WEB-GIS Platform to Visualize Small and Medium Enterprises with Circular Business Models in Mexico

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Abstract. The Circular Economy is a visionary concept for a new economic paradigm. It is founded on three fundamental principles: I) To regenerate nature by shifting our economy from linear to circular to preserve and enhance natural capital by controlling finite reserves and balancing renewable resource flows. II) To optimize resource yields by distributing products, components, and materials with their maximum utility in both technical and biological cycles (to pre-serve an extended life of products; and responsible use and manufacturing). III) To promote system effectiveness by detecting and eliminating negative externalities from the design (use waste as a resource). The Circular Economy advocates for specific measures to advance this model, encompassing additional actions beyond the established 3R principle of "Reduce, Reuse, and Recycle". These additional actions are known as the R-ladder or the 7-R hierarchy. This hierarchy was used to filter economic units from the 2019 Economic Census in Mexico (released by INEGI) to classify micro, small and medium-sized enterprises (MSMEs) that perform activities related to the circular economy principles. In fact, MSMEs companies (MIPyMES for their acronym in Spanish) dominate the nation's commercial landscape, comprising 99.8% of all businesses. The intention of this research is to create a web-GIS platform to visualize and empower businesses, especially micro, small and medium companies, that are contributing and will keep contributing to achieve the three circular economy principles. A web-GIS platform prototype was created using ArcGIS Pro soft-ware and the ArcGIS Online platform. According to the results, a total of 44,943 micro, small, and medium-sized companies across three Mexican states are involved in Circular Economy practices, although many remain unaware of their participation in this model. These companies can foster improved, sustainable employment opportunities. Efforts are underway to process and incorporate data from an additional 29 states into the Circular Economy Platform. Similar procedures will be implemented for the remaining Mexican states to ensure comprehensive nationwide coverage.

Keywords: Micro, small, medium companies, MSMEs, MIPyMES, economic units, circular economy, WEB-GIS platform.

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1 Introduction

1.1 Circular Economy

Our existing economic model adheres to linear production patterns, characterized by production, consumption, and waste, fostering an unsustainable environment that ac-celerates the depletion and degradation of our natural resources. It is within this context that the proposal for a Circular Economy model emerges. The Circular Economy is defined as "*an economic system designed to uphold the continued utility and value of products and their components, fostering a continuous cycle of sustainable develop-ment that safeguards and enhances natural capital, while optimizing the use of finite resources*"[1]. The Circular Economy (CE) is founded on three principles:

Principle 1: To regenerate nature by shifting our economy from linear to circular to preserve and enhance natural capital by controlling finite reserves and balancing renew-able resource flows.

Principle 2: To optimize resource yields by distributing products, components and materials with their maximum utility at all times in both technical and biological cycles (preserve an extend life of products; and responsible use and manufacturing of products).

Principle 3: To promote system effectiveness by detecting and eliminating negative externalities from the design (use waste as a resource).

Fig. 1 shows in detail what circular economy involves. It is known as the butterfly diagram.

According to the above principles, one of the main guidelines of the circular economy is to ensure that products, materials, and resources have a longer life and are not destroyed but reused. With this, it will be possible to eliminate a large percentage of waste that ends up in open dumps and to eliminate CO_2 emissions. By promoting the reuse of materials and energy, harmful impacts on the health of current and future generations are reduced and natural capital is preserved. Through a circular approach then, CE can significantly contribute to reducing waste, increasing resource efficiency, and promoting sustainable development [2, 3].

To successfully implement the circular economy model, it is imperative to engage various sectors of production, ranging from policymakers and legislators to end consumers who procure and dispose of finished products.

This transition requires a concerted effort toward a systemic and comprehensive transformation. As illustrated in Fig. 1, the Circular Economy advocates for specific measures to advance this model, encompassing additional actions beyond the established 3R principle of "Reduce, Re-use, and Recycle".

