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Environmental impacts of repurposing phone booths as COVID-19 sampling stations

Martin Schoch[a], Sunaree Lawanyawatna[a] and Shabbir H Gheewala[b,c]

[a]School of Architecture and Design, King Mongkut's University of Technology Thonburi, Bangkok, Thailand; [b]The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand; [c]Center of Excellence on Energy Technology and Environment, Ministry of Higher Education, Science, Research and Innovation, Bangkok, Thailand

ABSTRACT
The presented research examines the repurposing of decommissioned phonebooth units to COVID-19 sampling stations as a meaningful attempt to promote environmentally sustainable and socially resilient cities by contributing to a circular economy transition. The repurposing approach is compared to an adequate new build design using a life cycle assessment to evaluate the environmental implications and a time-cost comparison for their implementation. The results indicate that the remodelling of the phone booth improves environmental performance. The expanded need for refurbishment is offset by the need to use virgin material for the new stations. The benefit of finding reuse for the phone booths and extending their lifetime further supports this understanding, demonstrating the adaptive approach as a viable strategy for utilising an otherwise disused urban infrastructure with uncertain end-of-life. Cost-time results show that repurposing is less expensive due to the donated phone booths and low production numbers. On the other hand, new sampling stations take less time to produce. Future studies investigate user experiences and social benefits of the realised sampling station based on phone booth repurposing.

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KEYWORDS
COVID-19 sampling station; adaptive reuse; life cycle assessment; time-cost analysis; societal resilience

1. Introduction

This research paper investigates the adaptive reuse of decommissioned phone booths as COVID-19 sampling stations in Thailand's healthcare facilities and aims to compare the environmental and economic benefits of repurposing existing structures versus new construction.

During the COVID-19 pandemic, healthcare facilities in Thailand received aid from various organisations as emergency measures to improve protection and reduce the need for personal protective equipment (PPE), given the shortage (Doung-Ngern et al. 2020). Still, most smaller health facilities in urban residential areas, outskirts, and adjacent rural areas suffered from insufficient support and emergency measures by the respective state institutions. The presented sampling station was developed due to medical doctors' requests from several public health centres to provide safer and less exhaustive operational approaches for medical personnel (Joob and Wiwanitkit 2020). Designed for use in semi-open conditions in existing healthcare facilities in different peripheral districts of Bangkok and adjacent provinces to allow safe use to perform sample collection for testing.

The realisation bases on a collaboration with Thailand's national telecom operator (TOT) to equip local healthcare facilities with COVID-19 sampling stations based on repurposing decommissioned phone booths. Utilizing phone booths and converting them into COVID-19 sampling stations derives from providing cost-effective solutions for conducting safe reverse transcription polymerase chain reaction (RT-PCR) sampling by medical staff on screened patients. With the decommissioned phonebooth stockpile costly to recycle (Nathonglai 2021), their reuse through repurposing is considered a sensible option for reducing the accumulation of otherwise wasted resources.

Besides phone booths, a variety of pre-existing structures, such as drive-through testing sites (Zmora et al. 2022), tents (Nacher et al. 2021), shipping containers (El Ghonaimy 2020), and dedicated areas of healthcare facilities, have been used as COVID-19 sampling stations, based on each location's needs and resources. The sampling station design's positioning characteristics are intended to ensure sufficient physical separation (social distancing) between patient and medical staff while reducing the need to wear PPE, as it quickly leads to, and significantly increases, the exhaustion of medical staff when used in semi-outdoor settings, contribute to an increase in the generation of hazardous waste. In addition, the sampling station should ensure a safe environment during its operation, be easy to disinfect, and at the same time be flexible in the use of the site and meet simple infrastructure requirements (Schoch and Lawanyawatna 2021). Alternative approaches to COVID-19 test sampling include an outdoor drive or walk-through scenarios where healthcare workers must rely entirely on protective suits (Catellya 2020).

The featured study selected suitable units for repurposing based on their existing stock. The devices were then disinfected and cleaned, and individual components were repaired and replaced with salvaged spare parts. As a result, 16 units were rebuilt. As an adaptive reuse strategy, these converted phone booths support small healthcare facilities on the outskirts of Bangkok while reducing the accumulation of otherwise underutilised resources and discouraging raw material consumption

CONTACT Martin Schoch martin.sch@kmutt.ac.th School of Architecture and Design, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

(San 2021). Understanding the adaptive reuse of obsolete buildings or structures is essential (Langston 2011). Adaptive reuse is the practice of reusing an existing structure for a different function than what was originally built or designed. Also known as repurposing, it is a successful technique for maximising the use of constructed assets (Langston et al. 2008). It has become crucial to propose a sustainable and circular development mindset (Sanchez and Haas 2018). However, essential for decision-making is ensuring that reuse is cost-effective and entirely usable for the new use (Bullen and Love 2011). In a technical cycle, such as the phonebooth repurposing case, products are retained through reuse, repair, remanufacture, and recycling (Gheewala and Silalertruksa 2021).

The repurposing received positive feedback from users and the public due to the given demand and the unbureaucratic and independent emergency assistance as a reaction to prevalent undersupply. But also because of the sampling stations' familiar appearance and arguably eco-friendly solutions. However, its discussed environmental benefits and impacts as a perceived concept of economic circularity led to the realisation that a comparative Life Cycle Assessment (LCA) is needed to clarify the actual benefits of the repurposing versus new construction. As a way to study the environmental impacts associated with all stages of a product, process, or service (Hellweg and Mila i Canals 2014; Ilgin and Gupta 2010), LCA considers the environmental impact of a manufactured product is assessed from the extraction and processing of raw materials, through the manufacture, distribution, and use of the product, to the recycling or ultimate disposal of the materials that make it up (Hauschild, Rosenbaum, and Irving Olsen 2018). An LCA takes a comprehensive inventory of the energy and materials used in the industrial value chain of the product, process, or service and assesses the resulting environmental emissions. As a result, LCA assesses the potential for cumulative impacts to capture and improve the overall environmental profile (Rebitzer et al. 2004). The allocation principles for LCA and procedures also apply to reuse and recycling situations. For reuse and recycling, several attribution methods exist. A suitable method for the recycled content approach, often described as the 'cut-off' method, considers using recycled components in the product system to be assessed (Obrecht et al. 2021).

