

Reengineering Technologies for a Sustainable Solution: Ancient Stone Mills to Cutting-edge Drones as an Example



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ABSTRACT

In the pursuit of technological progress, we often overlook the environmental and social costs associated with modern advancements. Recognizing the need to redefine development through the aspect of sustainability, this study explores the integration of sustainable principles within technology innovation. By examining traditional technologies, we uncover inherent sustainable features that risk obsolescence due to modernization's neglect. Proposing a novel approach, we advocate for the reengineering of these traditional technologies by infusing contemporary techniques, thus preserving their essence while enhancing efficiency and sustainability. Our methodology is exemplified through the revitalization of stone mills, a cornerstone in the rural communities of Nepal, India, Bhutan, and beyond, demonstrating the potential for harmonizing tradition with innovation for a sustainable future.

1. Introduction *

In the pursuit of technological progress, we often overlook the social cost associated with modern advancement. This progress has been made in various sectors such as civil engineering, mechanical engineering, architecture engineering and lately in information engineering. We witnessed that the advancement of these technologies enhances our lives and progress however at the same time, it became the crucial cause of environmental degradation and societal division in terms of economy and poverty. In this article, we explore the disparities emerged due to engineering discipline, the root cause, the income distribution and finally propose the potential solution while designing the technology. We proposed stone grinder as an example and explore the cutting-edge drone for its potential deployment. The position of this article is a proposal and layout the platform for a discussion. Thus, we do not have experimental results however, we discuss the expected outcomes and the potential of our proposal.

2. Societal Disparities Induced by Engineering Advancements

The pursuit of engineering advancements, characterized by interdisciplinary collaboration, has been central to civilization's progress. While these advancements boost productivity, infrastructure development, services, and accessibility, they also contribute to disparities in income, social impacts, and environmental degradation. Furthermore, it has been the cause of inequality in terms of income, social impact, and environmental degradation. This challenge, faced globally, underscores the importance of making engineering disciplines both accessible and affordable across all societal sectors. Bridging the educational and developmental divide is crucial to preventing the widening gap between developed and underdeveloped communities. We explore these disparities across various engineering fields in the



Fig. 1 Visual Disparity Illustration in Mechanical Engineering Discipline subsequent sections. To further convey a sense of how inequality plays out in a tangible manner, this paper includes visual illustrations having comparative aspect.

2.1. Mechanical Engineering Discipline

Fig. 1 shows the visual disparity due to mechanical engineering. On one end, communities still rely on manual labor to transport goods, emblematic of regions where mechanical innovations are scarcely integrated. On the other, advanced countries showcase the zenith of mechanical engineering, where technology significantly eases physical burdens. The cause of this sort of disparity goes to the engineering innovation and its uneven adoption.

2.2 Architectural Engineering Discipline

The architecture and construction discipline stands as the foremost global consumer of resources and materials, accounting for approximately 50% of worldwide steel production. Annually, the



Fig. 2 Visual Disparity Illustration in Architecture Engineering Discipline industry utilizes 3 billion tons of raw materials globally to produce building products, highlighting its significant impact on resource use[1]. Fig. 2 showcases the disparities evident in architectural engineering. It demonstrates how real estate development, supported by architectural engineering, operates under certain assumptions. This includes the ownership of land, which may belong to a farmer or a landowner with minimal modern architectural adoption, contrasted with corporate or real estate housing possessing extensive land for skyscraper constructions, typical in metropolitan cities worldwide. Additionally, it highlights the varying degrees of technology adoption, such as Building Information Modeling (BIM), within the Architecture, Engineering, and Construction (AEC) industry.

2. Civil Engineering Discipline

The correlation between social infrastructure, such as highways and roads, and the quality of life and social wellbeing is significant. However, the uneven distribution and construction of such infrastructures exacerbate the disparities between communities. Figure 3 illustrates this divide, showcasing regions with dense road networks in contrast to communities lacking access to these essential social infrastructures.