The rise of ecological concern has made the 3R principle evolve to currently 7Rs (Reduce, Reuse, Recycle, Redesign, Renew, Repair and Recover), also known as the 7-R hierarchy [4]. Another version of these additional actions can be organized in what is known as the R-ladder [3]. It can be used as a checklist for designers and innovators (see Fig 2). This ladder is used to prioritize strategies and actions towards
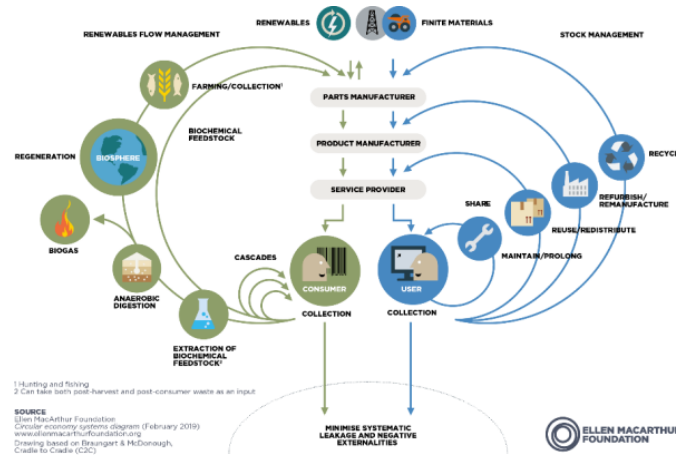
Fig. 1. The butterfly diagram explains in detail the three principles of circular economy.

Fig. 2. The R-Ladder [3] also known as the circular economy hierarchy.

circular economy so that the higher R up on the ladder, the more impact a solution has.

1.2 Directory of Economic Units (DENUE)

The National Statistical Directory of Economic Units (DENUE) is the minimum infra-structure of the National Economic Information Subsystem (SNIE) whose purpose is

Fig. 3. Number of establishments and enterprises censed by INEGI in 2023.

Table 1. Businesses classification by the number of employees.

Size	Number of employees	Annual sells (range) in Mexican pesos
Micro	1 - 10	4 to 4.6 million MXN
Small	11 - 30	40 to 100 million MXN
Medium	31 - 100 (commercial) 51 - 100 (services)	100 to 250 million MXN

to provide both, specialized and non-specialized users, with the identification, location, and contact data of the economic units active in the national territory for decision-making support and to optimize resources in both the public and private spheres. This data was also created to facilitate the development and assessment of public policies and economic development programs at all three tiers of government. The DENUE was created, and it is managed and updated by the Mexican National Institute of Statistics and Geography (INEGI). There, economic units are cataloged and categorized into two distinct groups: establishments and enterprises [5].

− **Establishment:** this category refers to an economic unit firmly rooted in a solitary physical location, demarcated by fixed structures and installations, and combining efforts and resources under the governance of a single owner or controlling entity to conduct various economic activities, whether for profit or not. This category includes domiciles where economic activities are undertaken, while excluding those pursued solely for self-consumption, and services rendered off-site. Also, information regarding activities in the manufacturing industry, commerce, private non-financial services, and financial and insurance services pertains to this unit.

− **Enterprise:** This refers to an organization, owned by a single legal entity, engaged in one or more economic activities, possessing autonomy in marketing,

financing, and investment decisions, and vested with the authority and responsibility to allocate resources in accordance with a production plan or strategy for goods and services. Such entities may be situated or operate across multiple locations.

The Directory excludes economic units conducting itinerant activities or those with demountable premises that are dismantled daily. One of the major advantages of using the DENUE database is that the directory is continuously updated by authorized in-formants, who can update or supplement the data of their businesses and incorporate commercial information online through the application found in the technical file of each economic unit. This information was previously validated by INEGI [6].

The economic units are already georeferenced. INEGI offers the information for free at its website and it can be downloaded in cvs or shape file format. This way, it was easier to manage data by state. The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S [7]. It has also become the standard for Mexico and Canada because of the free trade agreement (NAFTA) among these three countries. So, it is mandatory for INEGI to publish statistical data about economic activities using this standard [8].

