cost-benefit analysis of an irrigation unit with treated wastewater in Chihuahua, Mexico. ECORFAN Journal-Bolivia. 2024. 11-20:28-34.

Introduction

Water is a vital and fundamental resource for sustaining life and food security on planet Earth. Unfortunately, anthropogenic activities, climate change, and population growth, among other causes, have triggered water scarcity problems that pose a risk to food production in the world. Mekonnen and Hoekstra (2016) reported that two thirds of the global population are under conditions of water deficit in quality and quantity. Therefore, it has been estimated that by 2050 there will be a population of 9.2 billion inhabitants, which represents a challenge for the sustainability of the vital liquid (Mahfooz et al., 2020).

An alternative to counteract this problem in agriculture is the use of treated wastewater (TWW) (Ochoa-Rivero et al., 2023). Currently, about 20 million hectares in 50 countries are irrigated with TWW and wastewater, which represents 40 % of food production (Mahfooz et al., 2020). To mention a few cases are countries such as Australia (Shahrivar et al., 2019), Nigeria (Inyinbor et al., 2019), Pakistan (Mahfooz et al., 2020), and Mexico (Hettiarachchi et al., 2018). The example in Mexico is the Mezquital Valley, where according to Hettiarachchi et al. (2018) and Garcia-Salazar (2019) TWWs coming from Mexico City have been used to sustain agriculture in three Irrigation Districts (ID-003, ID-100, ID-112). Undoubtedly, the use of TWW is an alternative to counteract the lack of water for irrigation and provides an option for food production, because it contains a large amount of nutrients and organic and inorganic compounds such as nitrogen (N), phosphorus (P) and potassium (K) (Alvarez-Holguín et al., 2022).

Therefore, in 2020, a project was proposed for the establishment of an irrigation unit with TWW for the Tabalaopa-Aldama agricultural area, Chihuahua, Mexico. This project contemplated the reuse of TWW from the south wastewater treatment plant (WWTP) of the city of Chihuahua. The project considered irrigating 1,887.80 ha of crops with TWW to produce forage and pecan nuts. However, water reuse entails changes in traditional water allocation structures, financing structures, consideration of water and soil quality standards, regulatory frameworks, and institutional mandates.

This implies good management at all levels in order to develop a holistic approach and consistent policies for water allocation that meet the multiple needs of users (Lugo-Morin, 2009). Therefore, it is necessary, prior to any investment, to perform a financial analysis (Viñan et al., 2018).

The objective of this study was to carry out an economic evaluation using cost-benefit analysis for an irrigation unit with TWW in the Tabalaopa-Aldama agricultural land, Chihuahua, Mexico. The purpose was to determine the profitability of the project and to provide information for decision making to the stakeholders involved in water resource management in agriculture in northern Mexico.

Methodology

Description of the study area

The study area was located between the Tabalaopa-Aldama and Aldama-San Diego aquifers. The Chuviscar River is the primary water source for the agricultural land under study. This water mixes with TWW in the channel, which has supplied the agricultural land under study, with centroid coordinates of 28°43'52.80" north latitude and 105°58'14.26 west longitude (Figure 1) (Consejo Estatal Agropecuario de Chihuahua, 2020).

Box 1

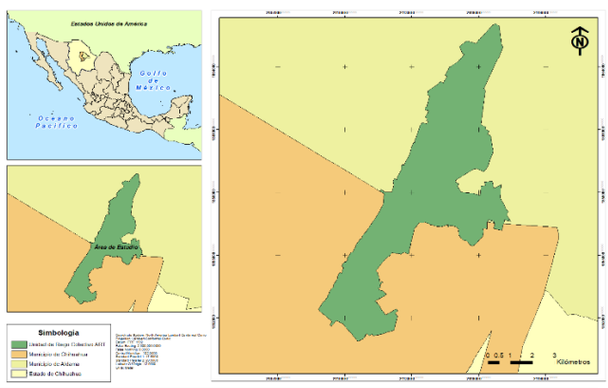


Figure 1
Location of the irrigation unit, Chihuahua.
Source: Own elaboration

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Water distribution in the study area

The TWW that serves as effluent for the irrigation unit comes from the WWTP with an average daily flow of 1,875 L/s. The WWTP started operations in 2006 and treats domestic water from the city of Chihuahua, it has a secondary treatment system with final disinfection with chlorine. Discharges from the WWTP are divided into irrigation (~800 L/s), graywater (~100 L/s) and the remainder to the Chuvíscar River (Ochoa-Rivero et al., 2023).