3. Analyzing the Root Cause

We argued and visualized the disparities between the communities mainly within three disciplines of engineering. The root causes of social disparities highlighted within the realms of mechanical,



Fig. 3 Visual Disparity Illustration in Civil Engineering Discipline

architectural, and civil engineering disciplines can be multifaceted and complex, involving a combination of social, economic, and political factors. Here (Table 1) are some potential root causes mostly reported in earlier literatures[2], [3].

Table 1 Factors affecting income inequality

Factors	Cause
Globalization[2]	skill-biased technological change due to globalization
Technology	technology has led the gaps
Tax Policy	tax-and-transfer systems to counteract rising market inequality
Labor Market Change	decline in organized labor institutions
Education	effect of increased educational attainment on income inequality
Skill Premium	skill premium exacerbate market income inequality
Government Spending	government redistributive spending

4. Sustainable Development Goals (SDGs) and Engineering Discipline

The 17 goals along with 169 development targets set by UN under the flagship of SDGs represent the common development agendas of international communities after overcoming the MDGs in 2015. However, achieving these goals within the set timeframe requires the co-operation from all nations around the world including local stakeholders such as city councils, NGOs, INGOs, Civil societies, Universities and Colleges etc. The 2023 report by the UN indicates that only 50% of the targeted Sustainable Development Goals (SDGs) are on track to meet their deadlines, while 30% are regressing[4]. The progress of the SDGs has been significantly hindered by the lingering effects of COVID-19 and natural disasters globally. This situation has been further exacerbated by the conflict between Russia and Ukraine. Nonetheless, the commitment to the goals and awareness across various sectors has become more pronounced worldwide. One of the reasons behind the rising popularity of this agenda is due to the increment of academic research which draw more attention to the problems which requires more sustainable approaches. In this report, we argue that the goals of SDGs are not possible to attain without comprehensive effort supported by research and education within Engineering disciplines. Furthermore, a cumulative determination and shared commitment are essential—in dedication, solidarity, financing, and action—to drive the world towards a more sustainable path.

5. Embracing Society 5.

As a strategic approach to achieving the Sustainable Development Goals (SDGs), the Japanese Government unveiled the Fifth Basic Plan for Science and Technology (2016–2020), known as "Society 5.0." This initiative aims to foster a sustainable society through the use of cutting-edge technologies, while prioritizing a human-

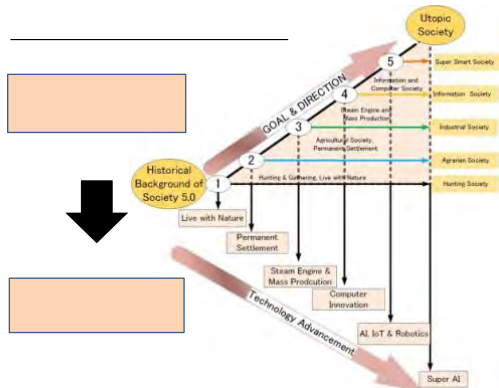


Fig. 4 Society 5.0 and Its Philosophy

centric approach[5], [7].

The concept of futuristic society and industry[8] have caught great attention to promote human centric society where humans and technologies including robots collaborate in a shared working environment.

The philosophy underpinning Society 5.0 is to harness advanced technologies such as AI, IoT, and sensors to forge a new future, moving beyond traditional problem-solving methodologies. This perspective recognizes that while addressing current issues through specific solutions is effective, it often results in a time-consuming process that may not be sustainable in the long term. In contrast, the future creation approach advocated by Society 5.0 aims to build a new world where existing challenges are addressed as part of the broader process of innovation and societal advancement. This proactive strategy is central to the vision of Society 5.0, aiming to solve present problems by shaping an entirely new societal framework.

This philosophy significantly influenced our research, particularly in the design of the stone mill project, named “*Aamako Jato*”[9], [10]. We integrated sustainable features into our project by adopting an eco-friendly power supply system and using locally producible materials. The comprehensive details of this project are elaborated further in section 6.

