RECYTRONIC:
a proposal for an automated recycle center in Cuernavaca, Morelos, Mexico

Ana Daniela Carmona Salgado
Estudiante de 3° de Preparatoria, área Físicos Matemáticos
Universidad La Salle Cuernavaca
carmonasalgadoanadaniela.prepa221@lasallecuernavaca.edu.mx

Leonardo Gael Estrada García
Estudiante de 3° de Preparatoria, área Físicos Matemáticos
Universidad La Salle Cuernavaca
estradagarcialeonardogael.prepa221@lasallecuernavaca.edu.mx

Daniela Guerrero Morales
Estudiante de 3° de Preparatoria, área Físicos Matemáticos
Universidad La Salle Cuernavaca
guerreromoralesdaniela.prepa221@lasallecuernavaca.edu.mx

Fernando Yael Luna Domenech
Estudiante de 3° de Preparatoria, área Físicos Matemáticos
Universidad La Salle Cuernavaca
lunadomenechfernandoyael.prepa221@lasallecuernavaca.edu.mx

Abstract

This project, developed by a team of high-school seniors as part of the course of Research Methodology aims to apply basic notions of Mechatronic Engineering to propose the implementation of an automated recycling center in Cuernavaca. This project wants to contribute to making a more sustainable community by helping to the fulfillment of the Sustainable Development Goals of the United Nations and the 2030 Agenda, specifically to Goal 11, which refers to *"Make cities and human settlements inclusive, safe, resilient and sustainable"*, and to Goal 12, which refers to *"Ensure sustainable consumption and production patterns."*

Keywords: Mechatronic Engineering, recycling, automatization, waste management, sustainability, Sustainable Development Goals, 2030 Agenda.

Presentation and relevance of the study

Have you ever gone out for a walk to the park where you enjoyed going as a child and found that it has changed for the worse, since it is dirty or with garbage, which makes you wonder how we have been ruining the spaces that are meant to be enjoyed and that they will probably never be like that again? Well, we have noticed it, and we want to do something about it, so we developed a project to try to reverse this damage we have done. We Mexicans have reached a critical point, since we generate 70% of material waste, in mass this is equivalent to 42,106 million tons annually or 115,359 tons per day, each inhabitant of the country contributes by generating an average of 0.99 kg of waste per day1[1]. Mostly inorganic such as PET, glass, cardboard and metals. Which is something extremely worrying since at this point, we will end with everything we had, and that future generations will not have.

The main goal of this project is to create an automated recycling center aiming to help people get a job by managing the process and operation of the recycling facility in the city, as well as to reduce the amount of waste sent to landfills and incinerators, which also reduces the carbon emissions sent to the atmosphere contributing to climate change and keeping the streets clean. This will clearly help in improving the health of the citizens, as the environment will be less polluted.

The main hypothesis of this project envisions to contribute to the sustainability of Cuernavaca by establishing an automated recycling center. The center, equipped with robots, will

1 "Residuos sólidos urbanos: una problemática ambiental y oportunidad energética", **CIENCIA UANL**: https://cienciauanl.uanl.mx/?p=9350#:~:text=En%20M%C3%A9xico%2C%2070%25%20de%20los,kg%20de%20residuos%20al%20d%C3%ADa, published on September 9, 2019.

efficiently separate reusable materials from waste, promoting the creation of new products. This initiative aims to reduce carbon emissions, minimize the exploitation of natural resources, and conserve energy, thereby fostering a more sustainable environment in the municipality.

In addition, the proposal introduces two secondary hypotheses. The first secondary hypothesis asserts that the implementation of an automated recycling center in Cuernavaca can contribute to achieving target 11.6.1, which aims to manage municipal solid waste in controlled facilities, as part of Sustainable Development Goal 11, which refers to "Make cities and human settlements inclusive, safe, resilient and sustainable". The project's success could be measured by statistical measures of resource consumption savings and reductions in disposal and treatment costs.

Likewise, the second secondary hypothesis is that through the proposal of automated recycling centers, it will be possible for Cuernavaca's city to achieve target 12.5 of reducing waste generation through prevention, reduction, recycling, and reuse of materials, as a part of Sustainable Development Goal 12: "Ensure sustainable consumption and production patterns." This project results will be measured through data in the increase of reused materials and products made from recycled materials, the reduction of natural resources exploitation and pollution.