Project cost-benefit analysis

Based on the guidelines for the preparation and presentation of cost-benefit analysis (CBA) of investment programs and projects, in section II: Types of Investment Programs and Projects, paragraph 2, item i, the project was classified as an "Economic infrastructure project" (DOF, 2020). Consequently, the CBA methodology was used, which is a tool for the economic evaluation of public projects, where the costs and benefits of the project were compared in monetary terms, based on the values, the economic profitability of the project in public investment and social benefits derived from the use of public resources were highlighted (Jacome and Carvache, 2017).

The application of the CBA consisted of five stages (Aguaza, 2012): 1) Identification of the project objective and valuation of alternatives, 2) Identification of all costs and benefits derived from project implementation, 3) Monetary valuation of costs and benefits, 4) Updating of the flow of costs and benefits to a base year by applying a discount rate, 5) Estimation of economic indicators: Social Net Present Value (SNPV), Social Internal Rate of Return (SIRR) and Benefit-Cost Ratio (BCR). Three scenarios were proposed, which considered the following: Scenario 1: increase in the initial investment of the project; Scenario 2: increase in costs and decrease in revenues making the project unviable; and Scenario 3: increases in costs and decrease in revenues by 30, 20 and 10 %, respectively. The costs and benefits used in the evaluation are shown in Table 1.

Box 2

Table 1

Costs	Benefits
Investment cost of the irrigation unit at current 2020 prices (initial investment).	Increase in water for domestic consumption in the city of Chihuahua of ~98,527 inhabitants.
Maintenance cost of the irrigation unit and was estimated at 25 cents per m^3.	Increase in the value of forage crop and pecan nut production with TWW.
Operating cost of the irrigation unit.	Economic savings due to less groundwater extraction.
Cost of public awareness campaign on the use of TWW in agriculture.	Economic savings due to the use of less fertilizer in the production of forage crops.
Cost of soil, water and crop monitoring in TWW irrigated plots.	
Cost of a training, technical assistance and technology transfer program for forage production with TWW.	

Source: Own elaboration

The information used for the evaluation was derived from secondary sources, official databases and information collected directly from farmers and key stakeholders in the study area. Once the data was collected, it was captured and analyzed in Microsoft Excel 2016.

Conversion to social costs and revenues

In the economic evaluation, social prices were used and the distortion method was considered for their estimation, where the value of costs at market price was taken as a basis and distortions such as inflation, taxes and/or subsidies were eliminated (CEPEP, 2012).

Financial evaluation considerations

The analysis considered an evaluation horizon of 50 years and a social discount rate of 12 %, which was taken from the guidelines for the preparation and presentation of cost-benefit analyses of investment programs and projects issued by the Ministry of Finance and Public Credit of Mexico (SHCP) (DOF, 2020).

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Results and discussion

The project cost estimates are shown in Table 2. The investment required for the execution of the works and actions of the project was $915,076,256.60 at current Mexican pesos prices for 2020 and was the most important, incorporated the sum of the operation and maintenance of the irrigation unit. Another cost of importance was the monitoring of water, soil and crops; since according to Cisneros and Saucedo (2016) measures must be taken to avoid salinization problems and mineral accumulation in soils irrigated with TWW. Therefore, monitoring represents a preventive measure to major problems that may represent a greater economic cost in the future. The authors also pointed out that the use of TWW in agriculture brings with it changes in the way farmers produce. Therefore, it is important to make a good selection of crops accompanied by management practices, ranging from the way of sowing, irrigation management, fertilization doses and cultural practices. For this reason, it is necessary to implement a technology transfer program where knowledge and techniques are shared with farmers so that they can produce efficiently.

Box 3

Table 2

Private and social costs of the Treated Wastewater Irrigation Unit (annual cost current Mexican pesos).

Concepts	Private Value	Social Value
	$	
Costs		
Installation of the irrigation unit	$915,076,256.60	$655,814,102.17
Operation of the irrigation unit	$391,491.00	$318,872.16
Irrigation unit maintenance	$95,203.52	$82,072.00
Public awareness campaign	$139,200.00	$120,000.00
Soil, water and crop monitoring	$6,503,848.56	$5,606,766.00
Technology transfer program	$1,679,800.00	$1,355,000.00
Benefits		
Clean water for human consumption	$177,423,875.00	$171,382,199.00
Increase in the value of agricultural production	$49,258,909.63	$27,896,627.40
Savings in groundwater extraction	$7,781,209.69	$6,536,216.14
Savings in fertilizer costs	$5,424,085.52	$4,556,231.89

Source: Own elaboration

The awareness campaign was considered based on Winpenny et al. (2013) statement that the acceptance of TWW and its reuse in agriculture by society depends on the awareness and understanding of the subject. According to Rubio (2012), in Mexico there has been a predominant exclusion of the participation of rural producers in the determination of new projects, specifically in the management of water resources.