1.3 Micro, Small and Medium Business (MSMEs)

According to INEGI [9], micro, small and medium-sized businesses are given their category by the number of their employees, as shown in table 1.

Based on the 2019 Economic Census results released by INEGI, micro, small and medium-sized enterprises (MSMEs) dominate the nation's commercial landscape, comprising 99.8% of all businesses. Among the 4,773,995 economic units scrutinized across both the private and parastatal sectors by INEGI, 95% fall within the micro-sized category (0 to 10 employed persons), 4% fall within the small-sized category (11 to 50 persons), and 0.8% are classified as medium-sized enterprises (51 to 250 persons). Merely 0.2% are categorized as large-scale enterprises (exceeding 251 persons) [9].

Moreover, MSMEs collectively contribute 68.4% to the overall tally of businesses, with micro-businesses accounting for 14.2% of the total generated income, small businesses for 16.1%, and medium-sized businesses for 21.9%. Consequently, MSMEs are responsible for generating 52.2% of the total income derived from commercial activities.

1.4 Sustainable Development Goals (SDG)

In 2015, during the Sustainable Development Summit held from September 25 to 27 in New York, the countries part of the UN approved the 2030 Agenda in which the 17 Sustainable Development Goals (SDGs) are established (see Fig.4). The 2030

Fig. 4. Sustainable Development Goals [10].

Agenda sets out these 17 Goals with 169 integrated targets covering the economic, social and environmental spheres. It will govern global development programs for the next years.

The States signed up to it are committed to mobilizing the necessary resources for its implementation through partnerships focused especially on the needs of the poorest and most vulnerable [6].

The Circular Economy is not indifferent to the Sustainable Development Goals (SDGs) or the 2030 Agenda; on the contrary, it can help to achieve it by supporting job creation, counteracting social problems arising from unemployment, and promoting social sustainability. Circular economy also has a strong potential to transform society toward environmental, economic, and social sustainability [11]. This project looks for contributing to the following SDG by generating information to these specific targets:

− SDG 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all (targets 8.2, 8.3, and 8.4).

− SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (targets 9.2, 9.3, 9.5, 9.b and 9n.3).

− SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable (target 11.6).

− SDG 12: Ensure sustainable consumption and production patterns (target 12.5 and 12n.1).

Table 2. Some SDG that this project seeks to contribute to, specific targets and their indicators.

SDG	Target	Indicator
SDG 8	8.4 Progressively improve, by 2030, the efficient production and consumption of global re-sources and strive to decouple economic growth from environmental degradation, in line with the 10-Year Framework of Programs on Sustainable Consumption and Production Patterns, starting with developed countries.	8.4.2.a Domestic material consumption in absolute terms.
SDG 9	9.n3 Increase the contribution of micro, small, and medium-sized enterprises to employment and GDP.	9.n3.1 Percentage of employed personnel generated by MSMEs (includes salaried, non-salaried and jobs provided by another co-pany).
SDG 11	11.6. By 2030, reduce the per capita negative environmental impact of cities, paying special attention to air quality and municipal and other waste management.	11.6.1.a Percentage of municipal solid waste collected and disposed of appropriately.
SDG 12	12.5 By 2030, significantly reduce waste generation through prevention, reduction, recycling and reuse activities. 12n.1 Promote the circular economy in production and consumption chains, understood as the redesign of products and services to reduce waste at the end of their useful life and from a shared value perspective.	12.5.1.a Percentage of municipal solid waste collected that can be recycled. 12n.1.1 Percentage of municipalities with adequate disposal of urban solid waste

– SDG 13: Take urgent action to combat climate change and its impacts (target 13.3).

An example of how this platform can help create information to achieve SDG at local level is shown Table 2. INEGI is also responsible for monitoring SDG in Mexico.

All the targets and specific indicators and their evolution through years is of public access at the web site Agenda 2030 [11].

