Statement

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Contents

1. Introduction

A university is more than just a place of formal instruction and a huge employer; it is also a location where students can build their personal and social identities at an important point in their life. For an expanding number and diversity of students, university campus sites and academic spaces provide an integral environment for daily routines of living, working, and learning. Students spend a significant amount of time on campus engaged in activities that necessitate constant attention and concentration. Mental health disorders are becoming more prevalent and severe among college and university students around the world. In this context, a healthy learning and working environment should assist people in striking an optimal balance between dealing with stress and getting enough rest.

The course EuroTeQ collider provided us an opportunity to work on the project of sustainable outside seating for students with our challenge presenter and mentor Plant a Seed. Plant a Seed is a unique interdisciplinary educational project for sustainability at the Technical University of Munich (TUM) with a mission to raise awareness about food production and consumption, link people with nature by encouraging and strengthening their connection and visualize sustainability on the university campus. We worked on the following problem statement: As the impacts of climate change intensify and urbanization continues to shape our communities, campuses worldwide are facing a pressing challenge: How can we combat the effects of climate change and urbanization while creating multi-functional and comfortable spaces that cater to the needs of students?

2. Methodology

In the EuroTeQ challenge, we have worked as a team on the following topic. To prove different aspects related to the efficiency of our model, we have worked on the following aspects:

Figure 1: Methodology

3. Material Analysis

The production of aluminium has a negative impact on the environment, as it generates excessive emissions and uses a great deal of energy. In contrast, wood materials have emerged as a sustainable construction option (Segovia et al., 2019). However, each material has its own benefits and drawbacks.

3.1 Aluminium

Advantages: Strong, lightweight, corrosion-resistant, and recyclable are some advantages of aluminium.

Negatives: It is energy-intensive to produce and can emit harmful pollutants.

3.2 Wood

Advantages: Renewable, insulating, sustainable

Negatives: Vulnerable to decay and pests

Material Selection

To determine the most environmentally friendly material for Green-Wheels, we conducted a material analysis. We weighed the following elements:

The environmental impact of the material, including the energy required to produce it, the emissions emitted during production, and the potential for pollution.

The sustainability of the material, which includes its renewability and availability of recycled materials.

Performance: The material's performance, including its strength, durability, and decay resistance.

Based on our analysis, we determined that the most sustainable material for Green-Wheels would be a combination of recycled aluminium and hardwood. Recycled aluminum is a durable and lightweight sustainable material. Hardwood is a renewable, sturdy, and long-lasting material (Beudon et al., 2022).

Figure 2: Materials depiction of the model

4. Design

4.1 Design Concept

The design concept revolves around creating an innovative resting bench for students at universities and schools. The objective is to provide a space where students can sit and relax outdoor in the nature while enjoying various modern facilities integrated into the structure. The unique structural combines sustainability of renewable energy, convenience of technology and tranquillity of nature all in a functional package.

4.2 Sustainability Focus

The most distinctive feature of the structure is its complete sustainability, aiming to minimize its carbon footprint on the environment. The design prioritizes the sustainable production and utilization of energy whilst using materials with low carbon footprint. This sustainable approach encourages students to explore and appreciate the sustainable use and development of Earth's resources.

4.3 Mobility and Flexibility

The structure is designed to be highly mobile, allowing easy relocation and storage. This mobility enables its placement in different locations as required and also makes it easy to store compactly in a storage room when not in use, making the space multi functional. The versatility of the bench ensures that students can make use of it not only for relaxation but also for studying purposes.

4.4 Structural Assembly

The key components of the structural assembly include fixed solar photovoltaic panels on the roof, hardwood roof material with an attached layer of recycled scraped aluminium sheet, and two handles for tilting the roof by 90 degrees. The roof's dimensions are carefully maintained to accommodate a maximum of four people comfortably. The roof also serves the purpose of dissipating heat radiation generated by the solar panels.

4.5 Support Structure

The structure is supported by two scrapped aluminium columns, which are attached to horizontal beams at the bottom. These columns, made from recycled aluminium, contribute to the sustainability aspect of the design. Metal rings are incorporated on either side of the columns to hold flower pots, adding an aesthetic touch to the structure. The dimensions of the columns are designed so as to ensure stability, with a diameter of 6cm and a vertical height of 1.5m.

