AMANDA FERNANDES PEREIRA DA SILVA
(ORGANIZADORA)

INGENIERÍA:

INVESTIGACIÓN, DESARROLLO E INNOVACIÓN

2

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CIÊNCIAS EXATAS E DA TERRA E ENGENHARIAS

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La triada Investigación, Desarrollo e Innovación es un pilar fundamental tanto desde el punto de vista económico como a la hora de buscar soluciones a los distintos problemas y retos vinculados a la sociedad y la industria. También hay que tener en cuenta que el mercado está en constante evolución y con demanda inmediata. Por lo tanto, surge la importancia de los estudios científicos que promuevan el progreso y uso de los servicios de las empresas, instituciones en el campo de la investigación.

Las tendencias de las nuevas tecnologías, cada vez más especializadas y con más foco en la ciencia científica, prestan más atención a la implementación de actividades rentables a largo plazo y con estrecha reacción a la evolución. Este trabajo destaca la investigación investigativa, estudios vinculados a un carácter más experimental, buscando siempre referirse al sector y dimensión de aplicaciones útiles para la industria y la sociedad.

Dado este contexto, en este trabajo se evidencia la obtención de nuevos conocimientos que permitan descubrir nuevos productos o servicios o mejorar los existentes. La motivación para difundir la investigación se basa en explorar y abordar problemas. Tener una mayor comprensión de un determinado concepto y garantizar una aplicación real es un claro objetivo de Atena Editora junto con este trabajo.

Entonces, ¡Feliz Lectura y Sumérgete en el conocimiento!

Amanda Fernandes Pereira da Silva

SUMÁRIO

SUMÁRIO

ESTIMATION OF THE QUANTITY OF COMPACTOR TRUCKS REQUIRED FOR MUNICIPAL SOLID WASTE COLLECTION IN THE CITY OF JAEN

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ABSTRACT: Municipal solid waste management (MSW) is a challenge facing local and national authorities. The objective was to determine the demand for compactor collection trucks (CRC) for the provision of the MSW collection service of the city of Jaen administered by the Provincial Municipality of Jaen (MPJ). The MSW generation data was extracted from the solid waste characterization studies (ECRS) of the MPJ. For the calculation of CRC, a weekly peak coefficient of 1.6 was used, a daily peak coefficient of heterogeneous distribution of 1.67 and six working days per week. It was evident that about 80% of MSW generated in the city of Jaen corresponds to organic waste and it was estimated that the current need for CRC is nine and will increase in one every eight years. It is concluded that the number of CRC with which the city of Jaen has is insufficient to cover the demand of the collection service of MSW that are generated daily.

KEYWORDS: Characterization study, Floating population, Organic waste.

ESTIMACIÓN DE LA CANTIDAD DE CAMIONES COMPACTADORES NECESARIOS PARA LA RECOGIDA DE RESIDUOS SÓLIDOS URBANOS DE LA CIUDAD DE JAÉN

RESUMEN: La gestión de los residuos sólidos urbanos (RSU) es un reto al que se enfrentan las autoridades locales y nacionales. El objetivo fue determinar la demanda de camiones recolectores compactadores (CRC) para la prestación del servicio de recolección de RSU de la ciudad de Jaén administrada por la Municipalidad Provincial de Jaén (MPJ). Los datos de

generación de RSU se extrajeron de los estudios de caracterización de residuos sólidos (ECRS) de la MPJ. Para el cálculo del CRC se utilizó un coeficiente de pico semanal de 1,6, un coeficiente de pico diario de distribución heterogénea de 1,67 y seis días laborables por semana. Se evidenció que cerca del 80% de los RSU generados en la ciudad de Jaén corresponden a residuos orgánicos y se estimó que la necesidad actual de CRC es de nueve y se incrementará en uno cada ocho años. Se concluye que el número de CRC con el que cuenta la ciudad de Jaén es insuficiente para cubrir la demanda del servicio de recogida de RSU que se generan diariamente.
PALABRAS CLAVE: Estudio de caracterización, Población flotante, Residuos orgánicos.

1 | INTRODUCTION

The MSW are composed of organic waste, paper, glass, plastics, cans, textiles and others (Jin et al., 2016; Jurič et al., 2006); its generation is daily and are considered a problem due to factors such as: demographic expansion, lack of economic resources in municipalities, deficiencies in education and environmental awareness. This problem is reflected in a poor collection system of MSW, scarce cleaning of public areas and the existence of dumps that are sources of pollution and damage the landscape beauty (Gonzales, 2021).