This study's research question compares the environmental and economic impacts of repurposing decommissioned phone booths into COVID-19 sampling stations versus constructing new sampling stations in Thailand, using an LCA and a cost-time comparison approach. The study's results can be general, as there may be variations depending on the availability of payphones and their types, local economic conditions, and the design and execution of the conversion. Yet, the expected outcome is to provide insights to the planning team and the public to scale the impact of the transition. The novelty of comparing LCA results with economic aspects lies in the judgement of environmental and economic considerations in decision-making processes. Traditionally, LCA has been used to evaluate the environmental impacts of a product or process throughout its life cycle, from raw material extraction to disposal. However, a product's or process's economic aspects are equally important, as they can affect its overall sustainability and viability (Jeswani et al. 2010). By comparing LCA results along with economic aspects, it is possible to identify the trade-offs between environmental performance and economic feasibility (Norris, 2001). Integrating economic aspects into LCA can help decision-makers choose more sustainable and cost-effective options considering environmental and economic considerations (Zamagni, Pesonen, and Swarr 2013). It can also provide valuable insights into the potential benefits and challenges of adopting sustainable practices and technologies.

2. Literature

2.1. COVID-19 sampling stations

Given the need to screen potentially infected, healthcare facilities must separate assigned medical personnel and affected citizens from general operations to avoid crowding and protect them from contamination (Udwadia and Raju 2020). Thus many facilities opt for separate locations to conduct the test nearby (Gan, Lim, and Koh 2020). Early practiced solutions are walking or drive-through options with healthcare workers working in PPE (Catellya 2020). Design guidelines to protect against severe acute respiratory infection, such as sample-taking procedures, have been developed to provide safer and less exhaustive approaches (WHO 2020). In such solutions that provide for physical separation, the healthcare worker works inside cabins supplied with pressurised, conditioned, high-efficiency particulate-absorbing (HEPA) filtered air to feel safe and avoid infiltration (Joshi 2020). Underserved healthcare facilities, often in urban sprawl or rural areas, still need solutions such as easy-to-instal sampling stations that can be used semi-outdoor to collect RT-PCR samples from potentially infected citizens. With the protection of medical staff a concern, it must be recognised that extensive PPE must also be reduced as supplies are expensive and not always guaranteed (Phasuk 2020). Consequently, such a sampling station must not be expensive to suit budget constraints.

2.2. Phonebooth repurposing

In most countries, the number of public payphones dramatically decreased due to the advent of mobile phones. Requiring storage and proving costly to recycle, many public telecommunications companies are offering their decommissioned inventory for use with little or no cost. As a result, ideas of converting and reusing these for different purposes have become abundant, with examples of creative approaches to converting and reusing phone booths worldwide (Moss 2019). An example of medically oriented utilisation is refitting units with defibrillators and emergency landlines (*One Button, One Device For 999 Calls*, 2020).

When considering phone booths for COVID-19 sampling station design, two types have emerged: creating phonebooth-like designs and converting existing, unused phone booths into a sampling station. An imitation-based sampling station first appeared at the Yangji Hospital in Seoul (Kim et al. 2021). Many other design suggestions are related to this design (Aroom et al. 2022; Brown 2020; Joshi 2020; Teo et al. 2021). Using phone booths as sampling stations for conducting COVID-19 test sampling in outdoor conditions originated from simple low-budget attempts by cutting holes in the glass screen to attach arm-length rubber gloves allowing healthcare workers in PPE to sample patients (Tortermvasana 2020). A variety of examples appeared in Thailand (Cheng et al. 2020) and in other countries (Lee 2020).

Although proven to be amenable to repurposing, these solutions merely offer psychological safety, as unsafe and exhausting conditions for operating healthcare workers still prevail if air filtering, pressurisation, and air temperature are not controlled. Air treatment such as air filtration, air conditioning, and pressurisation of such cabins is difficult to achieve; especially because of tropical climate conditions, the phone booth constructions provide natural ventilation through generous openings in the floor and ceiling areas. A significant improvement was realised by developing the booth's airtightness and installing air conditioning in conjunction with a HEPA filter and blower to create 'clean room' conditions (*Phone Booth Like Invention increases COVID-19 testing capacity*, 2020).

2.3. Economic and environmental considerations

The COVID-19 pandemic has led to the establishment of sampling stations to safely test people for the virus. While these stations have played a crucial role in identifying and controlling the spread of the virus, they have also raised economic and environmental concerns. The expense of setting up sampling stations for operations is an economic concern, especially as it is funded by donations. Feasibility studies and cost comparisons are often required to justify the decision-making process (Brodeur et al. 2021). In the case of the production of sampling stations, these costs include expenses for labour and work processes, materials and equipment, transport, and other associated costs. However, there are also environmental concerns associated with setting up COVID-19 sampling stations. The energy consumption associated with the construction of the sampling stations and the emissions cause an ecological burden and the associated necessary transport.

2.4. Time-cost analysis

Time and cost influence decision-making during a project's development (Nakhleh 2019). A systematic planning method can determine which actions should be taken and avoided. It is a method of examining the time-cost of each activity and the sequence of activities within the project structure (i.e. the one drawn by the lowest project cost value at a feasible project duration). A way of studying time-cost relationships is to consider the ratio of individual and total activities. Accordingly, the cost comparison focuses on analysing the comparative manufacturing costs resulting from their implementation, focusing on labour, raw materials, consumables, and general overheads. Production time is from introducing production equipment and material to completing the product. It is understood that reduced production time allows for higher production efficiency concerning the sampling station.

3. Methodology

A life cycle assessment (LCA) and time-cost analysis of a COVID-19 sampling station between a realised phone booth repurposing and planned new construction is conducted to assess both options' environmental and economic impacts. The following gives an overview of the design/manufacturing details of the options and the valuation methods used. The purpose is to provide stakeholders with a viable and effective view of the environmental impacts of using phone booth repurposing in COVID-19 sampling stations to understand its contribution to circular economy thinking.

3.1. Scope definition

The COVID-19 sampling station designs are to perform RT-PCR sampling for laboratory testing safely. The anticipated capacity of the units is around 50–100 potentially infected per day with an assumed lifetime of one year; the scenario studied focuses on the comparison of a 'repurposing' phone booth and a 'new build' sampling station, with an emphasis on the virgin materials used and associated manufacturing processes in the processing of raw materials into the components and their assembly during the construction process.