2 Research Objectives

To develop a geographically referenced GIS/Web platform prototype aimed at visualizing and advancing businesses dedicated to the reuse, remanufacturing, recycling, etc., of products, from DENUE datasets and enriched by crowd mapping.

2.1 Specific Objectives

− To classify and refine the DENUE platform to extract data concerning micro, small, and medium-sized enterprises actively involved in any of the R-ladder activities (product repair, remanufacturing, and recycling, etc.).

− To map out the businesses identified in the analysis of the DENUE on an online GIS platform to visualize the micro, small and medium-sized companies involved in the circular economy ladder activities (R ladder) in Mexico.

− To establish the pioneering platform in Mexico that advocates and consolidates business information encompassing all facets of the Circular Economy (R hierarchy).

3 Materials and Method

The materials used for this project are:

− Database of the National Statistical Directory of Economic Units (DENUE). Version 2019 (datasets) in vector files (georeferenced points).

− Map Digital Software version 6.3. Open software (v6.3) developed by INEGI.

− ArcGIS Pro Software and ArcGIS Online (for the creation of the WEB platform)

For the development of this research, the following steps were involved:

1. The DENUE database was downloaded from the INEGI website, for entities of the Mexican Republic.

2. Only three entities were selected for the web-platform prototype: Mexico City, Hidalgo and Aguascalientes. There was no specific reason to choose these states except that we wanted to include at least a state with large (Mexico City), medium (Hidalgo) and small number of economic units (Aguascalientes).

3. All the original data in DENUE is classified according to the NAICS standard used in the US, Mexico and Canada. Codes from the North American Industry Classification System (NAICS) were analyzed to find potential activities related to Circular Economy. For example, shoes repairing has the NAICS code: 316214. Repair of leather footwear and other leather goods has the NAICS code: 811430.

4. Then, these codes were filtered in the DENUE database of each state to save them in another file containing only these registers. Some fields from the dataset with no relevant information were eliminated. The databases were purged, eliminating all but the following categories:

   − Rental,

   − Alignment and balancing,

   − Confection,

   − Industrial design,

- Waste management,

- Repairs,

- Cleaning services,

- Tire revitalization (vulcanizers),

- Remediation,

- Treatment and final disposal.

5. A new field for each dataset was created. The new field contained a new R-category assigned to each company (depending on its original NAICS code and its activities and the R in the R-ladder that best suits it).

6. Additionally, some new categories such as public infrastructure for wastewater treatment, remediation, collection, and hazardous waste treatment were created to sub-classify the database. This, to differentiate activities that are not part of the R-ladder but could contribute to circular economy goals.

7. The "Rental" category was created (for all business codes regarding rental activities).

8. The "Collection and/or recycling" category was created to group solid waste companies that perform one or both activities.

9. The database was reviewed again, and certain companies (company name) were randomly selected to verify on the web what they do and to refine their classification in one of the created categories.

10. The verification was performed to check if certain businesses still existed. Google Streetview was used to corroborate that the business exists (because in the pandemic some businesses may have closed). It is important to mention that this verification was done during the Covid-19 pandemic lockdown period in 2021.

11. Once the records were reclassified into one of the R categories, the files were ex-ported as new georeferenced files (shapefiles) to integrate them into a GIS online platform.

3.1 Integration of Layers to the Platform

12. The suite ArcGISPro (which includes ArcGIS Online) was used to create the web platform prototype. The reclassified database (vector file) was uploaded as a point layer (each point represents an economic unit) and each layer contains all the data for a particular state (Mexico City, Aguascalientes or Hidalgo).

13. Each layer was added a legend to identify the R-ladder categories with a single color each.

Table 3. Economic units (MSMEs) before and after the reclassification process.

