

**IOT ECOSYSTEM IN EMERGING ECONOMY:
SELECT STUDIES IN INDIA**

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IOT ECOSYSTEM IN EMERGING ECONOMY: SELECT STUDIES IN INDIA

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CERTIFICATE

This is to certify that the thesis entitled “**IoT Ecosystem in an Emerging Economy: Select Studies in India**” being submitted by **Sudatta Kar** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy (Ph.D.)**, is a record of bonafide research work carried out by her. She has worked under our guidance and supervision and has full filled the requirement for submitting this thesis, which has attained the standard required for the Ph.D. degree of this institute. The results presented in this have not been submitted in part or in full to any other university or institute for the award of any degree or diploma.



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ABSTRACT

An attempt has been made in this research to study the Internet of Things (IoT) ecosystem from the perspective of stakeholders and associated emerging digital technologies in emerging economies like India. More specifically, it finds answers to a few key questions viz. How do the IoT ecosystem's key stakeholders deal with their aspirations and challenges? How do they deal with talent deficiency in IoT skills, particularly related to IoT skill shortage in emerging economies like India? What are the key factors and linkages in adopting artificial intelligence (AI) and the 5G network in the IoT ecosystem? In doing so, five studies were conducted viz. analysis of stakeholders and technologies within IoT ecosystem (study-1); understanding professionals' reskilling resistance and learning aspiration towards learning IoT and other emerging digital technologies (study-2); modeling IoT professional's intention to learn and learning behavior (study-3); identify drivers, barriers and linkages in adopting AI in organizational business functions of IoT ecosystem (study-4); identify drivers, linkages, and design policies of 5G technology adoption in IoT solutions (study-5).

As part of studying the IoT ecosystem in **study-1**, the IoT value webs were defined for key stakeholders and key emerging technologies. The study found the key reasons for stakeholders joining the IoT ecosystem, their aspirations, and areas requiring special attention to ensure the IoT ecosystem remains promising. It also identifies the technologies of the IoT ecosystem and their associations and mutual dependency.

The development of IoT-enabled products and solutions largely depends on the availability of skilled professionals to develop IoT solutions. Challenges related to the scarcity of IoT skilled professionals and the key factors that influence professionals to learn skills related to IoT are studied. In **study-2**, a case study of a multi-national corporation is used to study the ambidextrous behavior of employees towards learning IoT skills. This study proposes a non-linear relationship in the form of an S-curve of employees' reskilling resistance and inverse S-Curve of employees' learning aspirations towards IoT skills. It explains the moderation effect of the influencing factors like skill distance, performance rating, ease of access convenience, duration of the current project, the use potential of the new skill on the exploration, and exploitation behavior along the S-Curve.

Further, in **study-3**, ambidextrous learning theory and unified theory of acceptance and use of technology (UTAUT) are extended to develop the Learning Emerging Digital Skills (LEDS) behavioral model. The LEDS model describes the antecedents of professionals' learning

behavior towards fast-changing emerging digital technologies involved in IoT. A nationwide survey of 685 professionals across 95 firms engaged in IoT product and solution development in India was undertaken. Empirical research reveals that social influence and personal innovativeness substantially impact the intention to learn. Additionally, anxiety, long-term consequence, and job relevance also affect behavioral intention to learn. Gender, performance level, and technology preference moderate the relationship between antecedents and the intention to learn.

The technological revolution reveals that the new challenges of IoT solutions are overcome by 5G connectivity and AI-based solutions. We studied drivers of AI and 5G networks in the IoT ecosystem. In **study-4**, the hierarchical relationship among the drivers and barriers of AI adoption across organizational business functions of the IoT ecosystem is established using the total interpretive structural modeling (TISM) technique. AI solutions' decision-making ability and accuracy are the most influential drivers. Lack of AI adoption strategy, lack of AI talent, and lack of leadership commitment are the most significant barriers that affect other barriers. Based on the findings, recommendations are shared for practitioners and executive leadership to help address the challenges of IoT ecosystems.

Further in **study-5**, TISM is used to establish hierarchical relationships among the drivers of 5G adoption are established. The primary drivers are low energy consumption, broad wireless coverage, and low latency. Recommendations shared for policymakers, service providers to improve the demand and supply side of 5G networks for successful deployment of IoT solutions.