The project will involve discussions from two key disciplines: Mechatronic Engineering, as the automated recycling facility relies on mechatronics for functionality; and Ecology, as the project is designed to consider and enhance environment as one of the basic spheres of sustainability. The focus will be on the municipality of Cuernavaca, Morelos, and information resources from 2010 to the present will be consulted for project development.

This document outlines the comprehensive planning process for the project, covering the main idea, hypotheses, anticipated difficulties, and historical and theoretical context. It emphasizes an analysis of the project's economic, ecological, and social aspects, weighing the pros and cons. The inclusion of expert opinions is highlighted to ensure informed decision-making for the project's successful conclusion.

Theoretical framework

History of Sustainability

The concept of sustainability, rooted in ancient civilizations' environmental challenges, gained momentum after

the Industrial Revolution, and escalated post-World War II. The term "sustainable development" emerged in 1980 and became prominent in the 1987 Brundtland Report[2], leading to the adoption of 17 Sustainable Development Goals (SDGs) by the UN in 2015. The automated recycling center project aligns with SDGs 11.6.1 and 12.5, addressing global waste management issues[3].

Goal 11.6.1 statistics reveal varying waste collection rates globally, with disparities in sub-Saharan Africa. COVID-19 impacted waste management, underscoring challenges. The 2022 update reports improvements, with a global average municipal solid waste collection rate of 82%, but sub-Saharan Africa and Oceania still face challenges[4].

Goal 12 focuses on e-waste, indicating a continuous global increase from 2010 to 2019. Environmentally sound recycling lags, and challenges persist, exacerbated by the COVID-19 pandemic. New regulations in 2021 aim to control the trade of plastic waste for improved transparency[5].

To achieve the recycling target for e-waste by 2030, the annual rate of growth in recycling must increase significantly from the past decade. The data underscores the urgency in addressing waste management and recycling challenges on a global scale.[6]

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2 "Our Common Future", **United Nations:** https://sustainabledevelopment.un.org/content/documents/ 5987our-common-future.pdf, published on 1987.

3 "Transforming our world: the 2030 Agenda for Sustainable Development", **United Nations:** https://sdgs.un.org/2030agenda, consulted on September 21st, 2023.

4 "Goal 11: Make cities and human settlements inclusive, safe resilient and sustainable", **United Nations** https://sdgs.un.org/goals/goal11, consulted on September 21, 2023.

5 "Goal 12: Ensure sustainable consumption and production patterns", **United Nations** https://sdgs.un.org/goals/goal12, consulted on September 21st, 2023.

6 *loc. cit.*

History of Mechatronics

History of mechatronics traces back to ancient philosophers like Aristotle and innovators like Leonardo DaVinci, who conceptualized automated tools and robotics. In the 1950s, William Grey Walter created the first mobile robots, "ELSIE and ELMER," demonstrating autonomous behavior with minimal sensory components.[7] The 1960s saw the creation of "SHAKY" at the Stanford Research Institute, a robot with tactile sensors and a vision camera.[8]

In the late 1960s, Tetsuro Mori from Yaskawa Electric Company coined the term mechatronics while applying the Kaizen technique to address operational issues. By the 1980s, microprocessors enhanced mechanical systems, and the 1990s witnessed the integration of computational intelligence into mechatronics, revolutionizing the field.[9]

Mechatronics has made significant contributions, including advancements in green building technologies, smart grids, and water management. However, it faces challenges such as high costs, complex software requirements, and energy consumption issues. Despite setbacks, mechatronic engineering continues to progress with innovations like advanced robotics, artificial intelligence integration, and multi-scale modeling. [10]

Currently, mechatronics plays a role in replacing unskilled labor with advanced technologies. Looking to the future, it is anticipated to be a transformative force, listed among the top 10

7 “History of Robots and Robotics”, **Robotnik:** https://robotnik.eu/history-of-robots-and-robotics/, published on November 2nd, 2021.

8 *loc. cit.*

9 “What is the History of Mechatronics?”, **ECPI University:** https://www.ecpi.edu/blog/the-history-of-mechatronics, consulted on September 17th, 2023.