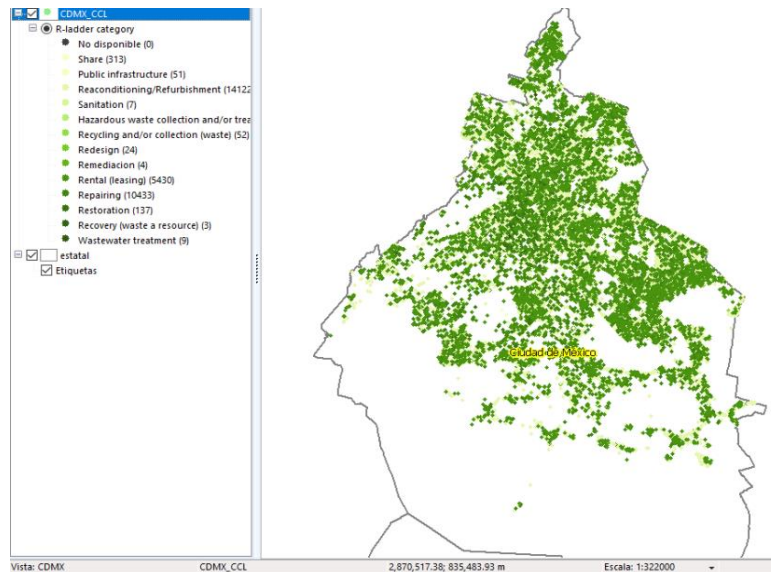| Mexican State	Economic Units in	Economic units (MSMEs) after
	Denue 2019	Reclassification using the R-ladder
Mexico City	476553	30607
Hidalgo	120570	10175
Aguascalientes	57840	4161
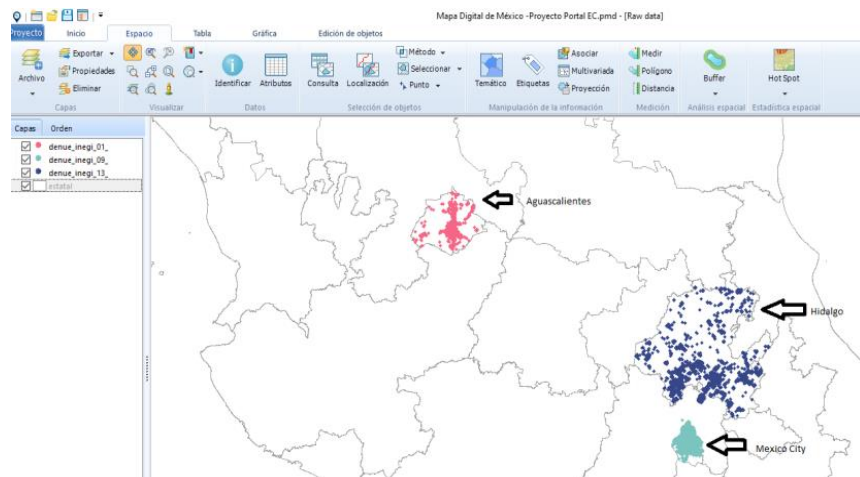
Fig. 5. Economic units in DENUE 2019 in Mexico City, Aguascalientes and Hidalgo.

14. Finally, the map created with the different layers was published as a Web Map so that anyone interested in finding a place or business that promotes any activity of the circular economy R-ladder can find its location.

4   Results

The original DENUE database containing approximately 675,261 economic units within the states of Mexico City, Hidalgo and Aguascalientes, was reduced (through the R-ladder filter classification) to less than 45,000 units involved in a circular economy activity. Table 3 shows the original number of economic units in each state (Fig. 5) and the numbers after the reclassification using the R-ladder.