सार

इस शोध में भारत जैसी उभरती अर्थव्यवस्थाओं में हितधारकों और संबंधित उभरती डिजिटल प्रौद्योगिकियों के दृष्टिकोण से इंटरनेट ऑफ थिंग्स (IoT) पारिस्थितिकी तंत्र का अध्ययन करने का प्रयास किया गया है। अधिक विशेष रूप से, यह कुछ प्रमुख प्रश्नों के उत्तर ढूंढता है जैसे। IoT पारिस्थितिकी तंत्र के प्रमुख हितधारक अपनी आकांक्षाओं और चुनौतियों से कैसे निपटते हैं? वे IoT कौशल में प्रतिभा की कमी से कैसे निपटते हैं, विशेष रूप से भारत जैसी उभरती अर्थव्यवस्थाओं में IoT कौशल की कमी से संबंधित हैं? IoT पारिस्थितिकी तंत्र में कृत्रिम बुद्धिमत्ता (AI) और 5G नेटवर्क को अपनाने में प्रमुख कारक और संबंध क्या हैं? ऐसा करने में, पांच अध्ययन किए गए अर्थात्। IoT पारिस्थितिकी तंत्र के भीतर हितधारकों और प्रौद्योगिकियों का विश्लेषण (अध्ययन -1); IoT और अन्य उभरती डिजिटल तकनीकों को सीखने के लिए पेशेवरों के कौशल प्रतिरोध और सीखने की आकांक्षा को समझना (अध्ययन-2); सीखने और सीखने के व्यवहार के लिए IoT पेशेवर के इरादे को मॉडलिंग करना (अध्ययन-3); IoT पारिस्थितिकी तंत्र के संगठनात्मक व्यावसायिक कार्यों में AI को अपनाने में ड्राइवर्स, बाधाओं और संबंधों की पहचान करना (अध्ययन -4); IoT समाधानों में 5G प्रौद्योगिकी अपनाने के लिए ड्राइवर्स, लिंकेज और डिजाइन नीतियों की पहचान करें (अध्ययन-5)।

अध्ययन-1 में IoT पारिस्थितिकी तंत्र के अध्ययन के हिस्से के रूप में, IoT मूल्य जाल को प्रमुख हितधारकों और प्रमुख उभरती प्रौद्योगिकियों के लिए परिभाषित किया गया था। अध्ययन में आईओटी पारिस्थितिकी तंत्र में हितधारकों के शामिल होने के प्रमुख कारण, उनकी आकांक्षाओं और उन क्षेत्रों पर विशेष ध्यान देने की आवश्यकता है जो यह सुनिश्चित करते हैं कि आईओटी पारिस्थितिकी तंत्र आशाजनक बना रहे। यह IoT पारिस्थितिकी तंत्र की प्रौद्योगिकियों और उनके संघों और पारस्परिक निर्भरता की भी पहचान करता है।

IoT- सक्षम उत्पादों और समाधानों का विकास काफी हद तक IoT समाधान विकसित करने के लिए कुशल पेशेवरों की उपलब्धता पर निर्भर करता है। IoT कुशल पेशेवरों की कमी से संबंधित चुनौतियों और IoT से संबंधित कौशल सीखने के लिए पेशेवरों को प्रभावित करने वाले प्रमुख कारकों का अध्ययन किया जाता है। अध्ययन -2 में, IoT कौशल सीखने के प्रति कर्मचारियों के उभयलिङ्गी व्यवहार का अध्ययन करने के लिए एक बहु-राष्ट्रीय निगम के केस स्टडी का उपयोग किया जाता है। यह अध्ययन कर्मचारियों के कौशल प्रतिरोध के एस-वक्र और आईओटी कौशल के प्रति कर्मचारियों की सीखने की आकांक्षाओं के व्युत्क्रम एस-वक्र के रूप में एक गैर-रेखीय संबंध का प्रस्ताव करता है। यह कौशल दूरी, प्रदर्शन रेटिंग, पहुंच सुविधा में आसानी, वर्तमान परियोजना की अवधि, अन्वेषण पर नए कौशल की

उपयोग क्षमता, और एस-वक्र के साथ शोषण व्यवहार जैसे प्रभावशाली कारकों के मॉडरेशन प्रभाव की व्याख्या करता है।

इसके अलावा, अध्ययन -3 में, उभरते हुए डिजिटल कौशल (एलईडीएस) व्यवहार मॉडल को विकसित करने के लिए अस्पष्ट शिक्षण सिद्धांत और प्रौद्योगिकी के उपयोग और स्वीकृति के एकीकृत सिद्धांत (यूटीएयूटी) का विस्तार किया गया है। LEDS मॉडल IoT में शामिल तेजी से बदलती उभरती डिजिटल तकनीकों के प्रति पेशेवरों के सीखने के व्यवहार के पूर्ववृत्त का वर्णन करता है। भारत में IoT उत्पाद और समाधान विकास में लगी 95 फर्मों में 685 पेशेवरों का एक राष्ट्रव्यापी सर्वेक्षण किया गया। अनुभवजन्य शोध से पता चलता है कि सामाजिक प्रभाव और व्यक्तिगत नवीनता सीखने के इरादे को काफी हद तक प्रभावित करती है। इसके अतिरिक्त, चिंता, दीर्घकालिक परिणाम और नौकरी की प्रासंगिकता भी सीखने के व्यवहार के इरादे को प्रभावित करती है। लिंग, प्रदर्शन स्तर और प्रौद्योगिकी वरीयता पूर्ववृत्त और सीखने के इरादे के बीच संबंध को मॉडरेट करती है।