The design of the sampling station integrates several design criteria to avoid the spread of infection, such as a spatial separation between potentially infected and healthcare workers realised as a transparent booth for the latter with protruding glove mount to reach the patient for swab testing or a movable platform structure with ground mounting to allow flexible deployment for semi-outdoor and outdoor conditions, and with the cabin and installed gear sufficiently sturdy and waterproof to withstand such. The focus of the scenario examined is the comparison of the telephone booth repurposing to a new build. Both units describe the approximately similar dimensions, as shown in the drawings in Figure 1.

Both options envisage a mixed steel/aluminium framework mounted to a movable platform structure. An outer shell made of transparent materials such as glass or acrylic panels, covering the structural frame and ending at the top with an opaque roof, defines the cabin's interior with a sufficiently airtight enclosure. In addition, provision is made on the front openings and holders for protruding arm-length medical gloves to allow the healthcare workers to perform the procedure from the cabin. At the rear of the cabin, air handling units containing an air conditioner, HEPA filtration system, and air blower are installed and connected to the cabin interior. Additional equipment installations include a microphone/speaker for communication and replacing the lighting fixture inside. In the case of the new build, all the materials are new and, therefore, part of the assessment. In addition, since all electrical equipment for the sampling station options is identical, they are excluded from the evaluation. The phone booth conversion process involved replacing the concrete foundation, including its steel supports, with a moveable platform consisting of a corrugated stainless-steel sheet supported by a steel frame of rectangular steel sections with wheels and stops fitted. Front and rear glass panels are replaced with acrylic panels to allow for protrusions for gloves and ventilation equipment, which is enclosed in acrylic boxes for protection. A door panel made of aluminium frames and acrylic panels is fitted to the cabin together with sealing and floor extensions to ensure a sufficiently airtight enclosure. At the front and back of the cabins, the tempered glass sheets are replaced with acrylic sheets to allow medical gloves and electrical equipment, such as the portable air conditioning unit, air filter, and blower, to be installed.

3.2. Cost-time consideration

The composition of the production costs of the two options includes material, labour, machine use, and delivery and transport if charged. The time cost is mutually adjusted if multiple units are included in a process. Costs are compiled from price offers based on established bills of quantities derived or services and from consultation with the executing assembly team of the repurposing prototype. This is also the case for time documentation, where data is based on either actual records or estimates from contractor requests. The time consideration includes the effort for the associated manual production process and, in the case of the repurposing option, the time to remodel a decommissioned phone booth. To determine the most efficient and cost-effective method, cost and time considerations are evaluated separately and comparatively.

3.3. Life cycle assessment

The LCA aims to facilitate decisions regarding the environmental impacts of using phonebooth repurposing as COVID-19 sampling stations based on multiple impact analyses regarding global, regional, and local effects such as pollution through emission or toxicity. Common environmental impact considerations for building construction-related LCA are Global Warming, Acidification, Eutrophication, Abiotic Depletion, Ozone Depletion, Photochemical Ozone Creation, and Total Primary Energy Usage (Hauschild, Rosenbaum, and Olsen 2018). The focus of the evaluation is foremost on the different production/construction of the sampling stations since their functionality, usability, and overall service life are of equal value. Accordingly, the study includes the material used and transportation associated with the actual production process and the energy used.

3.3.1. System boundaries

The unit of analysis is defined as the manufacturing of a single-chamber COVID-19 sampling station unit with internal dimensions of $0.9 \times 0.9 \times 2.1$ m using aluminium and steel profiles, acrylic panels, steel plates and mounting accessories, and epoxy paint as the primary construction materials for operation in a tropical climate with average temperature and humidity of 30 degrees Celsius and 70% relative humidity. The system boundary is defined as a cradle-to-gate setting, which evaluates the life cycle of the option from extraction to the point of manufacture and ends before it is transported to the user. Thus, the lifecycle stages include material production and their assembly process. The operational and end-of-life exclusion is due to the ambiguity of what will happen to the sampling stations once they are operated and finally no longer needed, leading to unpredictable end-of-life determination. Inputs consist of raw materials, grid power, and fuels such as gasoline, diesel, oil, and/or coal, and outputs consist of air, water, and solid waste emissions. The raw material extraction and the transport route to the assembly sites are included in the material production phase, focusing solely on fabricating the two optional sampling station considerations. By employing a cut-off evaluation, the repurposing option accounts for reusing the phone booth in the life cycle assessment by allowing for reused parts in the manufacturing process, eliminating the need for virgin materials (ISO 2006).

With the phone booth and later COVID-19 station being understood as part of the built environment and using construction materials and conventional techniques, this study follows the EN 15,978 definition of the life cycle stages of buildings. Accordingly, the boundary of this study includes product stages A1-A3 (Raw Material Supply, Transport, Manufacturing) and the construction process stages A4-A5 (Transport, Construction/Installation Process).

3.3.2. Data requirements

Material manufacturing data are compiled from established bills of quantities derived from drawing documentation and team consultation. In a spreadsheet-based approach, the material components, quantities, and associated work processes are listed systematically to match the units of the associated LCA data. An overview is provided in the appendix under Tables A1– A7. Since impact data of the Thai construction is not widely available, multiple data sources are used for this study. These include the ÖKOBAUDAT (2021), ESUCO (2014), ECOINVENT (2020), and manufacturer databases. For evaluations requiring electricity, the Thai energy mix is assumed.

ReCiPe 2016 was chosen as the lifecycle impact assessment method; the midpoint level indicators (Hierarchist) were used as is relatively recent and used in the construction sector (Feng et al. 2023). A comprehensive LCIA methodology typically assesses multiple impact categories, such as climate change, human toxicity, and ecosystem quality (Dong and Ng 2014). To improve clarity and reduce clutter in figures and tables, we have focused on a subset of impact categories that are most relevant or widespread (dos Santos et al. 2022), using the categories of Global

