ASSESSING EFFECTIVENESS FOR JUGAAD IN DIRECT EVAPORATIVE COOLING TECHNOLOGIES

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Abstract - The study aims to develop a framework for evaluating Jugaad cooling systems to identify affordable and sustainable cooling solutions for lower socio-economic groups. It compares three innovative Jugaad cooling systems (window, table, and ceiling coolers) with conventional desert coolers using a life cycle analysis to evaluate cost-effectiveness, CO2 emissions, energy consumption, and cooling capacity, for assessing functional effectiveness. The results highlight the table cooler as the most economical and resource-efficient option, despite its lower cooling capacity and higher CO2 emissions. The developed framework provides a tool for stakeholders to assess cooling solutions aligned with economic and environmental goals.

Keywords - Jugaad, Frugality, Sustainability, Affordability, Inclusivity.

I. INTRODUCTION

India's hot and dry summers pose significant challenges for air cooling, especially during heat waves from May to June(Van Oldenborgh et al., 2018). However, in developing countries like India, affording conventional air conditioning solutions,or even basic air coolers, is an issuefor a majority of the population due to financial constraints. For developing quality solutions that are affordable to low-income consumers in a resource-constrained environment, various sectors have witnessed a growing emphasis on frugal innovation (FI)(Chandni et al., 2021). According to Weyrauch & Herstatt (2017), there are three main aspectsof FI, viz. (i) substantial cost reduction, (ii) concentration on core functionalities, and (iii) optimised performance level. Kaur (2016) noted that FI follows phases of conceptualization, experimentation, and implementation, indicating that it is a systematic approach.On the other hand, Radjou et al. (2012) noted that Jugaad is an Indian concept related to generation of improvised, cost-effective solutions in response to pressing needs in critical areas like health, education, agriculture, energy, and housing.Jugaad is somewhat distinct from FI as it is a spontaneous creative response to constraints – most typically a makeshift solution by a lay person or 'Jugaadu', as against the systematic approach of FI for developing appropriate solutions. In fact,Kudva & Kamath (2021) argued that Jugaadcan be a crucial component of the design and innovation process but not be the design solution or innovation itself, as it is 'neither quality design nor frugal innovation'. Owing to its non-systematic nature, Jugaad does not involve a formal method of analysis of its efficiency and performance against various relevant criteria.Our studyproposes a structured method of analysis of Jugaad and, employing the same, investigatesand compares three cooling Jugaads, viz.,Window Air Cooler Jugaad (Next Innovation, 2022), Table Air Cooler Jugaad (Domestic Ideas, 2023), and Ceiling Air Cooler Jugaad (Next Innovation, 2023), along with the industrially manufactured Desert Cooler, with a view to evaluate the most economical and resource-efficient option. The results indicate that a Jugaad can indeed be a 'design solution or innovation itself' in a particular context, offering an acceptable level of quality with low cost.

II. LITERATURE REVIEW

To evaluate a Jugaadas an appropriate solution proving an acceptable level of quality with low cost, we conducted a literature review to identify relevant parameters of evaluation. The proposed evaluation framework includes:(i) Functional effectiveness, which must be analyzed to confirm the Jugaad meets its purpose with performance-based metrics (Zeschky et al., 2011;Bhatti, 2012;Santos et al., 2020; Gomera et al., 2020) (ii) Cost-effectiveness,which ensures resource efficiency and accessibility for various economic backgrounds (Niroumand et al., 2021;López-Sánchez & Santos-Vijande, 2022;Singh & Awasthy, 2023); and (iii) Sustainability, focusing on environmental impact, which is crucial for responsible solutions(Ebolor et al., 2022;Prabhu, 2022).This framework integrates functionality and performance, cost, and sustainability,offering a comprehensive way to assess Jugaadand identify a quality design solution in a particular context.

2.1 Data Collection

Assessment of functionality involved estimates of cooling efficiency and capacityusing manufacturer specifications of airflow rates for desert coolers and the fans used for the Jugaad coolers.

The methodology for comprehensively assessing the environmental and economic impacts of the cooling systems involved a life cycle assessment approach (LCA methodology outlined in ISO 14040). We

sourced data on CO2 emissions, energy consumptions, and costs from manufacturers' environmental product declarations of desert coolers, and assumed eight hours of daily use through four summer months each year for the operational stage, with a five-year lifespan. Computation of electricity costs were based on current rates. The end-of-life stage included estimates for emissions, energy use, and disposal costs, considering waste management and recycling.

III. ANALYSIS OF JUGAAD

The following sections outline the assessment of functionality and the LCA for the three Jugaad cooling systems.