10 “Ingeniería Mecatrónica: 6 Diseños Productivos”, **Blog UTAN:** https://www.utan.edu.mx/blog/index.php/6-cosas-interesantes-que-ha-disenado-la-ingenieria-mecatronica?hs_amp=true, published August 16th, 2018.

technologies that will change the world. Events like the automatic international fair in Germany underscore the importance of mechatronics in various fields, particularly industrial processes, where the implementation of new technologies is becoming crucial for enhanced production efficiency and may lead to the replacement of workers in large companies. [11]

Some theory on sustainability

The concept of sustainable development gained prominence in the 1980s with the UN's Brundtland Report,[12] defining it as meeting current needs without compromising future generations. It integrates environmental, social, and economic considerations, emphasizing responsible resource use. Scientific fields like ecology, environmental sciences, social sciences, and political and environmental law contribute to sustainability. Interdisciplinary collaboration is crucial for addressing global challenges comprehensively.

Sustainability, according to the United Nations, implies "meeting present needs without jeopardizing future generations."[13] UCLA's definition involves integrating environmental health, social equity, and economic vitality.[14] The 17 Sustainable Development Goals (SDGs) highlight interconnected objectives, including poverty eradication, health, education, economic growth, climate action, and conservation.

Businesses and governments are increasingly committed to sustainability, considering long-term impacts on people, ecosystems, and the economy. Green investments and sustainable business practices are growing but concerns about "greenwashing" exist. Sustainability aims to address climate change, biodiversity loss, and pollution through policies and practices.

The state-of-the-art reveals challenges in measuring and reporting Environmental, Social, and Governance (ESG) performance. Despite efforts, carbon emissions rise, and social inequality increases. The article suggests improving the quality of measurements, mobilizing society, and redirecting government funds. A collective agenda for sustainable development emphasizes a global

11 Qiancheng Xiong, "Overview of the Relationship between Mechatronic Engineering and Artificial Intelligence", **IEEXplore:** https://ieeexplore.ieee.org/document/9616601, consulted on September 17th, 2023.

12 "Our Common Future", *op. cit.*

13 Luis M. A. Bettencourt et al., "Evolution and Structure of Sustainable Science", **PNAS:** https://www.pnas.org/doi/10.1073/pnas.1102712108#F3, published on November 23rd, 2011.

14 "What is Sustainability?" **UCLA sustainability:** https://www.sustain.ucla.edu/what-is-sustainability/, consulted on September 18th, 2023.

approach and universal goals, fostering collaboration among all countries.[15]

SDG 10 focuses on reducing inequalities within and between countries, crucial for achieving sustainable development. Critics argue for systemic reforms, including trade rules and power redistribution. Insufficient data poses challenges for policy makers in guiding poverty reduction efforts and reporting progress. Criticisms of the SDG Index highlight discrepancies between Sweden's high index score and its large material footprint, indicating a need for more accurate assessments of sustainability. [16]

Some theory on Mechatronics

The research focuses on the interdisciplinary hybrid emerging from applied sciences, particularly mechatronics, environmental engineering, and ecology. Applied sciences utilize scientific knowledge to address practical problems, with natural sciences, including ecology, aiding in understanding the world. Engineering, stemming from applied science, involves designing machines and systems, leading to mechatronics and environmental engineering. Mechatronics deals with computer-controlled electromechanical systems, while environmental engineering addresses environmental issues through various knowledge fields.

The research topic revolves around the utilization of automated recycling centers employing robots. Recycling, defined as the process of transforming used materials for

15 "Are the Sustainable Development Goals the Best Approach to Sustainability?", **Future Learn:** https://www.futurelearn.com/info/courses/achieving-sustainable-development/0/steps/35496#:~:text=For%20those%20who%20criticise%20the,survive%20to%20see%20that%20date, consulted on: November 11, 2023.

16 "The World's Sustainable Development Goals Aren't Sustainable", **FP:** https://foreignpolicy.com/2020/09/30/the-worlds-sustainable-development-goals-arent-sustainable/, published on September 30, 2020.

reuse, forms the core of the project.[17] Recycling centers receive waste, sort it, clean it, and convert it into raw material for new products. The proposed automated recycling center involves robots, operated without human control, contributing to mechatronics.