The accounting of the benefits that the implementation of the project would provide are shown in Table 2. The economic valuation of the increased availability of water for first use was considered to be the highest. However, this benefit is not only centered on the economic aspect; it also has a contribution to the environment by counteracting the overexploitation to which the Tabalaopa-Aldama aquifer is currently subjected. For Melián-Navarro and Fernández-Zamudio (2016), recovered water plays a key role in the maintenance of wetlands, resulting in the preservation of green areas, flora and fauna, aspects of intangible value for future generations.

According to data from the Chihuahua State Agricultural Council (2020), during 2020, in the study area there is an agricultural area of 1,098.5 ha irrigated with TWW, which would increase to 1,885.5 ha with the implementation of the project. This increase in the area irrigated with TWW would lead to greater economic benefits and guarantee the sustainability of agriculture in the region, since, as mentioned by Villeta (2016), the expansion and sustainability of agricultural activity only prevails if there is a constant and reliable supply of water.

For farmers, the cost of groundwater extraction represents higher production costs for their crops; on average, a farmer spent $9,853 per ha in 2020 to extract groundwater, so with the project this cost would no longer be paid if they use the TWW (distributed by gravity). Another favorable aspect for farmers would be the savings from the purchase of fertilizers; various studies indicate that the reuse of TWW in adequate quantities improves the physical condition of the soil, while providing a considerable proportion of indispensable fertilizers (Borrego-Marín and Berbel, 2019; Álvarez-Holguin et al., 2022).

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According to the results obtained in the CBA, the Social Net Present Value (SNPV) was positive and greater than 0, which indicated that the execution of the project would result in a profit for society of $1,054.4 million. The Social Internal Rate of Return (SIRR) was 31.19 %, higher than the social discount rate and represents the average annual interest rate generated by the capital invested in the project during its useful life once the investment has been recovered.

The BCR was 2.48, greater than 1, which means that the benefits of the project exceed its costs and that for each Mexican peso invested, $1.48 Mexican pesos of benefit will be obtained for society, this situation is equivalent to 148 % of profitability (Table 3). With the results obtained, it can be deduced that the investment project of an irrigation unit with TWW is socially profitable for the population of the Tabalaopa-Aldama zone, since the economic welfare achieved with the project would be greater than that obtained if the project were not carried out (Contreras, 2004).

Box 4

Table 3

Project profitability indicators

Present Value of Social Costs (PVSC)	$714,085,921
Present Value of Social Benefits (PVSB)	$1,768,562,026
Social Net Present Value (SNPV)	$1,054,476,105
Social Internal Rate of Return (SIRR)	31.19%
Benefit-Cost Ratio	2.48

Source: Own elaboration

While the results of the indicators are important for decision making, authors such as Winpenny et al. (2013) pointed out that the basic indicators should be accompanied by comprehensive data showing the results of sensitivity analysis and change values, highlighting possible worst-case scenarios. The sensitivity analysis indicates the areas of the project where reducing uncertainty could bring particular benefits, by reducing a downward variation or improving the chances of an upward movement.

In Scenario 1 it was observed that, if social costs are considered equal to current costs (Table 4), it would imply an initial investment of $915,076,256 and the project would show an SNPV of $795.21 million Mexican pesos, a SIRR of 22.41 % and a profitability of 82 %, so it would still be socially profitable.

Box 5

Table 4

Results of the sensitivity analysis of the project's economic indicators, current Mexican pesos