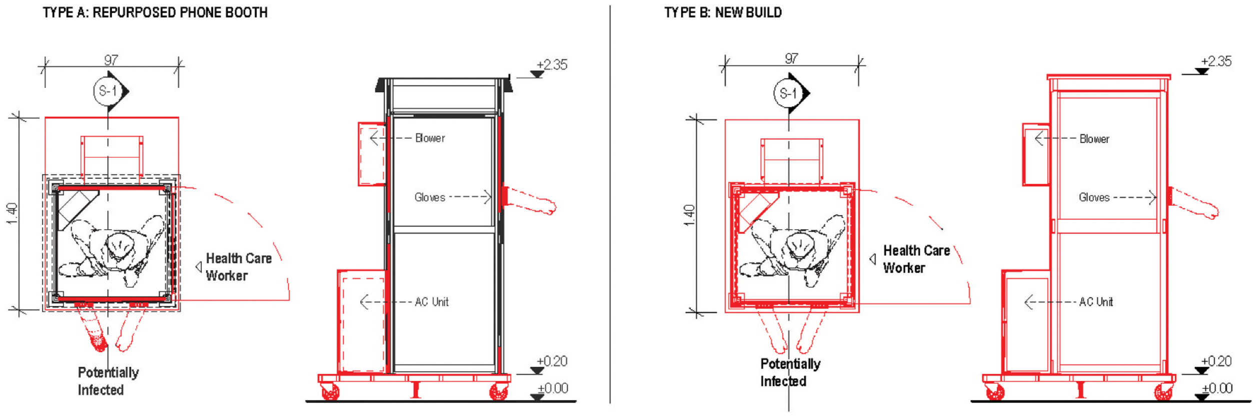

Figure 1. Drawings of Covid-19 sampling stations, indicating new (red) and existing (black) components, illustrating a wide range of dimensional and structural similarities to ensure adequate LCA comparison - approximate scale: 1/50.

Warming, Abiotic Depletion, Acidification, Eutrophication, Photochemical Ozone Creation, and Total Primary Energy usage selected for this analysis. Together with Ozone Depletion, these indicators are typically required for building certification, thus reflecting their wide recognition in the sector (Kofoworola and Gheewala 2009). Due to negligible amounts, Ozone Depletion is omitted from the study. The scope of the life cycle assessment ends with the characterisation of impact categories and comparing their results. An independent critical review is carried out to ensure realistic and verifiable results.

4. Results

The following results overview cost-time analysis outcomes in Table 1, and the LCA results are shown in Table 2 and Figures 2–4.

4.1. Cost-time consideration

An overview of cost-time considerations is provided in Table 1. Comparing the two variants shows the phonebooth refurbishment is cheaper than a new build sampling station. Such is mainly due to the reduced amount of virgin material needed as a structural framework already exists from reusing the phone booth. Yet, the renovation of the phone booth with unforeseen detail changes and eventual repairs makes it challenging to ensure that costs remain the same between renovations. Moreover, different production times must be expected between individual repurposing. Further, it is important to provide an actual price for the phone booth units in the future to make the cost comparison more accurate. In the present case, the telecom provider bears these unreported costs.

Regarding production time, the telephone booth renovation is clearly at a disadvantage. For instance, it takes five more days to complete the selection, repair, and sanitation process. Such is a real disadvantage in an evolving pandemic, making phone booth reuse problematic. The main drawback of the extended production time is uncertain fixes and overall customisations required. While appearing similar, all stations have slight differences in how they are constructed. Such an inconsistency also means pre-production preparation cannot be made. In addition, depending on individual takeoff measures and customisation requirements, possible optimisation processes that normally occur through simple, repeated assembly steps with identical components are further restricted.

4.2. Life Cycle Analysis (LCA)

Table 2 shows the calculated LCA results concerning the product and construction stages of the options considered: Repurposing and New build.

The result shows that repurposing generally has a lower environmental impact due to the lower use of virgin materials, except for Photochemical Ozone Creation. This is also attributed to the understanding that the materials and processes involved are similar for both options and that fewer material quantities have been used for the repurposing.

Table 1. Total Cost-time Assessment Results.

Indicator	Repurposing	New build	Difference	Unit
Time	80.0	25.0	55.0	h
Cost	2,730	3,100	370	USD

Table 2. Calculated Life Cycle Analysis Results.

Indicator	Repurposing	New build	Unit
Global Warming	3.76E+02	9.14E+02	kg CO_2e
Abiotic Depletion	6.12E+03	9.11E+03	kg Sbe
Acidification	1.25E+00	3.21E+00	kg SO_2e
Eutrophication	1.67E−01	3.30E−01	kg PO_4e
Photochemical Ozone Creation	6.65E+00	1.61E−01	kg C_2H_4e
Primary Energy	7.74E+03	1.71E+04	MJ

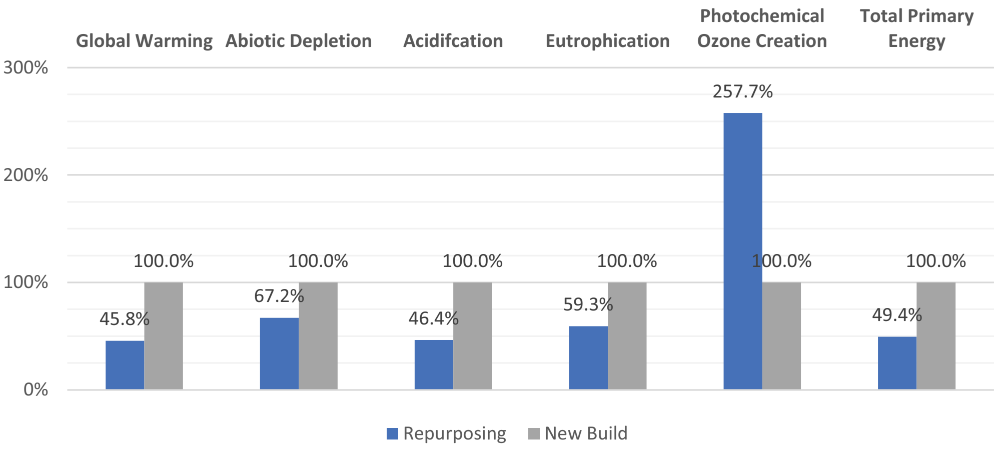

Figure 2. Illustrated Life Cycle Assessment (LCA) Results - Normalized to new build results.

4.2.1. LCA comparison

Figure 2 illustrates the lifecycle assessment results based on a normalisation of the new build option. In terms of Global Warming, a common indicator of the environmental impact of human activities, repurposing causes less than half the greenhouse gases of the new build option. The amount mainly results from producing new materials and the associated assembly processes of the sample station options. Other investigated environmental indicators respond similarly to the Global Warming result described. For instance, Acidification and Eutrophication of the repurposing are also around half the amount calculated for the new build.