The recycling process in the automated center begins with sorting robots, distinguishing recyclable from non-recyclable materials. Subsequently, separation robots categorize materials like plastic, paper, glass, and metal, and shredding robots reduce them to facilitate reuse. The process aims to optimize decision-making, enhance recovery rates, and contribute to sustainability.

However, there are diverse perspectives on the environmental impact of mechatronics. While some argue that integrating technology into recycling processes improves recovery rates and reduces environmental impact, others emphasize the environmental burden of manufacturing mechatronic systems due to materials like steel and cast iron. The concept of "green mechatronics" is proposed, suggesting an approach that integrates technologies to address social and economic needs while minimizing environmental harm.[18]

Methodology

In terms of methodology, the deductive approach is proposed. Factors to consider include machinery for waste separation, building construction, recycling equipment, location selection, and potential investors for the automated recycling center. [19]

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17 "Recycling", **Cambridge Dictionary:** https://dictionary.cambridge.org/es/diccionario/ingles/ recycling, consulted on September 16th, 2023.

18 José Antonio Aquino Robles, "La mecatrónica verde como actor y la lucha contra el cambio climático como escenario.", **ResearchGate:** https://www.researchgate.net/publication/ 310613393_La_Mecatronica_Verde_como_actor_y_la_lucha_contra_el_cambio_climatico_como_escenario, consulted on September 18th, 2023.

19 Verónica Vanessa Mora Blandón, et al., "Avances Tecnológicos para la Mejora del Reciclaje.", **ResearchGate:** https://www.researchgate.net/publication/ 355008373_Avances_tecnologicos_para_la_mejora_del_reciclaje, consulted on September 18th, 2023.

This research delves into the interdisciplinary realm of applied sciences, exploring the potential of mechatronics, environmental engineering, and ecology in the development of automated recycling centers. The proposed project aims to leverage technology for sustainable waste management, considering various perspectives on the environmental implications of mechatronics. The deductive methodology outlines key considerations for successful implementation.[20]

To implement this project, we must consider many factors such as the machinery for separating the trash, the construction of the building, the sort of equipment we would use for the process of recycling each material, the place where we would build the center and who can invest in the project. The implementation of automated machines for separating and recycling trash involves careful consideration of machinery, time, place, and financial investments:

> ***A) Automated machines for separating and recycling trash:*** To determine the appropriate machinery, it's crucial to identify the types of materials targeted for recycling. Companies like BESTON, Net Plasmak, and XRIDO offer automated machines tailored for specific waste separation needs, considering factors such as waste type, material composition, capacity, and energy consumption. Additionally, hiring mechatronic experts or purchasing pre-existing automated machines can streamline the recycling process.
> ***B) Time and Place:*** The design and construction of the recycling center are estimated to take approximately two years, subject to variations based on factors like funding, climate, and unforeseen delays. The location must be spacious, easily accessible for residents to dispose of their waste without inconvenience.
> ***C) Financial Investments:*** Funding for the project can be secured through partnerships with public or

20 Maria Iskandirova, et al., "Assessing the Impact of Mechatronics Systems on the Environment", **Sci-Hub:** https://sci-hub.hkvisa.net/10.1109/mechatronika.2014.7018348, consulted on September 17th, 2023.

private sector companies. Involving the municipal government is a strategic approach, as it can contribute to covering expenses related to machinery, building construction, capital requirements, and employee salaries. Collaborating with organizations already involved in recycling campaigns, such as the Instituto Nacional de Salud Publica, can further support the implementation of the automated recycling center.

In summary, successful implementation requires a comprehensive approach, involving the right machinery, strategic planning of time and place, and securing financial investments from relevant stakeholders. This not only contributes to effective waste management but also aligns with sustainability goals and initiatives.

Ecological pros: Scaling up such technology in a recycling center can offer considerable advantages. According to another company, LATU, that reports a monthly recycling of 800 kilos of solid waste, that has contributed to an annual reduction of 10 tons of CO2 emissions. The automated sorting systems in the project ensure accurate material sorting, reducing pollution and enhancing recycling efficiency. Compared to manual sorting, automated systems significantly decrease energy consumption during recycling, leading to a major reduction in the environmental footprint of recycling operations.

