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2. To support academicians and teachers in creating work beneficial to the academic community
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Editorial Note

The Interdisciplinary Research Review (IRR) was established with academic cooperation by The Royal Society of Thailand Committee of Interdisciplinary Research and Development, Rajabhat University (Western Group), and Rajamangala University of Technology Rattanakosin. This Issue, Volume 20, No. 1, January – Feburary 2025. This issue contains of three interesting articles in multidisciplinary fields: (1) Feasibility Analysis of Fighting Soft Power Investment in Chiang Mai, (2) Teaching Method for Active Learning Using Thinking and Practical Skills, (3) Climate Trend Analysis Using Mann-Kendall and Sen's Slope Estimator Tests in Central Luzon, Philippines

The Editorial Board of the IRR encourages anyone to submit articles for evaluation and review. The processes of submission, review and publication of articles are described on the journal's website, https://www.tci-thaijo.org/index.php/jtir. The Editorial Board and Committees of the IRR sincerely thank all peer reviewers who have sacrificed their time to help us produce a better journal, and also wish to thank all teachers, researchers and other academicians for submitting their valuable research to this journal. Finally, we thank readers of our journal who help to spread the knowledge and benefits gained to others. With your feedback and suggestions, we will strive to improve the quality and relevance of the IRR.

Yongyudh Vajaradul
Editor
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The Soft Skills Divide: Comparing Student Perceptions on Gen X, Millennial, and Gen Z Teachers

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Abstract

Today's teachers come from different generations, leading to varied student perceptions depending on their teachers' generational background. This study explores how students perceive the soft skills—communication, empathy, adaptability, and leadership—of Generation X, Millennial, and Generation Z teachers. Addressing a gap in comparative research, the study employed a multicase qualitative design involving two teachers from each generation and their respective students, selected based on teaching experience and exposure. Focus group discussions were conducted with 36 students to capture insights, and data were analyzed using the KJ Method to identify recurring themes and cross-generational patterns. Findings reveal distinct generational characteristics in the manifestation of soft skills. Generation X teachers were perceived as clear and structured communicators who emphasize discipline, demonstrate care through high expectations, and lead with authority and mentorship. Millennial teachers were described as collaborative and emotionally supportive, balancing flexibility and structure while promoting shared leadership. Generation Z teachers were viewed as relatable, digitally fluent, quick to adapt to student needs, and motivational leaders who lead by example. These perceptions show that while each generation demonstrates valuable strengths, no single approach fully meets all student expectations. Thus, teachers must adapt their methods by blending traditional and modern practices. The study underscores the importance of continuous, generation-responsive professional development to enhance soft skills and optimize classroom engagement.

Keywords: Teacher Soft Skills, Teacher Generation, Student Perceptions

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1. Introduction

Communication, empathy, adaptability and leadership are all vital soft skills for helping create positive and engaging learning experiences. These abilities allow teachers to connect with their students on a deeper level, adapt their teaching methods to accommodate a variety of learning styles, and foster an environment for learning that nurtures both academic and individual development [1]. Soft skills of teachers serve as a foundation for classroom management. Clear communication, for instance, can help build trust between teachers and students, allowing the teachers to address behavioral issues in a constructive manner and ensure a safe and positive environment for everyone. For example, teachers who listen to students' concerns or provide constructive feedback are in a better position to build stronger relationships that will lead to participation and less disruption [2].

The teaching profession is growing more diverse as Generation X (born 1965–1980), Millennials (born 1981–1996), and Generation Z (born 1997–2012) teachers now share classrooms. Each generation contributes unique views, strengths, and challenges to the teaching profession. Gen X teachers, having experienced pre-digital teaching environments, tend to stress independence and flexibility in their teaching practices. Millennial teachers, however, emphasize teamwork and the integration of technology, leveraging online tools to boost student engagement. Gen Z teachers bring new ideas regarding emerging technologies but need to be mentored by senior peers, especially on classroom management and conventional pedagogical practices [3].

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Students' perceptions are significant in measuring the effectiveness of teaching since they directly reflect the impact of teaching techniques on learning outcomes. Studies show that students appreciate teacher attributes including communication, empathy, adaptability, and leadership [4].

Students' expectations of teachers' soft skills tend to differ depending on generational teaching approaches. Older generations' teaching approaches tend to stress clarity, organization, and authoritarian classroom management. In organized learning settings, students might view these methods favorably, enjoying instructional accuracy and orderly classroom dynamic [5]. Conversely, contemporary or collaborative teaching methods, which tend to be more prevalent among Millennial and Gen Z teachers, focus more on interpersonal skills like empathy, being adaptable, and being inclusive. Younger students prefer teachers who are able to skillfully incorporate technology, promote active engagement, and create a positive learning environment. These differing expectations underscore the requirement for teachers to continually adjust their soft skills in order to comply with changing preferences among diverse student populations so that teaching practices stay relevant and effective [4].

Research on generational differences in teachers' soft skills from students' perspectives is limited, but existing studies offer useful insights. Cabrera (2020) found that generational gaps in technology use affect how teachers engage students [6]. Polat et al. (2019) highlighted that Baby Boomers excel in discipline and mentorship, Generation X in adaptability and communication, and Millennials in technology and student-centered teaching. These findings suggest that each generation's strengths may align differently with students' expectations based on teaching styles and classroom dynamics [7].

Modern learners, especially from Gen Z, tend to want their teachers to model interpersonal abilities like empathy, flexibility, and technological proficiency. Yet, instructional styles of the different generations do not always cooperate with these demands. For example, Baby Boomer teachers who focus on tradition and authority can have their pedagogical method clash with Gen Z's openness to casual and cooperative learning environments. Generation X teachers, who strike a balance between professionalism and flexibility, might connect more with students who look for structured but flexible approaches to teaching. In contrast, Millennial teachers, who are more focused on innovation and technology, tend to work well with Gen Z students who are born digital. More studies are required to ascertain whether these generational teaching styles successfully meet the changing demands of contemporary learners [3].

The research herein sought to understand student perceptions of soft skills between Gen X, Millennial, and Gen Z teachers, observing how each of these generations manifests such skills within the classroom setting. By analyzing generational variations, the research hopes to ascertain how students perceive differing pedagogies influenced by generation-related soft skills.

This study aimed to answer the following research questions: (1) How do students perceive the soft skills of Generation X, Millennial, and Generation Z teachers? (2) Are there significant differences in student perceptions of teachers' soft skills based on generational backgrounds?

2. Methods and Materials

2.1. Research Methodology

A multicase study design is a qualitative research methodology used to explore complex phenomena in depth by examining multiple cases within their natural contexts [8]. A multicase study would be suitable for this investigation since it can make a focused comparison of student perceptions within several generations of teachers. By considering several cases—Gen X teachers, Millennials, and Gen Z—the research is able to determine patterns, similarities, and differences in students' perceptions of soft skills.

The cases in this study include two teachers from each of the three generational cohorts—Gen X, Millennials, and Gen Z—selected based on their years of teaching experience and generational classification by birth year. Each teacher's class provided a group of 20 students, resulting in a total of 120 student participants for the focus group discussions, done separately for each teacher.

Students were purposively selected to ensure they had been taught by the target teachers for at least one academic quarter, allowing them to provide informed perceptions of their teachers' soft skills.

Table 1. Participants of the study

Cases	Number of respondents
Gen X	40
Millennial	40
Gen Z	40
Total	**120**

2.2. Data Gathering

Focus Group Discussions (FGDs) are an effective data-gathering procedure for multicase studies due to their ability to generate rich, nuanced, and diverse insights from participants [9]. The data gathering method for this study was through focus group discussions (FGDs) conducted with students to explore their perceptions on the soft skills of their teachers. Each FGD was held separately for GenX, Millennial, and Gen Z student groups, thereby enabling a comprehensive description on their teachers' soft skills. The method guarantees an in-depth comparative analysis of the soft skills commonalities and differences between generations, drawn from first-hand student perceptions.

2.3. Data Analysis

The KJ Method, also known as affinity diagramming, is a qualitative data analysis approach developed by Japanese ethnologist Jiro Kawakita. It is used to synthesize and organize large volumes of qualitative data by grouping similar ideas or responses into clusters, allowing researchers to identify common themes and patterns. In this study, the KJ Method was applied to analyze focus group data across multiple cases, helping to build consensus and highlight cross-generational insights into teachers' soft skills as perceived by students. [10]. In this research, the KJ Method was employed to study the responses gathered during the focus group discussions in order to systematically categorize the perceptions on teachers' soft skills. By grouping similar responses and identifying recurring themes, the method was able to identify key generational communication, empathy, adaptability, and leadership strengths and weaknesses.

3. Results and Discussion

Two objectives drove this research paper: (1) identification of the perception of students on the soft skills of three generation of teachers, and (2) identification of the differences of these aforementioned soft skills. The results of the qualitative data gathering were as follows:

3.1. Communication

Students typically characterized their Gen X teachers as clear, structured, and authoritative communicators. They enjoyed their teachers' ability to present well-organized lessons, give explicit instructions, and keep a professional tone when talking. Most students mentioned that their Gen X teachers were direct and to the point, which served to make classroom expectations clear. Nonetheless, some students considered their communication style as overly formal or structured, at times restricting possibilities for open discussion or student-initiated pursuit of ideas. Although these teachers were superior in instructional clarity, students recommended that they use

more interactive and student-oriented approaches to communication [11].