Photochemical Ozone Creation shows the opposite trend, with the repurposing's impact being far above the new build. Here, the rise derives primarily from involved transportation during construction/assembly due to the selection process of finding and delivering suitable phonebooths, leading to larger needs regarding vehicle types and driving distances. In addition, the new build option is relatively low since only one assembly location is foreseen, and all materials come from one supplier. Overall, the Photochemical Ozone Creation environmental impact is irrelevant due to its comparably small amounts. Comparing the primary energy use shows that repurposing consumes about half of the required amount, making it an attractive realisation option for countries with low renewable electricity generation.

4.2.2. Resource depletion using virgin material

Figure 3 illustrates the environmental impact comparison of virgin materials production (stages A1-A3) with the New Built option normalised.

Concerning different material impacts, the figure shows that for the repurposing option, acrylic panels have the most significant impact on Global Warming, followed by aluminium and steel components. Involving Abiotic Depletion, acrylic's influence dominates, with only steel further recognisable. For Eutrophication, too, acrylic shows the highest negative impact, whereas steel primarily influences Acidification. For the new build option, acrylic components significantly affect Global Warming, Abiotic Depletion, and Eutrophication, whereas aluminium and steel impacts Acidification higher than acrylic. For both options, aluminium and steel have a dominating effect on Photochemical Ozone Creation, whereas acrylic shows the highest impact on Total Primary Energy Usage.

Altogether, in the context of the materials and quantities used, the reuse option benefits from savings in acrylic products, which are derived from petroleum resources, as well as savings in steel and aluminium products, which are derived from resources such as iron ore, coal, or bauxite.

4.2.3. Repurposing components

With only the product and construction process stages included in the system boundary, the impact derives from the correlation between the two stages. For the repurposing option, as shown in Figure 4, most impact derives from the utilised materials' product stages (A1-A3). On the other hand, the construction process stages (A4-A5) are significantly smaller due to comparatively small assembly work and the associated use of electric tools. This behaviour is observed under the indicators for Global Warming, Acidification, Eutrophication, and Primary Energy, where respective values show that the product stages dominate and influence the environmental impact between 60.9–99.2%. Conversely, only Photochemical Ozone Creation shows the opposite behaviour where the construction stage, influenced by higher transportation needs, makes up for the indicator almost entirely on its own. This is due mainly to the overall negligible amounts.

5. Conclusion

This study compared the environmental and economic performance of repurposing a telephone booth into a COVID-19 sampling station versus constructing a new one. The study conducted a cost-time

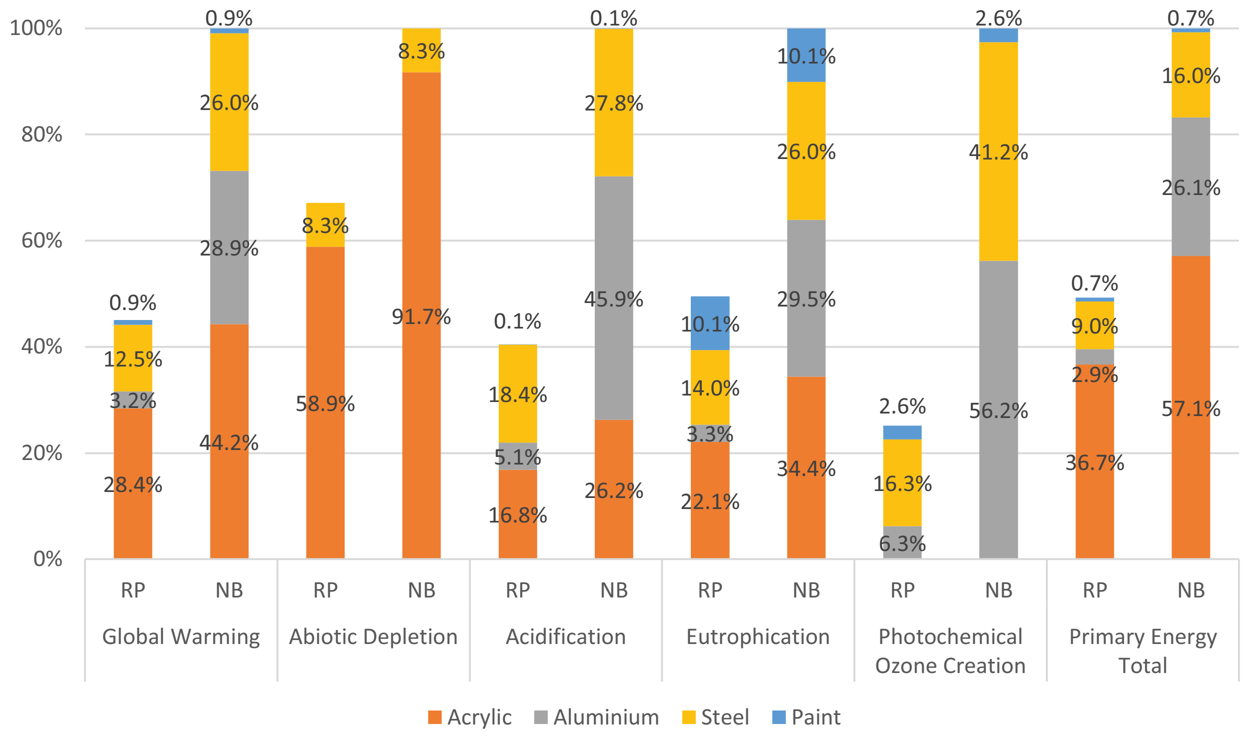

Figure 3. Comparison of Environmental Impact based on virgin material production between Repurposing (RP) and New Built (NB) option with New Build Normalization.