6. Case Study: Reimagining Traditional Technologies

While thinking sustainability, we can not ignore the contribution made by traditional technologies where the sustainability is highly practiced in many countries around the world. For example, rainwater harvesting[11], [12] solar drying techniques [13], [14] biogas production for cooking[15], terraced farming[16], green roofing[17], [18], natural buildings[19], [20], stone mills[10], [22], and agroforestry. These methods exemplify how ancient wisdom, combined with modern sustainability principles, can contribute significantly to our environmental and societal well-being. Among these technologies, our focus is on the stone grinder, a device widely used in the Himalayan regions, especially in Nepal. Locally known as “*Jatao*” this grinder is a crucial tool for Himalayan communities to process food in an organic way. However, its heavy

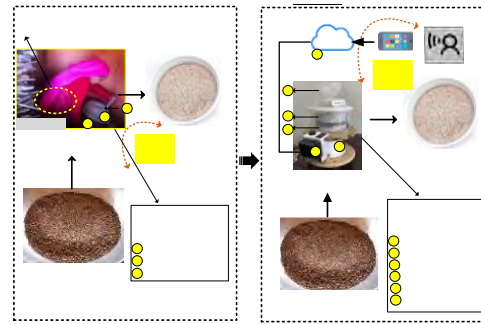


Fig. 5 Redesigned Stone Mill (Aamako Jato)

weight and the absence of integration with modern technologies have led to a decline in its popularity. Therefore, redesigning this device to retain its sustainable features, while enhancing its efficiency and modern appeal, is essential.

6.1 Redesigning Stone Mills for Sustainability

We have reimagined the stone mill, naming the project “*Aamako Jato*,” which translates to “mother’s stone grinder.” The redesign and architectural revision of the stone mill aimed to enhance its efficiency and modern appeal by incorporating IoT, Sensor, and AI technologies. Figure 5 showcases the redesigned stone grinder, featuring several innovative functionalities:

- Retains its traditional core structure, being crafted from stone.
- Offers remote control functionality via iPhone.
- Includes a sensor to alert when the grain supply is depleted.
- Employs a solar panel power system, underscoring Our commitment to sustainability.
- Utilizes locally available materials for construction.

Fig. 5 displays the traditional stone grinder in the left corner and the newly designed prototype on the right. Traditionally, due to the heavy load involved in operating the stone grinder, children and women often use a waistband (i.e locally know and “*patuka*”)for support. Moreover, its operation is entirely manual, consuming

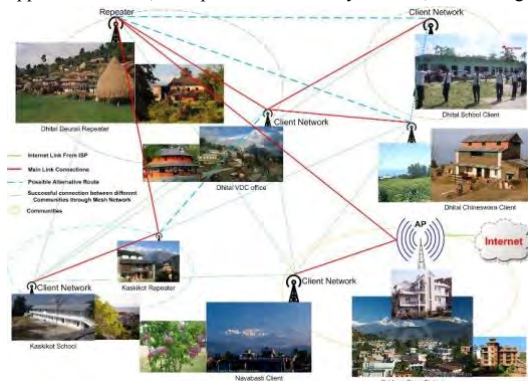


Fig. 6 Information network of Dhital-Kaski built on 2012

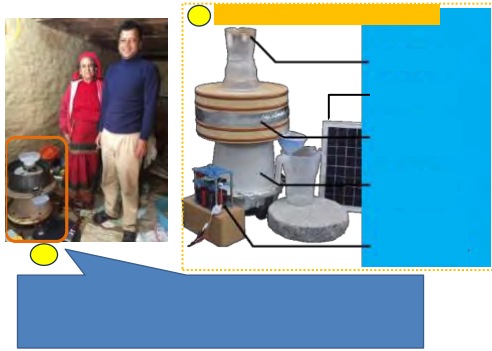


Fig. 7 Prototype setup in Dhital-Kaski Village of Nepal significant time for women in Himalayan areas. This manual labor leads to less time available for other income-generating activities, contributing to economic challenges. To address these issues, we have upgraded the device, enabling remote operation through IoT and AI technologies. This enhanced grinder can be controlled via voice commands over the internet, significantly reducing the physical labor required. As a result, women and children can allocate their time to other income-generating activities or educational pursuits. We anticipate that this innovation will not only empower women but also contribute to alleviating poverty and improving educational outcomes to a considerable degree.