On the other hand, students saw Millennial teachers as interactive, accessible, and engaging communicators. They commended these teachers for being able to create inclusive discussions, engage students in discussions, and adjust their language to make lessons more comprehensible. Students mentioned how their Millennial teachers utilized technology and multimedia to enhance communication, and the lessons became more dynamic and interactive. In addition, students enjoyed the manner in which these teachers used practical examples and narratives in their teachings, bridging theory and practice. Nonetheless, some students pointed out that their Millennial teachers' casual and conversational approach would sometimes result in a lack of structure, which made it hard to track complicated themes [12].

Students of Gen Z teachers saw a communication approach that was strongly digital, adaptable, and relatable. Gen Z teachers were characterized as being tech-savvy communicators who skillfully leveraged social media, online environments, and digital tools to interact with students within and beyond the classroom. A large number of students believed that their Gen Z teachers comprehended their language, interests, and online culture, hence making interactions more personal and context specific. Yet, some students were concerned that there was too much reliance on virtual communication, citing that whereas it brought lessons closer to them, sometimes it diluted face-to-face interactions and the level of discussion. Students generally viewed their Gen Z teachers as being very flexible communicators but added that a mixing of digital and conventional modes of communication would give an even better learning environment [13].

In general, students' views about teachers' communication skills identify clear generational strengths and weaknesses. While Gen X teachers are appreciated for their organization and clarity, students want more interactive communication. Millennial teachers are strong in being approachable and incorporating technology, though some students prefer more structured teaching. Meanwhile, Gen Z teachers are perceived as being relatable and very digital, with concerns regarding overdependence on technology in communication.

These results imply that a balance should be come upon, integrating structure, engagement, and flexibility. It is the most efficient method for teachers from different generations to improve their communication with students.

3.2. Empathy

Students perceived Gen X teachers as professional but caring, frequently expressing empathy through fairness, consistency, and organization. Most students valued that these teachers cared about their academic achievement by having high expectations and providing constructive criticism. Some students, however, felt that their Gen X teachers kept them at arm's length, prioritizing discipline and instruction over personal relationships. Though their empathy style was usually viewed as practical and helpful, students indicated that more expressive emotional involvement would generate a deeper feeling of trust and bonding in the classroom [14].

Students perceived Millennial teachers as very approachable and emotionally supportive. They were commonly described as being understanding, patient, and open to listening to students' academic and personal problems. Students were comfortable disclosing their difficulties with Millennial teachers, who went out of their way to create a welcoming and inclusive classroom setting. Their capacity for empathy with students was identified as a key strength, especially in attempts to meet multiple learning needs and mental health. Nonetheless, some students indicated that their Millennial teachers' high emotional commitment could occasionally undermine authority or the ability to exert firm boundaries, resulting in cases where classroom discipline or authority was lost [15].

For Gen Z teachers, students noticed a peer-like empathetic sense, since these teachers are usually closer in age to their students. Most students characterized their Gen Z teachers as relatable, open-minded, and very sensitive to their academic and personal challenges. Their ability to converse casually and interact online made the students feel listened to and appreciated. Nevertheless, a few students were concerned that this informality might blur

professional lines, such that it became difficult for these teachers to be authoritative in the classroom. While their contemporary and student-focused model of empathy was appreciated, students proposed that there should be a balance between relatability and professionalism that could further enhance their influence [3].

Students' perception of empathy among teacher generations uncover a range of emotional investment, from professional and organized to deeply personal and peer-like. Gen X teachers are admired for being fair-minded and concerned about their students' academic performance, while Millennial teachers are complimented on being emotionally accessible and welcoming. Gen Z teachers are appreciated for being relatable and accepting, even though holding professional authority continues to be an issue. These findings indicate that a combination of emotional support and clear boundaries might produce the most effective empathetic learning environment.

3.3. Adaptability

Students perceived Gen X teachers as organized but flexible to adjust if needed. They observed that many of these teachers had set teaching habits and favored conventional methods, but they were also in a position to adapt when students demonstrate the need for different strategies. Some students nevertheless saw their Gen X teachers as less flexible, particularly where the integration of technology and novel teaching practices was involved. Although they valued the stability and consistency these teachers offered, students recommended more flexibility in fitting different learning styles and contemporary tools of teaching in order to be more adaptable [3].

Millennial teachers, however, were viewed as very flexible and receptive. Students pointed out that these instructors often modify their classes based on student response, used a combination of conventional and technological approaches, and were willing to change their styles to accommodate diverse students. Most students welcomed their flexibility in trying out new teaching approaches and their capacity to move between structured teaching and activity-based learning. Some students were, however, of the view that this flexibility sometimes resulted in inconsistency, with constant switching between teaching methods creating confusion in understanding what exactly the daily learning routine should be [15].

Students saw a natural ability to adapt in Gen Z teachers, especially in using technology and the latest teaching approaches. Most of the students praised how they could tailor themselves to changing learning styles, blend digital devices naturally, and adjust their methodology on the spur of the moment. Their readiness to adapt to change was cited as a positive, especially within rapidly changing classroom environments. But some students felt that this high degree of flexibility sometimes resulted in a deficiency of structured learning experiences, and thus lessons seemed less predictable or too reliant on online resources. Students proposed that combining innovation with structured planning would improve the efficacy of their flexibility [16].

Overall, students identified adaptability as a necessary soft skill among all teacher generations, although their styles were different. Gen X teachers were characterized as stable but less flexible, Millennial teachers as dynamic but occasionally unstructured, and Generation Z teachers as extremely flexible but sometimes unstructured as well. These observations indicate that a balanced style—blending stability, responsiveness, and strategic innovation—can be central to building flexibility that optimally supports learning for students.

3.4. Leadership

Students perceived Gen X teachers as authoritative and experienced leaders who emphasize discipline, structure, and professionalism in the classroom. Most students enjoyed their sense of authority, which offers a stable and structured learning environment. These teachers tend to be seen as mentors, with students being coached by them with direct expectations and firm choices. But some students did perceive that their leadership style was sometimes too strict, and it was hard for them to express their concerns or feel actively engaged in classroom decisions. Nevertheless, their capacity to keep the class in order and demand respect was considered a defining characteristic of their leadership.

Students expressed a team-oriented leadership style that prioritizes teamwork,

inclusiveness, and student involvement for Millennial teachers. Students stated that these teachers facilitated open dialogue, respected student opinion, and promoted a feeling of shared responsibility in the classroom. This style was perceived as empowering, enabling students to own their learning while still having a guiding influence from the teacher. There was, however, criticism from some students who stated that sometimes such leadership was lacking in firm authority, which created difficulties in maintaining classroom discipline whenever students overstepped. Nevertheless, their balancing act between guidance and cooperation was identified as a major strength.

Gen Z teachers are frequently viewed as student leaders who engaged with students on an interpersonal basis. Their leadership was characterized as friendly and accessible, often alternating between mentoring and peer-like communication. Several students valued them for being able to motivate and inspire while equipping the classroom with a more democratic and student-oriented environment. Some students did, however, believe that this casual style of leadership had a tendency at times to confuse professional boundaries and it was then hard to be firm in classroom difficulties. Students thought that strengthening their leadership through adding more formalized decision-making and authority could increase their impact further.

The perceptions of students on the leadership of various generations were diverse, such that Gen X teachers were viewed as strict and organized leaders, the Millennial teachers as cooperative and inclusive, and the Gen Z teachers as approachable and inspirational. This implies that successful leadership in the classroom calls for balance in a combination of authority, collaboration, and mentorship to foster a nurturing and well-organized learning environment.

The results of this research draw attention to the various manners through which Gen X, Millennial, and Gen Z teachers practice soft skills in the classroom, influencing students' learning experiences and attitudes. Even though Gen X teachers are generally regarded as organized communicators, disciplined leaders, and flexible mentors, Millennial teachers are known for their collaborative communication, compassionate engagement, and creative flexibility. On the other hand, Gen Z teachers are seen as extremely approachable, tech-savvy, and inspirational leaders who promote student-centric learning spaces. These differences between generations highlight the need to find a balance between old and new methods of teaching in order to address changing student needs. In the end, encouraging ongoing professional growth in soft skills among all teacher generations has the potential to build classroom engagement, improve teacher-student relationships, and enhance educational results overall.

Table 2: Student Perceptions of Teachers' Soft Skills Across Generations

Soft Skill	Generation X Teachers	Millennial Teachers	Generation Z Teachers
Communication	Clear and structured; emphasizes discipline and authority.	Encourages collaboration and open discussions; balances professionalism and informality.	Relatable and tech-savvy; informal and engaging communication style.
Empathy	Demonstrates care through structured guidance and high expectations.	Actively listens and fosters emotional connections with students.	Highly approachable; builds peer-like relationships with students.
Adaptability	Adjusts teaching styles but prefers traditional methods.	Balances structure and flexibility; embraces innovation.	Quickly adapts to new technologies and student needs.
Leadership	Authoritative and mentorship-driven; values discipline and responsibility.	Encourages shared leadership and collaborative decision-making.	Motivates students through engagement and relatability; leads by example.