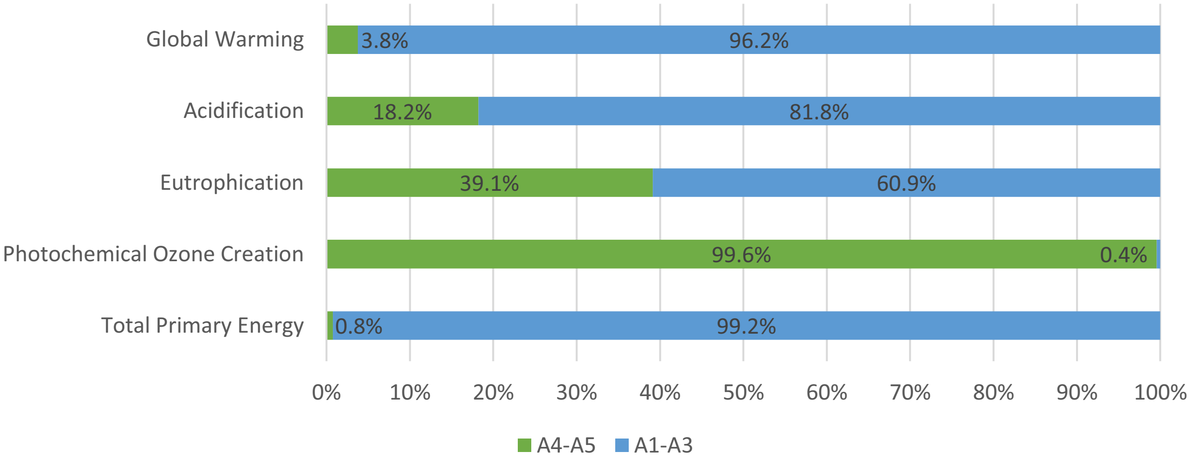

Figure 4. LCA results of the repurposing option by product stage (A1-A3) and construction process stage (A4-A5).

comparison and a comparative LCA to understand both options' environmental impacts and associated financial and time expenditures.

The results show that repurposing a phone booth into a COVID-19 sampling station has a lower environmental impact than manufacturing a new build sampling station. The LCA results indicate that the repurposing reduces CO^2 emissions, resource depletion, and other associated environmental impacts while reducing the need for new materials and avoiding the disposal of existing ones. The cost-time comparison shows that while repurposing appears slightly cheaper, the actual effort involved in a phone booth repurposing is more significant and less predictable, which makes it vulnerable to unforeseen costs.

These findings have significant implications for circular economy approaches and emergency response situations like pandemics. Repurposing outdated urban infrastructure into sensible and resilient solutions for sustainable use can significantly reduce environmental impacts and potentially reduce damage to human health and ecosystems. Future studies could consider extending into studying actual operational and end-of-live scenarios of sampling stations and further investigate alternative adaptive reuse strategies to maximise the usage phase of decommissioned phone booths and further reduce the environmental impact. In addition, the research could increase understanding of the use of phone booths as COVID-19 sampling stations and their social benefits, which could have important public health implications.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Martin Schoch is an assistant professor at the School of Architecture and Design of the King Mongkut's University of Technology Thonburi (KMUTT), Thailand, where he teaches architectural design and environmental technology. He has a Ph.D. in Information Technology on the topic of Building Volume Optimization. His research focuses mostly on sustainable building aspects.

Sunaree Lawanyawatna is an assistant professor at the School of Architecture and Design, King Mongkut's University of Technology Thonburi (KMUTT), Thailand. She lectures on the topic of residential architectural design and narrative design class. She is a director of the Humanitarian Design Laboratory; her research focuses on emergency response architecture, social aspects of architectural design, and design education.

Shabbir H. Gheewala is a professor at the Joint Graduate School of Energy and Environment (JGSEE), Thailand where he has led the Life Cycle Sustainability Assessment Lab for over 20 years. He also holds an adjunct professorship at the University of North Carolina Chapel Hill, USA. His research focuses on the sustainability assessment of energy systems; sustainability indicators; circular economy, and certification issues in biofuels and the agro-industry. He is a national expert on life cycle inventory as well as product carbon footprinting and water footprinting in Thailand. Shabbir mentors the research network on sustainability assessment and policy for food, fuel, and climate change in Thailand. With over 300 papers in peer-reviewed journals, he serves on the editorial boards of the International Journal of Life Cycle Assessment, Sustainable Production and Consumption, and the Journal of Cleaner Production. Along with graduate teaching and research, Shabbir has worked extensively with industry in Thailand providing training and consultancy to scores of companies with aspirations towards improvements in sustainability.

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Appendixes

Table A1. Bill of Material Repurposed Phone Booth.

Category	Element ID	Quantity	Type	Dimension [mm]	Area [mm2]	Surface [m2]	Volume [m3]
Material	Acrylic Screen Door Panel	1	Acrylic Sheet (Transparent) Laser Cut	8×740x790	584600	1.19368	0.0047
Material	Acrylic Screen Door Panel	1	Acrylic Sheet (Transparent) Laser Cut	8×740x960	710400	1.448	0.0057
Material	Acrylic Screen Front Panel	1	Acrylic Sheet (Transparent) Laser Cut	8×740x950	703000	1.43304	0.0056
Material	Back panel	1	Acrylic Sheet (White) Laser Cut	8×740x2100	1554000	3.15344	0.0124
Material	Cabin Lower Cover	2	Acrylic Sheet (White) Laser Cut	8×760x190×2	288800	0.608	0.0023
Material	Casing AC Unit	1	Acrylic Sheet (White) Laser Cut	6×450x760	342000	0.69852	0.0021
Material	Casing AC Unit	2	Acrylic Sheet (White) Laser Cut	6×760x370×2	566100	1.15944	0.0034
Material	Casing AC Unit	2	Acrylic Sheet (White) Laser Cut	6×450x370×2	333000	0.68568	0.0020
Material	Casing Blower	1	Acrylic Sheet (White) Laser Cut	6×400x460	184000	0.37832	0.0011
Material	Casing Blower	2	Acrylic Sheet (White) Laser Cut	6×400x210×2	168000	0.35064	0.0010
Material	Casing Blower	2	Acrylic Sheet (White) Laser Cut	6×460x210×2	193200	0.40248	0.0012
Material	Door Frame	2	Aluminum Profile 15 × 40 mm	15×40x1900×2		0.4204	0.0023
Material	Door Frame	3	Aluminum Profile 15 × 40 mm	15×40x76×3		0.2544	0.0014
Material	Floor Plate Cover	1	Stainless Steel Plate (Diamond Riffle) 1 mm	1×1520x1120	1702400	3.41008	0.0017
Material	Floor Plate Structure	5	Steel Profile 25 × 50 mm (Spray Paint)	25×50x1350×5		1.025	0.00034425
Material	Floor Plate Structure	7	Steel Profile 25 × 50 mm (Spray Paint)	25×50x920×7		0.9835	0.00049266
Material	Frame Mounting Plate	4	Steel Plate 5 mm (Spray Paint)	5×100x100	40000	0.088	0.0002
Material	Glove Mount	2	Acrylic Sheet (Transparent) Laser Cut	15×300x300	180000	0.396	0.0027
Material	Floor Stopper	2	Floor Fixation, Galvanized or Stainless Steel	H: 150, 400 Gramm	—	—	—
Material	Tray Mount	2	Stainless Steel Sheet 2 mm	5×400x400×2	—	0.6432	0.00032
Material	Coaster Wheel	4	Outdoor Spec. Zinc plated	H: 2 Inch, 350 Gramm	—	—	—

Table A2. Bill of Material New Build.