4.6 Mobility Enhancements

The beams supporting the columns are made of hardwood and equipped with eight wheels each. These wheels provide mobility to the structure, making it easy to move and place in different locations. The wheels are constructed with inflating rubber tires, ensuring smooth movement and usability. Energy storage batteries are placed inside each beam, providing power to the structure. The design allows for efficient maintenance of the batteries. The tires can be clamped to keep the structure fixed in one place when desired.

4.7 Special Features

The beams hosting the columns also incorporate four charging sockets at the bottom on either side. These sockets enable students to charge their electrical appliances conveniently. A foldable table made of softwood is clamped under the roof, serving as both a study surface and a tie to prevent the buckling of the columns.

4.8 Installation and Manufacturing

The structural design is intentionally simple, ensuring easy installation which could be facilitated at the Makers space at TUM. the only skilled labour requirement would be for the installation of batteries and solar photovoltaic panels. The expertise of highly skilled workers ensures the proper functioning and integration of these components to make it safe under EU safety laws.

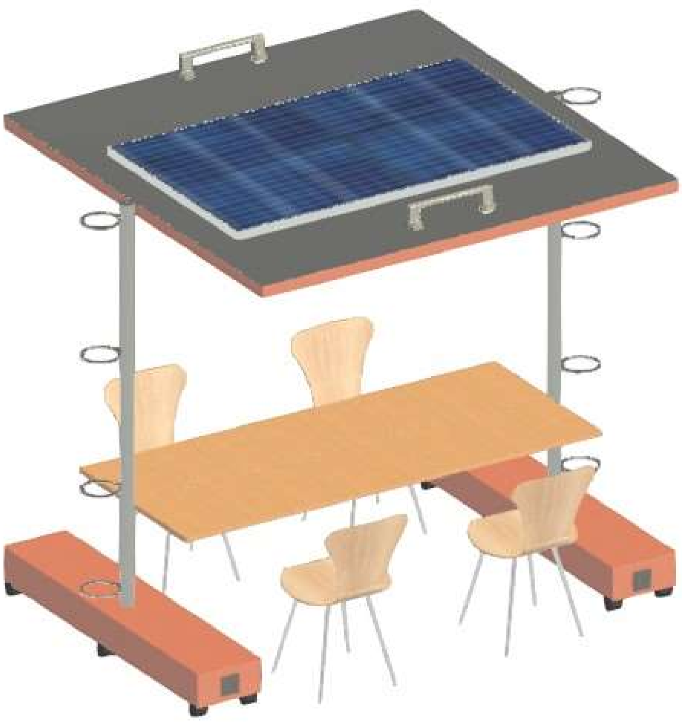

Figure 3: Green-Wheels concept

5. Cost Estimation

For this project, we have determined 7 different categories for the cost estimation of the structure.

Each of these categories represent a considerable cost and have been simplified to have a first prototype estimation. All the supplies have been chosen on the premise of local over international suppliers, therefore our research involved only German companies that could potentially supply us with the different categories.

5.1 Solar Panels

We decided on a model of 100W, this dimension allows us to charge up to 4 laptops at the same time. The selected solar panel was from a big retail store which specializes on outdoor and hardware. The total cost of this specific model is 199 euros. The size and dimensions are as follows: height=540mm, length=1370mm, weight=4,4kgs.

5.2 Battery Pack

The battery pack has an increased complexity because of the required inverter, voltage regulators and the logic card. We decided to eliminate the need of a specialized installer in favor of a simpler solution. The solution was to get the battery pack from the same brand as the solar panel, this solves the problem of having to design a complex stand-alone battery pack and ensures compatibility with the solar panel. This battery pack also comes in a weatherproof case. The cost of this battery pack is 310 euros. The dimensions of the battery pack are as follows: 20,7 x 14,6 x 16,6 cm, weight=3,1 kg.

5.3 Wood Structure

The wood structure of the mobile unit can be further subdivided in three different parts:

- Wooden Table
- Wooden Bases
- Wood structure for support of the aluminum roof

Each of these parts requires a different kind of wood, for example, the wooden table must not be of structural wood. While the wooden bases and wood structure for the roof does. The wood for this project has been selected from an online lumberjack that specializes on structural lumber. The dimensions of each part are listed in the annex at the end of this report, these dimensions are of the wood to be bought, not of the wood used in the final project. The total cost of the wood ascends to 67,39 euros.