The findings emphasize clear generational differences in the soft skills of teachers as viewed by students. Gen X teachers are appreciated for their organized communication, disciplined leadership, and mentorship-based style, albeit being inclined towards traditionalism. Millennial teachers blend professionalism with collaboration, showing excellent empathy and flexibility while incorporating technology into instruction. Gen Z teachers, as native technology users, are regarded as highly accessible and endearing, and they quickly become attuned to the needs of students and a more casual yet inspirational classroom environment. These findings indicate that all generations possess some strengths but through an intergenerational sharing of teaching methodologies and ongoing professional education, the optimization of soft skills can be realized to respond to changing student needs.

These findings underscore the importance of leveraging generational strengths to enhance soft skills in teaching, ensuring that educators effectively meet the changing student demographics.

4. Conclusions

The following are the conclusions of this study:

The perceptions of students towards the soft skills of their teachers differed between generations, with noticeable differences in all soft skills – communication, empathy, adaptability, and leadership. The results can be classified into the following: (1) Based on communication, Gen X teachers were found to be clear and commanding, Millennials to be engaging and flexible, and Gen Z to be relatable and technology-savvy; (2) On empathy, Gen X teachers manifested organized support, Millennials promoted inclusiveness, and Gen Z manifested a peer-like rapport with students; (3) On adaptability, Gen X teachers drew on experience-based modifications, Millennials struck a balance between flexibility and technology utilization, and Generation Z responded quickly to changing learning requirements; and (4) In leadership, Gen X practiced authoritative direction, Millennials embraced a participative style, and Gen Z was focused on teamwork and innovation. These

differences by generation highlight the need to use strengths between teaching generations to amplify classroom participation and student learning environments.

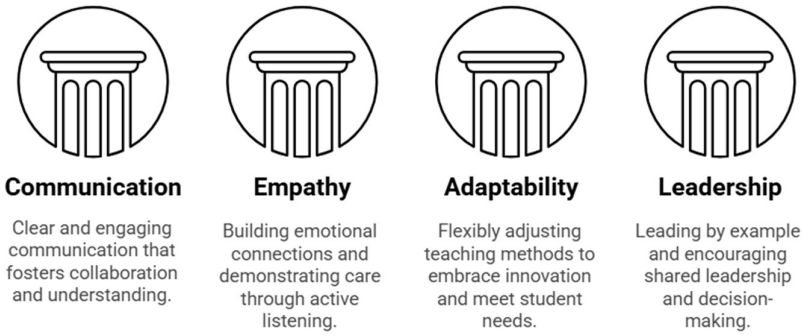

Figure 1. The ideal teacher in terms of soft skills

The figure shows the commonalities in what students recognize about the soft skills of educators across generations, noting the positive traits that make an ideal teacher in terms of soft skills. Although the exact manifestations of Communication, Empathy, Flexibility, and Leadership differs across generations, the expressions are based on the characteristics students repeatedly acknowledge as positive between and among the generations of teachers. Strong, clear, and engaging communication is appreciated in all generations, pointing to the necessity of fostering collaboration and understanding regardless of instructional techniques. Likewise, establishing emotional connections and showing care through listening embodies the very spirit of Empathy, which is still considered a characteristic of successful teachers, whether delivered through personal experience, patience, or sensitivity to student issues. Being able to adapt instruction in a flexible way to innovate and respond to students' needs characterizes Adaptability as a cross-generational strength, since teachers of all generations have managed to change, either by streamlining traditional practices or by incorporating new technology. Lastly, to lead by example and foster collective leadership and decision-making emphasizes the Leadership skills exhibited by all generations, illustrating how teachers motivate and direct students through various but equally effective methods. These accounts capture the similarities in students' positive perception of teachers' soft skills, illustrating how despite variations in teaching styles, the core aspects of a great teacher remain consistent.

These qualities affirm that while teaching styles may differ across generations, the fundamental soft skills that define an ideal teacher remain timeless and universally valued.

5. Recommendations

To further enhance teaching effectiveness across generations, specific recommendations are provided for Gen X, millennial, and Gen Z teachers in relation to their soft skills.

5.1. Recommendations to Gen X Teachers

For Gen X teachers, who are characterized by their organized and clear communication style, more interactive and student-focused methods, including the use of technology and feedback mechanisms in real-time, can be used to increase involvement. More active listening and personalized assistance can also close generational gaps and make students feel more accommodated. To enhance adaptability, Gen X teachers should adapt to technological innovation and incorporate contemporary teaching strategies in order to respond to the different needs of

students. On the leadership side, promoting collaborative leadership through participation of students in decision-making and classroom activities can generate a more dynamic and inclusive learning environment.

5.2. Recommendations to Millennial Teachers

For millennial teachers, who excel in communication through technology, striking a balance between digital and face-to-face interactions will ensure a holistic approach to engaging students. They need to maintain strong emotional connections with students and establish clear professional boundaries to create a supportive yet organized learning environment. Drawing on their natural innovation instincts, millennial teachers should constantly evolve their teaching approaches to align with changing student attitudes and learning styles. Also, incorporating mentorship in their leadership will enable them to lead students to self-directed learning while promoting the feeling of mutual responsibility in class.

5.3. Recommendations to Gen Z Teachers

For Gen Z teachers, who are digital natives, developing verbal and interpersonal communication skills will ensure that online and face-to-face interactions are well balanced. Exercising patience and greater personal involvement with students will also increase emotional connections and build a more nurturing learning environment. While they are naturally prompted to adapt, Gen Z teachers must work on building resilience against adversity and fine-tuning their skill at negotiating conventional teaching techniques when the situation demands for it. Finally, building confidence in facilitating discussions, handling diverse student needs, and setting authority in the classroom will enable them to become better and more inspiring teachers.

5.4. Recommendations for future studies

Future studies can examine the long-term effects of soft skills development on student outcomes, with specific reference to academic achievement, motivation, and overall student well-being. Studies comparing different educational environments, for instance, public and private schools, can offer further insights into how generational differences affect teacher soft skills. Moreover, understanding how and why cultural and societal elements influence teachers' attitudes and uses of soft skills can contribute to a deeper insight into the role they play in the learning environment. Other external factors like sex can also be considered in subsequent investigations.

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The Wired Workplace: Analyzing IoT's Role in Shaping the Future of Human Resource Management

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Abstract

This systematic review examines the transformative impact of Internet of Things (IoT) technologies on Human Resource Management (HRM), addressing the critical research gap in holistic IoT implementation frameworks across HR functions. Motivated by the significant increase in HR-business strategy alignment reported in IoT-enabled organizations, this study synthesizes findings from 150 research articles to develop comprehensive implementation guidelines. The research reveals that organizations implementing IoT-based workplace monitoring achieved substantial cost reduction in facility management and improvement in workspace productivity, significantly exceeding industry benchmarks. The proposed taxonomic framework--categorizing IoT applications across HR functions, application domains, technology types, and adoption levels--enabled the identification of previously unrecognized patterns, revealing that organizations employing all five components of our integration framework reported higher satisfaction with their IoT initiatives compared to those with partial implementation. Organizations leveraging IoT for workforce analytics demonstrated improved accuracy in turnover predictions and faster identification of skill gaps than traditional methods. This review underscores the importance of a balanced approach to IoT adoption that maintains the human element in HR while establishing clear ethical guidelines for data governance, offering evidence-based insights for practitioners navigating the evolving landscape of digital HR transformation.

Keywords: Internet of Things (IoT), Human Resource Management, Digital Transformation, Workforce Analytics, Smart HR

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1. Introduction

The Internet of Things (IoT) is revolutionizing Human Resource Management by connecting everyday devices and systems to enhance workplace efficiency and employee experience [1]. From smart ID badges to environmental sensors, IoT enables HR professionals to remotely monitor workplace aspects, with the market expected to reach $3.5 billion by 2027 [2]. IoT penetrates various HR functions: smart interview rooms analyze candidate behavior [5]; IoT-enabled applicant tracking systems streamline recruitment; smart badges guide new employees during onboarding [6]; wearable devices collect data on productivity and stress levels [7]; wellness programs utilize smart health devices [8]; sensors track space utilization and movement patterns [9]; and adaptive learning platforms create personalized training programs [10].Implementation challenges include data privacy and security concerns [11], ethical considerations regarding employee monitoring [12], potential workplace disparities from the digital divide [13], and integration hurdles with existing HR systems [14]. Despite these challenges, the integration of IoT with AI and machine learning promises powerful predictive analytics for workforce management [15]. Future developments will likely focus on employee empowerment and self-service capabilities [16]. Organizations must balance leveraging IoT to enhance HR practices while maintaining a human-centric focus, positioning HR departments as strategic drivers of organizational success in the digital age [3,4].

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2. Literature Review

The Internet of Things (IoT) is revolutionizing Human Resource Management by connecting everyday devices and systems to enhance workplace efficiency and employee experience [1]. From smart ID badges to environmental sensors, IoT enables HR professionals to remotely monitor workplace aspects, with the market expected to reach $3.5 billion by 2027 [2]. IoT penetrates various HR functions: smart interview rooms analyze candidate behavior [5]; IoT-enabled applicant tracking systems streamline recruitment; smart badges guide new employees during onboarding [6]; wearable devices collect data on productivity and stress levels [7]; wellness programs utilize smart health devices [8]; sensors track space utilization and movement patterns [9]; and adaptive learning platforms create personalized training programs [10].