Category	Element ID	Quantity	Type	Dimension [mm]	Area [mm2]	Surface [m2]	Volume [m3]
Material	Acrylic Screen Panels	2	Acrylic Sheet (Transparent) Laser Cut	8×870x2150×2	3741000	7.57864	0.029928
Material	Acrylic Screen Door Panel	1	Acrylic Sheet (Transparent) Laser Cut	8×740x790	584600	1.19368	0.0046768
Material	Acrylic Screen Door Panel	1	Acrylic Sheet (Transparent) Laser Cut	8×740x960	710400	1.448	0.0056832
Material	Back panel	1	Acrylic Sheet (White) Laser Cut	8×740x2100	1591000	3.22824	0.012728
Material	Casing AC Unit	1	Acrylic Sheet (White) Laser Cut	6×450x760	342000	0.69852	0.002052
Material	Casing AC Unit	2	Acrylic Sheet (White) Laser Cut	6×760x370×2	562400	1.15192	0.0033744
Material	Casing AC Unit	2	Acrylic Sheet (White) Laser Cut	6×450x370×2	333000	0.68568	0.001998
Material	Casing Blower	1	Acrylic Sheet (White) Laser Cut	6×400x460	184000	0.37832	0.001104
Material	Casing Blower	2	Acrylic Sheet (White) Laser Cut	6×400x210×2	168000	0.35064	0.001008
Material	Casing Blower	2	Acrylic Sheet (White) Laser Cut	6×460x210×2	193200	0.40248	0.0011592
Material	Ceiling Panel	1	Acrylic Sheet (White) Laser Cut	6×660x660	435600	0.88704	0.0026136
Material	Door Frame	2	Aluminum Profile 15 × 40 mm	15×40x1900×2		0.4204	0.00228
Material	Door Frame	3	Aluminum Profile 15 × 40 mm	15×40x760×3		0.2544	0.001368
Material	Floor Plate Cover	1	Stainless Steel Plate (Diamond Riffle) 1 mm	1×1520x1120	1702400	3.41008	0.0017024
Material	Floor Plate Structure	5	Steel Profile 25 × 50 mm (Spray Paint)	25×50x1350×5		1.025	0.00034425
Material	Floor Plate Structure	7	Steel Profile 25 × 50 mm (Spray Paint)	25×50x920×7		0.9835	0.00049266
Material	Frame Mounting Plate	4	Steel Plate 5 mm (Spray Paint)	5×100x100	40000	0.088	0.0002
Material	Glove Mount	2	Acrylic Sheet (Transparent) Laser Cut	15×300x300	180000	0.396	0.0027
Material	Roof Cover	1	Steel Sheet 0.5 mm (Spray Paint)	5×1000x1000	1000000	2.02	0.005
Material	Structural Framing	4	Aluminum Profile 30 × 60 mm	30×60x760×4	0	0.5616	0.00027816
Material	Structural Framing	4	Aluminum Profile 50 × 50 mm	50×50x2100×4	0.06	1.7	0.0006426
Material	Structural Framing	6	Aluminum Profile 30 × 60 mm	30×60x760×4	0.11	0.8424	0.00041724
Material	Tray Mount	2	Stainless Steel Sheet 0.5 mm	1×400x400×2	0.09	0.6432	0.00032
Material	Floor Stopper	2	Floor Fixation, Galvanized or Stainless Steel	H: 150, 400 gr	—	—	—
Material	Coaster Wheel	4	Outdoor Spec. Zinc plated	H: 2 ″, 350 gr	—	—	—

Table A3. Bill of Material Original Phone booth without Phone Apparatus (Grayed Materials have been removed).

Category	Element ID	Quantity	Type	Dimension [mm]	Area [mm2]	Surface [mm2]	Volume [mm3]
Equipment	Light Fixture	1	Metal Casing with Fluorescent Lamp	60 × 250 × 500	—	—	—
Material	Ceiling Cladding	1	MDF Perforated Panel with Cover Paint- 4 mm	4 × 790 × 790	624,100	1,260,840	5,043,360
Material	Fiberglass Formwork	1	Roof Cover: Fiberglass Formwork Painted	140 × 920 × 920	2,723,200	2,723,200	4,084,800
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x730	—	138,700	1,397,220
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x730	—	138,700	1,397,220
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x545	—	103,550	1,043,130
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x545	—	103,550	1,043,130
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x510	—	96,900	976,140
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x510	—	96,900	976,140
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x675	—	128,250	1,291,950
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x675	—	128,250	1,291,950
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x1900	—	361,000	3,636,600
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x1900	—	437,000	5,840,600
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x730	—	138,700	1,397,220
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x545	—	103,550	1,043,130
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x510	—	96,900	976,140
Material	Aluminum Profile	1	Glass Holder Horizontal (Profile Thickness 2 mm)	35×60x800	—	152,000	1,531,200
Material	Aluminum Profile	1	Glass Holder Vertical (Profile Thickness 2 mm)	20×45x2100	—	273,000	512,400
Material	Aluminum Profile	1	Glass Holder Vertical (Profile Thickness 2 mm)	20×45x2100	—	273,000	512,400
Material	Aluminum Profile	1	Glass Holder Vertical (Profile Thickness 2 mm)	20×45x2100	—	273,000	512,400
Material	Aluminum Profile	1	Glass Holder Vertical (Profile Thickness 2 mm)	20×45x2100	—	273,000	512,400
Material	Aluminum Profile	1	Glass Holder Vertical (Profile Thickness 2 mm)	20×45x2100	—	273,000	512,400
Material	Aluminum Profile	1	Glass Holder Vertical (Profile Thickness 2 mm)	20×45x2100	—	273,000	512,400
Material Removed	Glass Sheet	1	Tempered Clear 8 mm	8 × 710 × 1600	—	2,308,960	9,088,000
Material Removed	Glass Sheet	1	Tempered Clear 8 mm	8 × 525 × 1600	—	1,714,000	6,720,000
Material	Glass Sheet	1	Tempered Clear 8 mm	8 × 490 × 1600	—	1,601,440	6,272,000
Material	Glass Sheet	1	Tempered Clear 8 mm	8 × 2120 × 1770	—	7,567,040	30,019,200
Material	Plastic – Solid	1	Signage: Acrylic Sheet White 4 mm	4 × 200 × 490	—	201,520	392,000
Material	Plastic – Solid	1	Signage: Acrylic Sheet White 4 mm	4 × 200 × 525	—	215,800	420,000
Material	Plastic – Solid	1	Signage: Acrylic Sheet White 4 mm	4 × 200 × 710	—	291,280	568,000
Material	Plastic – Solid	1	Signage: Acrylic Sheet White 4 mm	4 × 250 × 320	—	164,560	320,000
Material	Plastic – Solid	1	Signage: Acrylic Sheet White 4 mm	4 × 250 × 320	—	164,560	320,000
Material	Steel	1	Door Hinge L Shaped	40 × 110 × 135	—	32,900	266,000
Material	Aluminum Profile	1	Structural Frame Vertical (Profile Thickness 3 mm)	80×45x2100	525,000	525,000	1,499,400
Material	Aluminum Profile	1	Structural Frame Vertical (Profile Thickness 3 mm)	80×45x2100	525,000	525,000	1,499,400
Material	Aluminum Profile	1	Structural Frame Vertical (Profile Thickness 3 mm)	80×45x2100	525,000	525,000	1,499,400
Material	Metal Sheet Painted	1	Structural Frame 3 mm Epoxy Paint	3×(300 + 300 + 45 + 45 + 361)×2100	2,207,100	4,414,200	6,621,300
Material Removed	Steel Bracket	3	Structural Frame to Footing 3 mm Epoxy Paint	3×40x70×300	54,000	54,000	187,200
Material Removed	Steel Bracket	1	Structural Frame to Footing 3 mm Epoxy Paint	3×80x80×300	72,000	72,000	277,200
Material Removed	Concrete – Structural	1	Reinforced Concrete 1.0 × 1.0 × 0.25	25×1000x1000	—	2,098,420	25,000,000
Material Removed	Steel – Structural	1	Footing Steel Bracket 3 mm Epoxy Paint	3×95x165	31,070	31,070	47,025

