SELECTION AND ANALYSIS OF TECHNOLOGIES DEVELOPED FOR THE BASE OF THE ECONOMIC PYRAMID

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MAY 2023

Selection and Analysis of Technologies Developed for the Base of the Economic Pyramid

by

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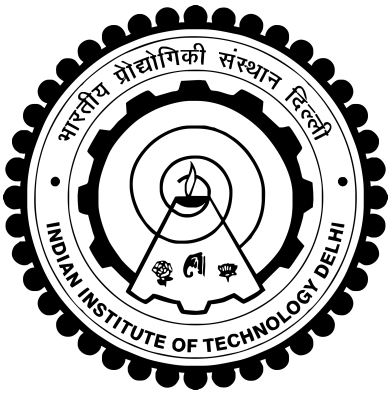
Submitted

in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

May 2023

CERTIFICATE

This is to certify that the thesis titled **Selection and Analysis of Technologies developed for the Base of the Pyramid**, submitted by **Suraj Bhat**, 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.

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Date: 17 May 2023

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ACKNOWLEDGEMENTS

This thesis would not have seen its day without the contribution of many. I want to use this opportunity to show my gratitude towards them.

I thank my supervisors, Prof. S. K. Saha and Prof. Vinay Gupta, for their continued support throughout my PhD journey. Their motivations and criticisms at the appropriate times helped me successfully navigate the ups and downs of this eventful journey. While Prof. Saha's academic proficiency is a given, his stories and anecdotes, which are an endless source of invaluable life lessons, deserve a special mention. I appreciate Prof. Vinay Gupta's patience, especially during our online interactions. In addition to his expertise in multibody dynamics, his experience as a PhD student helped me make plans, manage timelines, and execute the same.

I want to thank the members of my Student Research Committee (SRC) - Prof. S. V. Modak, Prof. D. K. Dubey, and Prof. B. P. Patel, for their timely comments and suggestions on my progress presentations.

I am thankful to my co-researchers, Mr. Vishnu Sukumar, Mr. Yashwant Prasad, Mr. Rajeevlochana, Dr. Sasanka Sinha, Mr. Sreejath, Mr. Sandeep, Mr. Alinjar Dan, Mr. Udayan, Mr. Deepak Raina, Mr. Rahul, Ms. Shivani, Mr. Deepak Bhola, Mr. Bhanu, and Mr. Shashwat, for their inputs during our monthly We Learn through Discussions (WeLD) sessions. Special thanks to my seniors Dr. Paramanand Nandihal, Dr. Riby Abraham Boby, Dr. Amir Abdullah Hayat, and Dr. Anil Kumar Sharma, for their inputs during my initial days and later for sharing their experiences in WeLD sessions.

I want to thank the Rural Technology Action Group (RuTAG) at IIT Delhi for their constant support and for making my time at IIT Delhi enjoyable and fruitful. I would like

to mention Prof. M. R. Ravi, Prof. Sangeeta Kohli, Late Prof. R. R. Gaur, Prof. Pramod Khadilkar, Prof. Debabrata Dasgupta, Prof. Bahni Ray, Prof. Bhupinder Godara, Prof. Ramakrishna, Prof. S.P. Singh, and Prof R. Chattopadhyay for their support and inputs in various RuTAG projects. I would also like to thank RuTAG staff, Mr. Rajkumar Gupta, Mr. Davinder Pal Singh, Mr. Mangal Sharma, Mr. Ashish, and Mr. Harsh Sharma, for their companionship and guidance at RuTAG.

I would also like to thank my hostel mates, Himanshu, Gopal, Chetan, Nandan, and Mayank, for helping me create memorable moments during my stay at Udaigiri. Special thanks to *Ankahi*, the dramatics society of IIT Delhi, for being an avenue of creativity and entertainment for me.

I can't thank my family enough for their support and belief in me. Thanks to my mother, Shwetha Bhat, my father, Shripathi Bhat, and my younger brother Sagar for always being there for me.

Suraj Bhat

ABSTRACT

The economic wealth of the entire adult population of the world can be represented in the form of a pyramid, where the majority are a part of the wider base of the pyramid. More than half of the world's adult population can be classified as the 'Base of the (economic) Pyramid' (BoP). The needs and constraints for the BoP are largely different from those at the top. Most of the BoP live in a resource-constrained environment where the spending habits and overall resource allocations are prioritised differently.

Technology plays an important role in poverty alleviation and the overall development of the society. However, most of the technology is designed for the top of the pyramid. As a result, poverty alleviation efforts through technology interventions often fail or have minimal impact. This is evident when one looks at the number of devices sent as aid to developing countries which are lying unused.

