A FRAMEWORK FOR SYSTEMS APPROACH TOWARDS SOLVING SOCIALLY RELEVANT ENGINEERING PROBLEMS

YASHWANT PRASAD

DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI

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A Framework For Systems Approach Towards Solving Socially Relevant Engineering Problems

by

Yashwant Prasad

Department of Mechanical Engineering

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CERTIFICATE

This is to certify that the thesis titled **A Framework For Systems Approach Towards Solving Socially Relevant Engineering Problems**, submitted by **Yashwant Prasad**, to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**, is a bona-fide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Prof. S. K. Saha
Professor
Dept. of Mechanical Engineering
IIT Delhi, 110 016

Prof. M. R. Ravi
Professor
Dept. of Mechanical Engineering
IIT Delhi, 110 016

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Place: New Delhi

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Yashwant Prasad

ABSTRACT

This thesis explores systems approach to address socio-technical problems of resource-constrained communities in rural areas of India. Specifically, it targets areas where a significant portion of the population belongs to the Base of the (economic) Pyramid (BoP) with limited purchasing power, who face challenges in accessing modern technologies. The research emphasizes cluster-specific technological interventions where specifications of similar needs vary significantly from region to region, demanding customizable solutions. Designers and researchers from various academic institutions voluntarily invest part of their professional engagements in developing technologies to enhance livelihoods of the resource constrained communities. However, academic professionals face several challenges, primarily due to limited bandwidth in terms of their time and expertise. To improve the effectiveness of technology interventions undertaken by academic institutions, current research was conducted.

A qualitative action research method was employed to identify the challenges faced by the academic institutions in developing technologies for resource constrained communities and strategies to mitigate them. The strategies were validated through their implementations in the projects of the Rural Technology Action Group.

This thesis proposes Human-Centered Systems Engineering (HCSE) framework as a systematic approach for addressing cluster-specific engineering problems of resource constrained communities. The HCSE framework integrates elements of the Human-Centered Design (HCD), the Systems Engineering Process (SEP), the Methodology for Systems Design for Sustainability (MSDS) and the Technology Readiness Level (TRL) scale. It emphasizes the development of Product-Service Systems (PSS) with a strong focus on socioeconomic sustainability. A Rural Technology Intervention Assessment (RTIA) tool is developed based

on the HCSE framework to monitor and evaluate cluster-specific technology interventions. The tool provides a structured approach to assess the progress of the intervention and the TRL.

HCSE framework was implemented to address the challenges faced by artisans in India who rely on traditional hand-operated lathes to craft beads from the stems of Holy Basil for making garlands, resulting in discomfort, physical strain and fatigue. The present research details two designs of wood-turning lathe specifically customized for making beads: one incorporating a timing belt and pulley and another with an electronic drive mechanism. The effectiveness and performance of the new devices were assessed by comparing them to traditional hand-operated lathes based on productivity, maintenance requirements, earnings and affordability. Results indicated that artisan productivity and earnings doubled with the new devices. The HCSE framework was also applied to the Potter's Kiln project, demonstrating its applicability to address rural technology interventions.

Keywords: rural technology development, resource-constrained communities, BoP, socioeconomic sustainability, cluster-specific technology, human-centered design, systems engineering, Product-Service System

सार

यह शोध संसाधन-संकटग्रस्त समुदायों की सामाजिक-तकनीकी समस्याओं को हल करने के लिए सिस्टम दृष्टिकोण की खोज करता है। विशेष रूप से, यह उन क्षेत्रों को लक्षित करता है जहाँ जनसंख्या का एक बड़ा हिस्सा आर्थिक पिरामिड (BoP) के निचले स्तर पर आता है और जिनकी क्रय शक्ति सीमित होती है, जिससे वे आधुनिक तकनीकों तक पहुंचने में कठिनाइयों का सामना करते हैं। यह शोध क्लस्टर-विशिष्ट तकनीकी हस्तक्षेपों पर जोर देता है, जहाँ समान जरूरतों की विशिष्टताएँ क्षेत्र के अनुसार भिन्न होती हैं और अनुकूलन योग्य समाधानों की आवश्यकता होती है। विभिन्न शैक्षणिक संस्थानों के डिज़ाइनर और शोधकर्ता स्वेच्छा से अपने व्यावसायिक दायित्वों का एक हिस्सा संसाधन-संकटग्रस्त समुदायों की आजीविका को बेहतर बनाने के लिए तकनीकों के विकास में लगाते हैं। हालांकि, अकादमिक पेशेवरों को कई चुनौतियों का सामना करना पड़ता है, जिनमें प्रमुख रूप से उनके समय और विशेषज्ञता की सीमित उपलब्धता शामिल है। शैक्षणिक संस्थानों द्वारा किए गए तकनीकी हस्तक्षेपों की प्रभावशीलता में सुधार करने के लिए यह शोध किया गया।