(*Continued*)

Table A3. (Continued).

Category	Element ID	Quantity	Type	Dimension [mm]	Area [mm2]	Surface [mm2]	Volume [mm3]
Material Removed	Steel – Structural	1	Footing Steel Bracket 3 mm Epoxy Paint	3×95x166	32,790	32,790	47,025
Material Removed	Steel – Structural	1	Footing Steel Bracket 3 mm Epoxy Paint	3×95x167	32,790	32,790	47,025
Material Removed	Steel – Structural	1	Footing Steel Bracket 3 mm Epoxy Paint	3×95x168	135,355	135,355	222,042

Table A4. Work Processes Repurposed Phone Booth.

	Work type	El. Device	Approx. Time (Min)	Power (W)	Load (W)
1	Cleaning	Water Blasting	20	1,700	566.67
2	Repair	Screwing, Drilling, etc.	10	1,000	166.67
3	Foundation Removal	Unscrewing	10	1,500	250.00
4	Glass Removal	Manual	10	0	0.00
5	Acrylic Sheet New	Laser Cutting	10	8,000	1,333.33
6	Acrylic Sheet New	Drilling, Screwing	20	1,500	500.00
7	Sanding	Sanding	20	250	83.33
8	Color Correction	Paint (Air Compressor)	20	3,300	1,100.00
9	Metal Tray Inst.	Laser Cutting	10	8,000	1,333.33
10	Metal Tray Inst.	Bending	5	10,000	833.33
11	Metal Tray Inst.	Welding	10	15,000	2,500.00
12	Power Supply Inst.	Drilling, Screwing	30	1,000	500.00
13	Door Frame Inst.	Cutting	10	5,000	833.33
14	Door Frame Inst.	Screwing	10	1,000	166.67
15	Floor Plate Inst.	Welding	45	15,000	11,250.00
16	Floor Plate Inst.	Cutting	20	1,000	333.33
17	Floor Plate Inst.	Bending	15	1,000	250.00
18	Floor Plate Inst.	Drilling, Screwing	10	1,000	166.67
19	Cartwheel Stopper	Drilling, Screwing	10	1,000	166.67
21	Graphic Foil	Manual	20	2,500	833.33

Table A5. Work Processes New Build.

	Work type	El. Device	Approx. Time (Min)	Power (W)	Load (W)
1	Steel Framing	Cutting	15	5,000	1,250.00
2	Steel Framing	Welding	30	15,000	7,500.00
3	Steel Framing	Paint (Air Compressor)	40	3,300	2,200.00
4	Acrylic Sheet New	Laser Cutting	30	8,000	4,000.00
5	Acrylic Sheet New	Drilling, Screwing	60	1,500	1,500.00
6	Metal Tray Inst.	Laser Cutting	10	8,000	1,333.33
7	Metal Tray Inst.	Bending	5	10,000	833.33
8	Metal Tray Inst.	Welding	10	15,000	2,500.00
9	Power Supply Inst.	Drilling, Screwing	30	1,000	500.00
10	Door Frame Inst.	Cutting	10	5,000	833.33
11	Door Frame Inst.	Screwing	10	1,000	166.67
12	Floor Plate Inst.	Welding	45	15,000	11,250.00
13	Floor Plate Inst.	Cutting	20	1,000	333.33
14	Floor Plate Inst.	Bending	15	1,000	250.00
15	Floor Plate Inst.	Drilling, Screwing	10	1,000	166.67
16	Cartwheel Stopper	Drilling, Screwing	10	1,000	166.67
17	Graphic Foil	Manual	20	2,500	833.33

Table A6. Transportation Refurbished Phone Booth.

	Transportation	Vehicle	Units	Distance (km)
1	Collection	6-Wheeler with Crane	4	33
2	Cleaning/Fixing	6-Wheeler with Crane	4	40
3	Workshop Delivery	Pickup Truck	1	21
4	QC Delivery	Pickup Truck	1	7.5

Table A7. Transportation New Build.

	Transportation	Vehicle	Units	Distance (km)
1	Material	Pickup Truck	4	30
2	QC Delivery	Pickup Truck	1	7.5