In the city of Jaen there is evidence of a population growth, this brings with it more generation of MSW. Added to this is the lack of environmental commitment of society to collaborate with the segregation and recovery of waste before being delivered to the collection service carried out by the Sub Management of Public Cleaning of the MPJ. This reality causes the generation of inadequate waste disposal areas and the possible purchase of vehicles for the raw collection of MSW (Campos & Cubas, 2022).

Through the solid waste management information system (SIGERSOL), the MPJ in 2019 reported that it has five CRC of manual load and fixed box, with an average capacity of 6.2 m^3, whose daily collection only serves 62 m^3 of RSM, Thus there is a gap regarding the amount of waste that is actually generated in the city evidenced in the continuous presence of areas intended for informal and illegal storage which generates unrest in the population (Campos & Cubas, 2022).

Hernández and Santana (2018) State that the vehicles used for the collection and transport of MSW must be according to the needs of the city and complying with the routes that are designed and facilitate the journey of vehicles in order to collect 100% of the MSW generated in the city. Huaccha (2017) argues that the CRC develop the collection service according to the mechanical state and the financial viability of the operation, which translates into alterations of route, frequency and coverage in specific areas of the city under different circumstances. The collection of MSW is a challenge according to the characteristics of the terrain, climatic conditions and limited space for CRC.

Zafra (2009) states that the production of MSW varies over the years, due to the

economic development and type of consumption of society, which is reflected in the high generation of MSW generating an environmental problem. Ronen et al. (1983) They note that methodologies need to be applied to correctly estimate the appropriate number of CRC needed to serve a locality. In addition, the collection of MSW is the responsibility of the authorities and comprises between 5 and 25% of municipal expenditures (McLeod & Cherrett, 2011).

Under this context, the research aims to (1) characterize the generation of MSW generated in the years 2013, 2015, 2017 and 2019, (2) estimate the demand for CRC needed in the MSW collection service in the years 2013, 2015, 2017 and 2019, (3) project the future demand for CRC needed for the MSW collection service in the city of Jaen.

2 | MATERIALS AND METHODS

2.1 Location of the study

The research was carried out in the city of Jaen, district and province of Jaen. It is located in the North Eastern sector of the Cajamarca region, at an altitude of 732 m. with a maximum temperature of 33 °C and a minimum of 12 °C and a precipitation of 780 mm per year (Figure 1).

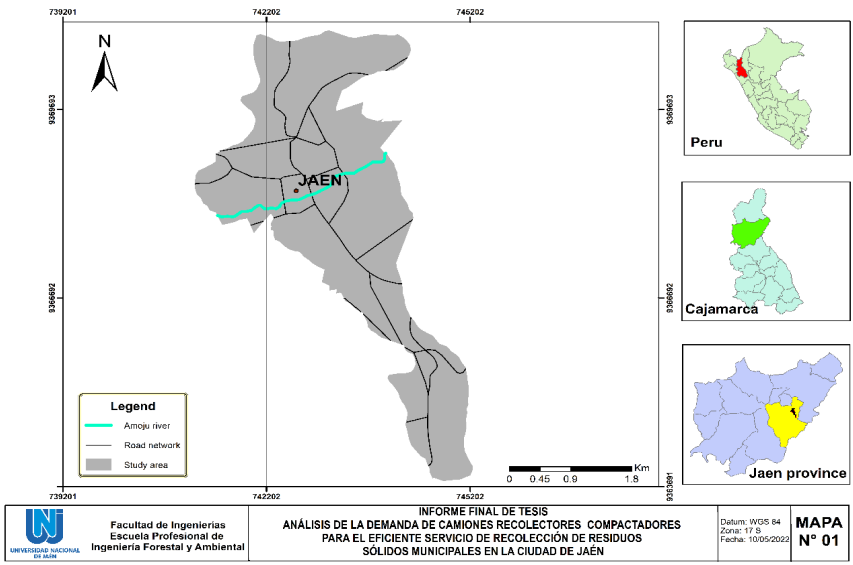

Figure 1. Study area location map.