With multiple technologies being developed as a result of developmental efforts worldwide, it becomes important that the right and appropriate technology reaches the user. In this thesis, using the design literature and field experiences, relevant technology attributes were identified and using multiple-attribute based decision-making techniques, a methodology has been proposed to rank the technology alternatives for various use-case scenarios. The methodology is demonstrated with some of the technologies developed for the BoP sector.

Further, design and realistic dynamic analysis of some BoP technologies were attempted to validate their suitability in a given context while considering the various socio-technical constraints encountered in a resource-constrained environment. In this, structural analyses have been carried out for two different technologies. Ergonomics was also considered one of the factors for the multi-body dynamics analysis of a treadle pump. Similarly, constraints

such as manufacturing facilities with larger tolerances were considered, and the effects of joint clearances were analysed. The limitations of designing with constraints were then addressed by formulating it as a design optimisation problem.

Finally, it is concluded that a suitable framework was attempted for the selection and analysis of technologies for resource-constrained settings using advanced analysis tools. Appropriate choices of technologies and optimised designs lead to increased adoption of technologies, because of which, the users at the BoP can reap its economic benefits.

Keywords: technology selection, design for BoP, design for the developing world, design analysis, design optimisation

सार

विश्व की समस्त वयस्क जनसँख्या की आर्थिक संपदा को एक पिरामिड के रूप में दर्शाया जा सकता है, जहां अधिकतम संख्या पिरामिड के बेस में स्थित होती है। विश्व की आधी से अधिक वयस्क आबादी को 'बेस ऑफ द (इकोनॉमिक) पिरामिड' (BoP) के रूप में वर्गीकृत किया जा सकता है। BoP की आवश्यकताएं एवं बाधाएं शीर्ष पर उपस्थित लोगों से अति भिन्न होती हैं। अधिकांश BoP एक संसाधन-बाधित वातावरण में रहते हैं जहाँ खर्च करने की प्रवृत्ति और समग्र संसाधन आवंटन की प्राथमिकता भिन्न रहती है।

गरीबी उन्मूलन एवं समाज के समग्र विकास में प्रौद्योगिकी महत्वपूर्ण भूमिका निभाती है। यद्यपि, अधिकांश तकनीक पिरामिड के शीर्ष के लिए डिजाइन की गई हैं। परिणामस्वरूप, प्रौद्योगिकी हस्तक्षेपों के माध्यम से गरीबी उन्मूलन के प्रयास प्रायः विफल हो जाते हैं या न्यूनतम प्रभाव डालते हैं। इसकी पुष्टि इस बात से होती है की जब हम यह पाते हैं की विकासशील देशों को सहायता के रूप में भेजे गए उपकरण प्रायः अनुपयोगी पड़े पाये जाते हैं।

दुनिया भर में विकासात्मक प्रयासों के परिणामस्वरूप कई प्रौद्योगिकियां विकसित हो रही हैं, तब यह आवश्यक हो जाता है कि सही और उपयुक्त तकनीक उपयोगकर्ता तक पहुंचे। इस थीसिस में, डिजाइन साहित्य और क्षेत्र के अनुभवों का उपयोग करते हुए, प्रासंगिक प्रौद्योगिकी ऐट्रिब्यूट्स की पहचान की गई हैं और मल्टिपल-एट्रिब्यूट बेस्ड डिसिशन मेकिंग तकनीकों का उपयोग करते हुए, विभिन्न प्रौद्योगिकी विकल्पों को रैंक करने की एक पद्धति प्रस्तावित की गई है। BoP क्षेत्र के लिए विकसित कुछ तकनीकों के साथ पद्धति का प्रदर्शन किया गया है।

साथ-साथ, कुछ BoP प्रौद्योगिकियों के डिजाइन और यथार्थवादी डायनामिक विश्लेषण को संसाधन-बाधिक वातावरण के हिसाब से तथा विभिन्न सामाजिक-तकनीकी बाधाओं को ध्यान में रखते हुए उनकी उपयुक्तता को सव्यापित करने का प्रयास किया गया। इसमें दो अलग-अलग तकनीकों का स्ट्रक्चरल एनालिसिस किया गया है। ट्रेडल पंप के मल्टी-बॉडी डायनेमिक्स विश्लेषण के लिए एर्गोनॉमिक्स को भी एक कारक माना गया है। इसी प्रकार, बड़ी टॉलरेंस को सम्मिलित करते हुए विनिर्माण सुविधाओं पर विचार किया गया और जॉइंट क्लीयरेंस के प्रभावों का विश्लेषण किया गया। बाधाओं के साथ डिज़ाइन करने की सीमाओं को डिजाइन ऑप्टिमिसेशन प्रॉब्लम के रूप में सूत्रित करते हुए संबोधित किया गया है।