5.4 Aluminum Structure

The aluminum structure can be divided in two main parts: the roof “sheet” and the columns. The supplier of this aluminum parts is a German company that sells to individuals, as such the prices here are considerably higher than with a big company. The aluminum of this prototype is recycled, this does not increase the cost, but it considerably decreases the carbon footprint of the study unit. The total cost of the aluminum structure is 129,26 euros.

5.5 Wheels

The mobile part of the study unit would be incomplete without the wheels. We have selected 8 wheels that will allow for free mobility in campus, these wheels can support the structure and are ideal for uneven terrain. The total cost of the industrial wheels is 83,92 euros.

5.6 Miscellaneous

This category includes all extra materials that would be needed to assemble the structure (bolts, nails, nuts, electrical wiring, etc.). We have made an estimation considering the total cost of the entire structure and have decided on no more than 5% of the total cost. This amounts to 75 euros.

5.7 Labor

Apart from materials, another significant cost is the labor. We estimated a minimum of 40 hours of labor at a fixed rate of 16 euros per hour. However, keep in mind that this cost may vary depending on the chosen construction personnel and location. We're also considering utilizing the in-house Makers-Space at TUM for the pilot project. The total cost of labor is 640 euros.

Table:1 Description of costs and parts

Part	Link to supplier	Dimensions	Unitary Price	Unit	Total units	Total
Wooden Table	https://holzhandel-deutschland.de/30x200-mm-fichte-bohlen-saegerau-gelattet-frisch-braun-impraegniert-gueteklasse-i-iii-p8112?c=228	30x200 mm	€ 3.61	per meter	4 planks of 2 meters	€ 28.88
Aluminium roof	https://metallstore24.de/en/aluminium-plate-15-mm	500 x 500	€ 29.57	per unit	4 planks	€ 118.28
2 Aluminium Columns	https://toom.de/p/alu-rundstange-04-x-200-cm/1705792	40 x 2000	€ 5.49	per unit	2 rods	€ 10.98
2 Wooden Bases	https://holzhandel-deutschland.de/24x160-mm-fichte-bretter-seitenware-saegerau-gelattet-frisch-braun-impraegniert-p8123?c=227	24x160	€ 2.05	per meter	8 planks of 1.5 meters	€ 24.60

Part	Link to supplier	Dimensions	Unitary Price	Unit	Total units	Total
8 Industrial wheels	https://toom.de/p/lenkrolle-mit-platte-50-mm/7365842	50mm	€ 10.49	per unit	8 wheels	€ 83.92
Solar panels	https://www.bauhaus.info/solar-panel-camping/yard-force-solarmodul-flex-lx-spp10/p/30419630	1370 x 540	€ 199.00	per unit	1 solar panel	€ 199.00
battery + inverter + connectors	https://www.bauhaus.info/powerstations/yard-force-powerstation-lx-ps300/p/30419603	3 kgs	€ 310.00	per unit	1 Battery	€ 310.00
Wood structure for aluminium roof	https://holzhandel-deutschland.de/24x160-mm-fichte-bretter-seitenware-saegerau-gelattet-frisch-braun-impraegniert-p8123?c=227	2 x 2 structure + crosses	€ 0.95	per meter	15.64 m	€ 13.91
Bots, nuts and nails					multiple	€ 50.00
Electrical wiring					multiple	€ 25.00
Labour costs					16 euros/hour	€ 640.00
Total Cost						€ 1,504.57

6. Life Cycle Analysis

We also performed a life cycle assessment (LCA) to assess Green-Wheels' environmental impact. LCA is a technique for assessing a product's environmental impact over its entire life cycle, from raw material extraction to disposal (Liu & Müller, 2012). The environmental impacts were assessed using Open LCA software (*Open Source | OpenLCA.Org*, n.d.) and the Eco invent database (*Ecoinvent Database - Ecoinvent*, 2020). Environmental impacts were estimated using the impact 2002+ method.