2.2 Data collection

The data were taken from documents approved and published by the MPJ and the Ministry of the Environment of Peru (MINAM) considering observations referring to the systematic, valid and reliable recording of the data collected. The data of the ECRS of the MPJ were collected and classified according to the type of waste in order to determine the percentage of generation in the period of occurrence of the characterization studies. In addition, MSW per capita generation (GPC) data were taken in 2013, 2015, 2017 and 2019 to determine the actual tonnes of MSW generated per day, and calculate the demand for CRC capacity of 8 m^3 considering the population increase and the geographical particularities of Jaen (road slope, direction of roads, access to controlled dump).

2.3 Estimation of the generation of design MSW (Gd)

Typical values were used for the peak coefficients of waste generation (weekly peak coefficient-Cps and daily peak coefficient of heterogeneous distribution-Cpddh) according to what was indicated by (Tejero et al., 2002). For the Cps was employed 1.6 for being Jaen a city that exceeds the threshold of 100,000 inhabitants in urban area, for the Cpddh was considered six days a week for the operations of collection of the MSW in Jaen, taking into account that on Sundays there is no municipal work. Its calculation was made by equation (1):

$$Cpddh = \left[\frac{7}{n}; 1 + \frac{7}{n}\right] \quad \ldots \quad \text{equation (1)}$$

Where, “n” represents the number of days per week in which MSW.

The calculation of Gd in t/day was made with the equation (2) proposed by

$$Gd = GPC * population * Cps * Cpddh \quad \ldots \quad \text{equation (2)}$$

2.4 Projection of future demand for CRC

To determine the amount of CRC needed for the next 20 years, the number of CRC itineraries per day was calculated using equation (3) proposed by Zafra (2009):

$$itineraries = \frac{Gd}{Vc * \rho c} \quad \ldots \quad \text{equation (3)}$$

Where, Vc is the cash volume of the CRC in m^3 (8 m^3) and ρc is the density of the MSW within the CRC expressed in t/m^3 (0.6 t/m^3); then the number of CRC trips per working day was estimated by equation (4):

$$trip = \frac{JL}{T_{itinerary}} \quad \ldots \quad \text{equation (4)}$$

Where, JL represents the working day (12 hours) and $T_{itinerary}$ (4 hours) is the total time of the itinerary of collection by the CRC in hours. Finally, the number of CRC required for the collection of MSW was calculated through equation (5):

$$CRC = \frac{T_{itinerary}}{trip} \quad \ldots \quad \text{equation (5)}$$

3 | RESULTS AND DISCUSSION

3.1 Generation per capita of MSW of the city of Jaen

With the records of the ECRS an increase of 1.6% is evidenced in the GPC between the years 2013 to 2015 and 2017 to 2019, however, the same does not happen between the years 2015 to 2017 period in which it is constant and an increase of 3.2% is observed in the GPC between 2013 and 2019 (Figure 2).

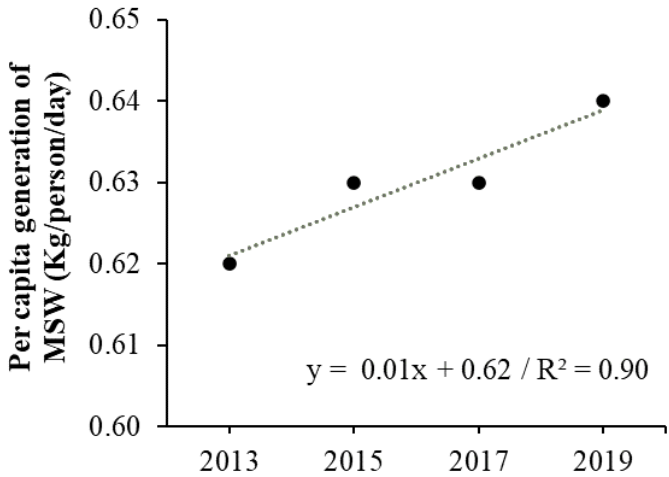

Figure 2. Generation per capita of MSW of the city of Jaen for the year 2013, 2015, 2017 and 2019.

3.2 Characterization of the MSW of the city of Jaen

The Figure 3 shows that organic matter is the component with the highest generation percentage during the four years with a linear growth from 2013 to 2017 and a decrease from 2017 to 2019, reaching the highest generation percentage (80%) in 2017. From 2017 to 2019 the components “paper, cardboard, plastics, polyethylene terephthalate (PET), foliage wood and others” show an increase of about 7%, however the waste classified as rest do not exceed 7% of the total generation.