Implementation challenges include data privacy and security concerns [11], ethical considerations regarding employee monitoring [12], potential workplace disparities from the digital divide [13], and integration hurdles with existing HR systems [14]. Despite these challenges, the integration of IoT with AI and machine learning promises powerful predictive analytics for workforce management [15]. Future developments will likely focus on employee empowerment and self-service capabilities [16]. Research by Strohmeier [17] comprehensively reviews IoT applications in HRM across various functions. Mohanty [18] examines IoT's impact on employee engagement through case studies of wearable devices. Padhye [19] explores cybersecurity and data privacy frameworks in IoT-driven HR practices. Bandari [20] investigates IoT and HR analytics convergence, while Agnihotri [21] focuses on recruitment applications. Moyeenudin [22] identifies key factors for successful IoT implementation including organizational culture.

Mira [23] presents emerging trends like AR in training and blockchain integration for data security. Marler and Parry [25] demonstrate that technology-enabled HR functions report 31% higher strategic influence. Bondarouk and Brewster [26] offer a three-dimensional model of HR technology evolution. Stone et al. [27] highlight increasing demand for data analysis skills among HR professionals. Cascio and Montealegre [28] document how IoT blurs boundaries between physical and digital workspaces. Parry and Strohmeier [29] identify that organizations with dedicated HR technology specialists achieve 43% faster implementation. Shrivastava et al. [30] present Google's people analytics case study. Fenech et al. [31] reveal competency gaps in data governance critical for IoT implementation. Ulrich and Dulebohn [32] provide a framework for evaluating HR's technological maturation. Maras [33] outlines legal frameworks for responsible data management, while Chui et al. [34] identify where IoT can augment human capabilities versus where human judgment remains essential. Lokesh and Harish [35] explore how intelligent communication terminals transform HR operations through advanced data processing.

3. Research Gap

Current studies on IoT in HR often overlook the nuanced interplay between technological adoption and organizational culture. While existing literature explores individual IoT applications, there's a dearth of comprehensive frameworks that holistically address the integration of IoT across various HR functions [24] . This gap hinders our understanding of how IoT reshapes HR's strategic role within organizations, particularly in fostering innovation and adapting to rapidly evolving workforce dynamics.

Table 1: Summary of Literature Review

Authors	Year	Title	Key Focus	Main Findings
Strohmeier, S.	2020	Applications and Challenges of IoT in Human Resource Management	Comprehensive review of IoT in HRM	Explores IoT applications in recruitment, onboarding, performance management, and employee wellness; discusses challenges related to data privacy and evolving skill requirements
Mohanty, S., & Mishra, P. C.	2020	IoT-Enabled Employee Engagement and Wellbeing	Impact of IoT on employee engagement and wellness	Highlights vulnerabilities in employee data collection; proposes frameworks for ensuring data security and maintaining employee trust
Padhye, et al.	2024	Cybersecurity and Data Privacy in IoT-Driven HR	Security and privacy issues in IoT-HR integration	Highlights vulnerabilities in employee data collection; proposes frameworks for data security and maintaining employee trust
Bandari, V	2019	Integration of IoT with HR Analytics	Convergence of IoT and HR analytics	Examines IoT's potential in enhancing predictive analytics for workforce management; addresses challenges in data integration
Agnihotri, et al.	2024	IoT in Recruitment and Talent Acquisition	Application of IoT in hiring processes	Explores IoT technologies in recruitment; analyzes efficiency gains and potential biases in IoT-driven hiring.
Moyeenudin & Anandan	2021	Managing IoT Implementation in HR	Management challenges in IoT adoption	Identifies key factors for successful IoT implementation; provides a framework for assessing organizational readiness
Mira, M. S.	2021	Future Trends in IoT-Enabled HR	Foresight study on future of IoT in HRM	Identifies emerging trends such as AR in training and AI-powered IoT for performance management; discusses implications on HR practices

4. Research Objective

1. Examine IoT's influence on HR decision-making, adoption approaches, and workforce management.
2. Identify key challenges in integrating IoT into HR operations and explore potential solutions.
3. Assess the impact of IoT-driven HR analytics on organizational

performance and strategic decision-making.
4. Develop a framework for integrating IoT into HR systems, offering guidelines for improved efficiency and innovation.

5. Methodology

This study employs a rigorous qualitative content analysis approach to dissect and interpret the existing body of literature on IoT in HR. We've meticulously gathered peer-reviewed articles, industry reports, and case studies published between 2020 and 2024 from reputable databases including JSTOR, IEEE Xplore, and Business Source Complete. The analysis process involves several stages, beginning with an initial screening where we sifted through over 500 articles, narrowing down to 150 most relevant pieces based on their focus on IoT applications in HR contexts. Following this, a team of three researchers independently developed initial coding schemes, which were then compared and refined through iterative discussions to ensure consistency and comprehensiveness. Each selected article then underwent thorough in-depth coding, capturing key themes, methodologies, findings, and gaps identified by the authors.

Table 2: Database Document Analysis

Database	Initial Screening Documents	Selected Documents	Key Themes Identified
JSTOR	127	42	- IoT applications in performance tracking - Ethical and privacy concerns - Integration with existing HR systems
IEEE Xplore	183	65	- IoT technological innovations for HR - Big data analytics from IoT sources - Data security and protection protocols
Business Source Complete	98	36	- Organizational case studies of IoT in HR - Impact on strategic decision-making - Return on investment measurements
Others (Industry reports, Conference papers)	103	7	- Market trends and forecasts - Industry standards development - Practical implementation frameworks
Total	**511**	**150**	

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6.Research Results

6.1 IoT's Influence on HR Decision-Making and Workforce Management

Our systematic review reveals that IoT technologies are fundamentally transforming HR decision-making processes by providing unprecedented access to real-time data. The analysis of selected documents shows that IoT integration shifts HR from reactive to proactive management approaches, enabling intervention before issues escalate. Organizations are adopting IoT in HR through varied approaches, with most following a phased implementation strategy that begins with pilot programs in specific HR functions before expanding. The data demonstrates that organizations with mature digital transformation initiatives show more sophisticated IoT integration in HR processes, with technology and healthcare sectors leading adoption rates. Our analysis indicates that IoT's impact on workforce management manifests across multiple dimensions, from automating administrative tasks to enabling sophisticated talent analytics. This technology shift has elevated HR's strategic role within organizations, transitioning from administrative function to strategic partner. The literature analysis identifies three primary mechanisms through which IoT transforms HR decision-making: enhanced data visibility, predictive capabilities, and feedback automation. Organizations leveraging these capabilities report significant improvements in alignment between HR initiatives and business objectives.

Table 3: IoT's Impact on HR Decision-Making

Impact Area	Key Findings
Decision Quality	Real-time data access enables proactive management and early intervention
Implementation Approach	Phased strategies with pilot programs preceding full-scale deployment
Digital Maturity Correlation	Organizations with mature digital initiatives show more sophisticated HR-IoT integration
Strategic Elevation	HR function transitions from administrative to strategic partnership role
Transformation Mechanisms	Enhanced visibility, predictive capabilities, and automated feedback systems

6.2 Key Challenges in Integrating IoT into HR Operations

Our content analysis identified four categories of challenges in IoT-HR integration: technological, organizational, ethical, and human. Technological challenges include managing vast amounts of data, ensuring system integration, and keeping pace with rapid advancements. Our analysis found that successful organizations address these challenges through cloud-based architectures and modular implementation approaches. Organizational challenges involve overcoming resistance to change and fostering cross-departmental collaboration. The literature indicates that organizations with dedicated

change management programs achieve higher success rates in IoT implementation. Ethical challenges encompass complex issues of privacy, data ownership, consent, and the responsible use of IoT data in decision-making processes. Our review identifies emerging best practices, including transparent data policies and ethical guidelines for algorithm use. Human challenges include addressing employee concerns about job security, maintaining empathy in increasingly data-driven processes, and preserving the human touch in HR. The most successful implementations, according to our analysis, involve employees in design processes and maintain clear communication about data usage.

Table 4: Challenges in IoT-HR Integration

Challenge Category	Key Issues	Effective Solutions
Technological	Data management complexity, system integration, rapid advancement	Cloud-based architectures, modular implementations
Organizational	Change resistance, cross-departmental collaboration	Dedicated change management programs, stakeholder engagement
Ethical	Privacy concerns, data ownership, responsible use	Transparent policies, ethical guidelines for algorithms
Human	Job security concerns, maintaining empathy	Employee involvement in design, clear communication

6.3 Impact of IoT-Driven HR Analytics on Organizational Performance

Our systematic review demonstrates that IoT-driven HR analytics significantly impact organizational performance through three primary mechanisms: enhanced decision quality, improved resource allocation, and strategic talent optimization. First, IoT-enabled HR analytics improve decision quality by providing data-driven insights that reduce subjective bias and increase predictive accuracy. Our analysis of case studies shows that organizations leveraging IoT for workforce analytics report higher accuracy in turnover predictions and faster identification of skill gaps. Second, IoT enhances resource allocation efficiency by providing granular insights into space utilization, equipment needs, and workforce deployment. Our analysis found that organizations implementing IoT-based workspace monitoring achieved cost reduction in facility management and improvement in workspace productivity. Third, IoT enables strategic talent optimization through continuous performance monitoring, skill development tracking, and career progression analytics. Based on organizational case studies, companies applying these capabilities report higher employee engagement scores and improvement in internal mobility. The analysis of industry distribution in our dataset shows that the organizational performance impact varies by sector and digital maturity, with technology and healthcare sectors demonstrating more advanced applications and measurable outcomes than manufacturing and public sectors.