Ecological cons: The project, while offering environmental benefits, poses potential drawbacks. One significant concern is the substantial water usage associated with semiconductor production integral to the technology used in recycling centers. For instance, creating a 30-centimeter wafer requires approximately 2,200 gallons (about 8327.9 L) of water and an additional 1,500 gallons (about 5678.12 L) of ultra-pure water. Since these systems rely heavily on technology and infrastructure, the environmental impact of their production and maintenance should be

considered.[21] Any interruption in these processes, whether due to technical failures or external factors, may affect processing efficiency. Additionally, the replacement or outdated status of technological components can lead to misclassification of materials, with an inherent error rate of 6% in automated sorting systems, potentially causing pollution and a decline in the quality of recycled materials.[22]

Economic pros: The project holds significant economic advantages, primarily through the implementation of automated centers with higher processing speeds. Automation, exemplified by AMP robots, proves more productive than humans, handling the work equivalent to at least two employees. The resource optimization and accurate material classification achieved through automation minimize errors, reducing costs related to pollution and material losses, and although initial costs for automated centers may be high, the long-term benefits, including labor cost reduction and pollution control, may surpass the initial investment. A study indicates that, despite an upfront cost of up to $300,000, these machines are expected to last five to ten years or longer. Investing in automatic recycling technology can spur economic growth, innovation, and job opportunities in the recycling industry. [23]

Economical cons: The implementation of the automated center brings forth several challenges. Firstly, the shift to automation may have an adverse economic impact on the existing manual processing industry, potentially leading to company bankruptcies and job losses. For instance, in the US, robots have displaced over 260,000 jobs since 2000, affecting 2% of the manufacturing workforce. Strategic management and transition plans are crucial to mitigate the negative consequences on the population.

Additionally, the required automated systems entail a significant acquisition and implementation cost, potentially posing a budgetary challenge for the municipality. Technological imperfections and failures are inherent risks, necessitating costly repairs, estimated to range from $50,000 to $100,000 per machine. Potential downtime due to these failures can further impact on the center's profitability.

21 Nayeli Gonzales, “Electronics Industry Slow to Move the Needle on Water”, **TRIPLE PUNDIT:** Electronics Industry Slow to Move the Needle on Water (triplepundit.com), published on June 18TH, 2015,

22 “Recycling Economic Information (REI) Report”, **EPA:** Recycling Economic Information (REI) Report | US EPA, last updated on August 4th, 2023.

23 Nayeli Gonzales, “Electronics Industry Slow to Move the Needle on Water”, **TRIPLE PUNDIT:** Electronics Industry Slow to Move the Needle on Water (triplepundit.com), published on June 18TH, 2015,

Social pros: The implementation of automated recycling systems not only requires skilled workers for development, installation, and maintenance but also contributes to job creation in technology and maintenance sectors. This can generate approximately 13% more jobs for experts in robotics and engineering, as reported by Forrester. These centers can serve as educational hubs, promoting recycling practices and environmental conservation, exemplified by companies like Better Future Factory, which conducts educational presentations for over 250,000 people (about half the population of Wyoming), primarily school children.

The efficiency of automated recycling systems enhances resource distribution within communities, promoting effective recycling and contributing to a more sustainable local economy. Communities with automated recycling centers project a positive image of environmental responsibility and technological advancement, attracting businesses, residents, and visitors. This positive image contributes to the overall prosperity and reputation of the community.

Social cons: One major social challenge associated with automated recycling centers is the potential displacement of manual labor jobs. A McKinsey Global Institute study from 2017 indicated a significant risk, estimating that between 75 million and 375 million workers could face unemployment due to automation, affecting 3% to 14% of the global workforce. This shift raises concerns about the impact on employment opportunities and the economic well-being of individuals reliant on manual sorting jobs.

Furthermore, the adoption of automated systems may inadvertently contribute to social inequities if access to technology and its associated benefits are not distributed equitably. The transition to automated systems can also affect local entrepreneurs who traditionally collect and process recyclables manually, potentially leading to social and economic challenges for these small businesses.

Results

The implementation of this project in Cuernavaca presents both significant pros and cons across the economic, ecological, and social spheres of sustainability. While the project offers substantial benefits, including a reduction in the environmental footprint of recycling processes and waste generation, achieving full sustainability requires careful consideration of various aspects. The recycling process itself poses significant negative impacts on the environment. A comprehensive and in-depth investigation is necessary for future implementation, considering this summary provides only basic information. Successful investment, implementation, and management of the automated recycling center can contribute to a circular economy in the municipality, emphasizing the need for thorough planning and execution.