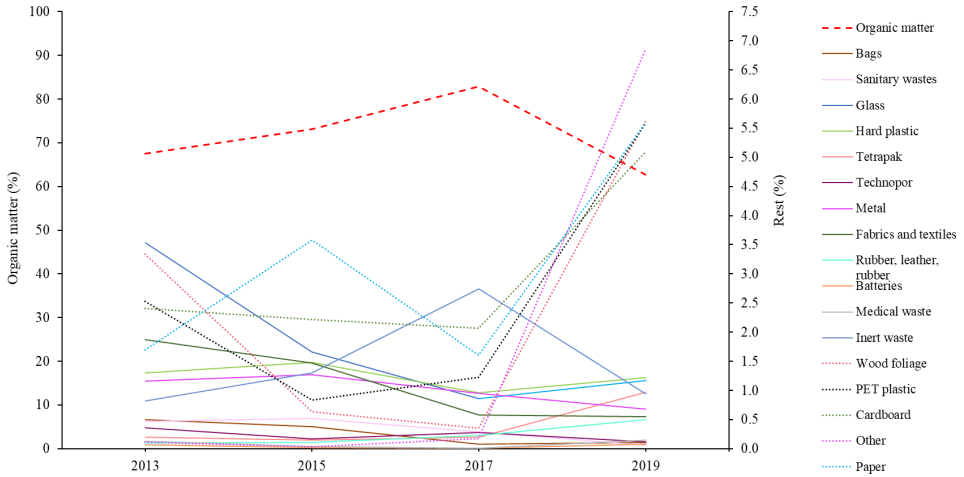

Figure 3. Characterization of the generation of MSW in the city of Jaen for the years 2013, 2015, 2017 and 2019.

It was evidenced that between 67 and 83% of the MSW generated in the city of Jaen corresponds to organic waste, data within the average reported for Latin America (Graziani, 2018) being an opportunity for its biological valorization through the composting process (Huamaní et al., 2020; Jaime-Huaman et al., 2021). Similar trends where the highest percentage of MSW corresponds to organic waste were reported in different studies (Burga, 2021; Cáceres, 2017; Castillo y De Medina, 2014; Salazar, 2013). This value of organic waste generation is due to the consumption habits of the inhabitants and the availability of products in the market (Durán et al., 2013); in contrast, in developed countries the percentage of organic matter is usually around 35% ((Siami et al., 2019). In addition, it was observed that plastic type PET presents between 0.8 and 5.6 % with results similar to those reported by (Jaime-Huaman et al., 2021; Ramírez et al., 2020; Ruiz, 2012), considering that the wide range of variation is due to the alterations in the consumption patterns of the population (Araiza et al., 2017) and to the containers without return manufactured with little or no degradable materials (Mosler et al., 2006).

3.3 Estimation of the generation of MSW design (Gd)

The Figure 4 shows that the generation of MSW takes into account the records of the ECRS (2013 to 2019) and thus the projection of the generation of MSW to 2039. It is expected that Gd will be higher than the generation of waste detailed in the ECRS since the latter do not consider the amount of fermented material, burned, thrown into sewers or urban pipelines, donated, sold and recovered for recycling (Tchobanoglous et al., 1994).

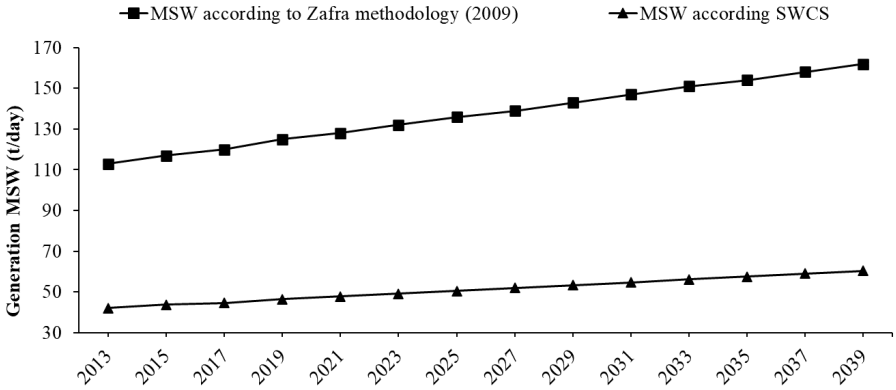

Figure 4. Generation of MSW according to the ECRS and the Zafra methodology (2009)