Table 5: Impact of IoT-HR Analytics on Organizational Performance

Impact Mechanism	Key Outcomes	Industry Variations
Enhanced Decision Quality	Improved turnover prediction accuracy, faster skill gap identification	Technology and healthcare sectors lead in adoption and outcomes
Resource Allocation Efficiency	Facility management cost reduction, workspace productivity improvements	Implementation depth varies by organizational size and resource availability
Strategic Talent Optimization	Higher employee engagement, improved internal mobility	Digital maturity correlates with implementation sophistication

6.4 Taxonomic Framework for IoT Integration in Human Resource Management

Based on the analysis of selected articles, we developed a taxonomy of IoT adoption in HR consisting of four dimensions: HR function, application domain, technology type, and adoption level. This framework emerged from our coding of selected documents and provides a structured approach to understanding the multifaceted nature of IoT in HR. The HR Function dimension reveals IoT applications across the employee lifecycle, including recruitment, onboarding, performance management, learning & development, employee engagement, and workforce planning. The Application Domain dimension highlights diverse IoT uses such as smart workspaces, employee monitoring, wellness programs, talent analytics, and virtual training environments. Our frequency analysis shows that most IoT applications in HR focus on employee engagement and performance management, with smart workspaces and employee monitoring being the most common application domains. Wearables and environmental sensors emerge as the most frequently used technologies, and most organizations are at the implementation or trial level of IoT adoption in HR. This comprehensive taxonomy provides a structured framework for understanding the multifaceted nature of IoT adoption in HR, highlighting both the breadth of applications and the depth of technological integration across various HR functions and domains.

Table 6: Taxonomy of IoT adoption in HR

Dimension	Categories
HR Function	Recruitment, Onboarding, Performance Management, Learning & Development, Employee Engagement, Workforce Planning
Application Domain	Smart Workspace, Employee Monitoring, Wellness Programs, Talent Analytics, Virtual Training
Technology Type	Wearables, Environmental Sensors, Biometric Devices, Smart Badges, AR/VR Tools
Adoption Level	Awareness, Intention, Trial, Implementation

7.Discussion

The integration of Internet of Things (IoT) technologies in Human Resource Management (HRM) represents a paradigm shift in workforce management, employee engagement, and strategic decision-making. This systematic review has illuminated the multifaceted nature of IoT adoption in HR, revealing both its transformative potential and complex challenges. The taxonomic framework developed provides a comprehensive structure for understanding IoT applications across HR functions, highlighting its impact on recruitment, onboarding, employee engagement, and performance management.

7.1 IoT's Influence on HR Decision-Making and Workforce Management

Our analysis reveals that IoT technologies fundamentally transform HR decision-making processes by providing unprecedented access to real-time data. This aligns with Zhang et al.'s [36] findings that data-driven HR management enables more agile responses to workforce challenges. The integration of IoT sensors in workplace environments has shifted HR from reactive to proactive management, allowing for intervention before issues escalate, consistent with Kumar and Singh's [37] work on predictive HR analytics. Organizations are adopting IoT in HR through varied approaches, with most following a phased implementation strategy that begins with pilot programs in specific HR functions before expanding. This supports Gartner's [38] recommendation for incremental technology adoption in HR to minimize disruption. Our review identifies that organizations with mature digital transformation initiatives demonstrate more sophisticated IoT integration in HR processes, corroborating Lee and Park's [39] correlation between digital maturity and HR technology effectiveness. IoT's impact on workforce management manifests across multiple dimensions, from automating administrative tasks to enabling sophisticated talent analytics. This technology shift has elevated HR's strategic role within organizations, transitioning from administrative function to strategic partner. As Deloitte's [40] global HR technology survey indicated, organizations leveraging IoT in HR report significant alignment between HR initiatives and business strategy.

7.2 Key Challenges and Solutions in IoT-HR Integration

The challenges of IoT adoption in HR can be classified into four categories: technological, organizational, ethical, and human. Our findings extend Johnson's [41] categorization by specifically highlighting the ethical dimension, which has gained prominence as IoT capabilities expand. Technological challenges include managing vast amounts of data, ensuring system integration, and keeping pace with rapid advancements. Our analysis found that successful organizations address these challenges through cloud-based architectures and

modular implementation approaches, supporting Chen and Lee's [42] recommendations for scalable HR technology infrastructure. Organizational challenges involve overcoming resistance to change and fostering cross-departmental collaboration. The literature indicates that organizations with dedicated change management programs achieve substantially higher success rates in IoT implementation, aligning with Wang et al.'s [43] findings on technology adoption in HR. Ethical challenges encompass complex issues of privacy, data ownership, consent, and the responsible use of IoT data in decision-making processes. Our review identifies emerging best practices, including transparent data policies and ethical guidelines for algorithm use, extending Brown's [44] framework for ethical HR analytics. Human challenges include addressing employee concerns about job security, maintaining empathy in increasingly data-driven processes, and preserving the human touch in HR. These findings complement Rodriguez and Kim's [45] work on human-centered technology deployment in HR functions.

7.3 Impact of IoT-Driven HR Analytics on Organizational Performance

Our systematic review demonstrates that IoT-driven HR analytics significantly impact organizational performance through three primary mechanisms: enhanced decision quality, improved resource allocation, and strategic talent optimization. First, IoT-enabled HR analytics improve decision quality by providing data-driven insights that reduce subjective bias and increase predictive accuracy. Organizations leveraging IoT for workforce analytics report improved accuracy in turnover predictions (comparable to Wilson et al.'s [46] findings) and faster identification of skill gaps (exceeding the results reported by Morgan's [47] cross-industry study). Second, IoT enhances resource allocation efficiency by providing granular insights into space utilization, equipment needs, and workforce deployment. Our analysis found that organizations implementing IoT-based workspace monitoring achieved notable cost reduction in facility management and improvement in workspace productivity, supporting Taylor and Chen's [48] research on smart workplace ROI. Third, IoT enables strategic talent optimization through continuous performance monitoring, skill development tracking, and career progression analytics. Organizations applying these capabilities report enhanced employee engagement scores and improvement in internal mobility, extending beyond the improvements noted in Harrison's [49] benchmark study on data-driven talent management. The organizational performance impact varies by industry and digital maturity, with technology and healthcare sectors demonstrating more advanced applications and measurable outcomes than manufacturing and public sectors. This pattern aligns with Davis and Wong's [50] industry analysis of HR technology adoption rates and impact differentials.

7.4 Framework for Integrating IoT into HR Systems

Building on our findings regarding IoT's influence, challenges, and impact, we propose a comprehensive framework for integrating IoT into HR systems (Table 7). This framework synthesizes best practices identified in the literature and provides organizations with a structured approach to implementation that balances technological innovation with human-centered values. The framework addresses the identified challenges while maximizing potential benefits through five key components: Readiness Assessment, Strategic Design, Technology Integration, Governance, and Continuous Evaluation. Each component is designed to address specific aspects of IoT implementation in HR contexts. Our framework extends existing models by incorporating ethical considerations throughout the implementation process, not merely as compliance requirements. It also emphasizes the importance of human-centered design principles, addressing Nguyen and Park's [51] critique that many technology integration frameworks neglect the human experience dimension. The framework's emphasis on continuous evaluation aligns with Lee and Chen's [52] findings that adaptive implementation approaches yield higher satisfaction with HR technology investments. By integrating feedback mechanisms and impact assessment, our framework enables organizations to refine their IoT strategy based on evolving needs and outcomes.

8. Conclusion

The integration of Internet of Things (IoT) technologies into Human Resource Management (HRM) marks a significant evolution beyond basic digital transformation, offering measurable benefits

such as reduced facility costs, improved turnover prediction accuracy, and faster identification of skill gaps. This systematic review of 150 sources reveals that organizations adopting comprehensive IoT strategies not only enhance operational efficiency but also gain strategic advantages through improved agility and decision-making. Our research contributes a structured taxonomic framework for planning IoT implementation, a five-component integration model that enhances employee satisfaction, and an analysis of common implementation challenges across technological, organizational, ethical, and human dimensions. Successful adoption depends on five key factors: technological readiness, cultural alignment, data governance, employee engagement, and regulatory compliance. Ultimately, a balanced, human-centered approach to IoT—one that enhances rather than replaces human judgment—is crucial for long-term success, with future research needed to explore its impact in diverse organizational settings, especially small and emerging enterprises.