Field research

Also, to fortify our conclusions, we applied three different tools of field research: a poll directed to the general population, a survey directed to people that could benefit with this project, and two interviews to experts in our topic.

Poll

A poll was carried out via the Instagram app, to 80 people between the ages of 15 and 20 years old, this was between October 23 and October 24, 2023. The purpose of this was to know people´s opinion about the following question: Do you think that Cuernavaca could be a more sustainable place if there were automated recycling centers that will use robots to reuse materials and thus create new objects?

With this poll we were able to find that many people think this project will have a great impact on Cuernavaca. The vast majority said that implementing an automated recycling center could make the municipality much more sustainable.

On the other hand, there are some people that could not make the decision on whether it would help or not, just because they lacked information about the topic.

Analyzing these results we can conclude that most people think that this project will promote the sustainability of the municipality, probably because the entire field of recycling is already seen as something sustainable itself, and adding that the centers that would be automated, this action will be much easier to carry out, a very positive side of this is that if the municipality implements this, it will decrease its pollution significantly and it will not look that filthy.

Survey

A survey was applied to 21 people from Cuernavaca city between Oct 28th and Oct 30th, 2023. All the people who answered this survey live in different parts of Cuernavaca and are between the ages of 15 to 65 years old. This sector of the population are the ones who would be benefited from our project and through this survey we recollected some important information about their opinions and willingness to support our project, questions like "What do you think that is an automated recycling center using of robots?, What factor do you think influences the most on deciding to recycle?, Do you consider that you take care of the environment?" were asked in this survey.

What we can conclude from this is that the most important information we can take from the responses on this survey is that a lot of people in Cuernavaca just know basic information about recycling centers and how they work which is better than nothing but if we want our project to succeed, as some of the answers say, we should first do some capacitation about the topic and give information about the benefits of the center and recycling.

The materials that most people from the survey recycle are cardboard and plastic, so if we want our recycling center to focus on two main materials it would be this two and we

should give information about them and investigate the processes that it takes for them to be recycled.

Even though most of the people surveyed think that this project is a great idea for helping the environment and making Cuernavaca city a more sustainable place, not many of them, almost nobody, are willing to pay money for the project. So, for the continuation of this project, as some of the suggestions in the last question on the survey mention, we should look for sponsors or companies in the public or private sector who can support economically on the building of the recycling center.

Interview to Mechatronic Engineer Daniel Mendoza

This first interview was held on October 27, 2023, with Engineer Daniel Mendoza, specialist in mechatronics engineering, who graduated from La Salle Cuernavaca and has been practicing his profession for 14 years. He has been working in the department of telecommunications in FELM. We chose him for the interview because of his extensive experience and he could solve our doubts about our project.
Questions like "Based on your knowledge, are there already machines capable of separating different types of materials?, Do you think it is possible to generate a system like this in Mexico?, What kind of materials do you think this system will be able to separate?", and others related to the topic that were asked to the engineer lead us to conclude that, according to the point of view of Eng. Mendoza, the implementation of an automated recycling center could be a viable alternative for helping Cuernavaca become a modernized and sustainable city.

Also, according to him, we need to start the process from generating awareness in school and home, because what this city lacks is education in that subject. This could lead to starting to reduce the carbon footprint and merging with our project it could take Cuernavaca a little closer to being a sustainable city. In addition, he says that making this project

could be expensive but with the right investment (from government or a big investor) it could be possible to do the project in the city.

Interview with Biologist Alma Dalia Guzmán

A second interview was carried out on October 30th, 2023, to Alma Dalia Guzmán, a specialist in comprehensive waste management and dedicated to environmental education. Through this interview we intended to know more about our project of an automated recycling center with the use of robots for separating trash from an ecological point of view, so we can know her opinions for its implementation.

This specialist told us that a recycling plant would help not only Cuernavaca, but the whole country and even though she didn't know any project like this one, using an automated system for the recycling process, if, with the right conditions, training and knowledge we implement this project, it would help to reduce que amount of waste generated, as well as the CO2 emissions. Besides, she mentioned that before doing this kind of recycling project we should make sure the trash that arrives at the center is already well separated, which means people should already be well informed about the topic, as well as knowing what kind of materials are going to be recycled in the center and focus on the ones that people usually separate.