Table:2 Environmental Impact Indicators of Greenwheels and Wood Structure

Impact category	Greenwheel	Wood Structure	Reference unit
Fine particulate matter formation	0.790	1.089	kg PM2.5 eq
Fossil resource scarcity	119.383	144.326	kg oil eq
Freshwater ecotoxicity	-1,761.069	-183.391	kg 1,4-DCB
Freshwater eutrophication	0.170	0.246	kg P eq
Global warming	420.433	532.994	kg CO2 eq
Human carcinogenic toxicity	29.864	43.213	kg 1,4-DCB
Human non-carcinogenic toxicity	-500.115	788.030	kg 1,4-DCB
Ionizing radiation	39.853	49.353	kBq Co-60 eq
Land use	95.166	211.913	m2a crop eq
Marine ecotoxicity	-2,094.722	-207.600	kg 1,4-DCB
Marine eutrophication	0.046	0.051	kg N eq
Mineral resource scarcity	0.017	3.070	kg Cu eq
Ozone formation, Human health	1.089	1.407	kg NOx eq
Ozone formation, Terrestrial ecosystems	1.151	1.479	kg NOx eq
Stratospheric ozone depletion	0.000	0.000	kg CFC11 eq
Terrestrial acidification	1.162	1.941	kg SO2 eq
Terrestrial ecotoxicity	5,203.667	10,565.296	kg 1,4-DCB
Water consumption	12.248	15.186	m3

6.1 Comparison of Environmental Impact Results

Between Green-Wheels and wood structures in several of the most significant impact categories:

Freshwater ecotoxicity: With a difference of -1,761.069 kg 1,4-DCB, Green-Wheels have a significantly lower impact on freshwater ecotoxicity than wood structures. This is because the production of aluminum from bauxite ore releases harmful pollutants, such as fluoride and sulfuric acid, into the environment. We can avoid these emissions and protect marine and freshwater ecosystems by utilizing recycled aluminum.

Green-Wheels have a significantly lower impact on marine ecotoxicity compared to wood structures, with a difference of -2,094,722 kg 1,4-DCB. This is for the same reason as ecotoxicity in freshwater.

Global warming: Green-Wheels have a -112.561 kg CO_2 equivalent lower impact on global warming than wood structures. This is due to the fact that the production of aluminum requires less energy than the production of wood.

Green-Wheels have a greater impact on land use than wood structures by 116.747 m2a crop equivalents. This is because aluminum production requires a substantial amount of land. However, land use has a relatively small environmental impact in comparison to other impact categories.

6.2 Interpretation

In most impact categories, the data indicates that Green-Wheels have a lower environmental impact than wood structures. Green-Wheels, for instance, have a significantly smaller impact on freshwater and marine ecotoxicity. This is because the production of aluminum from bauxite ore releases harmful pollutants, such as fluoride and sulfuric acid, into the environment. We can avoid these emissions and protect marine and freshwater ecosystems by utilizing recycled aluminum.

Green-Wheels have a greater impact on land use than wood structures, according to the data. This is because aluminum production requires a substantial amount of land. However, land use has a relatively small environmental impact in comparison to other impact categories.

Overall, Green-Wheels have a lower environmental impact than wood structures. This makes Green-Wheels a more eco-friendly alternative.

7. Conclusion

In this report, we worked on a challenge presented by Plant a Seed on the concept of sustainable outside seating for students. We developed a model which can be directly made by students and can be introduced on the campus of TUM. We named our model Green Wheels and first worked on structural integrity so that it will be safe for students. We tried to focus on sustainability aspects and made our design more economically feasible. The materials used in Green Wheels are mostly made In Germany to have minimum carbon footprint.

Also, the design is foldable and has wheels on the bottom so that it can be carried and stored by a student in bad weather. We have also introduced solar panels on the top that can power 4 laptops at one time. Battery is provided in the base to be an additional power source in case of cloudy weather. There are also plants attached to give students a sense of studying in nature. Two Green Wheels can also be attached side by side if students want to study in a group. We also did the cost estimation and life cycle analysis of the model.

In conclusion considering all the data, it can be said that after implementation Green Wheels can prove highly beneficial to the students.

8. Distribution of Work

9. List of figures

10. References

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