3.1 Functionality

The functional effectiveness of the Jugaad coolers, as against the Desert cooler, needs to be assessed through their cooling capacities. Estimating the cooling capacity of a desert cooler requires values for the airflow rate, temperature difference, and cooling efficiency. It is assumed that all coolers operate under a constant temperature difference of 10°C and the baseline cooling efficiency of 0.62 is consistent due to the uniform vetiver pad thickness across the systems. However, the cooling capacity varies significantly due to differences in airflow rates and vetiver pad surface areas. The desert cooler, with an airflow rate of 1000 CFM and a vetiver pad surface area of 2.025 m², demonstrates the highest cooling capacity, generating 12,555 BTU/min. In contrast, the table cooler, operating at 200 CFM with apad surface area 0.36 m², achieves a cooling capacity of only 446 BTU/min. The ceiling cooler, with a pad surface area of 0.9 m², delivers 1,116 BTU/min, while the window cooleroperating at 200 CFM units with a pad surface area of 1.08 m², produces 1,339 BTU/min.

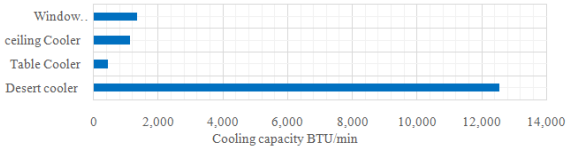


Figure G: Cooling capacity Source: Manufacturer (Bluestar) Specifications

3.2 Life cycle assessment

The various stages of the LCA may be out linedas follows:

Goal and Scope Definition:"Gate to grave", thus the following life cycle steps have been analyzed:

(i)Acquisition,

(ii)Use phase,

(iii)End-of-life. The impact categories considered in the study include CO2 emissions, energy consumption, and cost. Data for the impact categories is collected from USLCI (U.S. Life Cycle Inventory Database) and few secondary sources and specification is taken from manufactures' report declaration.

Life Cycle Inventory (LCI): An extensive inventory has been compiled for the materials used in the coolers. This inventory includes:

(i) detailed records of the quantities of each material used at every stage of the cooler's life cycle,

(ii) the cost of each material, documented at every stage of the cooler's life cycle, and

(iii) CO2emissions associated with each material, calculated for each stage of its life cycle, energy consumption of each material, measured at every stage of its life cycle.

Life Cycle Impact Assessment: This analysis provides a comprehensive comparison of the life cycle costs, energy consumption, and CO2 emissions among the Jugaad coolers and a Desert cooler.

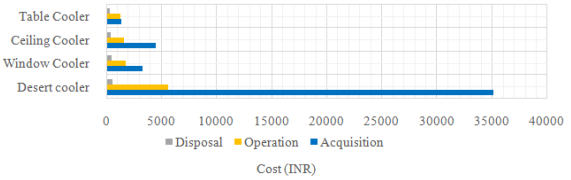


Figure D: Cost throughout Life cycle

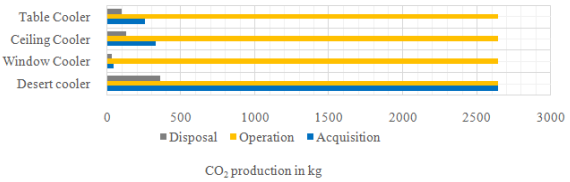


Figure E: Carbon dioxide emission throughout Life cycle

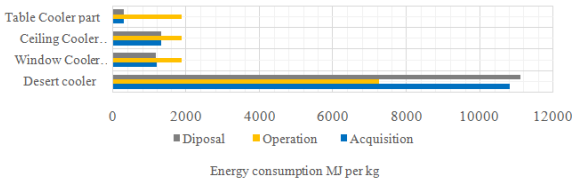


Figure F: Energy Consumption throughout Life cycle

Interpretation: The LCA of Desert Coolers, Window Coolers, Ceiling Coolers, and Table Coolers evaluates their environmental and economic impacts across acquisition, operation, and disposal phases. Desert coolers have the highest energy consumption (29177 MJ), with significant acquisition (10815 MJ) and disposal (11114 MJ) needs. Window and ceiling coolers also show high operational energy (1867MJ each) but have lower acquisition and disposal values. Table coolers, though efficient in disposal (284 MJ), have moderate operational energy. CO2 emissions are significant, with desert coolers producing the most during acquisition and operation (2,643.2 kg), and lower emissions during disposal (356 kg). Window coolers have high operational emissions but lower acquisition and disposal emissions. Ceiling coolers show similar patterns, while table coolers, despite

efficient disposal, still have notable operational emissions. This highlights the need to reduce operational CO2 in cooler design. Life cycle costs vary significantly. Desert coolers incur high acquisition (10,000) and operational costs (5,625), with moderate disposal costs (566). Window and ceiling coolers have similar operational costs (1,617) but differ in acquisition and disposal costs. The table cooler is the most cost-effective, especially with low disposal costs. This underscores the importance of minimizing operational and disposal costs in cooler design and selection.

IV. RESULTS AND DISCUSSIONS

The analysis reveals significant variations in cooling techniques suitable for lower socio-economic groups. Desert coolers, while offering high cooling capacity (12,555 BTU/min), incur substantial operational energy consumption (29,177 MJ/kg) and CO2 emissions (5,642kg) with high acquisition costs (₹10,000). Table coolers are cost-effective with minimal acquisition (₹1,366) and disposal costs (₹290.88), and lower operational energy use (1,867 MJ/kg), but offer lower cooling capacity (446 BTU/min). Window and ceiling coolers balance operational costs and emissions but still have moderate cooling capacities. For lower socio-economic groups, optimizing operational efficiency and minimizing CO2 emissions should be prioritized to enhance affordability and sustainability.