Indicators			
Scenario 1	Value		
Present value of social costs ($)	973,348,075		
Present value of social benefits ($)	1,768,562,026		
Social Net Present Value ($)	795,213,950		
Social Internal Rate of Return (%)	0.22		
Benefit-Cost Ratio	1.82		
Scenario 2	Social costs	social income	
Present value of social costs ($)	1,768,562,026	714,085,921	
Present value of Social Benefits ($)	1,768,562,026	714,085,921	
Social Net Present Value ($)	0	0	
Social Internal Rate of Return (%)	0.12	0.12	
Benefit-Cost Ratio	1	1	
Scenario 3	Cost increase		
	30%	20%	10%
Present value of social costs ($)	927,804,118	856,413,571	785,065,023
Present value of Social Benefits ($)	1,768,562,026	1,768,562,026	1,768,562,026
Social Net Present Value ($)	840,757,908	912,127,455	983,497,003
Social Internal Rate of Return (%)	0.24	0.26	0.28
Benefit-Cost Ratio	1.91	2.07	2.25
	Decrease in income		
	30%	20%	10%
Present value of social costs ($)	714,085,921	714,085,921	714,085,921
Present value of Social Benefits ($)	1,237,993,497	1,414,849,621	1,591,705,823
Social Net Present Value ($)	523,907,497	700,763,700	877,619,902
Social Internal Rate of Return (%)	0.22	0.25	0.28
Benefit-Cost Ratio	1.73	1.98	2.23

Source: Own elaboration

Scenario 2 considered an increase in costs and decrease in revenues, to the point where the project becomes unfeasible, i.e., SNPV is equal to 0, BCR is equal to 1 and SIRR is equal to 12 %. The above is achieved only if costs were to increase by 147.66 % and benefits were to remain constant; the same occurs if benefits were to decrease by 59.62 % and costs were to remain constant. These results indicate that the implementation of the project would not generate any benefit to society and it is indifferent whether it is carried out or not.

Finally, in Scenario 4, the variation in costs increased and benefits decreased by 30, 20 and 10 % (Table 4). The results obtained show that even if costs increase and benefits decrease at the different levels proposed, the project would still be economically viable and would provide social benefits to the population of the study region.

Conclusions

The implementation of an TWW irrigation unit in the agricultural area of Tabalaopa-Aldama in Chihuahua will generate economic benefits for society, which is supported by the results obtained in the evaluation, where the SNPV was positive and implies that the economic welfare achieved with the project would be greater, compared to what would be obtained if the project were not carried out.

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The SIRR was 31.19 %, which is higher than the social discount rate used (12 %), indicating that public investment in the development of the project generates profitability. The BCR was 2.48, meaning the benefits of the project exceed its costs. For every Mexican peso invested in the project, 1.48 Mexican pesos of benefits will be generated for society. In the work carried out, the valuation of environmental benefits was not considered, so it is recommended that this topic be included in future research. The analysis of these benefits would provide valuable information for the decision of the actors involved in the management and development of projects of this type and the implementation of the first collective irrigation unit with TWW in northern Mexico.

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported in this article.

Authors' contribution

The contribution of each researcher in each of the points developed in this research was defined on the basis of:

Borja Bravo, Mercedes: Contributed to the project idea, research method and technique. Designed the field instrument. Conducted data analysis and systematization of results.

Sánchez-Toledano, Blanca Isabel: Contributed to the project idea and research method. Conducted data analysis and systematization of results, in addition to writing the article.

Arellano-Arciniega, Sergio: Systematized the background information for the state of the art.

Ochoa-Rivero, Jesús Manuel: Supported in the application of the field and systematization instrument.

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Abbreviations

TWW: Treated wastewater
CBA: Cost-benefit analysis
SNPV: Social Net Present Value
SIRR: Social Internal Rate of Return
BCR: Benefit-Cost Ratio

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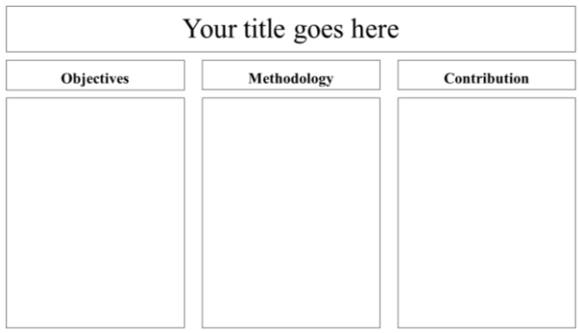

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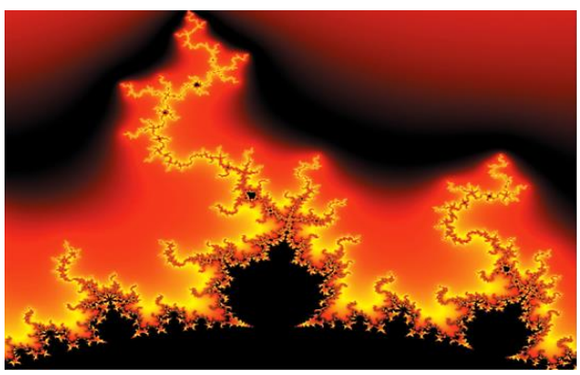

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