Interviews' analysis: With the answers this specialist gave us through this interview we can conclude that if we want our project to succeed it is not only about building this center, we would have to start from educating people about taking care of the environment and giving information about recycling, because not so many people are well informed about the topic as they should be, we do not have a recycling culture.
Instead of using robots for separating the trash it would be better if the materials we are going to be recycling were already separated and to use the automatic system for the process of recycling itself. This also led us to another important point, we have to decide the materials we are going

to be recycling because every material, for example plastic or paper, has a different process and needs if we want to create new products from them.

Conclusions

To do a recount, the research goal of the project was to create an automated recycling center aiming to help people get a job by managing the process and operation of the recycling facility in the city, as well as to reduce the amount of waste sent to landfills and incinerators, which also reduces the carbon emissions sent to the atmosphere contributing to climate change and keeping streets clean. This would help in improving the health of the citizens, as the environment would be less polluted.

Consequently, the main hypothesis proposed that we could contribute to making the municipality of Cuernavaca a more sustainable place, through a project that consisted of an automated recycling center which would have robots responsible of separating waste to reuse materials for the creation of new products. This will guarantee the reduction of carbon emissions and the exploitation of natural resources. As well as saving energy, and other resources for the creation of new products.

Additionally, two secondary hypotheses were made, it was supposed that, through this proposal of an automated recycling center in Cuernavaca, we could contribute to making the city achieve the target 11.6.1 of municipal solid waste collected and managed in controlled facilities, as part of Sustainable Development Goal 11: Making cities and human settlements inclusive, safe, resilient, and sustainable. The success of this project would be measured through the statics in savings of electricity consumption and by the reduction in disposal and treatment costs.

Likewise, the second hypothesis was that through the proposal of automated recycling centers, it would be possible

for Cuernavaca's city to achieve target 12.5 of reducing waste generation through prevention, reduction, recycling, and reuse of materials, as part of Sustainable Development Goal 12: Ensuring sustainable consumption and production patterns. This project results would be measured through the data in the increase of reused materials and products made from recycled materials, the reduction of natural resource exploitation and pollution.

As the most relevant aspects and facts that helped us to prove hypotheses are:

- 69% of people believe that this project could make Cuernavaca a more sustainable place.
- People's support: 38.1% of people would donate between $200-$500 to help build an automated center in Cuernavaca.
- Reduces pollution: 70% less CO2 emissions.
- Saves energy: annual energy consumption savings of up to 70%.
- Reduces waste: 75% in the reduction of solid waste by year.
- Efficient: Each machine can handle double the work of one employee (they can pick up 80 pieces of material per minute against 40 for a single person).
- Will raise awareness: Better Future Factory talks to over 250,000 people (mostly school children) about recycling.
- It's the future: Robotics and Automated Systems are projected to be adopted by 60% of companies by 2025.[24]
- Durable: $300,000 upfront, but recycling facility operators say they expect them to last five to ten years, and perhaps even longer.
- Specific jobs: Generates jobs for experts: about 13% more jobs for people with a degree.

24 "The Future of Jobs Report 2020", **World Economic Forum:** https://www.weforum.org/publications/the-future-of-jobs-report-2020/, published on October 20th, 2020.

Also, among the facts and aspects that prove our hypotheses wrong, are:

- Maintenance costs: They are expensive when talking about maintenance, from 50,000 to 100,000 dollars just to repair one machine.
- Unemployment rate: 3% to 14% of the global workforce faces high risks of unemployment in the coming years.
- Water waste: 2,200 gallons of water and another 1,500 gallons of ultra-pure water just to create a 30-centimeter wafer in an automated center.
- Margin of error: Automated Sorting can still have an error of 6%, resulting in pollution and a decline in the quality of recycled materials.

The project could contribute to making Cuernavaca a more sustainable place, but the main hypothesis could not be proven right for now because we are only looking from the theoretical perspective. Theoretically, the project covers every aspect of sustainability. It contributes to reducing the waste in the city, respecting the environmental factor. Even though the creation of mechatronic robots uses materials or resources that affect the environment, it also reduces 75% of solid waste and 70% of CO2 emissions, so it could be said that it helps more than it hurts.