निष्कर्ष निकलता है कि उन्नत विश्लेषण टूल्स का उपयोग करके संसाधन-बाधित सेटिंग्स के लिए प्रौद्योगिकियों

के चयन और विश्लेषण की एक उपयुक्त रूपरेखा का प्रयास किया गया है। उपयुक्त टेक्नोलॉजी के चयन एवं अनुकूलित डिज़ाइनो के द्वारा टेक्नोलॉजी के स्वीकार करने की संभावना बढ़ जाती हैं और इसके कारण BoP उपयोगकर्ता इसका आर्थिक लाभ ले सकते हैं।

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ACRONYMS

AHP	Analytical Hierarchy Process
AT	Appropriate Technology
BoP	Base of the Pyramid
DeNOC	Decoupled Natural Orthogonal Complement
DoF	Degrees of Freedom
ELECTRE	Elimination et Choix Traduisant la Realite
HCD	Human-Centred Design
IDE	International Development Enterprises
IITD	Indian Institute of Technology Delhi
IRRI	International Rice Research Institute
LINMAP	Linear Programming Technique for Multidimensional Analysis of Preferences
MADM	Multiple Attribute Decision Making
MAUT	Multi-Attribute Utility Theory
MCDM	Multiple Criteria Decision Making
MODM	Multiple Objective Decision Making
MVC	Maximum Voluntary Contraction
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
PSA	Principal Scientific Adviser
RDRS	Rangpur-Dinajpur Rural Service
RuTAG	Rural Technology Action Group
SAW	Simple Additive Weighting
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
USAID	United States Agency for International Development

NOTATION

Latin letters

Letters	Description
a	Cross-section area of cylinder
$\mathbf{A}$	Pairwise comparison matrix for analytical hierarchy process
c	Radial clearance of journal and bearing
C_d	Coefficient of drag
C_i^*	C^* score of i^{th} alternative
d_{ij}	Elements of decision matrix
$\mathbf{D}$	Decision matrix
e	Eccentricity of journal and bearing
E	Young's Modulus
F_{cem}	Current exertable maximum force
F_d	Drag force
F_f	Foot force
$F_{load}(t)$	Current external load on the muscle
F_r	Reaction force from opposite treadle
F_s	Suction force
g	acceleration due to gravity
$\mathbf{g}_i$	Vector of gravity terms for each link
$\mathbf{g}$	Generalised force vector
h	Depth of water source
h_s	Seat height of treadle pump
$\mathbf{h}$	Vector of convective inertia
$\mathbf{I}$	Generalised inertia matrix
$\mathbf{I}_i^c$	Inertia tensor of the i^{th} link about its mass center
$\mathbf{J}$	Constraint Jacobian
l_f	Distance of foot pedal from pivot
l_s	Distance of seat from pivot
m	Mass of a body
$\mathbf{M}$	Mass matrix
$\mathbf{N}$	Normalised decision matrix
$\mathbf{O}$	Null matrix of compatible size
r_{ij}	Elements of relative importance matrix
R_i	Radius of i^{th} link
$\mathbf{R}$	Relative importance matrix
S_i	Seperation measures

v	Linear velocity of piston
$\mathbf{V}$	Weighted decision matrix
$\mathbf{w}$	Vector of attribute weights
$\mathbf{1}$	Identity matrix of compatible size

Greek letters

Letters	Description
$\boldsymbol{\gamma}$	n-dimensional vector of gravitational accelerations
δ	Depth of penetration
$\boldsymbol{\theta}$	Vector of generalised coordinates
$\dot{\theta}_i$	Angular velocity of i^{th} link
λ_e	Eigenvalue of a matrix
$\boldsymbol{\lambda}$	Vector of Lagrange multipliers
ν	Poisson's coefficient
ρ	Density of water
$\boldsymbol{\tau}$	Vector of generalised forces
τ	Joint torque
τ_{cem}	Current exertable maximum torque
$\tau_{joint}(t)$	Current external torque on the joint
$\boldsymbol{\Phi}$	Set of holonomic constraints
$\boldsymbol{\omega}$	Angular velocity vector

Currency

Symbols	Description
\$	US Dollar
₹	Indian Rupee