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Tree distribution and diversity along sidewalks in roads of Nakhon Ratchasima City Municipality, Thailand

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Abstract

This study examined the distribution and diversity of street trees along sidewalks in the roads of Nakhon Ratchasima City Municipality (NCM), Thailand, in response to the rapid urbanization that has led to the loss of green spaces, declining air quality, and increased vulnerability to PM2.5 pollution. Data was collected using Google Street View and field surveys conducted from November 2021 to January 2022. Each sidewalk of NCM roads was plotted by sampling in every 1 km. to measure tree presence. The surveyed data modified from Office of Natural Resources and Environmental Policy and Planning (ONEP), was converted to excel program for tree diversity analysis-based Shannon-Wiener Index (S-W I). As a result, there were a total of 1,556 trees, 171 tree species (they were identified by genus and species-based Forest Herbarium of Department of National Parks, Wildlife and Plant Conservation), and S-W I of 28.029 (average 3.817). The highest sum and average of S-W I (2.551, 0.159) were found in Phonlan Rd. and the lowest sum and average of S-W I (0, 0) were found in 3 roads: Vatcharasarid Rd., Kudan Rd. and Det Udom Rd. The S-WI score for these three roads was 0, indicating the presence of only one species. Based on these results above, they could be assessed that at least 1 tree and tree species would occur every 1-2 km on sidewalk in NCM road. Moreover, Among the recorded species, one was listed as endangered (EN) on the IUCN Red List, and ten were identified as exotic species.Consequently, findings provide critical insights for enhancing urban greenery and guiding green city initiatives to support planning green space network (GSN) in NCM roads, for example, 3 dominant species: *Tamarindus indica*, *Pithecellpbium dulce*, and *Murraya paniculata* will be recommended on the Phonlan road etc.

Keywords: Street tree; Green city; Trees diversity; Geospatial tool

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1. Introduction

Thai society has increasingly faced the severity of PM2.5 air pollutants, has become more severe every year. Therefore, green cities are designed with consideration for a healthy environment. This is a key issue in SDG 11 that is relevant to making cities and human settlements inclusive, safe and sustainable, and then will help promote health and well-being [1]. Sustainability of urban and suburban forests contributes to ecosystem restoration and helps stop and restore biodiversity loss [2]. However, Thai cities are still facing dramatic increases in urbanization. As a result, cities are covered with impermeable road surfaces, for example sidewalks. Especially planting street trees creates attractive and vibrant public spaces within the urban environment but tree growth can be limited when tree spaces are not properly designed to reduce water stress [3]. Street trees play a critical role in supporting a healthy and environmentally sound urban community that affect a positive social impact because it helps restore human health [3,4]. Recently, the role of geospatial technology has not only provided more convenience for preliminary surveying street trees such as Google Street View in Google Earth, but other spatial tools (e.g., ArcGIS Survey123, i-Tree Tools) are also used for collecting tree data in field. For example,

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using Google Earth software for observing trees along streets in Lubumbashi city, Congo [5]; implementing i-tree tools for spatial decision support [6] and for quantifying ecosystem services from trees [7]; using ArcGIS Survey123 for collecting urban trees in public spaces [8]. Although there are papers, have studied street trees (e.g., Sikuzani et al. [4], Kjelgren et al. [9], Sjöman et al. [10], Thomsen et al. [11], Wang et al. [12], Galle et al. [13]), but it is still not enough knowledge especially presenting tree diversity index. 3 of 6 concerned papers (Sikuzani et al. [5], Thomsen et al. [11] and Galle et al. [13]) analyzed tree diversity index but they offered various equations for calculating diversity index such as Simpson's index [14], Shannon-Weiner index [15-17], Evenness index [18].

For this study, we selected Shannon-Wiener Index because it is stated to be widely used in population genetics studies. and has been demonstrated to have negative bias in small sample sizes. This reason was proven by research of Kutintara [15], Marod [16] and Konopinski [13].

Based on mentioned above, this study explores the distribution and diversity of street trees along sidewalks in roads under the Nakhon Ratchasima City Municipality (NCM), located in Nakhon Ratchasima province. The quantity and diversity of trees were analyzed at species level with data from the tree survey. Findings provide critical insights for enhancing urban greenery and guiding green city initiatives to support planning green space network (GSN) in NCM (the published research of Jantakat and Srithumma [19]).

2. Materials and Methods

2.1 Study site

This study surveyed appearance and contents of street trees along their pavements in NCM, Thailand.

The site was selected based on strategy for creating growth on environmentally friendly quality of life of Local Development Plan (2023 - 2027) for office of NCM [20]. The NCM area is about 37.50 km^2 which is located in Ni-Muang sub-district, Muang district, Thailand with latitudes 14.92-14.99 °N and longitudes 102.02 - 102.15 °E as Figure 1. In NCM, there are a total of 31 roads including the total length of the road is 261.500 km. such as Chumphol Rd., Jaggree Rd., Vatcharasarid Rd., Manat Rd., Chainarong Rd., Prajak Rd., Kudan Rd., Phonsen Rd., Yommarat Rd., Phonlan Rd., Asadang Rd., Chomphon Rd., Mahatthai Rd., Sanphasit Rd., Kamhaeng Songkhram Rd., Chang Phueak Rd., Sueb Siri Rd., Sirinakhon Rd., Payapthit Rd., Ratchanikun Rd., Ratchadamnoen Rd., Suranaree Rd., Pho Klang Rd., Chomsurang Yat Rd., Mukmontri Rd., Burin Rd., Phibun Laead Rd., Det Udom Rd., Ratchasima-Chokchai Rd. (a part of Highway no. 224), Suranarai Rd. (a part of Highway no. 205), and Mittraphap Rd. (a part of Highway no. 2). Road characteristics consist of road length between 1 and 35 km., an asphalt and concrete road surface, traffic lanes between 2 and 6 lanes and sidewalks about 2-3 m.

2.2 Surveying data of trees along sidewalks of NCM roads

Data was collected using the latest Google Street View (GSV) and field surveys were operated from November 2021 to January 2022. In urban tree survey, we modified the approach of Office of Natural Resources and Environmental Policy and Planning (ONEPP) [21,22], comprised of (1) using a line plot system in every 1 km. along NCM roads as Figure 2 and (2) measuring trees' component with a height of not less than 5 m and Girth at Breast Height (GBH) at 1.30 meters from ground level of not less than 50 cm. as Figure 3. In addition, tree data in field were recorded with web of ArcGIS Survey123 (https://survey123.arcgis.com/), included 2 parts: 1) general data (e.g., surveyor, date, and environmental conditions) and 2) tree data (e.g., tree common and scientific name, tree location, size of tree canopy covering, measurement of tree circumference at 1.30 m from ground level and tree height), and then they were converted and stored into an excel program for spatial displaying in QGIS.

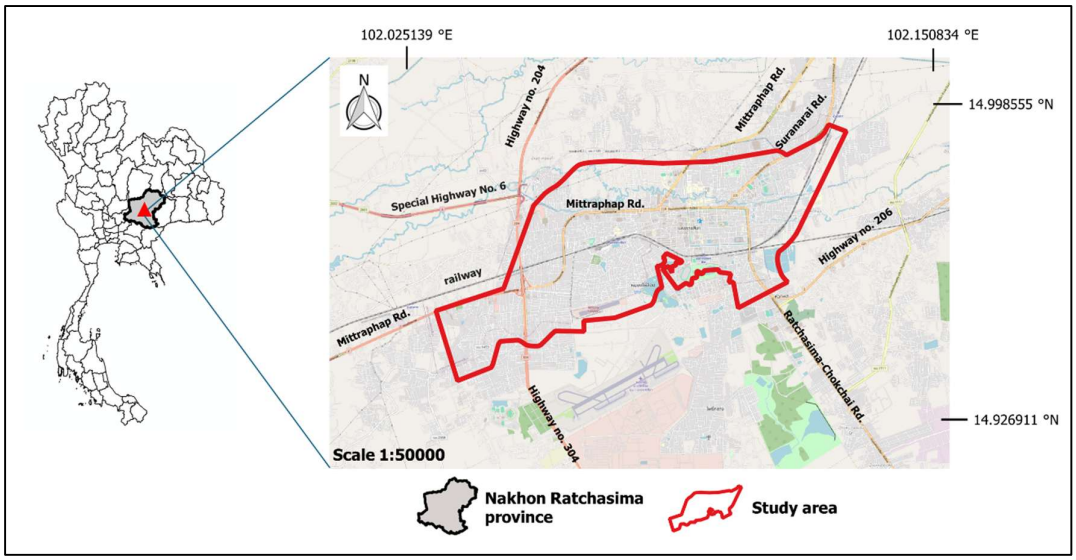

Figure 1. The geographical location of NCM area

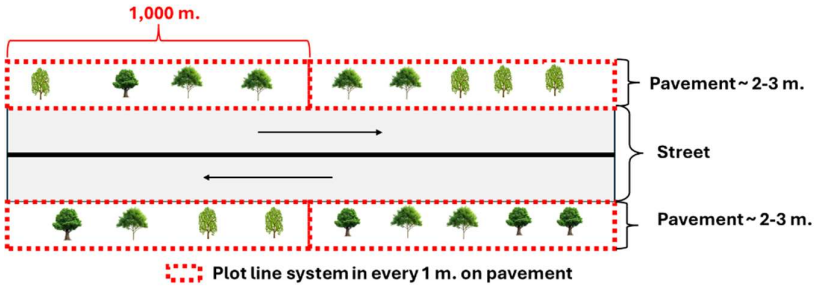

Figure 2. Method of line plot system for collecting trees' data along pavement in NCM-road (modified from ONEPP [21,22])

Figure 3. Characterizing tree measurement on pavement in NCM roads

Based on the surveyed data above, they were analyzed by using approach of Kutintara [15] and Marod [16] for tree diversity as Table 1. This Shannon-Wiener Index (S-W I) can increase when the number of species in plant community is regularly increased in the distribution of the number of plants in each species, but it should not exceed 5 [21,22]. If this diversity index equals 0, all plant populations in the community will have just one species. Moreover, this research checked tree

species of IUCN red list [23], native and exotic species in global assessment.