There were some instances of ambiguity in classifying certain businesses. Some NAICS codes were difficult to reclassify because they comprised many kinds of companies and not necessarily all of them were related to circular economy activities. In the future, we want to automate this reclassification process using machine learning techniques, but at this point, all was done by human analysis.
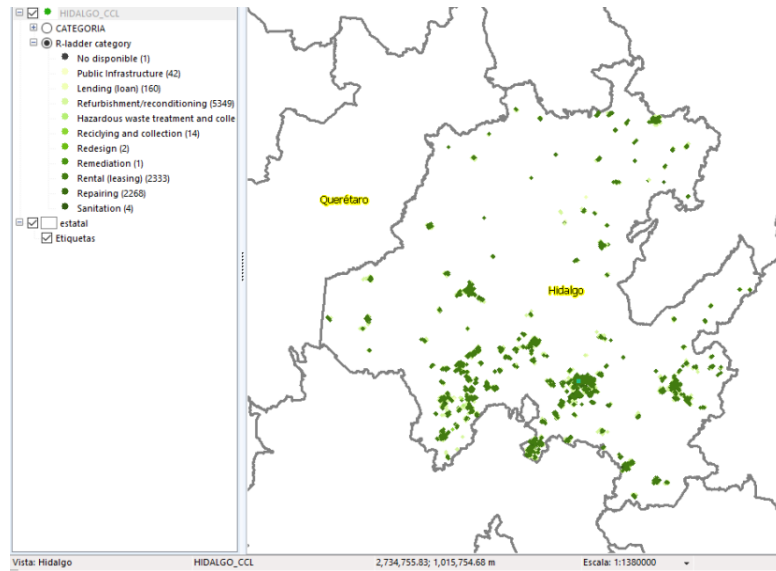
Fig. 6. Economic units with circular economy related activities in Mexico City.

We decided to keep some economic units entirely in a new category. For example, bioremediation service companies. Bioremediation would be a form of "recovery", but we decided to keep it in its own category and include it in the platform because of the relevance of these companies to preserving natural capital.

4.1 Reclassification of Economic Units (Micro, Small and Medium Businesses)

In Mexico City, according to the reclassification results, we found 30607 economic units that potentially do circular economy activities. They got subclassified like this (Fig. 6):

− 14122 are within the Reconditioning/Refurbishment category • 10433 are in the Repairing category,

− 10433 are in the Repairing category,

− 5430 Rental (loan),

− 313 Sharing,

− 137 Restoration,

− 52 Recycling and/or waste collection (micro and small places that receive materials such as plastics, paper, metal, etc., to sell them to bigger companies),

− 51 Public infrastructure,

− 24 Redesign,

− 22 Collection and treatment of hazardous waste,

− 9 Wastewater treatment companies,

Fig. 7. Economic units with circular economy related activities in Hidalgo.

- 7 Sanitation companies,

- 4 are Remediation (wastewater or waste) companies and

- 3 are Recovery (waste as resource) consultancies.

As for the state of Hidalgo, the number of economic units within an R-ladder activity is 10175. At the same time, they are subclassified as follows (see Fig. 7).

- 5349 belong to the Refurbishment and/or Reconditioning category,

- 2268 belong to the Repairing category,

- 160 economic units are in the lending (loan) category (for example, book loans in public libraries). This category is not in the R-ladder, but it is considered a circular business model since it changes the focus from selling to lending something, thus contributing to the circular economy's second principle,

- 42 economic units are public infrastructure (such as water treatment plants, vehicle emissions check centers),

- 14 are Recycling/waste collection centers,

- 4 are Sanitation businesses,

- 2 are design companies (Redesign),

- 1 is a Remediation company and

- 1 is a hazardous waste treatment company.
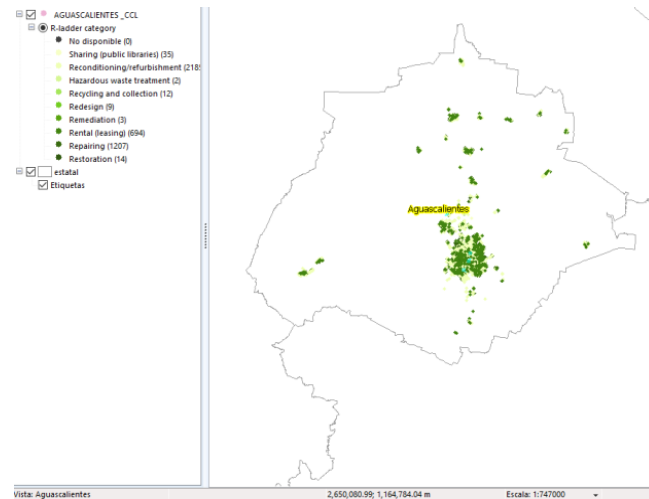
Fig. 8. Economic units with circular economy related activities in Aguascalientes.