The per capita generation of MSW is in the range of 0.62 to 0.64 kg/hab/day, similar to that reported in the district of Panao, Huánuco whose GPC was 0.64 kg/hab/day (Cabello et al., 2020) and higher than the data reported in the district of Roque (Peruvian jungle) whose GPC was 0.42 kg/hab/day (León y Meléndez, 2017); similarly in the district of Huancabamba province of Oxapampa the GPC was 0.44 kg/hab/day (Quispe, 2018); these variations are related to population growth and the level of development of cities (Al-Khatib et al., 2010; Benítez et al., 1998).

The generation of MSW design taking into account the peak coefficients proposed by Zafra (2009) was 2.7 times the amount of solid waste estimated in the MSW characterization studies; this result is due to the fact that the tip coefficients consider fermented waste, burned, thrown into sewers, pruning, cleaning of gardens, holidays, waste sold and recovered through recycling (Tchobanoglous et al., 1994), added to this, MSW characterization studies do not consider the floating population, therefore they underestimate the generation of MSW (Rhyner et al., 2017).

3.4 Number of CRC itineraries and trips per working day.

The Table 1 shows the number of itineraries and trips that the CRC must make for the collection service of the MSW of the city of Jaen considering the 12 hours of work and the time it takes each CRC to make a trip (start and end of journey).

items	unit of measure	year			
		2013	2015	2017	2019
Gd	t/day	113	117	120	125
itineraries	itineraries/day	24	24	25	26
Number of trips	trips/working day	3	3	3	3

Number of CRC needed to meet the demand for collection of MSW

Table 1: Number of CRC itineraries and trips per working day.

The Figure 5 shows the amount of CRC with capacity of 8 m^3 needed to provide a collection service in the city of Jaen, being necessary to purchase an additional CRC of 8 m^3 every eight years, this considering that the city of Jaen maintains this same population growth and the same trend regarding the generation of MSW.

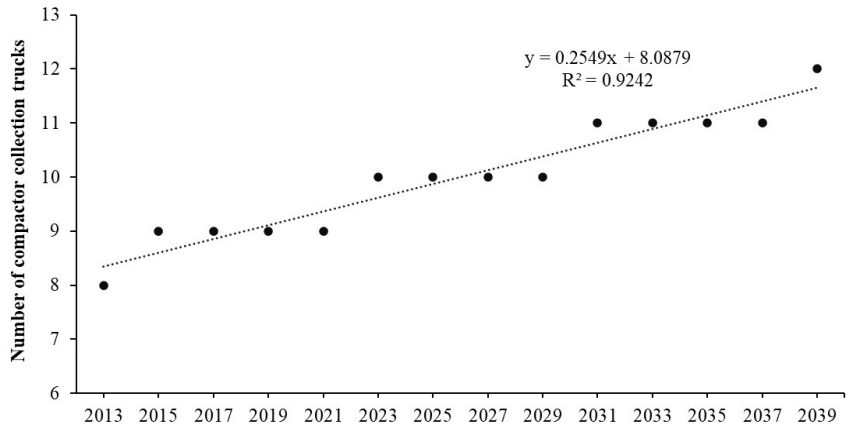

Figure 5. Projection of CRC required between 2019 and 2039

The city of Jaen has four CRC that are operational, however, due to the lack of availability of CRC, inadequate vehicles are used for the collection of MSW as a van, baranda truck, dumpers and trucks that generate problems of cumulus - waste spillage on public roads, inadequate transport and different collection routes, so it is necessary to have adequate vehicles for the collection and transport of MSW, in order to improve the quality of management of MSW (Huaccha, 2017). Considering the generation of design and the physiographic particularities of Jaen (Huaccha, 2017; Ronen et al., 1983) it was determined that Jaen does not have the number of CRC needed to provide the MSW collection service, and that this number of CRC would be increased by one every eight years taking into account population growth and the per capita generation of MSW, what is of the utmost importance to know the absolute amount of CRC necessary to cover the real demand in

the study area (Hernández & Santana, 2018), additional to this, collection routing should be considered in order to be more efficient in this work (Ronen et al., 1983), it should also be considered that for proper management of MSW should prioritize the collection and transport system from its origin to its final disposition, to improve the quality of life of the population and the conservation of natural resources (Cárdenas-Ferrer et al., 2019).