6.2 Stone Grinder Deployment in Himalayan Villages

The primary author of this article has been involved in research aimed at enhancing the communication networks of Dhital-Kaski school networks in the Himalaya, Nepal, since 2010 [22], [23]. Deploying any IoT and AI related tools such as "Aamako Jato" is not possible without reliable communication networks. In this context, IoT enabled stone grinder that we proposed in this article requires stable communication network. In 2018, we successfully deployed the prototype of "Aamako Jato," a sustainable tool augmented with IoT and AI technologies. The enhanced prototype, as illustrated in Figure 7, consists of two parts: the left section displays the stone grinder, developed locally with sustainability in mind, while the right section showcases the components devised in the author's laboratory.

6.3 Potential of Cutting-Edge Drone Applications

In terms of arial transportation, it is very difficult to implement sustainable technology in rural mountain. However, we explored the history of logistics technology traces back to the invention of the wheel mounted on vehicles, an event that occurred after 4000 BC, marking a pivotal transition from human and animal-powered transport to mechanical means[24]. While technological advancements have revolutionized logistics and brought numerous benefits, they have also cast a dark shadow of environmental burden. These Ancient technologies like waterwheels and windmills, which harmonized with nature, remind us of the bridge to a sustainable future. However, turning our attention to aerial logistics, humanity has only acquired the means of air transport in just over a century, lacking the clean past that ground and maritime transport possess. Air transport technology has enabled mass



Fig. 8 Income inequality analysis in various countries

transportation and rapid delivery but at the cost of increasing greenhouse gas emissions. In this new frontier, looking back to the past offers no solutions; instead, we must create new clean technologies for a sustainable future.

Between 1990 and 2019, while the overall greenhouse gas emissions in the EU decreased by 24%, emissions from the transport sector increased by 33%, with the aviation sector recording the most significant growth in passenger kilometers [25]. Many view drones as a promising technology to break the environmental load structure. Comparative studies between drones and traditional transport methods have reported that drone deliveries can reduce energy consumption by 94% and CO₂ emissions by 84% [26].

6. Application of MAS (Multi Agent System) in Drone Control

The Multi-Agent System (MAS) supports drone logistics to address the impacts of communication lag and natural environmental changes, challenges that make centralized control difficult. Drones, acting as autonomous agents gathering information from sensors, work together through MAS to achieve collective goals. Although formulating MAS control is an optimization problem[27], real-world unpredictabilities often challenge practical applications. Recently, researchers have proposed algorithms that ensure the safety of drones, making route choices based on new trajectory information from other drones.

In addition to the focus on efficient operation mentioned above, we have proposed an approach aimed at sustainable drone operations. Our system facilitates the use of drones by a diverse range of people through control interfacing free from reliance on traditional controllers or automated programming. Instead, this system utilizes human gestures recognized by image processing for drone control. This initiative aims to make drone operations accessible to individuals without hardware or who cannot receive formal training[28]. This method has been implemented multiple times in lectures for Japanese high school students, serving as a valuable resource for SDG and IT education. Such advancements not only broaden the application of drone technology but also enhance its accessibility, reflecting a commitment to inclusivity in technological progress. The evolution of logistics, from the invention of the wheel to the shift from natural to mechanical power, has dramatically transformed human life and the distribution of goods over long distances. This technological evolution has brought convenience but also the cost of



Fig. 9 showcases a drone interfacing system controlled by hand signs using a machine learning-based skeleton extraction model. The left image illustrates skeleton extraction from drone-transmitted video for hand sign detection. The right image depicts a lecture on SDGs and drone technology delivered to high school students on June 18, 2023 environmental impact. The latest challenge in air transport, particularly highlighted by drone technology, offers hope for improving sustainability. However, numerous challenges remain to overcome, such as increasing per-unit transport capacity, adapting to changes in the natural environment, ensuring safety, enhancing battery capacity, and developing infrastructure for charging stations.