तकनीकी क्रांति से पता चलता है कि आईओटी समाधानों की नई चुनौतियों को 5जी कनेक्टिविटी और एआई-आधारित समाधानों से दूर किया जाता है। हमने IoT पारिस्थितिकी तंत्र में AI और 5G नेटवर्क के ड्राइवर्स का अध्ययन किया। अध्ययन-4 में, कुल व्याख्यात्मक संरचनात्मक मॉडलिंग (TISM) तकनीक का उपयोग करके IoT पारिस्थितिकी तंत्र के संगठनात्मक व्यावसायिक कार्यों में एआई अपनाने के ड्राइवर्स और बाधाओं के बीच पदानुक्रमित संबंध स्थापित किया गया है। एआई समाधानों की निर्णय लेने की क्षमता और सटीकता सबसे प्रभावशाली चालक हैं। एआई अपनाने की रणनीति का अभाव, एआई प्रतिभा की कमी और नेतृत्व की प्रतिबद्धता की कमी सबसे महत्वपूर्ण बाधाएं हैं जो अन्य बाधाओं को प्रभावित करती हैं। निष्कर्षों के आधार पर, IoT पारिस्थितिक तंत्र की चुनौतियों का समाधान करने में मदद करने के लिए चिकित्सकों और कार्यकारी नेतृत्व के लिए सिफारिशें साझा की जाती हैं।

आगे अध्ययन -5 में, TISM का उपयोग 5G अपनाने के ड्राइवर्स के बीच पदानुक्रमित संबंध स्थापित करने के लिए किया जाता है। प्राथमिक चालक कम ऊर्जा खपत, व्यापक वायरलेस कवरेज और कम विलंबता हैं। IoT समाधानों की सफल तैनाती के लिए 5G नेटवर्क की मांग और आपूर्ति पक्ष में सुधार के लिए नीति निर्माताओं, सेवा प्रदाताओं के लिए साझा की गई सिफारिशें।

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List of Abbreviations

ACM CCS	Association for Computing Machinery Computing Classification System
AGFI	Adjusted Goodness of Fit Index
AHP	Analytical Hierarchy Process
AI/ML	Artificial Intelligence/Machine Learning
ALB	Actual Learning Behaviour
AMOS	Analysis of Moment Structures
ANP	Analytic Network Process
ANX	Anxiety
AR/VR	Augmented Reality/Virtual Reality
ARCS	Attention, Relevance, Confidence, and Satisfaction
AVE	Average Variance Extracted
BIL	Behavioral Intention to Learn
BRIC	Brazil, Russia, India, China
BYOD	Bring Your Own Device
CFA	Confirmatory Factor Analysis (CFA)
CFI	Comparative Fit Index
CIVET	Colombia, Indonesia, Vietnam, Egypt, and Turkey
CR	Construct/Composite Reliability
DF	Degree of Freedom
EFA	Exploratory Factor Analysis
EMMNE	Emerging Market Multi-National Enterprise
ERP	Enterprise Resource Planning
ETSI	European Telecommunications Standards Institute
FGD	Focus Group Discussion
Gbps	Giga bits per Second (1 billion bits per second)
GFI	Goodness of Fit Index
HRM	Human Resource Management
ICT	Information and Communication Technologies
IDT	Innovation Diffusion Theory
IEEE	Institute of Electrical and Electronics Engineers

IETF	Internet Engineering Task Force
IIoT	Industrial Internet of Things
IoT	Internet of Things
ISM	Interpretive Structural Modelling
IT	Information Technology
ITES	Information Technology Enabled Services
ITU	International Telecommunication Union
LEDS	Learning Emerging Digital Skills model
LTC	Long-Term Consequence
M&A	Merger and Acquisition
MCDM	Multi-Criteria Decision Making
MICMAC	d'Impacts croises-multiplication appliqué an classment OR cross-impact matrix multiplication applied to classification
MIMO	Multiple-In Multiple-Out
MINT	Mexico, Indonesia, Nigeria, and Turkey
MIoT	Massive Internet of Things
ML	Machine Learning
MM	Motivational Model
MNC	Multi-National Corporation
MNE	Multi-National Enterprise
MPCU	Model of PC Utilization
MSV	Maximum Shared Variance
NASSCOM	National Association of Software and Service Companies
NIST	National Institute of Standards and Technology
NTBF	New Technology-Based Firm (NTBF)
OASIS	Organization for the Advancement of Structured Information Standards
PIN	Personal Innovativeness
QoS	Quality of Service
R&D	Research and Development
REL	Relevance
RFID	Radio-Frequency Identification

RMSEA	Root Mean Square Error of Approximation
RoI	Return on Investment
RPA	Robotic Process Automation
RQ	Research Question
SCT	Social Cognitive Theory
SEM	Structural Equation Modelling
SI	Social Influence
SoC	System on Chip
TAM	Technology Acceptance Model
TISM	Total Interpretive Structural Modelling
TLI	Tucker–Lewis index
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
URLLC	Ultra-Reliable Low Latency Communication
UTAUT	Unified Theory of Acceptance and Use of Technology
W3C	World Wide Web Consortium
WEF	World Economic Forum