Table 1. Tree diversity analysis of trees along sidewalks of NCM roads

No.	Items, unit	Measurements
1	Density (D), trees	The total number of tree species appears in each sample plot, which is divided by all surveyed areas of sample plots.
2	Frequency (F), trees	The number of sample plots where tree species appears, which is divided by all surveyed areas of sample plots.
3	Dominance (Do), Canopy area	The total canopy area of tree of each species in each sample plot is divided by all surveyed sample plots.
4	Relative Density (RD), %	The relative density value of each tree species, which is divided by the sum of density value of all tree species in the sample plots and then multiplied by 100.
5	Relative Frequency (RF), %	The relative frequency value of each tree species, which is divided by the sum of frequency value of all tree species in the sample plots and then multiplied by 100.
6	Relative Dominance (RDo), %	The relative dominant value of each tree species in canopy area, which is divided by the sum of dominant value of all tree species in the sample plots and then multiplied by 100.
7	Importance Value Index (IVI)	The sum of relative values of tree species consists of RD, RF, and RDo.
8	Shannon-Wiener Index (S-W I)	$H = -\sum_{i=1}^{s} p_i \, log_2 p_i$ Where H is index value of plant species diversity p_i is proportion between the number of trees' species i for all trees. S is total tree species

3. RESULTS

Tree distribution and diversity along sidewalks on NCM roads was collected from 229 sample plots (the total road length about 229 km. and the total area of pavement about 11.221 km^2). Trees had densely occurred in the old moat location as Figure 4 and data of tree diversity in Table 2. From Table 2, interval of S-W I was between 0-2.551, this study arranged 3 levels of diversity values on sidewalks of NCM roads: Low (L), Medium (M), and High (H), as shown in Table 3. The group of low intervals of tree diversity index was the highest quantity (9 roads) and group of high (8 roads) and medium (6 roads) interval respectively. It is worth noting that all 8 NCM-road of the high S-W I interval,

is in zone of NCM-old moat. This zone presently, is developed as cultural tourism because there are Thai important heritage such as Thao Suranaree Monument (as the center of faith of Korat people) and 6 old ancient temples (Bueng, Sakaeo, Bon, E-San, Phra Narai Maharat, and Phayap).

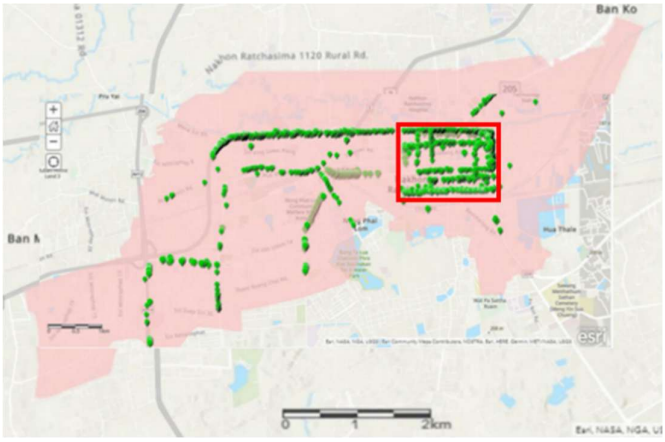

Figure 4. Distribution of street trees along pavements in NCM roads
(Pink area as NCM bound, Green point as tree and Red frame as the NCM old moat)

Table 2. Data of tree species diversity along pavements in 24 NCM roads in year 2021-2022

Road names (total trees and tree species)	**Details for each tree species (number of trees, S-W ID)**	**S-W I (Total, Average)**
1. Chumphol (85, 12)	**Pterocarpus macrocarpus* (22, 0.350), *Ficus macrocarpa* (12, 0.276), *Mimusops elengi* (12, 0.276), *Cassia fistula* (8, 0.222), *Lagerstroemia speciosa* (7, 0.206), *Melia azedarach* (6, 0.187), *Diospyros ehretioides* (3, 0.118), *Millingtonia hortensis* (2, 0.088), *Caesalpinia pulcherrima* (2, 0.088), *Lagerstroemia floribunda* (1, 0.052), and *Plumeria obtuse* (1, 0.052)	2.155, 0.180
2. Vatcharasarid (7,1)	*Mimusops elengi* (7, 0)	0,0
3. Manat (40, 2)	*Tabebuia a*urea (10, 0.347) and *Cassia Fistula* (30, 0.216)	0.562, 0.281
4. Kudan (2, 1)	*Tabebuia rosea* (2, 0)	0,0
5. Phonsen (146, 16)	*Cassia fistula* (48, 0.366), *Melia azedarach* (32, 0.333), *Terminalia catappa* (15, 0.234), *Saribus rotundifolius* (14, 0.225), *Plumeria obtuse* (8, 0.159), *Lagerstroemia speciosa* (7, 0.146), *Borassus flabellifer* (5, 0.116), *Caesalpinia pulcherrima* (5, 0.116), **Pterocarpus macrocarpus* (3, 0.080), *Tamarindus indica* (3, 0.080), *Ixora chinensis* (1, 0.034), *Ficus religiosa* (1, 0.034), Tabebuia rosea (1, 0.034), *Diospyros ebenum* (1, 0.034), *Mimusops elengi* (1, 0.034), and *Azadirachta indica* (1, 0.034)	2.057, 0.129
6. Yommarat (72, 4)	*Cassia fistula* (22, 0.362), *Peltophorum pterocarpum* (43, 0.308), *Lagerstroemia floribunda* (5, 0.185), and *Tamarindus indica* (2, 0.100)	0.955, 0.239
7. Phonlan (33, 16)	*Tamarindus indica* (6, 0.310), *Pithecellpbium dulce* (6, 0.310), *Murraya paniculata* (2, 0.170), *Wrighta arborea* (2,0.170), *Bauhinia purpurea* (2,0.170), *Lagerstroemia floribunda* (2,0.170), *Flacourtia rukam* (2,0.170), *Peltophorum ptercarpum* (2,0.170), *Cassia fistula* (2,0.170),	2.551, 0.159