7. Expected Results and Evaluation

The authors anticipate several impactful outcomes from this research and deployment. However, fully realizing these results is challenging until a sufficient number of stone grinders are deployed locally. We expect significant economic empowerment for women and an enhancement in family bonding as a direct consequence of these devices. Figure 8 illustrates that income inequality in Nepal is notably higher compared to other countries, including Japan, China, and even the USA. Japan showcases a relatively even income distribution, presenting fewer challenges in this regard. Conversely, Nepal's income distribution was markedly uneven between 2000 and 2005. Overall, the situation concerning income distribution in Nepal appears unsatisfactory, highlighting the need for targeted interventions to address these disparities and move towards a more equitable society. Analyzing income distribution is crucial for identifying communities disproportionately affected by economic disparities. This analysis becomes especially important when introducing new technologies, as these innovations have the potential to uplift and empower underprivileged communities. Our innovative tool (i.e. *Aamako Jato*), designed with sustainability and efficiency in mind, aims to support this objective by reducing the time required for daily tasks, thereby allowing individuals more opportunities for income-generating activities. Through targeted deployment and thoughtful integration into daily life, technologies like ours can play a significant role in narrowing the income distribution gap and advancing towards a more equitable society.

7.1 Strengthen family bonding

The migration of local youth to urban areas and foreign countries has led to a demographic shift in Himalayan villages, characterized by decreasing populations and aging communities. Many villages are experiencing a dwindling youth population, leaving primarily

senior citizens behind while their children pursue education or work in cities or abroad. This shift signifies not only a growing social challenge but also a depletion of the close-knit family bonds that were prevalent in the past.

In this context, we propose that a remotely controllable stone grinder could act as a catalyst for strengthening family ties. Children residing in cities or studying abroad could assist with their parents' household tasks via the internet, as our enhanced "Aamako Jato" can be operated remotely to aid in meal preparation for their parents. This anticipated outcome could be further enriched through the integration of VR (Virtual Reality) and AR (Augmented Reality) technologies, offering an innovative approach to maintaining and enhancing family connections despite geographical separations.

7.2 Empower women, children, and elder citizens.

Another anticipated outcome is the conservation of time for women, children, and elderly citizens by minimizing the effort spent on grain grinding for meal preparation. Our findings indicate that income distribution is uneven across various regions. Achieving a sustainable society becomes a formidable challenge without addressing the disparities in income distribution among all communities and without further widening the gap. This project not only aims to enhance efficiency and convenience in daily tasks but also contributes to a broader objective of fostering economic equality and sustainability.

8. Conclusions and Next Steps

We explored several concepts related to achieving a sustainable society, the role of traditional technologies, and their enhancement in the context of the modern era. Our analysis of income inequality revealed that Nepal faces significant challenges in this area, underscoring the need for sustainable solutions. In response, we concentrated on improving traditional food processing systems to better the lives of women, children, and elderly citizens in the Himalayan regions. Our goal is to empower women and elderly citizens to dedicate their time to additional income-generating activities by enhancing traditional technology and lifestyles, rather than relying heavily on modern technology. In this context, we introduced an innovative approach that upgrades a traditional food processing tool with cutting-edge technologies, such as IoT and AI, transforming it into a sustainable system tailored for rural communities. We argue that meeting the Sustainable Development Goals (SDGs) is attainable and sustainable when development processes are inclusively based on traditional knowledge and augmented with the latest technologies. To foster sustainable development, these solutions must be developed using local resources and gain acceptance within local communities. We proposed a conceptual framework and development process that enhances traditional tools by integrating intelligent features without significantly altering their fundamental design, knowledge, and attributes. In our future work, we aim to assess the direct impact of "Aamako Jato," alongside other advanced technologies like drones, on the livelihoods of local people, contributing to the local economy, improving quality of life, and fostering sustainable community development towards realizing a super smart village.

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