V. CONCLUSION

The study highlights the critical challenges faced by lower socio-economic groups in India, particularly the unaffordability of cooling techniques during hot and dry summers. It proposed a framework for evaluating Jugaad based on cost-effectiveness, resource use, sustainability, and functionality. This framework was used to analyze Jugaad cooling systems, including window, table, and ceiling coolers, compared to desert coolers. The analysis reveals that Jugaad systems, especially the table cooler, offer significant benefits in affordability and resource efficiency, making them suitable for lower socio-economic groups in developing countries.

This framework helps stakeholders balance economic and environmental factors, supporting frugal innovation in resource-constrained environments. By promoting accessible and sustainable cooling solutions, the study contributes to socio-economic inclusivity and long-term environmental sustainability, aligning with global efforts to mitigate climate change and promote sustainable development.

REFERENCES

[1] Bhatti, Y. A. (2012). WHAT IS FRUGAL, WHAT IS INNOVATION? TOWARDS A THEORY OF FRUGAL INNOVATION. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2005910

[2] Chandni, N. H., Antonacci, G., Barlow, J., & Harris, M. (2021). Defining frugal innovation: A critical review. BMJ Innovations, 7(4), 647–656. https://doi.org/10.1136/bmjinnov-2021-000830

[3] Ebolor, A., Agarwal, N., & Brem, A. (2022). Sustainable development in the construction industry: The role of frugal innovation. Journal of Cleaner Production, 380(P2), 134922. https://doi.org/10.1016/j.jclepro.2022.134922

[4] Gomera, W. C., Suhonen, J., Tukiainen, M., Oreku, G. S., Tedre, M., & Oyelere, S. S. (2020). Usability evaluation of frugal innovation: A case of mobile training for micro businesses in Tanzania. African Journal of Science, Technology, Innovation and Development, 1–14. https://doi.org/10.1080/20421338.2020.1772951

[5] Kaur, R. (2016). The innovative Indian: Common man and the politics of jugaad culture. Contemporary South Asia, 24(3), 313–327. https://doi.org/10.1080/09584935.2016.1214108

[6] Kudva, N., & Kamath, D. (2021). Against Jugaad. Ekistics and The New Habitat, 80(2), 47–57. https://doi.org/10.53910/26531313-e2020802560

[7] Leng, J., Wang, Q., & Liu, K. (2020). Sustainable design of courtyard environment: From the perspectives of airborne diseases control and human health. Sustainable Cities and Society, 62(July), 102405. https://doi.org/10.1016/j.scs.2020.102405

[8] López-Sánchez, J. Á., & Santos-Vijande, M. L. (2022). Key capabilities for frugal innovation in developed economies: insights into the current transition towards sustainability. Sustainability Science, 17(1), 191–207. https://doi.org/10.1007/s11625-021-01071-1

[9] Niroumand, M., Shahin, A., Naghsh, A., & Peikari, H. R. (2021). Frugal innovation enablers, critical success factors and barriers: A systematic review. Creativity and Innovation Management, 30(2), 348–367. https://doi.org/10.1111/caim.12436

[10] Prabhu, J. (2022). Frugal Innovation: "Doing more with less." VDI Berichte, 2022(2395), 193–202. https://doi.org/https://doi.org/10.1098/rsta.2016.0372

[11] Radjou, N., Prabhu, J., & Ahuja, S. (2012). Jugaad innovation: A Frugal and Flexible Approach to Innovation for the 21st Century. Radmon House India.

[12] Santos, L. L., Borini, F. M., & Oliveira Júnior, M. de M. (2020). In search of the frugal innovation strategy. Review of International Business and Strategy, 30(2), 245–263. https://doi.org/10.1108/RIBS-10-2019-0142

[13] Singh, D., & Awasthy, R. (2023). Expanding the Horizons of Social Entrepreneurship Through Indigenous Research: A Review and Research Agenda. Journal of Social Entrepreneurship, 0(0), 1–26. https://doi.org/10.1080/19420676.2023.2178484

[14] Van Oldenborgh, G. J., Philip, S., Kew, S., Van Weele, M., Uhe, P., Otto, F., Singh, R., Pai, I., Cullen, H., & Achutarao, K. (2018). Extreme heat in India and anthropogenic climate change. Natural Hazards and Earth System Sciences, 18(1), 365–381. https://doi.org/10.5194/nhess-18-365-2018

[15] Weyrauch, T., & Herstatt, C. (2017). What is frugal innovation? Three defining criteria. Journal of Frugal Innovation, 2(1), 1–17. https://doi.org/10.1186/s40669-016-0005-y

[16] Zeschky, M., Widenmayer, B., & Gassmann, O. (2011). Frugal Innovation in Emerging Markets. Research-Technology Management, 54(4), 38–45. https://doi.org/10.5437/08956308x5404007

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