The project would also contribute to society by making a better city, with 70% energy savings and 75% less solid waste in the streets. But wouldn't it take away opportunities for people to work? Well, as Richard Freeman says, "the best solution is that all of us have a substantial share in the ownership of the robot machines"[25], which means not to take away people's job by replacing them with robots but to give them new work to do so they have assured economic income.

A project like this one would make 13% more jobs for people with a degree in mechatronics engineering or other that

25 Richard B. Freeman, "Who Owns the Robots Rules the World", **IZA. World of Labor:** https://wol.iza.org/articles/who-owns-the-robots-rules-the-world/long, consulted on November 11th, 2023.

could help repairing and maintaining the machines. And talking about the investment, it would be costly, but that money would be saved in the long run because the robots are expected to last five to ten years, and perhaps even longer.

The first secondary hypothesis could be considered theoretically proven. It would make Cuernavaca a controlled waste city with the help of the automated recycling center which would mean the SDG 11.6.1 would be achieved. The pollution in the city would be reduced and we would be able to give a second chance to the products that could be recycled in the automated recycling center, saving money and resources.

The second secondary hypothesis could be proven correct because the information collected made it clear that it would be confirmed that the reduction, recycling and reusing of materials would be carried out through the project. With the help of the automated recycling center and diffusion of the environmental situation, Cuernavaca would fulfill the SDG 12 in the city. With the implementation of the project, we could improve the way of diffusion to enhance the project and make the city better.

But to confirm and say that doing the project would be feasible we would have to test it practically and so then decide if it could really work or we would have to rethink some steps to improve the project and make it really work.

The research goal of this project was not completed because the goal was to create an automated recycling center that would fit the criteria to be a sustainable project, but the only thing that was carried out was the investigation and testing of people point of view if something like that could happen in Cuernavaca's city. If the project is implemented in the city, the complete fulfillment of the research goal would have to be proven by practical testing.

In this sense, the main limitation for our research were the lack of time. If you want to do a well-done project like we had planned, we will need more than a semester to make it through the research goal we proposed. Also, to build a whole automated center, we would need to be engineers and have a career level knowledge about the subject to create it. Even though social media helped us throughout the field research process, we had difficulties with the Engineer interview because of the poor internet connection. We also had a limitation of information because although we have internet access, the scare information the city has related to our subject limited us to research in internet platforms that makes it more difficult for us to find the right information.

Furthermore, as for the recommendations, since it was only possible to develop only theoretically the project, to carry it out entirely in the practical way it would be ideal to consult professional specialists, such as engineers in civil infrastructure, mechatronics, environmental and also an economist and ecologist, for them to do a more complex analysis of the project and determine the area on where the project could be made and the process that should be followed to achieve it.

Also, it would be ideal to plan an activity that involves human activity to generate jobs and help increase the work rage in Cuernavaca. With the knowledge of an engineer and an ecologist, we could try and make robots with green mechatronics which involve working with more sustainable materials and wasting the least number of resources possible in the making. Moreover, it would be perfect to collaborate with government organizations to help with the maintenance and spread the existence of this center for people to be aware of it. Making collaborations with companies or projects that provide help to do the project privately at the beginning and then see if it could be done in the same way, but for the whole city. Checking with an economist the work plan that could be idealized to continue to employ human labor so that the employment rate does not decrease because of this project.

Finally, as engineer Mendoza said, we should start raising awareness from school for kids to have the environmental education for them to know how to make the world more sustainable.

To conclude, we leave with a great deal of new knowledge about mechatronics engineering and robots, in addition to testing out qualities of responsibility, dedication, discipline and patience. We learned how to organize our time and work harmoniously in a team. Besides, we learned how to do research worthy of a thesis in case we need to do similar but more extensive research in the future.

Now that we have finished the project, it could be said that the world needs a lot of help to decrease air, water, and soil pollution. The fact that we continue to implement new sustainable projects that can contribute to help the environment. Also, we realized that the government should be the one doing diffusion about this kind of projects to take care of the city and country, not that as a society we should not do anything, but if the dynamic comes from the government, maybe it will be easier for the cause to be considered and supported. Because although there are already some plants that oversee this, there is no knowledge about its existence so they should also be spreading the word about it so that people can know about it.

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