4 | CONCLUSION

The results show that the city of Jaen by 2019 needed 9 CRC of 8 m^3 capacity and that it would be increased by one every eight years so it is necessary to have adequate vehicles available for the collection and transport of MSW, in order to improve its management in the city of Jaen since to date it has four CRC resulting in a deficit which leads to the use of inadequate vehicles and limits the collection service of MSW in the city of Jaen. It is also necessary for the MPJ to develop annual ECRS in several periods in order to have a more specific vision on the generation and physical composition of MSW.

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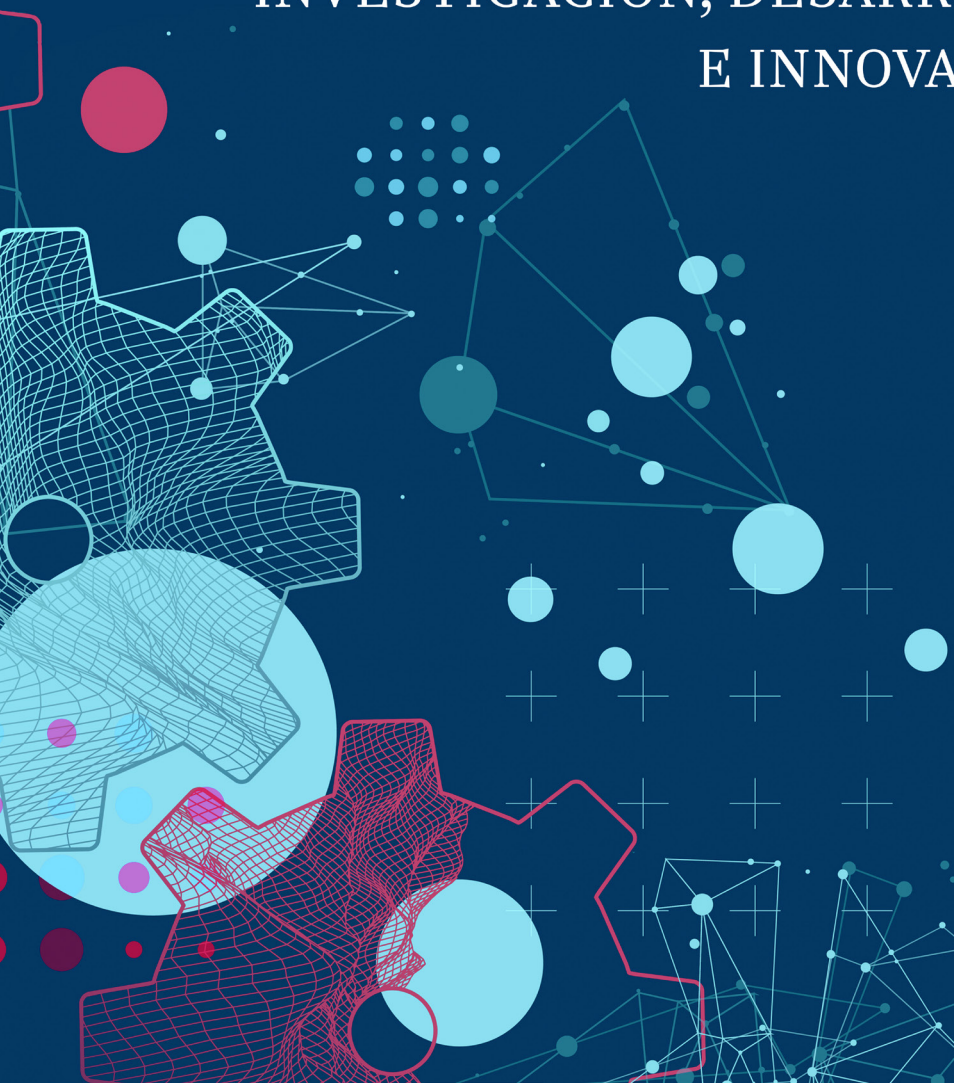

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