Finally, for Aguascalientes we found 4161 economic units divided into the following categories (see Fig. 8).

− 2185 belong the reconditioning/refurbishment category reconditioning/refurbishment category,

− 1207 are repairing businesses,

− 695 are rental (leasing) companies,

− 35 are sharing entities (such as public libraries),

− 14 are within the restoration category,

− 12 are recycling and collection centers,

− 9 are redesign companies,

− 3 are remediation companies,

− 2 are hazardous waste treatment companie.

4.2 Circular Economy Web-Platform Prototype

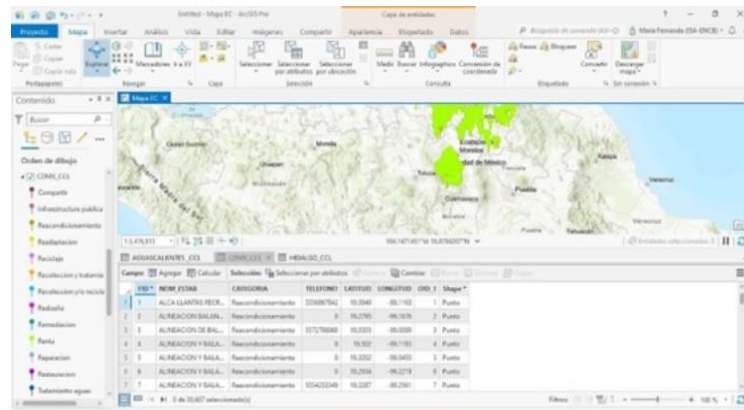The web map showing SMMEs with R-ladder activities is shown in Fig. 9.

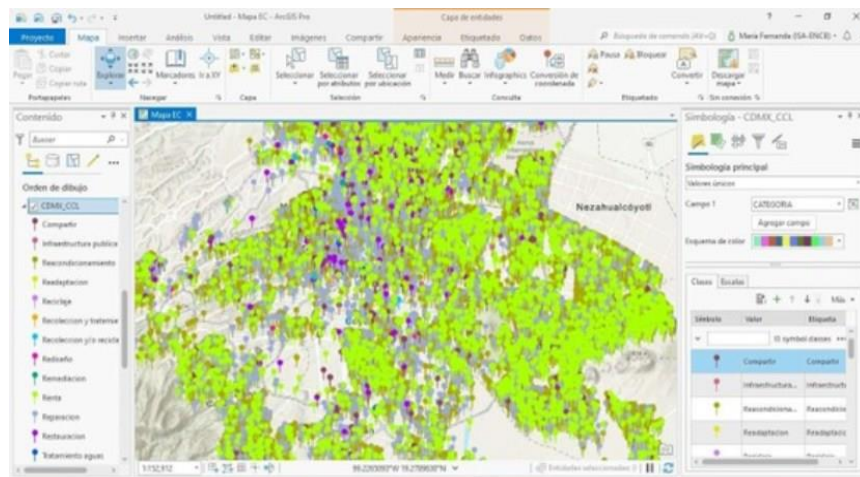**Fig. 9.** Web-GIS layout using ArcGIS Pro.

Fig. 10. Points representing the economic units with R-ladder activities in Mexico City.

ArcGIS Pro and ArcGIS Online are partner platforms that enable users to create, explore and visualize georeferenced information. They also allow data from multiple sources to be integrated, edited and analyzed to perform spatial analyses among many other things. In addition, the ArcGIS suite enables the creation of geographic data platforms and websites without the hassle of computer programming. This is the reason this software was chosen for the creation of the circular economy platform. Arc GIS Online was used to create the web platform prototype.