संसाधन-संकटग्रस्त समुदायों के लिए प्रौद्योगिकी विकसित करने में शैक्षणिक संस्थानों द्वारा अनुभव की गई चुनौतियों की पहचान करने और उन्हें दूर करने के लिए रणनीतियाँ विकसित करने हेतु क्वालिटेटिव एक्शन रिसर्च विधि का उपयोग किया गया। इन रणनीतियों को रूरल टेक्नोलॉजी एक्शन ग्रुप की एक परियोजना में लागू करके मान्य किया गया।

यह शोध क्लस्टर-विशिष्ट इंजीनियरिंग समस्याओं को हल करने के लिए एक प्रणालीगत दृष्टिकोण के रूप में ह्यूमन-सेण्टरेड सिस्टम्स इंजीनियरिंग (एचसीएसई) रूपरेखा का प्रस्ताव करता है। यह रूपरेखा ह्यूमन-सेण्टरेड डिज़ाइन (एचसीडी), सिस्टम्स इंजीनियरिंग प्रोसेस (एसईपी), डिज़ाइन फॉर सस्टेनेबिलिटी (एमएसडीएस), और टेक्नोलॉजी रीदनेस लेवल (टीआरएल) स्केल को एकीकृत करता है। यह सामाजिक-आर्थिक स्थिरता को ध्यान में रखते हुए प्रोडक्ट-सर्विस सिस्टम (पीएसएस) के विकास पर जोर देता है। एचसीएसई रूपरेखा के आधार पर एक ग्रामीण प्रौद्योगिकी हस्तक्षेप मूल्यांकन (आरटीआईए) टूल विकसित किया गया है। जो क्लस्टर-विशिष्ट हस्तक्षेपों की निगरानी और मूल्यांकन के लिए एक संरचित दृष्टिकोण प्रदान करता है। यह टूल ग्रामीण प्रौद्योगिकी विकास के संदर्भ में प्रगति और टीआरएल का आकलन करने के लिए एक संरचित दृष्टिकोण प्रदान करता है।

एचसीएसई रूपरेखा को उन भारतीय कारीगरों की चुनौतियों को हल करने के लिए लागू किया गया, जो तुलसी

के तनों से माला बनाने के लिए मनकों को तराशने हेतु पारंपरिक हाथ से चलने वाली खराद मशीनों पर निर्भर करते हैं, जिससे उन्हें असुविधा, शारीरिक तनाव और थकान का सामना करना पड़ता है। वर्तमान शोध में मोती बनाने के लिए विशेष रूप से अनुकूलित खराद के दो डिजाइनों का विवरण दिया गया है: एक में टाइमिंग बेल्ट और पुल्ली प्रणाली का उपयोग किया गया है, जबकि दूसरे में इलेक्ट्रॉनिक ड्राइव तंत्र शामिल है। इन नए उपकरणों की प्रभावशीलता और प्रदर्शन का मूल्यांकन हाथ से संचालित खरादों की तुलना में उत्पादकता, रखरखाव आवश्यकताओं, आय और वहनीयता के आधार पर किया गया। परिणामों से संकेत मिला कि नए उपकरणों के उपयोग से कारीगरों की उत्पादकता और आय दोगुनी हो गई। एचसीएसई रूपरेखा को कुम्हार की भट्टी परियोजना में भी लागू किया गया, जिससे यह सिद्ध हुआ कि यह ग्रामीण प्रौद्योगिकी हस्तक्षेपों को संबोधित करने में प्रभावी है।

Contents

List of Figures

List of Tables

ACRONYMS

AC	Alternating Current
BoP	Base of the (economic) Pyramid
CAD	Computer-Aided Design
CCK	Circular Cross-section Kiln
CSR	Corporate Social Responsibility
DC	Direct Current
FMEA	Failure Mode and Effect Analysis
HCD	Human-Centered Design
HCDT	Human-Centered Design Toolkit
IIT	Indian Institute of Technology
HCSE	Human-Centered Systems Engineering
MED	Model with Electronic Drive
MSDS	Methodology for System Design for Sustainability
MTBP	Model with Timing Belt and Pulley
NGO	Non-Governmental Organization
NPD	New Product Development
PhD	Doctor of Philosophy
PK	Potter's Kiln
PSS	Product-Service System
RTIA	Rural Technology Intervention Assessment
RuTAG	Rural Technology Action Group
SCK	Square Cross-section Kiln
SE	Systems Engineering

SEP	Systems Engineering Process
SHS	Sheep Hair Shearing
TMBM	*Tulsi Mala* Bead Making
TMBMD	*Tulsi Mala* Bead Making Device
TRL	Technology Readiness Level

NOTATION

Latin letters

Letters	Description
a	Cross-section area of cylinder
e	Eccentricity
F	Fluctuating point load
m_e	Eccentric mass

Greek letters

Letters	Description
ρ	Density
ω	Angular speed

Currency

Symbols	Description
$	US Dollar
₹	Indian Rupee