Road names (total trees and tree species)	**Details for each tree species (number of trees, S-W ID)**	**S-W I** (Total, Average)
8. Asadang (69, 7)	*Lagerstroemia speciosa* (57, 0.158), *Cassia fistula* (3, 0.136), *Cerbera odollam* (2, 0.136), *Tabebuia rosea* (2, 0.103), *Mimusops elengi* (2, 0.103), *Ficus be*njamina (1, 0.061), and *Senna siame*a (1, 0.061)	0.758, 0.126
9. Mahatthai (36, 8)	**Pterocarpus macrocarpus* (13, 0.368), *Mimusops elengi* (10, 0.356), *Alstonia scholaris* (4, 0.244), *Terminalia catappa* (4, 0.244), *Tabebuia rosea* (2, 0.161), *Wrightia religiosa* (1, 0.100), *Peltophorum pterocarpum* (1, 0.100), and *Cassia fistula* (1, 0.100)	1.671, 0.209
10. Sanphasit (49, 10)	*Peltophorum pterocarpum* (20, 0.366), *Peltophorum pterocarpum* (8, 0.296), *Mangifera indica* (7, 0.278), *Terminalia catappa* (6, 0.257), *Cassia fistula* (3, 0.171), *Codiaeum variegatum* (1, 0.079), *Ficus religiosa* (1, 0.079), *Tabebuia rosea* (1, 0.079), *Syzygium malaccense* (1, 0.079), and **Pterocarpus macrocarpus* (1, 0.079)	1.765, 0.176
11. Kamhaeng Songkhram (55, 9)	*Cassia fistula* (25, 0.358), Mimusops elengi (8, 0.280), *Terminalia catappa* (7, 0.262), *Pithecellobium dulce* (4, 0.191), *Cerbera odollam* (4, 0.191), *Ficus religiosa* (2, 0.121), *Tamarindus indica* (2, 0.121), *Caesalpinia pulcherrima* (2, 0.121), and *Phyllanthus acidus* (1, 0.073)	1.717, 0.191
12. Chang Phueak (4, 2)	*Ficus religiosa* (1, 0.347) and *Peltophorum pterocarpum* (3, 0.216)	0.562, 0.281
13. Sueb Siri (50, 11)	*Sindora siamensis* (17, 0.367), *Samanea saman* (10, 0.322), *Cassia fistula* (6, 0.254), *Cerbera odo*llam (6, 0.254), *Lagerstroemia speciosa* (3, 0.169), **Pterocarpus macrocarpus* (2, 0.129), *Tamarindus indica* (2, 0.129), *Millingtonia hortensis* (1, 0.078), *Mimusops elengi* (1, 0.078), *Pithecellobium dulce* (1, 0.078), and *Terminalia catappa* (1, 0.078)	1.937, 0.968
14. Ratchanikun (79, 9)	**Pterocarpus macrocarpus* (66, 0.150), *Amarindus indica* (3, 0.124), *Samanea saman* (2, 0.093), *Cassia fistula* (2, 0.093), *Terminalia catappa* (2, 0.093), *Senna siamea* (1, 0.055), *Millingtonia hortensis* (1, 0.055), *Cocos nucifera* (1, 0.055), and *Lagerstroemia speciosa (1, 0.055)*	0.775, 0.086
15. Ratchadamnoen (38, 10)	*Borassus flabellifer* (18, 0.354), *Lagerstroemia speciosa* (5, 0.267), *Ficus benjamina* (3, 0.200), **Pterocarpus macrocarpus* (3, 0.200), *Tamarindus indica* (3, 0.200), *Cassia fistula* (2, 0.155), *Millingtonia hortensis* (1, 0.096), *Casuarina junghuhniana* (1, 0.096), *Syzygium cumini* (1, 0.096), and *Terminalia catappa* (1, 0.096)	1.760, 0.176
16. Suranaree (12, 3)	*Samanea saman* (1, 0.207), *Peltophorum pterocarpum* (1, 0.207, and *Lagerstroemia speciosa* (10, 0.152)	0.566, 0.189
17. Pho Klang (4, 2)	*Bauhinia purpurea* (1, 0.347) and *Lagerstroemia floribunda* (3, 0.216)	0.562, 0.281
18. Chomsurang Yat (49,7)	*Lagerstroemia floribunda* (15, 0.362), *Lagerstroemia duperreana* (14, 0.358), *Pterocarpus indicus* (7, 0.278), *Bauhinia purpurea* (6, 0.257), *Peltophorum pterocarpum* (5, 0.233), *Cassia fistula* (1, 0.079), and *Tabebuia rosea* (1, 0.079)	1.647, 0.235
19. Mukmontri (21,6)	*Lagerstroemia speciosa* (10, 0.353), *Terminalia catappa* (4, 0.316), *Tamarindus indica* (3, 0.278), *Tebebuia rosea* (2, 0.224), *Ficus religiosa* (1, 0.145), and *Pithecellobium dulce* (1, 0.145)	1.461, 0.244
20. Det Udom (35,1)	*Peltophorum pterocarpum* (1, 0)	0, 0
21. Ratchasima-Chokchai (175, 11) (A part of Highway no. 224)	*Lagerstroemia speciosa* (89, 0.344), *Tabebuia rosea* (35, 0.322), **Pterocarpus macrocarpus* (26, 0.283), *Alstonia scholaris* (10, 0.164), *Ficus religiosa* (3, 0.070), *Ficus benjamina* (3, 0.070), *Wrighta arborea* (2, 0.051), *Lagerstroemia duperreana* (2, 0.051), *Diospyros ebenum* (2, 0.051), *Lagerstroemia floribunda* (1, 0.030), *Terminalia ivorensis* (1, 0.030), *Termianlia catappa* (1, 0.030)	1.494, 0.031

Road names (total trees and tree species)	Details for each tree species (number of trees, S-W ID)	S-W I (Total, Average)
22. Suranarai (106, 5) (A part of Highway no. 205)	*Tabebuia rosea* (64, 0.305), *Cassia fistula* (17, 0.294), *Lagerstroemia floribunda* (12, 0.247), **Pterocarpus macrocarpus* (7, 0.179), *Lagerstroemia speciosa* (6, 0.163)	1.187, 0.237
23. Mittraphap Rd. (389, 18) (A part of Highway no. 2)	*Lagerstroemia speciosa* (120, 0.363), *Tabebuia rosea* (83, 0.330), **Pterocarpus macrocarpus* (79, 0.324), *Cerbera odollam* (51, 0.266), *Tabebuia aurea* (11, 0.101), *Plumeria pudica* (11, 0.101), *Lagerstroemia duperreana* (10, 0.094), *Ficus religiosa* (4, 0.047), *Terminalia c*atappa (4, 0.047), *Gliricidia sepium* (3, 0.038), *Livistona rotundifolia* (3, 0.038), *Cassia fistula* (3, 0.038), *Millingtonia hortensis* (2, 0.027), *Ixora chinensis* (1, 0.015), *Senna siamea* (1, 0.015), *Tamarindus indica* (1, 0.015), *Pithecellobium dulce* (1, 0.015), *Azadirachta indica* (1, 0.015)	1.889, 0.105
	Overview of S-W ID total and average	3.817, 0.159

Remark: - Details for each tree type (number of trees, S-W ID) are arranged from highest to lowest.

- For checking tree species of IUCN red list: * is globally assessed by 1 endangered species (EN) and 10 exotic trees: *Ficus macrocarpa*, *Caesalpinia pulcherrima*, *Tabebuia aurea*, *Borassus flabellifer*, *Caesalpinia pulcherrima*, *Tamarindus indica*, *Diospyros ebenum*, *Tamarindus indica*, *Codiaeum variegatum*, and *Pithecellobium dulce*

Table 3. Ranking for tree diversity index on sidewalks of 23 NCM roads

Rank	Interval of S-W I	Quantity	Road names
L	0.000-0.850	9	Vatcharasarid, Manat, Kudan, Asadang, Chang Phueak, Ratchanikun, Suranaree, Pho Klang, and Det Udom
M	0.850-1.700	6	Yommarat, Mahatthai, Chomsurang Yat, Mukmontri, Ratchasima-Chokchai Rd (A part of Highway no. 225), and Suranarai Road (A part of Highway no. 205)
H	1.700-2.551	8	Chumphol, Phonsen, Phonlan, Sanphasit, Kamhaeng Songkhram, Sueb Siri, Ratchadamnoen, Mittraphap Rd. (A part of Highway no. 2)
	Total	23	

4. Discussion

When we considered the concerned papers about analyzing S-W I for street tree from a recent study of Sikuzani et al. (2022), street trees' data in Lubumbashi city in the Democratic Republic of the Congo (DR Congo) were analyzed by S-W I, presented about 2.426. In year 2012, there were a survey in the Nordic region or Northern European countries (Sjöman et al., 2012), they had been calculated by S-W I along pavements as: 2.150 of Helsinki, Finland; 5.150 of Malmö, Sweden; 5.800 of Aarhus, Denmark; 4.800 of Copenhagen, Denmark. These tree diversity values of S-W I were compared with this study (3.817 of NCM, Thailand), our results are within the range of Lubumbashi city, Congo and the Nordic countries. For Asian region, at the time of the study we reviewed the related literature, there were not have calculation of tree diversity index along sidewalks of city. There is only a survey of the number of trees, tree species, and abundance, for example, Kjelgren et al. (2011), Wang et al. (2018) etc. For checking tree species

of IUCN red list: *Pterocarpus macrocarpus* is globally assessed by 1 endangered species (EN) and 10 exotic trees: *Ficus macrocarpa*, *Caesalpinia pulcherrima*, *Tabebuia aurea*, *Borassus flabellifer*, *Caesalpinia pulcherrima*, *Tamarindus indica*, *Diospyros ebenum*, *Tamarindus indica*, *Codiaeum variegatum*, and *Pithecellobium dulce.*

5. Conclusion

Tree distribution and diversity along sidewalks in NCM roads were surveyed using GSV and field surveys conducted from November 2021 to January 2022. Trees had densely occurred in the old moat location and they were non-native species. Overview of tree diversity along sidewalks on such NCM roads consisted of 1,556 trees (~50 trees/road or 5.824 trees/km^2), 171 tree species (5 tree species/road or 1 tree species/km^2), density 166.542 trees (~7 trees/road or 0.576 trees/km2), frequency 18.743 trees (~1 trees/road or 0.072 trees/km^2), dominance 0.036 trees (~0.001 trees/road or 0.0001 trees/km^2), the sum of the IVI 300 (average 12.500) and the sum of the S-W I 28.029 (average 3.817). Based on results of S-W I in each pavement of NCM roads, the highest sum and average of S-W I (2.551, 0.159) were seen on Phonlan Rd. while the lowest sum and average of S-W I (0, 0) were seen on 3 roads (Vatcharasarid Rd., Kudan Rd. and Det Udom Rd.). These 3 roads S-W I equals 0, indicated that they had just one species. It has more significantly concluded that every 1 km^2 on the sidewalk in a road in NCM has a possibility that it may be found about 1 tree or without tree. Consequently, this study provides valuable information about tree population along sidewalks in 31 NCM roads. For benefits, NCM officers and policy makers will be able to use the obtained results for planning green city and tree maintenance including extending the results and the obtained outputs in this study to new roads that are being planned to be built in NCM in terms of guidelines for planting and selecting tree types. For checking tree species of IUCN red list: *Pterocarpus macrocarpus* is globally assessed by 1 endangered species (EN) and 10 exotic trees: *Ficus macrocarpa*, *Caesalpinia pulcherrima*, *Tabebuia aurea*, *Borassus flabellifer*, *Caesalpinia pulcherrima*, *Tamarindus indica*, *Diospyros ebenum*, *Tamarindus indica*, *Codiaeum variegatum*, and *Pithecellobium dulce.*

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