Each state has a different number of economic units. However, since all the information provided by INEGI is already georeferenced and standardized to the Mexican norms to publish geographic information it was no problem at all to upload the data for the EC platform in the same standard.
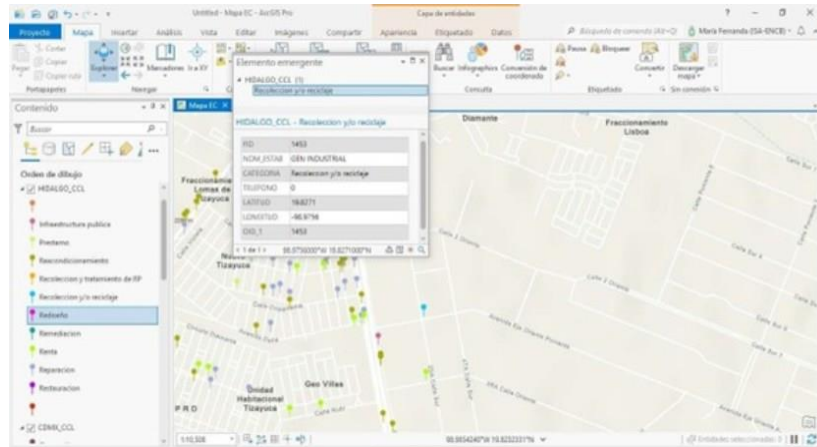
Fig. 11. Web-GIS platform prototype showing details of an economic unit in Mexico City.

A unique color for each R-ladder category was set for the three layers (CDMX, Hidalgo and Aguascalientes) to easily identify each R (see Fig. 10).

We are still working on improving the visualization feature to make it as user-friendly as possible. In another step of this project, we also aim to use the platform as an educational tool to explain what circular economy it is about and how it relates to the activities that many MSMEs do.

Before publishing the Web-map in ArcGIS Online, some points were randomly checked so that the descriptive table corresponds to the R-ladder category assigned (see Fig. 11)

Beyond visualization, this platform aims to provide quantitative and qualitative in-formation of companies engaged in circular economy activities and be a data analysis source of MSMEs involved in CE. According to Nery et al, digital technologies can be used to foster the circular transition by MSMEs [12] and MSMEs can accelerate the global green transition due to their proximity to the local environment and work force. [13]. However, while large enterprises and policymakers have made steps in adopting CE practices, small and medium-sized enterprises (SMEs) face unique challenges due to limited resources and expertise [14].

The web-GIS platform can be accessed in the following link: https://arcg.is/8THKP0.

5   Conclusions

According to the results, a total of 44,943 micro, small, and medium-sized companies across three Mexican states are involved in Circular Economy practices, although many remain unaware of their participation in this model. The platform aligns the eco-nomic units and their activities with the R-Ladder which at the same time is a hierarchical way to present the three principles of circular economy.

One of the main challenges of the reclassification step was to select DENUE codes (in NAICS standard) that relate to activities on the circular economy ladder and reclassify them into some R (repair, remanufacturing, recycling, etc.). Although there is room for further improvement the categories shown are true to their activity.

Efforts are underway to process and incorporate data from an additional 29 states into the Circular Economy Platform. Once the NAICS codes related to circular economy activities are identified, it is easier to filter them out in any other state database. Still, we are coming up with an algorithm to download and process the information automatically (from the DENUE website) so that it can be updated at least every year.

Completing and updating the GIS platform is crucial to release the platform to the public. The crowdsourcing tool is not ready yet, but its intention is to provoke public involvement in support of circular economy activities and, at the same time, be a way to keep the platform updated. We will make sure to implement a similar procedure as INEGI does. Since DENUE is under control of the Mexican Institute for Geography and Statistics and all the information is censed and updated using international standards, our data (DENUE) will also be reliable for next years.

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